Analysing Pensions: Modelling and Policy Issues

Tim Callan and Philip J. O'Connell
(Editors)

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Table of Contents

Introduction

Tim Callan and Philip J. O'Connell

Pension systems in OECD countries face challenges arising from increases in life expectancy and from downward pressures on public expenditure. Changes to public and private pension systems have effects that are both complex and long-lived. Careful analysis is needed to tease out the implications of different reform options. Recognising this, the EU Directorate-General for Employment, Social Affairs and Inclusion set up a call for research which specifically included models for the analysis of pensions. The first two papers in this volume flow directly from that work, while the third tackles a complementary topic in the pension area.

Pension contributions and entitlements are typically built up over the working lifetime, and pension benefits drawn down in retirement. In order to capture the impact of policy changes which affect both the build-up and draw down of pensions, best practice is to analyse a model which follows a cohort of individuals over their lifetime. While it is not possible to follow an actual cohort in real time, the key features can be captured in what are termed dynamic cohort simulation models: these take a cohort of diverse individuals, and apply changes over time to their age, relationship status, labour market and savings behaviour which reflect the changes experienced by real people. In a series of papers, Justin van de Ven has developed this approach in the UK, building what is known as the National Institute pension model or NIBAX.

The first paper (by Justin van de Ven, of the National Institute of Economic and Social Research and Melbourne University) is one application of this approach. Decisions on pension savings may be skewed because undue weight is given to short-term considerations. As a result, individuals may regret their past decisions in later years. Justin van de Ven's paper gives a more precise characterisation of such "myopic" behaviour, and finds that there is evidence that this bias is important in practice. He uses the National Institute's dynamic cohort model to examine whether defined contribution pensions can help to correct for this bias in consumer decision-making. In particular, he looks at one element of recent pension reform in the UK, introducing a state-run defined contribution pension scheme, known as the National Employment Savings Trust (NEST). This was introduced following recommendations made by the UK Pensions Commission, which found that administration costs made it unprofitable for existing private sector pension providers to serve employees on modest incomes. Key features of the UK system include a requirement for employers to provide a matching contribution and low management charges (0.3 per cent annually). Van de Ven's analysis finds that the pre-commitment involved in a defined contribution scheme such as the UK's NEST can help to offset myopic tendencies, and make for a smoother pattern of consumption over the life course. These results have implications not just for the UK, but for the wider group of countries – including Ireland – facing similar challenges due to population ageing.

Changes in pension policy have complex and long-term effects. In order to understand the impact of alternative policy choices, models are needed that can capture the long-term dynamic impact of the policy changes. It is not enough to base decisions on a "snapshot" of the current population; policies need to take into account how people's employment and pension savings evolve over their life course. Responding to this need, the new model for analysing Ireland's pension policies has been constructed by Tim Callan and Claire Keane of the ESRI in collaboration with Justin van de Ven of the National Institute of Economic and Social Research and the University of Melbourne. The National Institute model was taken as a building block, and calibrated to the Irish situation. We first document the technical approach, the difficulties encountered, and the approaches used to overcome them. An indication of the potential of the approach is given by applying the model to explore the trade-off, for given tax rates, of raising the State Pension Age or reducing the level of the State Pension. Work of this type can provide an improved evidence base on which policy debate and policymakers can draw.

The final paper, by Gerard Hughes of Trinity College Dublin examines a more specific policy issue: whether the current system of tax reliefs for pensions represents a level-playing field as between executive directors and employees. Using information from the annual accounts for 2009 of 48 large companies, most of which are quoted on the Irish Stock Exchange, Hughes found that the average pension contribution rate for executive directors was almost 26 per cent of salary – as against a rate of about 7 per cent for other private sector employees. The average value of an executive director's pension fund amounts to €4.1 million or 34 times more than the average value of the pension fund of €120,000 for other employees. Given these disparities, the benefit of the current tax treatment of pension contributions is correspondingly greater for executive directors as compared with other employees. In 2011 the government reduced the cap on the annual earnings contribution eligible for pensions tax relief from €150,000 to €115,000 and it reduced the lifetime cap on the size of an individual pension fund from €5.4 million to €2.3 million. Hughes argues that further reductions in the both the annual earnings ceiling and lifetime cap on fund size would help to focus relief on low and middle income earners.

The complexities of pension systems mean that careful analysis is needed to tease out the implications of potential changes to policy over the long term. The papers included in this volume bring insights from research in the UK into the potential for low-cost DC schemes (van de Ven), from a new model for analysis of pension issues in Ireland (Callan *et al.*) and from careful analysis using data on company accounts (Hughes). These papers are intended as a contribution to policy debate, and as a springboard for further research in this area.

Do Defined Contribution Pensions Correct for Short-Sighted Savings Decisions? Evidence from the UK[*]

Justin van de Ven[†]

Introduction

Without government intervention, individual decisions on provision for retirement may pay insufficient attention to the longer term, and be unduly influenced by near term considerations. Recent policy debate in the United Kingdom has emphasised the role of such "myopia"[1] in justifying state involvement in retirement provisions (e.g. Pensions Commission, 2005, pp. 68-69, Department for Work and Pensions, 2006, p. 31). Very few studies have, however, examined the empirical support for myopia in the real world, or the practical implications of myopia for responses to pension alternatives. Without such work, 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 therefore 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), a Defined Contribution (DC) pension scheme that will be introduced in the UK from 2012.

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1 In this study myopia is defined as a state in which preferences are biased in favour of consumption in the short term. The term "bias" is used here to indicate that the associated preferences are inconsistent – the individual will later regret having given such weight to the short term. Technically, the compensation required to agree to delay consumption by say, one month, is lower for a deferral of consumption in the more distant future compared to a delay in the near-term.

The introduction of the NEST reflects a contemporary trend toward greater reliance on DC pension provision in the (third tier) private sector of 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 existing private sector pension providers to serve employees on modest incomes. The NEST is consequently designed to improve saving incentives by reducing management charges, and by requiring all employers to offer a 3% matching pension contribution on banded earnings to participating employees. It has been forecast that the scheme will serve between 6 and 10 million people – 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. The success or failure of the scheme will have a profound influence on the future of the UK pensions system, and will have important implications for the wider group of countries that face similar challenges due to population ageing.

2. Previous studies of retirement behaviour and myopia

Although retirement behaviour has been studied at length in realistic policy contexts and on the assumption of time consistent preferences, few studies have considered the associated implications of myopia. Some aspects of this information gap are effectively addressed by the extensive literature that focuses upon policy design where the objective function of the government is different from that of individuals (e.g. Kanbur et al. (2006)). But this literature does not address the welfare advantage of commitment mechanisms in the context of time-inconsistent preferences, which has an important bearing on the responses of myopic agents to (illiquid) pension schemes.

A number of studies have focused upon the implications of myopia for the distinction between funded and Pay As You Go systems of social security, without focusing upon responses to voluntary pension schemes in particular (e.g. Schwarz & Sheshinski (2007), and Fehr & Kindermann (2009)). The only study of which I am aware that has explored responses of myopic agents to voluntary DC pensions is by Laibson et al. (1998), who used a structural model calibrated to the US economy to consider responses to IRA and 401(k) plans. Laibson et al. find that saving in the pension asset responds positively to agent myopia, increasing by a factor of between 1.2 and 1.6 on their preferred model specification, relative to time consistent preferences. Furthermore, they find that myopia tends to improve the welfare response to the introduction of a DC pension measured at the beginning of the simulated life.

2 On contemporary pension arrangements in OECD countries, see OECD (2009).

These results add support to the premise that myopia tends to justify the introduction of a DC pension scheme. The intuition behind this proposition is well understood; sophisticatedly myopic agents, who are aware of the time-inconsistency of their own preferences, attach a welfare benefit to commitment mechanisms that resolve their intra-personal conflict in favour of their present self. An individual, for example, may be happy to lock their money away in an (illiquid) pension fund, if they believe that they will exhibit a propensity to over-consume in the future.

However, the analysis reported by Laibson et al. is based upon a model of endogenous saving in a liquid asset and a pension asset; it omits endogenous labour supply. This is potentially important because labour supply and savings are likely to be jointly determined, particularly close to retirement. The stylised analysis by Diamond & Köszegi (2003) – which omits a pension asset, but includes both saving and labour supply – also highlights the potential for interesting intertemporal feed-back effects between saving and labour supply in the context of time-inconsistent preferences.[3] Furthermore, an important caveat that Laibson et al. raise in relation to their results is the degree of sensitivity to their model calibration, particularly in relation to the intertemporal elasticity of substitution.

An alternative approach to model calibration is to specify the model using an econometric criterion. Very few studies have, however, investigated the empirical evidence for myopia beyond controlled laboratory experiments. The small number of studies that have estimated models with myopic preferences on field data focus upon margins of decision making that are distinguished by the timing of their associated welfare effects. Laibson et al. (2007), for example, estimate a life-cycle model of consumption and investment decisions that distinguishes between (net) liquid assets on the one hand, and a composite illiquid asset that is specified to reflect housing and pensions on the other.

Laibson et al. (2007) estimate their model on US data for households with a high-school but not a college degree. They report that restricting their model to constant exponential discounting results in an estimate for the (per period) discount factor of 0.846/0.942 (depending on the weighting matrix applied). Allowing for quasi-hyperbolic discounting results in an estimate for the short-run discount factor of 0.674/0.687 and a long-run discount factor of 0.958/0.960. These results imply that individuals are strongly averse to any delay of immediate consumption, but otherwise exhibit a high degree of patience. This combination of short-term impatience and longer-term patience generates a range of interesting behavioural

3 See Cremer et al. (2007) and Fehr & Kindermann (2009) for studies that take account of savings and labour supply decisions when exploring the implications of myopia for the design of social security. Neither paper, however, focuses upon the implications for DC pension schemes that are the focus here.

effects, including demand for commitment mechanisms that is a focus of the current study. Almost all of the specifications that Laibson *et al.* consider reject the restriction that discount rates are equal across all time horizons, and suggest that myopia is of practical importance.

In a similar vein, Fang & Silverman (2007) estimate a model of labour supply and welfare programme participation for never-married mothers, again on US data. Like Laibson et al. (2007), Fang & Silverman (2007) allow for present biassed preferences in the form of quasi-hyperbolic discounting. They consider the hypothesis that people with myopic preferences fail to account fully for the experience effect on future wages of short-run labour supply decisions (an illiquid investment in human capital), resulting in a bias toward welfare dependency. The estimates that Fang and Silverman report reflect in exaggerated form those reported by Laibson *et al*.: the short-run discount factor at 0.296/0.308 (depending on assumed preferences) is significantly lower than the long-run discount factor at 0.875/0.868.

However, neither of these studies, nor others that have estimated time varying discount rates on survey data (e.g. DellaVigna and Paserman, 2005, Paserman, 2008, and Shui and Ausubel, 2004), take into account joint decisions over savings and labour supply. This paper consequently extends the literature in two important dimensions: by reporting estimates for myopic preferences in relation to joint decisions over liquid savings, pension savings, and labour supply calculated on data for a broad segment of the UK population; and by exploring the associated implications of myopia for DC pension schemes.

Section 2 describes the model that was used to conduct the analysis. Section 3 reports parameter estimates for the model. The influence of myopia on responses to the introduction of a DC pension are analysed in Section 4; readers who are interested only in the policy relevant results may skip to Section 4 without excessive handicap. A summary and directions for further research are provided in the conclusion.

2. The structural model

The unit of analysis is the household, defined as a single adult or partner couple and their dependent 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, pension rights, and survival. 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 there are no feed-back effects from the macro-economy on wages or the returns to investment. The rationality of the belief structure also extends to expectations over future preferences, so that myopic consumers are aware of the time-inconsistency of their preferences. This section gives an abbreviated description of the structural model; for a more detailed description, see van de Ven (2009).

A. Preferences

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

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

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

so that intratemporal utility u takes a Constant Elasticity of Substitution form, where $\alpha > 0$ is the utility price of leisure, and $\epsilon > 0$ 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 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. A discrete specification is adopted for labour supply to reflect the substantial labour market rigidities that continue to exist, despite the increased flexibility of working time arrangements that has occurred since the 1970s.[4]

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 IV explores how alternative values of β influence responses to a DC pension scheme.

[4] Fagan (2003), for example, reports that approximately 1 in 5 employed people in Europe work full-time when they would prefer to work part-time. The reasons most commonly given for the mis-match include the perception that it would not be possible to do a desired job part-time, that part-time employment is not offered by a desired employer, and that it would damage career prospects.

$\theta_{i,t} \in R^+$ is adult equivalent size based on the "modified" OECD scale. It is included in the preference relation to reflect the empirical finding that household size is an important determinant of the evolution of consumption during the life course. To fix terms, the model assumes that both members of a couple are of the same age, which defines the household's age, t. E_t is the expectations operator at time t, t_{death} is the age at death, which defines the time of death of all adult household members and is assumed to be uncertain. Define $\varphi_{j-t,t}$ as the probability of surviving to age j given survival to age t, where $\varphi_{T-t,t} = 0$ for all t. Then it is possible to replace t_{death} by T, bring the expectations operator into the summation sign, and include $\varphi_{j-t,t}$ as an additional discount factor. $\varphi_{j-t,t}$ 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.

B. The liquidity constraint

Define $w_{i,t}$ as liquid net worth, which covers total non-pension wealth, including the value of housing, cash balances, and other tradeable assets. Equation (1a) 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).

$\tau(.)$ 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.

C. 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 first 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. Household *benefits* (excluding adjustments for childcare and housing costs) are then calculated, given aggregate household take-home pay – this reflects the provision of benefits at the level of the family unit. Next, non-discretionary *net childcare costs* (after adjusting for childcare related benefits) are evaluated, given aggregate household take-home pay. This is of separate importance because childcare costs influence labour supply decisions. Non-discretionary *net housing costs* (after adjusting for relevant benefits) are then calculated on aggregate take-home pay plus benefits less childcare costs – this reflects the means testing of housing related benefits in the UK, which is administered with respect to income net of most other elements of the tax and benefits system. Finally, *disposable income* is 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:

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

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

$pp_{i,t}$ denotes private pension annuity, sp_t denotes state pension income, and χ is the annuity rate. This specification reflects the EET form of taxation applied to pension savings in the UK, which is in common with most other OECD countries.[5] 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 dies.[6]

5 EET taxation of pension savings, *E*xempts pension contributions, *E*xpempts pension investment returns, and *T*axes pension fund dispersals.

6 When a household transitions from being comprised of a couple at age t to a single adult at age $t+1$, then it is assumed to be the result of divorce if $t+1 < t_{SPA}$, and of death otherwise.

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:

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

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.

D. 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 labour income in excess of a lower limit in the prevailing year, $g_{i,t} > \pi^{pl}$, choose whether, and what fraction of their labour income, $\pi_{i,t}^{pc}$, to contribute to their pension, subject to the lower bound π_0^{pc}. 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_{ec}^p. All pension contributions are tax exempt (as discussed above). The balance of household i's pension account at any age, $t < t_{SPA}$, is given by:

$$w_{i,t}^{p} = \begin{cases} \pi_{div}\hat{w}_{i,t}^{p} & n_t^a < n_{t-1}^a \\ \hat{w}_{i,t}^{p} & \text{otherwise} \end{cases}$$

$$\hat{w}_{i,t}^{p} = \begin{cases} \left(1+r^p\right) w_{i,t-1}^{p} + \left(\pi_{i,t-1}^{pc} + \pi_{ec}^{p}\right) g_{i,t-1} & \text{if } \pi_{i,t-1}^{pc} \geqslant \pi_0^{pc}, g_{i,t-1} > \pi^{pl} \\ \left(1+r^p\right) w_{i,t-1}^{p} & \text{otherwise} \end{cases} \tag{6}$$

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

E. Labour income dynamics

Three household characteristics influence labour income: the household's labour supply decision $l_{i,t}$, 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, $p^{wo}\left(n_{i,t}^a\right)$, 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; $g_{i,t} = \mu\left(l_{i,t}\right) h_{i,t}$. 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:

$$\ln\left(h_{i,t+1}\right) - \ln\left(h_{i,t}\right) = f_h\left(n_{i,t}^a, t\right) + \kappa\left(n_{i,t}^a, l_{i,t}\right) + \omega_{i,t} \tag{7a}$$

$$\omega_{i,t} \sim N\left(0, \sigma_{\omega,n_{i,t}^a}^2\right) \tag{7b}$$

where $\kappa\left(.\right)$ is an experience effect, and $\omega_{i,t}$ is a household specific disturbance term.

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, 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 the context of the strong wage growth that is typically

[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.

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 young people, and an experience effect is included to capture this; see Sefton et al. (2008) and Sefton & van de Ven (2009).

F. Household demographics

Household relationship status is modelled explicitly, and is uncertain from one year to the next. The probabilities of relationship transitions – including the formation of cohabitating unions and their dissolution through death, divorce, and annulment – are described by the reduced form logit equation:

$$s_{i,t+1} = f_s(t) + \alpha^A s_{i,t} \tag{8}$$

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: $n^c_{i,t} = n^c\left(n^a_{i,t}, t\right)$.

G. Model solution

The allowance for uncertainty in the model implies that an analytical solution to the utility maximisation problem does not exist, and 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^a_t, 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 $V_T(n^a_T, w_T, p_T)$:

$$V_T(n^a_T, w_T, p_T) = u\left(\frac{\widehat{c}_T\left(n^a_T, w_T, p_T\right)}{\theta_T}, 1\right) \tag{9}$$

$$W_T(n^a_T, w_T, p_T) = V_T(n^a_T, w_T, p_T) \tag{10}$$

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^a_T, 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:

$$V_{T-1}(n^a_{T-1}, w_{T-1}, p_{T-1}) = \max_{c_{T-1}} \frac{1}{1-\gamma} \left\{ u\left(\frac{c_{T-1}}{\theta_{T-1}}, 1\right)^{1-\gamma} + \beta\delta\varphi_{1,T-1} E_{T-1}\left[W_T(n^a_T, w_T, p_T)^{1-\gamma}\right] \right\} \quad (11)$$

$$W_{T-1}(n^a_{T-1}, w_{T-1}, p_{T-1}) = \frac{1}{1-\gamma} \left\{ u\left(\frac{\widehat{c}_{T-1}}{\theta_{T-1}}, 1\right)^{1-\gamma} + \delta\varphi_{1,T-1} E_{T-1}\left[W_T(n^a_T, w_T, p_T)^{1-\gamma}\right] \right\} \quad (12)$$

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.[8] Where labour supply is permitted, the optimisation includes the alternative labour decisions, and 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 the 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

8 In the context of time-inconsistent preferences, the solution consequently takes the form of a Stackelberg equilibrium, where younger selves have a first-mover advantage. Solution by backward induction is made possible by the assumption that future selves cannot commit to strategies that react to the decisions of past selves.

recursively for any further solutions. This process is repeated until no further solutions are found, and 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

A. 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.[9] 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.

B. Data

The model parameters were estimated on data for individuals aged 25 to 45 in 2007/08, on the assumptions that observed households behaved as though they

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

would be subject to the 2007 policy environment for the remainder of their lives; that they expected labour incomes to increase at a constant rate based on the observed growth between 1990 and 2007; that expectations regarding cohabitation reflected transitions observed between 1991 and 2007; and that expected mortality rates reflected official projections for the cohort aged 35 in 2007. Furthermore, the micro-data upon which the estimation is based were screened to omit public sector employees who are eligible to non-contributory pensions[10], and the self-employed whose circumstances upon reaching retirement often depend crucially upon the sale of their respective businesses. The omitted population subgroups accounted for just under 20 per cent of the total work force in the UK in 2007/08.[11]

These assumptions represent a balance between the prevailing computational limitations, and the objective to obtain a faithful reflection of the household decision making context. The principal simplification of the estimation is that it limits variation of the policy environment. The importance of this consideration is exaggerated by the focus on endogenous labour supply, which requires the model to take explicit account of tax and benefits policy. The alternative aspects of the estimation are designed to militate against the distortions that are consequent upon this simplification. Financial statistics were adjusted to reflect real wage growth to capture expectations that individuals may reasonably have had over how their circumstances were likely to evolve with age. The dynamic model of cohabitation was estimated on data for a time period that forms a reasonable basis for the specification of agent specific expectations. Mortality rates reflect official projections for improvements in longevity. The generational age band considered for estimation controls for the heterogeneous circumstances of different birth cohorts. This last consideration is particularly relevant in the current context, as recent reforms to the UK pensions system substantially alter the circumstances of workers distinguished by year of birth. The age band was selected to focus upon the period in life when the illiquidity of pension wealth is likely to have the most pronounced influence on behaviour in the context of time inconsistent preferences.

Individual data sources are reported alongside the parameter estimates throughout the discussion that follows.

C. First stage parameter estimates

The structural model is based upon a total of 395 parameters. Of these, 3 describe interest rates on liquid net worth; 13 parameters describe the evolution

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

11 Calculated on 2007/08 FRS data, which indicates 12 per cent of all workers self employed, and 7.6 per cent employed in public sector (SIC code 75).

of household demographics (relationship status and dependent 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 7 to 10 of Appendix A.

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 7. Real interest and growth rates are reported in the top panel of Table 8. The lower limit cost of debt $\left(r_l^D\right)$ was set to 11.5 per cent per annum, and the upper limit $\left(r_u^D\right)$ to 19.8 per cent, 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 $\left(r^l\right)$ 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 $\left(r_t^p = r^p\right)$ 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 and 2006, as reported by Khoman & Weale (2008). The real rate of wage growth, used to adjust moments of financial characteristics in the second stage of the model estimation, was set to 1.3 per cent 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 per cent per annum, based on growth of the income threshold for the highest rate of income tax over the period 1997 to 2007.

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 (13). This equation was estimated on pooled data from waves 1 (1991) to 17 (2007) of the British Household Panel Survey (BHPS), which were 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.[12] Throughout the analysis, household age for

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

adult couples reported in survey data was set equal to the age of the eldest spouse. Parameter estimates are reported on the left hand side of the middle panel of Table 8.

The numbers of children by age and relationship status were described by equation (14) (the density function of the normal distribution), which provides a close reflection of the average numbers of children by parental age described by survey data. Equation (14) was estimated separately for singles and couples on 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 (14) are reported on the right hand side of the middle panel of Table 8,

$$s_{i,t+1} = \alpha_0^A + \alpha_1^A t + \alpha_2^A t^2 + \alpha_3^A t^3 + \alpha_4^A s_{i,t} \quad (13)$$

$$n_{i,t}^c = \alpha_0^C \exp\left\{\alpha_1^C \left(t - \alpha_2^C\right)^2\right\} \quad (14)$$

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 same-aged 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.

The official data permit survival rates to be calculated to age 94, whereas a maximum age of 120 was 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 used are reported at the bottom of Table 8.

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.E) 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 Family Resources Survey (FRS) (described in Section 2.C). The associated sample statistics are reported in the top panel of Table 9.

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 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 Section C.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.[13] These statistics are reported toward the top of Table 9.

The distribution of wages at age 20 Each simulated household that is generated by the model (discussed in Section 2.G) 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.[14] 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 9.

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 (7a) as:

$$\begin{aligned} \ln\left(g_{i,t+2}\right) - \ln\left(g_{i,t}\right) &= \ln\left(\mu\left(emp_{i,t+2}\right)\right) - \ln\left(\mu\left(emp_{i,t}\right)\right) + .. \\ &+ f_h\left(n^a_{i,t}, t\right) + f_h\left(n^a_{i,t+1}, t+1\right) + .. \\ &+ \sum_{k=t}^{t+1}\sum_{j=1}^{n} \kappa_j\left(emp^j_{i,k}\right) + \omega_{i,t+1} + \omega_{i,t} \end{aligned} \tag{15}$$

[13] 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.

[14] 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 Section C.5.

where n is the number of potential labour states, $emp^{j}_{i,t}$ 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 respective experience effect; all other variables are as defined previously.[15] Where relationship status was observed to change between adjacent periods, omission of an experience effect enabled equation (7a) 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 waves 1 to 17 of the BHPS for households aged between 20 and 64 were consequently used for estimation, organised and screened as described in Section C.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.[16]

The results of unrestricted estimations are reported for newly married and newly single households in Table 9. 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 10.

Taxes and benefits As discussed in Section 2.3, 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 reflect the schedules by household demographic category that are reported

15 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.

16 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.

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 assumption was made because the White Paper was both freely available and widely publicised during the period covered by the estimation, and is a sensible data source for the specification of agent expectations. In line with the pensions White Paper, the model assumes a state pension age of 68. At this age, all individuals were 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 were assumed to keep pace with the increased generosity of the flat-rate state pension, so that they could 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 assumed a 10% discount to the value of these state retirement benefits, to reflect on-going concerns over their sustainability.[17]

Private pensions There is a great deal of diversity in private pension arrangements in the UK, and in the details of occupational pensions in particular. This aspect of the model specification was further complicated by a lack of data at the household level regarding the magnitude of pension contributions, and the contributions of employers in particular. The endogenous pension decision was consequently restricted for the estimation to focus upon the issue of pension participation. Any household with a wage in excess of $\pi^{pl} = \$317$ per week – 75% of the median household wage in 2007 – was considered eligible to participate in the pension during the given year. The pension contribution rate for employees who choose to participate in a private pension was set to $\pi^{pc} = 8\%$ 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 $\pi^{p}_{ec} = 11\%$ of employee earnings, which is the average contribution rate to employer sponsored pensions that is reported in Forth & Stokes (2008).

[17] The benefits adopted for analysis applied 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).

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.[18] 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.

D. Second stage preference parameter estimates

Moments for the second stage estimation The statistical analysis that is reported here is structured around the observation that, relative to time-consistent agents, sophisticatedly myopic consumers will perceive as valuable commitment mechanisms that resolve conflict between the preferences of different intertemporal selves in favour of the present self. The unobserved preference parameters of the model were consequently 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, in common with Laibson et al. (2007). Age and relationship specific means of log household *consumption* are important in determining discount factors and the isoelastic parameter γ, given the 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 offered by wages that respond to an experience effect, in common with Fang & Silverman (2007). 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 focusing on the age band 50 to 59 to capture retirement behaviour.

The moments considered for estimating the model preference parameters are reported in Table 11 of Appendix B.

Parameter estimates Table 1 reports regression statistics 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 per cent per annum, which is insignificantly different from the estimated rate of return to positive balances of

[18] 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.

liquid net worth described in Section C. 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.[19] 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 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 for the proposition that the discount rate associated with the first prospective year – at 21 per cent – exceeds the long-run discount rate – at 2.5 per cent 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, non-durable consumption obviously not being one of these.

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 attributable to the broader subgroup of the population that is considered for estimation, relative to Laibson et al. and Fang and Silverman.

The analyses reported in Section 4 are principally based upon the parameter estimates reported in Table 1. To facilitate sensitivity analysis of the results obtained to the degree of myopia, δ was re-estimated for a given set of parameter values $(\gamma, \epsilon, \alpha, \beta)$. Starting from the estimates set out in Table 1, the isoelastic parameter γ was restricted to 1.4, the intratemporal elasticity ϵ to 0.55, and the utility price

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

of leisure to 1.3983.[20] Seven alternative values for the short-run excess discount factor β are considered, centered over 0.85, and spaced evenly over the domain $[0.70, 1.00]$. δ was re-estimated for each of these alternative values of β to focus the analysis upon the influence of myopia, by (imperfectly) controlling for impatience. The estimates obtained for δ, given the parameter restrictions set out above, are reported in Table 2.

Measures reported for the loss function in Table 2 indicate that the best overall fit to the sample moments was obtained for $\beta = 0.85$, consistent with the results reported in Table 1. 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 2 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 which the discount factors under each form of discounting are equivalent, $\hat{t} = \ln(\beta_1) / [\ln(\delta_0) - \ln(\delta_1)]$. For time periods less than the term-to-equivalence, quasi-hyperbolic discounting applies a lower discount factor (higher annualised discount rate), relative to exponential discounting, and vice versa for periods in excess of the term-to-equivalence. The statistics that are reported at the bottom of Table 2 all imply a term-to-equivalence of around 20 years, indicating that lower values of β imply greater disparity between short-run and long-run discount rates – and therefore more pronounced time-inconsistency of preferences – while maintaining the period over which the myopic specifications imply greater impatience, relative to exponential discounting.

Table 1: Structural estimation of full set of preference parameters

	exponential		quasi-hyperbolic	
parameter	estimate	std error	estimate	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		3.471 E-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

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

Table 2: 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)

4. THE EFFECTS OF INTRODUCING A DEFINED CONTRIBUTION (DC) PENSION SCHEME

A. Policy counterfactuals

The analysis 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. Long-run 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 compared simulations is the considered policy environment.[21] 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 was conducted by comparing behaviour and welfare under two principal policy environments, which are distinguished from one another by the existence of a DC pension scheme structured around the National Employment Savings Trust (NEST). This central policy counterfactual is consistent with the motivation underlying the introduction of the NEST, which is to extend pension eligibility to people who are not currently served by the existing system of private pensions in the UK. The terms of the DC pension that is considered here are also specified to reflect the broad strokes of the NEST. Where the DC pension exists, then all employees under age 68 are eligible to choose to participate in the scheme. If they do choose to participate, then they must also specify the proportion of their gross labour income to contribute to the scheme during the given year, subject to a lower bound of 5%. Any employee who chooses to participate in the DC pension receives a matching

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

employer contribution worth 3% of gross 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, with the remainder used to purchase a life annuity, paying an actuarially fair dividend subject to a capital charge of 4.7% (as set out in Sections C and D).

The terms of the DC pension that are set out above differ from the NEST in four respects. *First*, the assumption that the pension fund is illiquid until age 68 contrasts with the minimum pensionable age of 55 that is currently imposed in the UK. 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. 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, 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 contributions can be invested. The current analysis abstracts from the detailed asset allocation problem, by focusing 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 tend to understate contribution rates, and ultimately rates of 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 offset the pecuniary impact of the DC pension scheme consequently have an important bearing upon the results obtained. These adjustments were administered through the government budget constraint on the assumption that the matching (employer) 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 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 (returned to below). As similar results were obtained under both methods of tax adjustment, results assuming the fixed proportional tax on labour income are reported in the following subsections, and those obtained under the alternative tax adjustment can be obtained from the author upon request.

I begin by discussing effects of the DC pension simulated under the preference parameters reported in Table 1. Section 4.B reports responses on the assumption of exponential discounting, and Section 4.C explores the effects of myopia on the assumption of quasi-hyperbolic discounting. Sensitivity of the analysis to the extent of myopia is then explored with reference to the preference parameters that are reported in Table 2.

B. Behavioural responses in the context of time-consistent preferences

Table 3 reports the long-run behavioural and welfare effects of introducing the DC pension set out in Section A, given the model parameters reported for exponential discounting in Table 1, and on the assumption that the pension fund earns the same real rate of return as positive balances on liquid net worth (2.7 per cent per annum). I report the effects of the DC pension in per-capita terms because the NEST is explicitly designed to address the needs of individual employees in the UK, rather than an economy-wide reform.

Table 3 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 3, 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.

Table 3: 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

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 E). Furthermore, households toward the bottom of the lifetime income distribution that expect weak wage growth, also 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 3 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. These shifts reflect two factors. First, and most important, the DC pension encourages increased retirement saving, which allows households to enter retirement on preferable terms from pension age. Second, it is driven by the timing of the influence of the DC pension – and the compensating tax adjustments – on the returns to labour. Prior to pension age, the DC pension tends to raise the return to labour supply, which is partly off-set by the coincident 5.9 per cent fixed tax rate applied to all wage income. In contrast, only the effect of the fixed tax on wage income applies from pension age, which tends to dampen the incentive to supply labour. 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 per cent, well below the 40 per cent average off-set currently projected for the NEST by the government.

There is extensive uncertainty in the empirical literature regarding the impact of pensions on aggregate household saving, and theory provides little guidance about what we should expect. One of the first studies to consider the effects of retirement pensions on private saving is by Feldstein (1974), who used US macro-data to find that social security depresses personal saving by 30-50 per cent. During the 1980s a number of papers reported econometric estimates based upon micro-data, which generally suggest that retirement pensions have a small effect on private saving (see, for example, King & Dicks-Mireaux (1982), and Diamond & Hausman (1984)), with the implication that reserves built up under retirement pensions generally represent an net addition to national wealth. More recently, however, Gale (1998) and Attanasio & Rohwedder (2003) have reported much larger offsets – between 70 and 80 per cent – depending upon the focus of the analysis and the specification adopted. Like the studies undertaken in the 1980s, these more recent papers are based upon econometric estimates from micro-data, but they differ from the earlier studies in that the specifications considered for analysis are based upon inferences drawn from the life-cycle model, adjusting for age and time effects on the relationship between private saving and pension wealth.

The inconclusive nature of the econometric evidence has been attributed to a number of factors. These include lags in the adjustment of saving behaviour to policy reforms (see, for example, Börsch-Supan & Brugiavini (2001) for discussion); heterogeneity of agent behaviour with regard to individual circumstances (eg. Gale (1998) and Attanasio & Rohwedder (2003)); and the availability of suitable data (eg. Miles (1999)).

The low rates of pension off-setting that are reported here are attributable to disparities between the policy environment assumed for estimating the model, and the policy counterfactuals considered for analysis. The estimations assume a pension scheme that offers generous terms, relative to either saving in liquid wealth or the pension asset that is considered here. Simulations based on the estimated model parameters and in the absence of any pension asset consequently tend to result in small measures of household wealth, which limits the extent to which saving in a pension can be off-set when this asset is included for analysis. The results that are reported here highlight the need to take account of agent specific circumstances when considering how far pension saving is likely to substitute for other forms of saving, particularly when the target population possesses modest financial means as is the case for the NEST.

Welfare effects in the form of compensating variations are reported at the bottom of Table 3. These statistics indicate that the 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 the 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 the 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 welfare effects of a DC pension become positive (negative compensating variations) as age increases, reflecting the increase in saving that is motivated by the DC pension scheme. Furthermore, the profile of the welfare effect is reasonably flat through the income distribution at age 20, which reflects the uncertainty that is associated with how lifetime prospects will evolve. 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 per cent. This is almost twice the value of the matching employer contribution of 3 per cent 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 smaller proportional adjustment to wages relative to the current analysis, which is sufficient to result 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 wealth effect of the proportional tax on earnings is sufficient to increase rates of employment, relative to a counterfactual where no proportional tax is applied (not reported). 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 the context of the DC pension from state pension age. The earlier retirement ages simulated in the context of the DC pension reduce tax receipts levied on the foregone labour income, and increase the fiscal burden of welfare payments to retirees, which are all off-set by the tax adjustment to wages.

C. Responses when preferences are myopic

The policy counterfactual that is considered here is identical to that of the preceding subsection, with the exception that behavioural responses are generated assuming the estimated model parameters that describe quasi-hyperbolic discounting reported in Table 1.

Comparing the top panel of Tables 3 and 4 reveals that the allowance made for myopia tends to exaggerate rates of participation in the DC pension scheme, which increase by 2.5 percentage points 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 3). That these same households also tend to reduce their pension participation later in life if they have myopic preferences, reflect the fact that savings accrued early in life are most at risk of premature consumption in the context of present biased preferences.

Table 4: 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 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

Employment prior to retirement (not reported in Tables 3 or 4) is not much affected by the allowance made for quasi-hyperbolic discounting; average rates of employment between ages 20 and 55 (not reported) increase by 0.2 per cent in response to the DC pension under quasi-hyperbolic discounting, and by 0.3 per cent under exponential discounting. Hence the alternative commitment mechanism considered by the model (labour supply in the 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 3 and 4 indicate that employment participation between ages 45 and 64 increases by 0.75 percentage points on average in response to the DC pensions when preferences are myopic, as compared with 0.3 percentage points in the 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 percentage points on average under the assumption of exponential discounting, and by over 16 percentage points under quasi-hyperbolic discounting. The more pronounced reduction in employment from pension age that is generated under quasi-hyperbolic discounting is consistent with the dampened saving incentives due to the time inconsistency of myopic preferences, 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 mitigate this effect.

The statistics reported for pension wealth in Tables 3 and 4 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 highlights the relative importance of the commitment mechanism provided by the pension asset early in the working lifetime.

The statistics for total net worth reveal that aggregate saving rises in response to a DC pension by almost 10 per cent more on average between ages 50 and 67 when preferences are myopic, relative to the case of exponential discounting[22]. The distributional statistics that are reported in the respective tables indicate that this excess savings response in the 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 weaker life-cycle savings motives of low income households relative to those on higher incomes, 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 because the imperfect substitutability between pension wealth and liquid wealth is exaggerated in the 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 3 and 4. 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 insufficient 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 per cent of median annual household disposable income at age 20 in the context of the DC pension to be as well off as in the absence of the scheme, and this payment increases to

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

between 4 and 5 per cent for households on higher lifetime incomes. Furthermore, between ages 20 and 49, the welfare effect of a DC pension switches from being more preferable under myopic preferences, to more preferable 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.

D. Sensitivity to the 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 2. 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.

Table 5: 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 with no pension asset.
* Wealth expressed as ratio of median annual household disposable income between ages 20 and 67, worth £52,043.

Statistics that describe the effects of the introduction of the pension asset on savings behaviour are reported in Table 5. 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 per cent 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 that is 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 per cent per annum (approximating the rate considered in Table 4) to 4 per cent 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 per cent (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 per cent (from 22.5 to 28.3 per cent, not reported in the table).

The top panel of Table 5 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 5 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 the 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 the 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 in the return paid to pension wealth.

The middle panel of Table 5 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 Section C 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 5, 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 Section C, 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 Section B is that the DC pension is associated with a net welfare loss equivalent to 15 per cent of average annual household disposable income at the beginning of the simulated lifetime. Although this loss is reduced to 4 per cent under the myopic specification considered in Section C, it is nevertheless reported for households throughout the earnings distribution. Table 6 reports how these welfare effects vary by the interest rate on pension wealth and the degree of myopia. The table indicates that the 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

Table 6: 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 (negative values indicate positive effects)

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.

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 of the justifications raised for the introduction of the NEST. 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 6 reveals that the welfare effect of a rise in the return to the pension asset trails off at higher rates of return. This is due to the diminishing marginal utility of consumption, and because, at high interest rates, the wealth effect dominates leading to a fall in pension scheme participation. The largest differences for the welfare effects of the DC pension between alternative specifications for myopia are observed when the return to the pension asset is low. The 7 per cent rate of return to pension wealth is included in the table to consider the welfare response in the region of the apparent 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. Conclusions

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. The analysis is structured around the National Employment Savings Trust that will be introduced in the UK in 2012, and the parameters of the structural model used to conduct the analysis were estimated on survey data for a broad subgroup of the UK population. Particular attention is paid to the influence on the analysis of allowing for joint decisions of labour supply and saving, which are crucial to understanding retirement behaviour.

The parameter estimates that are reported for the structural model support the hypothesis of quasi-hyperbolic discounting, indicating an estimate of the excess short-run discount factor equal to 0.845 with a standard deviation of 0.040. The allowance for myopia is identified as improving the model's match to survey data regarding pension scheme participation and labour supply, consistent with the potential role of these factors in providing commitment mechanisms within the model. The estimate for the excess short-run discount factor exceeds those reported in previous studies (implying less pronounced myopia), which may be due to the relatively broad population subgroup upon which the current econometric analysis is based.

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 response, increasing average total net worth between ages 50 and 67 by between 6 and 22 per cent depending upon the household income quintile, when measured under the central policy scenario. Associated sensitivity analysis, however, indicates that the impact of myopia on aggregate savings depends upon the return to pension wealth. At low rates of return to pension wealth, myopia tends to increase savings held in the pension asset, but at high rates of return myopia tends to reduce saving in the pension asset. These results reflect the role of the pension scheme as a commitment mechanism, relative to its role as an efficient vehicle for saving.

Labour supply is increased very slightly prior to pension age by the DC pension scheme throughout the analysis, but falls substantially after households gain access to their pension wealth. Labour supply falls by an average of 11 percentage points between ages 65 and 74 under the central policy scenario and on the assumption of exponential discounting, and by 16 percentage points under quasi-hyperbolic discounting. The fall in labour supply from pension age has an important bearing upon the compensating adjustments that are applied in the analysis to off-set the effect that the DC pension has on the average returns to labour supply. Under the central policy scenario, this results in the finding that introduction of the DC pension would reduce welfare at the beginning of the life, by an average amount worth 15 per cent of average annual disposable income under exponential discounting, and by 4 per cent of average annual disposable income under quasi-hyperbolic discounting. Notably, however, the welfare effect of the DC pension at the beginning of life is found to respond positively to the rate of return to the pension asset, and to the disparity between the short-run and long-run discount rates. In the region of the unrestricted parameter estimates for the structural model, the analysis suggests that the DC pension would improve welfare if the NEST's target of reducing annual management charges by 1 per cent of capital is achieved.

The current analysis is limited to considering the implications for responses to a DC pension of sophisticated myopia, so that agents are assumed to be fully aware of their propensity to over-consume. However, it is quite likely that at least some people are naïvely unaware of their myopia, which would negate the welfare benefits of the commitment mechanism offered by pension fund illiquidity. Furthermore, even if the idea that some people are naïvely myopic is rejected, accommodating such behaviour could facilitate a more nuanced interpretation of the results that are reported here.

More substantively, 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 aspect of the scheme reflects extensive empirical evidence 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 (see, for example, Madrian & Shea (2001)). It would consequently be of 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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A. First Stage Parameter Estimates

Table 7: 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 (2006 b), paragraph 3.34
** paid on top of flat-rate state pension no standard errors obtained

Table 8: 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		
	proportion of households single at age 20*	**0.45**
	all households single from age*	**100**

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	

non-linear regressions for number of children

variable	singles coefficient	singles std. error	couples coefficient	couples 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 - see equation (16) 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 9: 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^*						
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 10: 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 statistic				
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 *

B. Moments for Second Stage Estimation

Table 11: 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	0.00650	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).*

A Framework for Pension Policy Analysis in Ireland: PENMOD, a Dynamic Simulation Model*

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1. Introduction

Public policy towards both private pensions and state-provided pensions must be framed in a long-term context. Decisions regarding participation in private schemes, and the extent of contributions thereto, have implications which unfold over time. In defined contribution (DC) schemes, an individual's pension fund is built up over the working lifetime, and then drawn down in retirement. Government's budget constraint also leads to trade-offs between the level of the state pension, the age at which it becomes payable, and the taxes required to finance it. Because of the essential dynamic elements in pension contributions and payments, the impact of policy changes is not well captured by static models, which take a "snapshot" of the impact at a point in time. While such models (including SWITCH, the ESRI tax-benefit model) can provide some insights into the impact of pension-related policies, a fuller analysis must take account of the complex interplay of forces over time.

The approach taken here is well established in the economic literature on pensions. Essentially, our model (PENMOD) takes a representative cohort of individuals and simulates key elements of their lifetime experience. This includes both economic elements such as labour market participation and wages as they age as well as demographic elements (marriage, divorce, children, death). Crucially, decisions

* The model described here is based upon the NIBAX model architecture, as described in van de Ven (2011). We are grateful to Gerry Hughes and to Pete Lunn for helping to plug gaps in our knowledge. We are also indebted to several members of CSO staff for assistance: Tom McMahon, Pamela Lafferty, Marion McCann, Deirdre Cullen, and Shaun McLaughlin. Responsibility for any errors or obscurities rests with the authors.

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regarding savings and pensions are also taken into account. Policy instruments in terms of income tax and social welfare are also included.

The need to take into account a sequence of decisions over each individual's full lifetime (up to the age of 120) imposes a very strict discipline on the degree of detail that can be incorporated into the model. Static models (such as SWITCH) can include a very high degree of detail in their description of the tax and welfare system. Dynamic models (such as PENMOD) must use a broader brush, in order to be able to provide greater depth in terms of the analysis over time. Thus, it is not a case of one class of model being "better" than another; rather it is a question of different classes of model being more suitable for different purposes.

A number of strategic simplifications are needed to ensure that the dynamic microsimulation model captures key features of the tax/welfare and pension systems while remaining tractable. One major simplification is that the model does not attempt to deal with public sector pensions, where the issues which arise are of a different type. We focus instead on the private sector, where decisions regarding the balance between contributions towards pension savings and the income in retirement are more subject to the influence of economic and policy variables. Second, we focus on private sector employees rather than the self-employed. This is because the terms of retirement for the self-employed often depend upon the envisaged income arising from ownership of a family business, or revenues arising from its sale that are distinct from the pension system with which we are immediately concerned. Third, we do not attempt to deal with issues of illness and longer-term incapacity to work. There are both state schemes (Illness Benefit, Invalidity Pension, Disability Allowance) and private schemes (permanent health insurance) which are geared towards dealing with income support for those unable to work. The issues arising are, however, too complex to include when modelling the long-term evolution of incomes and pensions and are, therefore, outside the scope of the present model. Simplifications of this type are common in the international literature in this area.

As regards the pension regime itself, this is characterised by up to five different types of pension scheme running in parallel. Each scheme takes a defined contribution form, where the approach adopted is to allow for schemes of differing "quality", with the probability of obtaining higher quality pensions rising with income – details of the approach are set out in Section 2.3.

The remainder of the paper is set out in 7 sections as follows. First, a full description of the characteristics that are reflected by the model, and the behavioural framework upon which it is based, are provided in Section 2. Section 3 provides technical details of how the model generates behavioural responses to policy change. The approach taken to calibrate the model against Irish survey data is described in Section 4, and calibrated model parameters are reported in Sections 5 and 6. A brief example of the type of policy analysis that can be conducted using the model is reported in Section 7, and a summary and directions for further research are provided in the conclusion.

2. Model specifics

The decision unit in the model is the nuclear family unit, defined as a single adult or partner couple and their dependent children.[1] The model divides the life course into annual increments, and can be used to consider household decisions regarding: consumption, labour supply, the portfolio allocation of liquid wealth between safe and risky assets, and private pension contributions. These decisions are simulated 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 their age, number of adults, number of children, wage rate, liquid wealth, pension opportunities, private sector pension rights, and time of death. The belief structure is rational, in the sense that expectations are calculated on probability distributions that are consistent with the intertemporal decision making environment.

Of the eight characteristics that define the circumstances of a household, seven can be considered stochastic (relationship status, number of children, private sector pension scheme eligibility, private sector pension rights, wage rates, liquid wealth, and time of death), and only age is forced to be deterministic.

As a brief overview, the model permits:

- the adjustment of preferences over consumption, leisure, and bequests
- adjustment of the imposed liquidity constraints, which are defined both in terms of hard credit limits and variable interest charges that depend on the debt to income ratios
- inclusion of uncertainty over relationship status (single or couple)
    - provided that relationship status is considered to be uncertain, the number of children in a household can also be modelled stochastically
- alternative options in regard to the nature of uncertainty associated with labour incomes, including the possibility of receiving a low (zero) wage offer
- households to invest some of their liquid wealth in a risky asset

1 For convenience, we use the term "household" interchangeably with "narrow nuclear family unit", which has the advantage of brevity at the cost of a slight abuse of language. It should nevertheless be understood that adult children are treated as independent units in our analysis.

  - the nature of the uncertainty associated with returns to the risky asset can also be altered
- households to choose their labour supply between discrete alternatives
- adjustment of a detailed tax and benefits structure
- private sector pensions
  - contribution rates (and ultimately membership) can also be made a decision variable
  - contribution rates (employee and employer) can be made stochastic
  - the stochastic nature of the return to private pension wealth can be adjusted

This section begins by defining the assumed preference relation, before describing the wealth constraint, the simulation of pensions, and the processes assumed for the evolution of income and household size.

2.1. The utility function

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

$$U_{i,t} = \frac{1}{1-1/\gamma}\left\{u\left(\frac{c_{i,t}}{\theta_{i,t}}, l_{i,t}\right)^{1-1/\gamma} + \right.$$
$$+ E_t\left[\beta_1\delta\left(\varphi_{1,t}u\left(\frac{c_{i,t+1}}{\theta_{i,t+1}}, l_{i,t+1}\right)^{1-1/\gamma} + (1-\varphi_{1,t})\left(\zeta_a + \zeta_b w^+_{i,t+1}\right)^{1-1/\gamma}\right) + \right.$$
$$\left.\left. + \beta_1\beta_2\sum_{j=t+2}^{T}\delta^{j-t}\left(\varphi_{j-t,t}u\left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,j}\right)^{1-1/\gamma} + (1-\varphi_{j-t,t})\left(\zeta_a + \zeta_b w^+_{i,j}\right)^{1-1/\gamma}\right)\right]\right\} \tag{1}$$

where $1/\gamma > 0$ is the (constant) coefficient of relative risk aversion; E_t is the expectations operator; T is the maximum potential age; β_1, β_2, and δ are discount factors (assumed to be the same for all households); $\varphi_{j-t,t}$ is the probability of living to age j, given survival to age t; $c_{i,t} \in R^+$ is discretionary composite consumption; $l_{i,t} \in [0,1]$ is the proportion of household time spent in leisure; $\theta_{i,t} \in R^+$ is adult equivalent size based on the "revised" or "modified" OECD scale; the parameters ζ_a and ζ_b reflect the "warm-glow" model of bequests; and $w^+_{i,t} \in R^+$ is net liquid wealth when this is positive and zero otherwise.

The labour supply decision (if it is included in the model) is considered to be made between discrete alternatives, which reflects the view that this provides a closer approximation to reality than if it is defined as a continuous decision variable for given wage rates. When adults are modelled explicitly, then households with one adult can choose from up to three labour options; full-time $\left(l^{FT}_{i,t}\right)$, part-time $\left(l^{PT}_{i,t}\right)$, and not employed $(l_{i,t} = 1)$. Similarly, couples can choose from up to five labour options; both full-time employed $\left(l_{i,t}^{2FT}\right)$, one full-time and one part-time employed $\left(l_{i,t}^{FtPt}\right)$, one full-time and the other not employed $\left(l_{i,t}^{FtNe}\right)$, one part-time and the other not employed $\left(l_{i,t}^{PtNe}\right)$, and both not employed $(l_{i,t} = 1)$. When adults are not modelled explicitly, then labour supply is restricted to one of two options: employed or not employed.

To the extent that the focus on discrete labour options limits employment decisions relative to the practical reality, it will dampen the responsiveness of labour supply behaviour implied by the simulation model, and dampen variation in employment incomes. The former of these effects implies that the parametrisation of the model may require a labour elasticity that overstates the practical reality, while the latter suggests that excessive variation in labour incomes may be required to reflect the wage dispersion described by survey data.

The modified OECD scale assigns a value of 1.0 to the household reference person, 0.5 to each additional adult member and 0.3 to each child, and is currently the standard scale for adjusting incomes before housing costs in European countries. Its inclusion in the preference relation reflects the fact that household size has been found to have an important influence on the timing of consumption (e.g. Attanasio & Weber (1995) and Blundell et al. (1994)).[2]

The model incorporates an allowance for behavioural myopia, through its assumption of quasi-hyperbolic preferences following Laibson (1997). Such preferences are interesting because they are time inconsistent, giving rise to the potential for "conflict between the preferences of different intertemporal selves" (Diamond & Köszegi (2003), p. 1840). The current version of the model focuses exclusively on rational expectations, and consequently does not permit consideration of decisions by so-called "naïve" consumers, who are unaware of their self-control problems in the context of quasi-hyperbolic discounting. The model assumes that all discount parameters are the same for all individuals, and time invariant. This is in contrast to the approach that is adopted by Gustman & Steinmeier (2005), who allow variation in the rate of time preference to be an important factor in reflecting heterogeneity in household retirement behaviour. We have chosen not to do this to ensure that heterogeneity of household behaviour generated by the model is driven by heterogeneity in observable household characteristics.

2 An empirical study by Fernandez-Villaverde & Krueger (2006) of US data from the Consumer Expenditure Survey suggests that roughly half of the variation observed for lifetime household consumption can be explained by changes in household size, as described by equivalence scales. See Balcer & Sadka (1986) and Muellbauer & van de Ven (2004) on the use of this form of adjustment for household size in the utility function.

The warm-glow model of bequests simplifies the associated analytical problem, relative to alternatives that have been considered in the literature.[3] Including a bequest motive in the model raises the natural counter-party question of who receives the legacies that are left. The most accurate approximation to reality would involve including the possibility that households receive a bequest at any age, and then to growth adjust the value of bequests received to the value of bequests made. This would add to the uncertainty associated with the decision problem, and so is omitted from the current version of the model. Rather, it is assumed that households leave their legacies to the state (potentially in the form of a 100% inheritance tax), which is a common simplifying assumption.

A Constant Elasticity of Substitution function was selected for within period utility,

$$u\left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,t}\right) = \left(\left(\frac{c_{i,j}}{\theta_{i,j}}\right)^{(1-1/\epsilon)} + \alpha^{1/\epsilon} l_{i,t}^{(1-1/\epsilon)}\right)^{\frac{1}{1-1/\epsilon}} \quad (2)$$

where $\epsilon > 0$ is the (period specific) elasticity of substitution between equivalised consumption $(c_{i,t}/\theta_{i,t})$ and leisure $(l_{i,t})$. The constant $\alpha > 0$ is referred to as the utility price of leisure. The specification of intertemporal preferences described by equations (1) and (2) is standard in the literature, despite the contention that is associated with the assumption of time separability (see Deaton & Muellbauer (1980), pp. 124-125, or Hicks (1939), p. 261). This specification of preferences implicitly assumes that characteristics which affect utility, but are not explicitly stated, enter the utility function in an additive way.

2.2. The wealth constraint and simulation of disposable income

Equation (1) is considered to be maximised, subject to an age specific credit constraint imposed on liquid net worth, $w_{i,t} \geq D_t$ for household i at age t.[4] The age profile of D_t can either be exogenously defined in the model, or be relaxed subject to the constraint that all households must have repaid their debts by an exogenously defined age, $t_D \leq T$ (the maximum terminal age assumed for the model).[5] Liquid net worth is defined as the sum of safe liquid assets, $w^s_{i,t} \in [D_t, \infty)$, and risky liquid assets, $w^r_{i,t} \in [0, \infty)$. Intertemporal variation of $w_{i,t}$ is described by:

3 See, for example, Andreoni (1989) for details regarding the warm-glow model.

4 Note that $w^+_{i,t}$ referred to above is related to $w_{i,t}$, with $w^+_{i,t} = 0$ if $w_{i,t} < 0$, and $w^+_{i,t} = w_{i,t}$ otherwise.

5 Note that the structure of the decision problem considered here implies that relaxing the upper limit on debt does not permit households to consume an infinite amount prior to the age by which all debts are forced to be repaid. In the context of uncertainty, and when marginal utility approaches infinity as (discretionary) consumption tends toward zero, relaxing the constraint on debt implies an upper bound on consumption that is defined in terms of the minimum potential income stream that a household may receive in all future periods up to the date by which all debts must be repaid.

$$w_{i,t} = \begin{cases} \hat{w}_{i,t} & t \neq t_{SPA} \\ (1-\pi_a^l)\hat{w}_{i,t} + (1-\pi_a^p)w_{i,t}^p + (1-\pi_a^o)w_{i,t}^o & t = t_{SPA} \end{cases} \quad \text{(3a)}$$

$$\hat{w}_{i,t} = \begin{cases} \pi_{div}\left(w_{i,t-1} - c_{i,t-1} + \tau_{i,t-1}\right) & n_t^a < n_{t-1}^a, t < t_{SPA} \\ w_{i,t-1} - c_{i,t-1} + \tau_{i,t-1} & \text{otherwise} \end{cases} \quad \text{(3b)}$$

$$\tau_{i,t} = \tau(l_{i,t}, x_{i,t}, n_{i,t}^a, n_{i,t}^c, r_{i,t}^s w_{i,t}^s, r_t^r w_{i,t}^r, pc_{i,t}, t) \quad \text{(3c)}$$

$$\ln(1+r_t^r) \sim N\left(\mu_r - \frac{\sigma_r^2}{2}, \sigma_r^2\right) \quad \text{(3d)}$$

where $w_{i,t}^p$ denotes wealth held in personal pensions; $w_{i,t}^o$ is wealth held in occupational pensions; π_a^l, π_a^p, and π_a^o are, respectively, the proportions of liquid wealth, private pension wealth, and occupational pension wealth that are used to purchase a life annuity at state pensionable age, t_{SPA}; π_{div} is the proportion of liquid wealth that is assumed to be lost upon marital dissolution prior to t_{SPA} (to capture the impact of divorce); and $\tau(.)$ denotes disposable income net of non-discretionary expenditure.

As the model has been designed explicitly to undertake public policy analysis, particular care was taken in formulating the module that simulates the effects of taxes and benefits on household disposable incomes. Equation (3c) 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, $n_{i,t}^a$, and children, $n_{i,t}^c$; the return to safe liquid assets, $r_{i,t}^s w_{i,t}^s$ (which is negative when $w_{i,t}^s < 0$); the return realised on risky liquid assets, $r_t^r w_{i,t}^r$ (possibly negative); contributions to private sector pensions, $pc_{i,t}$; and age, t.

The form of the budget constraint described by equation (3a) has been selected to minimise the computational burden of the utility maximisation problem. For the purposes of taxation, and in a discrete time model such as this, investment returns can be calculated on the basis of wealth held at the beginning of a given period, or wealth held at the end of the period. Calculating taxes with respect to wealth held at the beginning of a period (as it is here) implies that disposable income is made independent of consumption. This is advantageous when consumption is a choice variable, as it implies that the numerical routines that search for utility maximising values of consumption do not require repeated evaluations of disposable income for each consumption alternative that is tested.

We now describe details of the function that is used to evaluate disposable income. The lifetime is divided into two periods for the purpose of calculating disposable income: the working lifetime $t < t_{SPA}$, and pension receipt $t_{SPA} \leq t$. In each of these periods of life, 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 Ireland
2. simulating receipt of benefits from aggregate household take-home pay – this reflects the fact that benefits tend to be provided at the level of the family unit
3. household *disposable income* is then equal to aggregate take-home pay, plus benefits.

Calculation of taxable income for each adult in a household depends on the household's age, with property and non-property income being treated separately. Prior to state pensionable age, $t < t_{SPA}$, household non-property income $x_{i,t}$ considered for tax purposes is equal to labour income $g_{i,t}$ less the proportion of pension contributions that is considered tax exempt, π^{pe}; from state pensionable age it is equal to labour income plus the proportion of pension annuity income that is considered taxable, π^{pt}:

$$x_{i,t} = \begin{cases} g_{i,t} - \pi^{pe} pc_{i,t} & t < t_{SPA} \\ g_{i,t} + \pi^{pt} p_{i,t} & t \geq t_{SPA} \end{cases} \tag{4}$$

$$\text{where} \ : \ p_{i,t} = \begin{cases} \chi(\pi_a^p w_{i,t}^p + \pi_a^l \hat{w}_{i,t}) & t = t_{SPA} \\ \left(\dfrac{\pi^s + (1-\pi^s).(n_{i,t}^a - 1)}{\pi^s + (1-\pi^s).(n_{i,t-1}^a - 1)} \right) p_{i,t-1} & t > t_{SPA} \end{cases} \tag{5}$$

$p_{i,t}$ denotes pension annuity income, and χ is the annuity rate considered for analysis. The annuity purchased at age t_{SPA} is assumed to be inflation linked, and to reduce to a fraction π^s of its (real) value in the preceding year if one member of a couple departs the household in response to the mortality of a spouse.

Where the household is identified as supplying labour, and is younger than state pensionable 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 that is identified with a single wage earner has all of its non-property income allocated to that one earner; a household with one full-time and one part-time earner has non-property income allocated on the basis of an exogenously defined ratio; and a separate ratio is used to divide non-property income when both spouses of a household are full-time employed. 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 pensionable age, and who supply some labour. In this case, property income is allocated on the basis of an exogenous ratio that defines the proportion of wealth that is assumed to be held in the name of the lowest earning spouse. Property income, $y_{i,t}$, is equal to the sum of returns from the safe and risky liquid assets:

$$y_{i,t} = \begin{cases} r_t^r w_{i,t}^r + r_{i,t}^s w_{i,t}^s & \text{if } w_{i,t}^s > 0; r_t^r > 0 \\ r_{i,t}^s w_{i,t}^s & \text{if } w_{i,t}^s > 0; r_t^r \leq 0 \\ r_t^r w_{i,t}^r & \text{if } w_{i,t}^s \leq 0; r_t^r > 0 \\ 0 & \text{if } w_{i,t}^s \leq 0; r_t^r \leq 0 \end{cases} \tag{6}$$

Hence, the model assumes that the interest cost on loans, and losses due to negative risky asset returns cannot be written off against labour income for tax purposes.

The interest rate on safe liquid assets is assumed to depend upon whether $w_{i,t}^s$ indicates net investment assets, or net debts:

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

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 means 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.

The model is specified on the assumption that r_t^r is distributed such that $\mu_r < r_l^D$, in which case no rational (and risk averse) household will choose to borrow to fund investment in the risky liquid asset ($w_{i,t}^r > 0$ only if $w_{i,t}^s \geq 0$). Disposable income is consequently given by:

$$\tau_{i,t} = \begin{cases} \hat{\tau}_{i,t} & \text{if } r_t^r \geq 0; w_{i,t}^s \geq 0 \\ \hat{\tau}_{i,t} + r_t^r w_{i,t}^r & \text{if } r_t^r < 0; w_{i,t}^s \geq 0 \\ \hat{\tau}_{i,t} + r_t^s w_{i,t}^s & \text{if } w_{i,t}^s < 0 \end{cases} \tag{7}$$

$$\hat{\tau}_{i,t} = \begin{cases} x_{i,t} + y_{i,t} - tax_{i,t} + benefits_{i,t} - (1 - \pi^{pe})\left(pc_{i,t}^o + pc_{i,t}^p\right) & \text{if } t < t_{SPA} \\ x_{i,t} + y_{i,t} - tax_{i,t} + benefits_{i,t} - hsg_{i,t} + (1 - \pi^{pt})p_{i,t} & \text{if } t \geq t_{SPA} \end{cases} \tag{8}$$

where $tax_{i,t}$ denotes the simulated tax burden, and $benefits_{i,t}$ welfare benefits received.

2.2.1. Intertemporal indexing

It is likely that individuals take some account of wage growth when planning for the future: a 20 year old today can reasonably expect that labour incomes will be higher when they reach age 45 than are currently paid to today's 45 year olds. If this is true, then it is important that the rational agent model be calibrated against data that take wage growth into account (discussed at further length in Section 4). This gives rise to a host of complications regarding the appropriate intertemporal development to assume for the tax and benefits system: holding taxes and benefits fixed in the context of rising wages, for example, will result in widespread tax bracket creep and marginalisation of the welfare state, with important implications for simulated behaviour.

Two parameters of the model control the way in which the tax system evolve with time in the model. The first controls the rate at which tax thresholds grow with time, thereby offsetting bracket creep, and the second controls the rate of growth of welfare benefits. These parameters adjust the tax and benefits schedules in a way that is designed to omit the creation of poverty traps. Nevertheless, rapid temporal adjustment of the tax system can give rise to analytical problems, and the the model is programmed in a way that is designed to indicate when excessive variation has been called for. Separate routines have been developed that allow the disposable income schedules that are generated by the model to be viewed directly, and these are reviewed to verify that a model simulation is sensible.

2.3. Private Sector Pensions

Private sector pensions in the model 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. Although DC pensions account for less than half of all pensions that currently attract contributions in Ireland, there has been a strong temporal trend toward DC schemes since the 1990s (in common with countries throughout the OECD), which motivates our modelling in this regard. Up to five private sector pension schemes can be considered in parallel in the model, where schemes are distinguished by their respective rates of (exogenously defined) employer contributions. Pension contribution rates are defined as percentages of (total) labour income, implying that pension membership requires employment participation. Households are considered to be eligible to participate in only one pension scheme in any year, where eligibility to each scheme is identified stochastically with reference to a set of income dependent probabilities, and uncertainty between adjacent years can be suppressed in cases of continuous pension participation. Membership of a pension to which a household is eligible can either be exogenously imposed, or modelled as an endogenous decision. Similarly, the rate of private contributions to a pension scheme, $\pi^{p}_{i,t}$, can either be exogenously imposed, or considered endogenous in the model. Where private pension contributions are considered endogenous in the model, then these can be subject to a series of lower $\left(\pi_l^p\right)$ and upper $\left(\pi_u^p\right)$ bounds on eligible incomes, lower $\left(\pi_l^{pc}\right)$ and upper $\left(\pi_u^{pc}\right)$ bounds on contribution rates, and a ceiling on the value of the aggregate pension pot, $\pi_{\max}^p$.

Accrued rights to a private pension are described by:

$$w_{i,t}^p = \begin{cases} \left(1 + r_{t-1}^p\right) w_{i,t-1}^p + \left(\pi_{i,t}^p + \pi_{ec,j}^p\right) \left(g_{i,t} - \pi_l^p\right) & \text{member of scheme } j \\ \left(1 + r_{t-1}^p\right) w_{i,t-1}^p & \text{otherwise} \end{cases} \tag{9a}$$

$$\ln\left(1 + r_t^p\right) \sim N\left(\mu_p - \frac{\sigma_p^2}{2}, \sigma_p^2\right) \tag{9b}$$

2.4. Labour income dynamics

Up to three household characteristics influence labour income: the household's labour supply decision, the household's latent wage, $h_{i,t}$, and whether the household receives a wage offer $wo_{i,t}$. Households can be exposed to an exogenous, age and relationship specific probability of receiving a wage offer, $p^{wo}\left(n_{i,t}^a, t\right)$. This facility is designed to capture the incidence of (involuntary) unemployment. If a household receives a wage offer, then its labour income 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, in contrast, is assumed to receive $g_{i,t} = 0$ regardless of its labour supply decision (implying no labour supply where employment incurs a leisure penalty).

The decision to measure wage potential at the household level rather than at the level of the individual significantly simplifies the analytical problem. Separately accounting for the wages of each adult in a household is properly addressed only by the addition of a state variable to the model where households are comprised of an adult couple. Furthermore, there is significant empirical evidence to suggest that men and women have quite different labour market opportunities, with those of women exhibiting a relatively high degree of heterogeneity.[6] Hence, accounting for the wage potential of individuals could not ignore the sex of adult household members, thereby introducing an additional state variable. These issues are further

[6] On recent evidence regarding the labour market experience of women see, for example, Connolly & Gregory (2008).

complicated by the difficulties involved in characterising sex-specific wage generating processes, imperfect correlation of temporal innovations experienced by spouses, and so on. The model side-steps these issues, as the current state of computing technology makes it impractical to address them, and to analyse endogenous decisions over pension contributions.

In the first period of the simulated lifetime, t_0, each household is allocated a latent full-time wage, h_{i,t_0}, via a random draw from a log-normal distribution, $\log(h_{i,t_0}) \sim N\left(\mu_{n^a,t_0}, \sigma^2_{n^a,t_0}\right)$, where the parameters of the distribution depend upon the number of adults in the household, n^a. Thereafter, latent wages follow a random walk with drift described by the equation:

$$\log\left(\frac{h_{i,t}}{m\left(n^a_{i,t},t\right)}\right) = \log\left(\frac{h_{i,t-1}}{m\left(n^a_{i,t-1},t-1\right)}\right) + \kappa\left(n^a_{i,t-1}, t-1\right)\frac{(1-l_{i,t-1})}{(1-l_W)} + \omega_{i,t} \quad (10)$$

where the parameters $m(.)$ account for wage growth (and depend on age, t, and the number of adults in the household, $n^a_{i,t}$), $\kappa(.)$ is the return to another year of experience, and $\omega_{i,t} \sim N\left(0, \sigma^2_{\omega,n^a_{i,t-1}}\right)$ is a household specific disturbance term.

A change in the number of adults in a household affects wages through the experience effect, κ, and the wage growth parameters m. This model is closely related to alternatives that have been developed in the literature (see Sefton and van de Ven, 2004, for discussion), and has the practical advantage that it depends only upon variables from the current and immediately preceding periods $\left(t-1, n^a_{i,t-1}, n^a_{i,t}, h_{i,t-1}, l_{i,t-1}\right)$, which limits the number of characteristics that describe the circumstances of a household (and thereby the number of state variables in the optimisation problem). Furthermore, although the concept of an experience term in a wage regression is well established[7], its inclusion is an innovation for the related literature (e.g. Low, 2005, and French, 2005). Most related studies omit an experience term because it complicates the utility maximisation problem by invalidating two-stage budgeting. We have, however, found that its inclusion enables us to better capture the profile of labour supply during the lifecourse.

[7] With regard to statistical evidence of the effect of experience on income, Mincer & Ofek (1982) report that in the short run, every year out of the labour market can result in a 3.3%-7% fall in wages relative to those who remain employed. This study also finds, however, that the restoration of human capital tends to be faster than the original accumulation, so that the impact of early labour breaks reduce to 1.3%-1.8% in the long run. Eckstein & Wolpin (1989) do not make a distinction between the long run and short run impact of actual experience, but find that the first year out of the labour market reduces wages by around 2.5%, with subsequent years having a marginally diminishing effect. See also, Waldfogel (1998) and Myck & Paull (2004) for the role of experience in explaining the gender wage gap.

2.4.1. Complicating the standard decision making problem

The preferences defined by equations (1) and (2) are homothetic. Hence, if consumption and leisure were each defined over a continuous domain, and if the price of leisure was exogenous, then the preferred consumption to leisure ratio would be independent of an agent's wealth endowment. In this case, within period utility – equation (2) – at the decision making optimum can be expressed in terms of the period specific measure of total expenditure (on goods and leisure), and the maximisation problem can be resolved by two-stage budgeting. This decision making structure is fully consistent with the original analysis of Arrow, so that interpretation of $1/\gamma$ as relative risk aversion (and, similarly, of γ as a measure of the intertemporal elasticity of substitution of total expenditure) carries over.[8]

However, the focus on discrete labour options, and the inclusion of an experience effect on wages, complicate the intertemporal decision making problem. The discrete nature of labour supply implies that it is not possible to restate intratemporal utility at the decision making optimum as a function of within period total expenditure. Nevertheless, optimised intratemporal utility remains a continuous function of total within-period expenditure (albeit one that is subject to kinks at labour transitions) so that it remains sensible to interpret $1/\gamma$ as relative risk aversion (and, similarly, γ as a measure of the intertemporal elasticity of substitution of total expenditure). Meanwhile, the experience effect on wages implies that the price of leisure is endogenous to the decision making problem, thereby invalidating two stage budgeting. Furthermore, a positive experience effect on wages tends to depress savings rates as wealth rises.[9]

2.5. Household composition

The model allows for households to form and to split, for the arrival of children, and for the risk of death at different ages. The technical approach in terms of numbers of adults and children in a household is to allow these to evolve stochastically, following a "reduced form" nested logit model. The first (highest) level determines the number of adults in a household, and the second ("nested" within that) determines the number of children, given the age and number of adults in the household.

If the number of adults is selected to be uncertain, then a household can be comprised of either a single adult or adult couple, subject to stochastic variation

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[8] There is the separate issue of disentangling the intertemporal elasticity of substitution from relative risk aversion, which is not addressed here. See Epstein & Zin (1989).

[9] To see this, note that an experience effect on wages tends to increase the present-discounted cost of reduced labour supply, to the extent that an individual expects to want to work in the future. As wealth rises, labour attachment is weakened, which also weakens the experience effect on incentives to work in the short run. Including an experience effect on wages consequently tends to exaggerate the negative relationship between wealth and labour supply, thereby depressing the savings rate as wealth rises.

between adjacent years. The fact that children typically remain dependants in a household for a limited number of years implies that it is necessary to record both their numbers and ages when including them explicitly in the rational agent model. This substantially increases the computational burden. If, for example, a household was considered to be able to have children at any age between 20 and 45, with no more than one birth in any year, and no more than six dependent children at any one time, then this would add an additional 334,622 state variables to the computation problem (with a proportional increase in the associated computation time). In view of this, the model is currently specified to permit households to have up to three children at each of two discrete ages, so that the maximum number of dependent children in a household at any one time is limited to six.

This may seem somewhat artificial (it is as if larger families must involve multiple births, and births only occur at two specific ages). The precise timing of births is not a central focus of interest, however, and the approach taken here means that the presence and number of children can be taken into account, while abstracting somewhat from the associated detail.

The logit model that is considered to describe the evolution of adults in a household is given by equation (11):[10]

$$s_{i,t+1} = \alpha_0^A + \alpha_1^A t + \alpha_2^A t^2 + \alpha_3^A t^3 + \alpha_4^A dk_{i,t} + \alpha_5^A s_{i,t} \tag{11}$$

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, and $dk_{i,t}$ is a dummy variable that equals 1 if household i at age t has at least one child. With regard to the simulation of births, four separate ordered logit equations are applied; one for each of single and couple households, at each of the specified childbirth ages. The ordered logit equations assumed for the first childbirth age, for both singles and couples, do not include any additional household characteristics. The ordered logit equations for the second childbirth age includes the number of children born at the first childbirth age as an additional descriptive characteristic.

3. Solving the life-time decision problem

This section begins by discussing the conceptual approach adopted to solve the lifetime decision making problem, before describing details of the analytical routines used to implement the numerical solution.

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[10] When children are not modelled explicitly, then the cubic term in age and the dummy variable for children is omitted from the logit equation.

3.1. Conceptual approach

The procedures that we adopt use backward induction to solve for decisions that maximise expected lifetime utility. A terminal age T is assumed, following which death occurs with certainty. Utility maximising decisions at this terminal age are free of temporal dynamics, and are consequently straightforward to solve, for given numbers of adults n_t^a, wealth w_T, and annuity income p_T, omitting the household index i for brevity. We refer to the utility associated with this solution as the value function, $V_T(n_T^a, w_T, p_T)$. Furthermore, we can calculate the intermediate measures of welfare:

$$\widehat{u}(n_T^a, w_T, p_T) = u\left(\frac{\widehat{c}_T\left(n_T^a, w_T, p_T\right)}{\theta_T}, 1\right) \tag{12}$$

$$\widehat{X}(n_T^a, w_T, p_T) = E_t\left(\frac{1}{(1-1/\gamma)}\left(\zeta_a + \zeta_b \widehat{w}_{T+1}^{+}\left(n_T^a, w_T, p_T\right)\right)^{1-1/\gamma}\right) \tag{13}$$

where $\widehat{c}_T$ and $\widehat{w}_{T+1}$ denote the optimised measures of consumption and next period wealth, on the assumption that labour supply at the terminal age is not possible. We calculate these functions at all nodes of a three dimensional grid in the number of adults, wealth, and retirement annuity.

At age $T-1$, suppose that households are permitted to invest in risky assets and to supply labour. Here, the problem reduces to solving the Bellman equation:

$$\begin{aligned}
&V_{T-1}(n_{T-1}^a, w_{T-1}, h_{T-1}, wo_{T-1}, p_{T-1}) = \\
&= \max_{c_{T-1}, v_{T-1}, l_{T-1}} \left\{ \frac{1}{1-1/\gamma} u\left(\frac{c_{T-1}}{\theta_{T-1}}, l_{T-1}\right)^{1-1/\gamma} + \right. \\
&+ E_{T-1}\left[\frac{\beta_1 \delta}{1-1/\gamma}\left(\varphi_{1,T-1}\widehat{u}(n_T^a, w_T, p_T)^{1-1/\gamma} + (1-\varphi_{1,T-1})\left(\zeta_a + \zeta_b w_T^{+}\right)^{1-1/\gamma}\right) + \right. \\
&\left.\left. + \beta_1 \beta_2 \delta^2 \varphi_{1,T-1} \widehat{X}(n_T^a, w_T, p_T)\right]\right\}
\end{aligned} \tag{14}$$

subject to the intertemporal dynamics that are described above, where wo_{T-1} is a wage offer identifier taking the value 1 if a wage offer is received and zero otherwise, and v_{T-1} is the proportion of liquid wealth invested in the risky asset. We solve this optimisation problem for the $T-1$ value function, at each node of the five dimensional grid over the permissable state-space. The expectations operator is evaluated in the context of the log-normal distributions assumed for wages and risky asset returns, using the Gauss-Hermite quadrature, which permits evaluation at a set of discrete abscissae. Interpolation methods are used to evaluate the value function at points between the assumed grid nodes throughout the simulated lifetime.

Solutions for earlier ages then proceed via recursive repetition of the procedure outlined for age $T - 1$, given the solutions (previously) obtained for later ages. Prior to t_{SPA}, solutions may also be required for pension contributions, and the state space may be expanded to include children and the pension assets permitted in the model. A more complete description of the analytical problem, including the treatment of boundary conditions, is reported in the technical appendix.

The above procedure generates a grid that spans all possible combinations of characteristics that the model considers a household might have (the state space). The utility maximising decisions identified by the numerical procedure are stored at each grid intersection, alongside the numerical approximation of expected lifetime utility (the value function). Although this set of information can be informative in its own right, most analyses are based upon panel data for the life-course of a cohort of households that are generated using the grid defined above. The life course of a birth cohort is generated 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 reading the decisions stored at their respective grid co-ordinates. Given household *i*'s characteristics (state variables) and behaviour, its characteristics are aged one year following the processes that are considered to govern their intertemporal variation. Where these processes depend upon stochastic terms, random draws are taken from their defined distributions (commonly referred to as Monte Carlo simulation). This process is repeated to produce data for the entire life-course.

3.2. Details of solution routines

The model described here is complex and generates behaviour where no analytical solution exists. As such, it is reasonable to describe it as a 'black-box' routine, which raises concerns over the accuracy of the behavioural responses that it generates. These concerns are exaggerated by the fact that the value function may be both non-smooth and/or non-concave (although it is designed to be increasing and continuous), which can complicate the solution due to the existence of multiple local maxima.

It is important to recognise from the outset that *any* numerical solution is likely to be associated with a degree of error – the problem is to assess whether the scale of the inaccuracies generated by the model are qualitatively important for the purpose to which it is applied. The model includes *three* principal tools for assessing the accuracy of the numerical solutions that it derives: variation of solution detail, variation of interpolation methods, and variation of the numerical search routines that are used. The first is the most simple, and often the most powerful of the three.

When *varying the solution detail*, the size and number of grid points adopted for each of the continuous state variables can be altered, as can the number of abscissae used in the Gaussian quadrature.[11] Increasing the grid points provides a more detailed solution of the utility maximising problem, though it can also imply a rapid increase in computational burden. Increasing the grid points in multiple dimensions increases the computational burden geometrically rather than arithmetically; a problem that is commonly referred to as the curse of dimensionality.

The model includes both linear and cubic *interpolation methods*, for evaluating behaviour between discrete grid points.[12] Relative to linear interpolation, cubic interpolation produces a smoother functional form, and ensures continuous differentiability. Cubic interpolation also requires evaluations at 4^n grid points, rather than 2^n points, where n is the number of dimensions over which the interpolation is being taken. If the user indicates that cubic interpolation is to be used, then the model performs an internal check to determine whether the surface over which an interpolation is being conducted is reasonably smooth, before selecting the cubic interpolation for analysis; otherwise, it selects the linear interpolation.[13] It is of note that the cubic interpolation, and linear interpolation routines have been programmed separately, and so can be used to validate against one another.

Finally, the model includes three alternative *numerical search routines*, which are used to find utility maximising values of consumption. A 'brute force' procedure uses grid search methods to identify the local optimum associated with the highest numerical approximation of the value function. The advantage of this approach is that it makes no assumptions regarding the form that the value function takes. This advantage is, however, purchased at a very substantial increase in the computational burden associated with the search routine. Alternatively, Brent's method can be used to search over the consumption domain, based upon parabolic interpolation with a golden section search of repeated evaluations of the value function. This approach has been found to be efficient, particularly where the surface over which the search is conducted is reasonably well behaved, but is not designed to take account of multiple local optima. The third search alternative is based upon the Bus & Dekker (1975) bisection algorithm, which can be used to identify the consumption that evaluates the Euler condition to zero. Like Brent's method, the Bus & Dekker (1975) algorithm is recognised as efficient, and is not designed to account for

11 Evaluation of weights and abscissae of the Gauss-Hermite quadrature are based upon a routine reported in Chapter 4 of Press et al. (1986).

12 The interpolation routines that are used are based on Keys (1981).

13 This involves distinguishing the "inner" 2^n points in closest proximity to the co-ordinate to be interpolated, from the "outer" 4^n points considered in evaluating the cubic interpolation. If the smallest difference between any of the outer points and any of the inner points is more than 5 times the maximum difference between the inner points, then the model reverts to linear interpolation.

multiple local optima. Relative to Brent's method, optimisation of the Euler condition can – in some circumstances – result in improved accuracy, but at the cost of increased computational burden (as repeated calls to the value function do not require the additional computational burden involved in evaluating first derivatives). Furthermore, some analytical contexts may argue against the use of Euler conditions, as in the case where non-exponential discounting is assumed.

A *supplementary search routine* is included in the model to mitigate concerns regarding identification of multiple local optima where Brent's method or the Bus & Dekker algorithm are applied. Here the model can be directed to explore a localised grid above and below an identified optimum for a preferred level of consumption, based upon value function calls. If an alternative value of consumption is identified by this supplementary routine as strictly preferred to the original local maximum, then the routine will search recursively for any further solutions above and below. This process is repeated until no further solutions are found. Of all feasible solutions, the one that maximises the value function is selected.

4. Data and calibration methodology

4.1. Data considered for calibrating the model

Cross-sectional data for Ireland observed in 2005 were primarily considered for calibrating the model. This focus on cross-sectional data was adopted after careful consideration, taking into account the limitations of the structural model and the primary purpose for which the model has been devised. The model is limited in the sense that it does not capture real-world uncertainty over a range of characteristics, including the evolving tax and benefits system, conditions of the macro-economy, household demographics, and so on. As such, calibrating the model to survey data reported for a population birth cohort requires the implicit assumption that either changes in the policy environment have an incidental impact on behaviour, or are perfectly foreseen. The former of these assumptions is difficult to maintain when the primary purpose of the model is to explore behavioural responses to policy reform, and the latter is patently inaccurate. Cross-sectional data avoid these problems because they describe behaviour observed under a single policy environment. The assumptions implicit in the calibration are then that: a) individuals base their decisions on the belief that the existing policy environment will be maintained into the indefinite future; and[14] b) that expectations regarding the future evolution of individual specific characteristics – including demographics, wages, employment opportunities, and so on – can be based upon age profiles exhibited by contemporary

14 This assumption is not uncommon in the associated literature.

survey data. The former of these assumptions appears to us to be plausible (if not necessarily accurate), as does the latter after an allowance is made for trend improvements in wages and survival probabilities. These underlying assumptions should be borne in mind when interpreting the discussion that follows.[15]

4.2. Calibration approach

Models of the type referred to above are parameterised against observed data via a two-stage process that adapts to the large number of parameters involved and the computation times required to determine the implications of a given parameter combination. In the first stage, observable model parameters – including those governing inter-temporal wage dynamics and transitions in relationship status – are each estimated separately on available survey data. Given the parameter estimates obtained in the first stage, the second stage involves adjusting the (unobserved) model parameters to match simulated moments implied by the structural model to sample moments estimated from survey data.

The second stage of the model parameterisation is usually conducted either by manual calibration or optimisation of a loss function using an econometric criterion.[16] Various methods exist, each with their own advantages and disadvantages. We chose to manually adjust unobserved model parameters in the second stage of the parameterisation, based upon the sum of squared errors for each age specific model characteristic and graphical representations of the respective characteristics, following the approach by Sefton et al. (2008). Although this approach sacrifices some objectivity in the method by which the parameter estimates are obtained, it also facilitates a detailed understanding of the behavioural implications of alternative parameter combinations, relative to an automated econometric "black-box".

4.2.1. Specification of the model considered for calibration

As the second stage of the calibration requires testing over a very large number of parameter combinations, the model was limited to the following eight characteristics:

[15] A third possibility, which has been considered in the associated literature, is to calibrate the model to population characteristics that control for time and cohort effects (e.g. (Sefton et al. 2008)). This option has the problem that the details of the policy environment implicit in such profiles represent an average of the policy environments that applied during the period considered for estimation, and as a consequence are not well defined.

[16] Econometric methods include Simulated Minimum Distance (Lee and Ingram, 1991), Method of Simulated Moments (Stern, 1997), Indirect Estimation (Gourieroux et al., 1993) and Efficient Method of Moments (Gallant and Tauchen, 1996).

- age	- number of adults	- wage offers	- wage rates
- net liquid assets	- pension eligibility	- pension rights	- time of death

This restricted model focuses on decisions over labour supply (including the possibility of part-time employment), consumption, and pension participation, given a household's age, its number of adults, liquid assets, wage offer, wage rate, pension scheme eligibility, pension wealth, and survival. Household decisions were considered at annual intervals between ages $t_0 = 20$ and $T = 120$, with labour supply possible to age 75. State Pensionable Age was set to $t_{SPA} = 65$, the pensionable age that prevailed in 2005. Uncertainty was taken into consideration for the intertemporal development of the number of adults in a household, wage offers, wage rates, private pension eligibility, and the time of death – age, liquid wealth, and pension wealth were all considered to evolve deterministically.

As noted above, the model solves decision making problems by dividing the permissable state space (the range of characteristics that any household might conceivably have) into a series of grids. The domains of wages and wealth between ages 20 to 69 were each divided into 34 points using a log scale. The domain of pension wealth between ages 20 to 64 was divided into 16 points using a log scale. It was assumed that 25% of pension wealth at age $t = t_{SPA}$ is taken as a tax free lump, with the remainder taken as a retirement annuity. The domain of the retirement annuity was divided into 16 points using a log scale between ages 65 and 75. From age 76 to age 120, the wealth and retirement annuity domains were each divided into 151 points using a log scale.

Three additional dimensions – reflecting the number of adults in a household, wage offers, and pension scheme eligibility – complete the grids that were considered for the calibration. These grid dimensions differ from those described above in that they refer to characteristics that take discrete values. From age 20 to 95 (inclusive), solutions were required for single adults and couples; from age 96 all households were considered to be comprised of a single adult. Between ages 20 and 75, solutions were required for households with and without a wage offer. Furthermore, 3 private sector pension schemes were considered for analysis.

This specification of the model required utility maximising decisions to be numerically evaluated for 12,283,729 different combinations of household characteristics, for each alternative parameter combination tested as part of the calibration process.[17] For reference, this specification of the model takes 25 minutes to run on a computer with an Dell T5500 workstation with dual Xeon X5650 processors and 6Gb of RAM.

[17] =(64-19).34.34.16.3.2.2 +(75-64).34.34.16.2.2 + (95-75).151.151.2 + (120-95).151.151

4.2.2. Calibration strategy

The parameters of the model that were not estimated on observable data (or otherwise exogenously assumed) were calibrated by comparing age profiles at the household level for both singles and couples of:

1. the geometric mean of household employment income
2. the variance of household log employment income
3. the proportion of adult household members employed full-time, part-time and not at all
4. the geometric mean of household consumption
5. the variance of household log consumption

Statistics for calibration were drawn mainly from 3 surveys by the Irish Central Statistics Office. Statistics on employment were derived from SILC 2005. Proportions employed full-time, part-time or not in work were derived from the Quarterly National Household Survey (April 2005), while statistics on consumption expenditure were derived from the Household Budget Survey, again for 2004/2005.

Age specific geometric means of household employment income were matched by altering the distribution mean of the simulated cohort at entry to the model (age 20), μ_{n^a,t_0}, and by adjusting the age and relationship specific trend parameters of human capital described by $m\left(n^a_{i,t}, t\right)$ in equation (10). The variance of log employment income by age and relationship status was matched by adjusting the variance of the distribution at entry to the model, $\sigma^2_{n^a,t_0}$, and the variance of age specific innovations, $\sigma^2_{\omega,n^a_{i,t-1}}$. Age and relationship specific rates of employment participation were matched by adjusting the utility price of leisure, α, the learning by doing effects, $\kappa\left(n^a_{i,t-1}, t-1\right)$. Learning by doing effects, $\kappa\left(n^a_{i,t-1}, t-1\right)$ were also adjusted to match the model to the split between full-time and part-time employment described by survey data, as were the ratios of part-time to full-time wages. Finally, the timing of consumption was adjusted by altering the exponential discount rate δ, and the parameter of relative risk aversion $1/\gamma$. The variance of consumption by age was a residual that depends heavily upon the associated income parameters $\left\{\sigma^2_{n^a,t_0}, \sigma^2_{\omega,n^a_{i,t-1}}\right\}$.

It was necessary to select a set of starting values for the model from which to commence the calibration process. Starting with the wage parameters, we began with a flat wage profile over the life course, assuming zero experience effects, $\kappa = 0$, and no risk of a low wage offer. The leisure cost of full-time and part-time employment were defined as non-stochastic and age invariant proportions of the total time available to an adult, assuming 18 'viable' hours per day. Similarly, the ratio of the part-time to full-time wage was assumed to be independent of age and relationship status. The initial ratios considered for the calibration were calculated using data from the 2005 wave of the SILC; associated statistics are reported in Table 1. Finally, the preference parameters of the model were taken from UK econometric regressions (see (van de Ven 2010)), but the search routine meant that parameters were free to vary in response to characteristics in the Irish data. The exception is the utility price of leisure, which was set deliberately low to ensure an adequate sample for calculating moments of employment income.

The model calibration was conducted using a cascading procedure designed to subject the most flexible aspects of the model to the most frequent instances of re-adjustment. From the list of moments referred to above, the model exhibits the greatest degree of flexibility in relation to the geometric means of household employment income, where the number of associated model parameters $\left\{\mu_{n^a,t_0}, m\left(n_{i,t}^a, t\right)\right\}$ is identical to the number of moments considered for the calibration. The calibration consequently focused in the first instance upon adjusting the parameters $\left\{\mu_{n^a,t_0}, m\left(n_{i,t}^a, t\right)\right\}$ until a close match was obtained between the simulated and sample estimates for the geometric means of employment income.

Given the calibrated parameters for employment income, the calibration focused next upon matching the incidence of employment participation/non-employment. Here, the utility price of leisure α serves to reduce the preference for employment in general, and the learning-by-doing effects κ increase employment early in the working lifetime, relative to later life. The parameter adjustments necessary to match the model to employment participation, also serve to distort the match obtained to labour income, both through the direct effect that varying the parameters κ have on the intertemporal development of latent full-time wages, and indirectly through distributional heterogeneity in labour supply responses to employment incentives. Hence, the calibration process proceeded in an iterative loop to match the model to both the geometric mean of employment income and employment participation at the same time.

The calibration procedure focused next upon matching the model to rates of full-time and part-time employment. This aspect of the calibration proceeded in a very

Table 1: Model Parameters to Distinguish the Effects on Leisure and Labour income of Alternative Labour Supply Decisions

employment option	leisure cost	proportion of full-time wage
not employed	0.00	0.00
part-time employed	0.145	0.188
full-time employed	0.322	1.000

Source: authors' calculations on data from SILC 2005
Notes: based on population average statistics for full-time and part-time employed leisure cost assumes 18 allocatable hours per day and 7 days per week

similar fashion to that set out for employment participation, with the ratio of part-time to full-time wages replacing the utility price of leisure in the adjustment of parameters. It is important to note that this adjustment procedure has the very significant advantage that the wage parameters derived via the calibration take full account of the endogeneity of labour supply decisions, with which so much of the associated econometric literature has been concerned following the seminal contribution by James Heckman.

Having obtained a close match to moments of both employment income and labour supply, the calibration then focused upon matching the model to sample moments of household consumption. The model offers relatively blunt tools with which to achieve this match, and the associated calibration is somewhat more approximate as a result – in particular, we focused upon achieving a match between the peaks in consumption described by the simulated and sample data, and the general trend of age specific variances in consumption. In this regard, the discount rate δ tends to shift consumption into later periods of life, increasing the slope of the lifetime consumption profile. The parameter of relative risk aversion $1/\gamma$ motivates increased precautionary saving early in the working lifetime, which diminishes as the working lifetime proceeds. An alternative aspect that has been recognised as important here is the bearing that demographic needs have on consumption preferences; this aspect of the model was omitted from the calibration, due to the exogenous assumption of age specific demographics (reported in Section 5.4), and the revised OECD equivalence scale upon which the preference relation is based.

To summarise, the model parameters $\left\{\mu_{n^a,t_0}, m\left(n^a_{i,t}, t\right)\right\}$ were then adjusted until a close match was obtained to the age and relationship specific geometric means for employment income. Given the parameters $\left\{\mu_{n^a,t_0}, m\left(n^a_{i,t}, t\right)\right\}$, the model parameters $\left\{\alpha, \kappa\left(n^a_{i,t-1}, t-1\right)\right\}$ and the ratio of part-time to full-time wages were adjusted to match the simulated to sample rates of employment. This process was then repeated a number of times until the model obtained a reasonable match to both geometric means for employment income and rates of employment at the same time. The parameters $\{\delta, 1/\gamma\}$ were then adjusted to to obtain a better match to age specific geometric means for consumption described by survey data, and the parameters $\left\{\sigma^2_{n^a,t_0}, \sigma^2_{\omega,n^a_{i,t-1}}\right\}$ were adjusted to obtain an improved match to the age specific moments of both consumption and labour income. The entire process was then repeated to obtain the calibrated results that are reported in Section 6.

5. Estimates for observable parameters

The model parameters for which exogenous estimates were obtained are principally concerned with four key issues: life expectancy, the terms of the available pension schemes, taxation, and household demographics. A conspicuous omission from this list is the treatment of wages, the parameters for which were addressed as part of the second stage calibration to ensure the approach taken to account for sample selection is consistent with the wider analytical framework. The specification of these five aspects of the model are described in turn below.

5.1. Life expectancy

The survival probabilities assumed for calibrating the model are based upon CSO Population and Labour Force Projections, 2006-2036. These data are based upon observed survival rates between 2006 and 2007, and Official projections for improved longevity thereafter. The Official data permit survival rates to be calculated to age 99. Age specific survival probabilities between 100 and 120 were exogenously specified to obtain a smooth sigmoidal progression from the official estimate at age 99 to a 0 per cent survival probability at age 120. These probabilities are reported in Table 2.

Table 2: Exogenously estimated model parameters

rates of return / growth (% per annum)					
pension wealth:	4.1%	min. cost of debt:	6.0%	wage growth:	1.6%
positive liquid wealth:	4.1%	max. cost of debt:	19.0%		

children						probability of mortality			
age	singles	couples	age	singles	couples	age	prob.	age	prob.
20	0.054	0.000	40	0.656	1.952	81	0.007	101	0.415
21	0.049	0.336	41	0.706	2.006	82	0.008	102	0.486
22	0.078	0.355	42	0.724	2.044	83	0.009	103	0.555
23	0.110	0.428	43	0.752	1.984	84	0.010	104	0.619
24	0.120	0.569	44	0.634	1.843	85	0.012	105	0.679
25	0.156	0.572	45	0.595	1.683	86	0.014	106	0.733
26	0.188	0.728	46	0.503	1.604	87	0.017	107	0.781
27	0.238	0.822	47	0.407	1.389	88	0.020	108	0.823
28	0.283	1.004	48	0.390	1.244	89	0.022	109	0.860
29	0.360	1.069	49	0.360	1.174	90	0.025	110	0.890
30	0.380	1.161	50	0.328	1.074	91	0.028	111	0.916
31	0.402	1.363	51	0.310	0.934	92	0.034	112	0.936
32	0.422	1.419	52	0.242	0.773	93	0.041	113	0.953
33	0.466	1.453	53	0.147	0.715	94	0.050	114	0.966
34	0.550	1.615	54	0.133	0.595	95	0.063	115	0.975
35	0.587	1.721	55	0.087	0.515	96	0.075	116	0.983
36	0.593	1.708	56	0.071	0.418	97	0.120	117	0.988
37	0.671	1.790	57	0.058	0.418	98	0.197	118	0.992
38	0.631	1.892	58	0.057	0.357	99	0.273	119	0.995
39	0.638	1.944	59	0.029	0.336	100	0.343	120	1.000

Source: age profiles for children equal to arithmetic averages calculated from ** survey data mortality probabilities calculated for couples where both members are aged 20 in 2005 on life-tables published *** return to pension wealth and positive balances of liquid wealth set equal to real growth observed for Irish GNP between 1970 and 2005 cost of debt exogenously assumed real wage growth calculated on data for workers in all industries between 1985 to 2006

5.2. The terms of private sector pension schemes

The terms of private sector pensions in Ireland are complex and diverse (see, for example, the *Pension Market Survey 2007*, IAPF). Defined benefit schemes remain important, but in the private sector, and especially for younger workers, defined contribution schemes have become much more common. In order to summarise Irish private sector pensions in a tractable fashion, we have opted to characterise the system in terms of a set of pension options which a worker may face. We represent DB schemes in terms of a DC scheme with a higher employer contribution – this helps to capture a key feature of DB schemes, while at the same time keeping the complexity of the problem to a manageable level.[18]

Three schemes are considered for the calibration, designed to reflect low, middle, and high pension contribution rates by employees and their employers. Employees are considered to be able to decide over whether to participate in these schemes, but not their respective rates of pension contributions, as is common for occupational pensions. The terms applied to each of the representative pension schemes are summarised in Table 3.

The top panel of Table 3 reports the rates of employee and employer pension contributions assumed for each alternative pension scheme. In each year between ages 20 and 64, households are allocated a pension scheme that they may choose to participate in during the respective year. The pension scheme to which a household is eligible in any given year is either carried over from the scheme that they chose to participate in during the preceding year, or – if they chose not to participate in a pension during the preceding year – then it is taken as a random draw with reference to the income specific probability distributions reported at the bottom panel of Table 3.

The statistics that are reported in Table 3 reflect the stylised observation that employer pension provisions tend to improve with employee wages, where pension support is virtually non-existent for employees on low wages – defined here as those with full-time wages worth less that €16,000. In contrast, many employees toward the top of the wage distribution tend to enjoy relatively generous pension support from their employers, while the majority of workers lie between these two extremes.

Furthermore, we ignore associated decisions regarding the portfolio allocation, and assume that all returns to investment are risk free. The rate of return to pension

[18] Note that in our context, where there is no investment uncertainty and mortality rates are know, a career average DB scheme can be equivalently restated in terms of a DC scheme without loss of generality.

wealth is set to 4.1% per annum, equal to the average real growth of Gross National Product in Ireland during the period 1970 to 2005 (reported in the top panel of Table 2). Pension wealth is converted into an actuarially fair annuity at age 65 based on the assumed rate of return to pension wealth and the mortality rates discussed in Section 5.1. The value of this annuity is assumed to fall by 50% upon the death of a spouse.

Table 3: Terms Assumed for Private Sector Pensions: contribution rates and probabilities of eligibility

	scheme 1	scheme 2	scheme 3
contribution rates (% of labour income)			
employee	3%	4%	7%
employer	0%	7%	11%
eligibility probabilities by annual income band			
to € 16,000	90%	10%	0%
to € 38,400	10%	70%	20%
€ 38,400 and over	0%	40%	60%

Notes: authors' assumptions for terms of private sector pensions real return to pension wealth set to 4.1% p.a . income thresholds for probability distributions indexed to real wage growth of 1.6 % p.a .

5.3. Taxes and benefits

We adopt a simplified representation of the tax/welfare system, which nevertheless captures some of the key features of interest. For the cohorts now entering the labour market, coverage of the State Contributory Pension scheme will be much higher than heretofore. We consequently adopt the simplifying assumption that, in future, all those aged above State Pension Age will be eligible for the State Contributory Pension. The model allows for both the State Pension Age and the level of payment to be varied.

For those of working age, we take account of the following schemes:

- Jobseekers' Allowance
- One Parent Family Payment
- Child income support via child benefit, qualified child increase and Family Income Supplement

On the income tax side, we allow for the basics of personal and PAYE tax credits, tax bands and rates, and for PRSI and levies (which may be structured along the lines of the Universal Social Charge). Special attention is given to alternative possible tax treatments of pensions, varying from the EET (exempt, exempt, taxed) structure which approximates that in place until recent years to a potential new system with tax relief at a single hybrid rate, as per the recommendations of the National Pension Framework.

An additional issue of concern in relation to the simulated tax and benefits system is the way that it is assumed to evolve with time. Given the wage growth that is used to adjust the financial statistics against which the model is calibrated (reported in Section 4), ignoring indexation would result in "fiscal drag" (or tax bracket creep) and a decline in the relative value of benefits. Three main approaches to this issue can be distinguished. One is to allow for full indexation of tax parameters and welfare payment levels with respect to wage growth. This has the merit of ensuring that the ratio of tax to income remains constant, and that welfare incomes rise in line with general wage growth. This approach is in line with the distributionally neutral benchmark adopted in analysis of budgetary impact.

An alternative approach would be to project indexation of tax parameters and of welfare rates in line with past experience; the indexation parameters applying to tax and welfare might then differ from each other, and from wage indexation. Data for the period 1987 to 2005 indicate benefit parameters, and especially tax parameters, were adjusted by more than the growth in wages. Projecting forward on the basis of this experience does not seem advisable. It must be remembered that the public finance situation in 2005 was boosted by revenues arising from the house price bubble. When projecting forward on a very long term basis, it would be desirable to incorporate the adjustment currently under way to bring a sustainable fiscal balance. Part of the challenge, therefore, is to construct a scenario which takes account of the required adjustment, while not imposing an excessive adjustment over the very long term. We have consequently adopted the former approach here, adjusting tax thresholds and benefits in line with wage growth of 1.6% per annum.

5.4. Household demographics

The calibration that is reported here assumes that a household can be comprised of one or two adults between ages 20 and 95, where the number of adults is considered to be uncertain between adjacent years. From age 96, all households are comprised of a single adult. The logit model considered to describe the evolution of adults in a household is described by equation (15):

$$s_{i,t+1} = \alpha_0^A + \alpha_1^A t + \alpha_2^A t^2 + \alpha_3^A t^3 + \alpha_5^A s_{i,t} \tag{15}$$

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. This logit equation was estimated using data derived from waves 7 and 8 of the Living in Ireland survey. Regression statistics are reported in Table 4.

Table 4: Regression Statistics for Logit Model of Relationship Status

variable	coefficient	std. error
single(t-1)	9.031	0.371
age	-0.679	0.138
age_2	1.34E-02	2.96E-03
age_3	-7.53E-05	1.94E-05
Constant	4.450	1.933
sample size		6137
proportion single		0.418
correct predictions		0.985

Source: authors' calculations on data from waves 7 and 8 of the Living in Ireland survey

Dependant children were modelled deterministically when calibrating the model, based on age and relationship specific averages reported in Living in Ireland survey data. These age specific averages are reported in Table 2.

6. Calibrated model parameters

Our calibrated model parameters are reported in Table 5, and the associated fit between the simulated and sample moments is reported in Figures 1 to 4. We begin by interpreting the calibrated model parameters, and the key considerations underlying the parameter values that we settled upon. We then discuss the ways in which our calibration could be improved, which remain for further research.

6.1. Interpreting the calibrated parameters

Starting with the parameter of relative risk version, the calibrated value of 3.1 implies an intertemporal elasticity of substitution for consumption calculated at population averages of 0.16, which lies firmly within the range of estimates reported in the associated empirical literature. Grossman & Shiller (1981), Mankiw (1985) and Hall (1988), for example, report econometric estimates for the intertemporal elasticity between 0 and 0.4, Blundell et al. (1994) report an estimate of 0.75, while Hansen & Singleton (1983) and Mankiw et al. (1985) report estimates just over 1. Although values of the coefficient of risk aversion required to explain the equity premium puzzle (Mehra & Prescott (1985)) are large by comparison, evidence from attitudinal surveys suggest that the value is unlikely to larger than 5 (Barsky et al. (1997)).

The relative values of the intra-temporal elasticity (ϵ) and relative risk aversion $(1/\gamma)$ imply that consumption and leisure are direct substitutes, which has been suggested as a potential explanation for the fall in consumption that is commonly observed about retirement (e.g. Heckman (1974)). The discount factor indicates more impatience than the assumed real rate of return (5.0% c.f. 4.1% per annum), and the utility price of leisure for singles and couples is in the region of 1.0 by construction.[19] The probability of a low wage offer is 20% at any age between 20 and 75 for single adults, and 1% for couples. These parameters appear to display a passable level of internal consistency, given the imperfect correlation associated with the likelihood of involuntary unemployment for a husband and wife.[20] The ratio of part-time to full-time hours of employment was set equal to the associated sample averages reported in SILC data, as defined in Table 1. In contrast, the ratio of part-time to full-time wages was reduced by one third, relative to the associated survey data, to dampen incentives to take up part-time employment.

Turning to the age specific model parameters reported in Table 5, the calibration produced experience effects that tend to decline with age, where the experience effects identified for singles exceed those for couples throughout the simulated working lifetime. This difference is most pronounced early in the simulated lifetime, where the population tends to be primarily comprised of singles adults: at age 20, a single adult who chooses to work full-time can expect to earn 25% more by age 21 than they would have done had they chosen not to work at all at age 20. This compares with a 2.5% expected wage premium for couples at age 20. This focus of experience effects early in the working lifetime is consistent with the use of an experience effect as a tool for motivating employment participation early in the simulated lifetime.

The parameters that describe the age dependent component of the intertemporal evolution of latent full-time wages are best interpreted taking account of the experience effects that are described in the preceding paragraph. For singles, these parameters imply positive wage growth of 6% per annum on average for individuals who work full-time between ages 20 and 40, relative to wage decline of 12% per annum for individuals who do not work – part-time employment falls between these two extremes. In contrast, full-time employment implies an approximately flat wage profile (in real terms) between ages 40 and 65, relative to real wage decline of 6% per annum in respect of non-employment. A similar profile is described for adult couples, subject to smaller experience effects. In the case of full-time employed couples, for example, average wage growth between ages 20 and 40 is 1% per annum, relative to an average wage decline of 1% where employment is not supplied. From age 65, wages tend to fall quite sharply for both singles and couples, even where full-time employment is maintained.

19 This is achieved by multiplying the equivalence scale by 550, to normalise equivalised consumption (c/θ).

20 If there is a 20% probability of any adult being unemployed, and the probability of employment is independent of spouse labour status, then there would be a 4% probability of both members of a couple being unemployment at the same time. The calibration is not sufficiently precise to distinguish between a 1% and 4% probability of unemployment.

Table 5: Model Parameters Calibrated to Match Simulated to Sample Moments

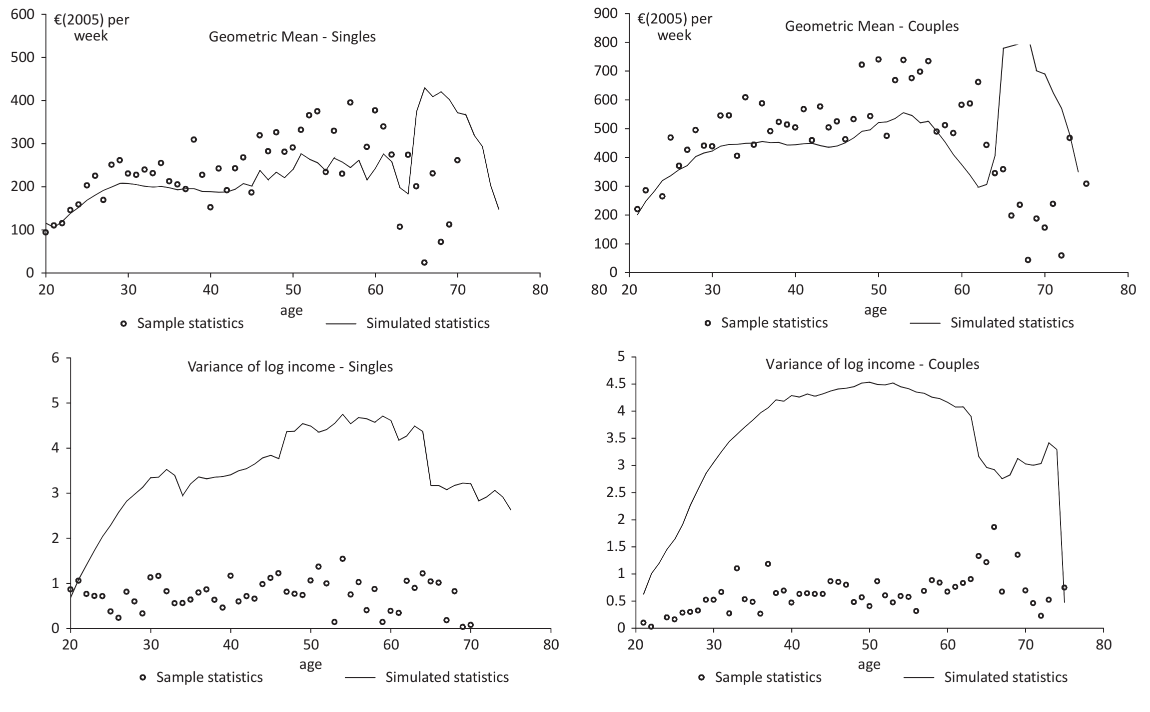
Preference Parameters								
relative risk aversion (1/gamma)		3.10	elasticity of substitution (epsilon)				0.55	
discount factor (delta)		0.95	utility price of leisure (alpha)				0.55*	1.7**
Wage Parameters								
prob of low wage offer - singles		0.20	part-time to full-time leisure cost				0.463	
prob of low wage offer - couples		0.01	part-time to full-time wage ratio				0.400	
Age Specific Parameters								
	trend income		experience effect			trend income		experience effect	
age	singles	couples	singles	couples	age	singles	couples	singles	couples
20	1000.000	1000.000	0.250	0.025	48	34.514	662.168	0.082	0.015
21	857.021	1333.375	0.244	0.025	49	33.264	664.906	0.076	0.014
22	781.609	1547.855	0.238	0.024	50	32.015	685.152	0.070	0.014
23	770.084	1653.848	0.232	0.024	51	30.765	683.423	0.064	0.013
24	729.782	1603.066	0.226	0.024	52	29.515	687.220	0.058	0.013
25	684.510	1601.240	0.220	0.023	53	28.266	703.668	0.052	0.013
26	628.312	1590.876	0.214	0.023	54	27.016	681.389	0.046	0.012
27	565.330	1594.449	0.208	0.022	55	25.767	650.762	0.040	0.012
28	494.661	1650.370	0.202	0.022	56	24.517	636.596	0.034	0.012
29	417.112	1539.240	0.196	0.022	57	23.268	614.606	0.028	0.011
30	358.136	1446.184	0.190	0.021	58	22.018	581.439	0.022	0.011
31	287.453	1390.094	0.184	0.021	59	20.768	548.271	0.016	0.010
32	240.418	1298.615	0.178	0.021	60	19.519	515.103	0.010	0.010
33	183.914	1212.764	0.172	0.020	61	18.269	481.935	0.010	0.010
34	147.897	1142.045	0.166	0.020	62	17.020	448.767	0.010	0.010
35	138.391	1051.007	0.160	0.019	63	15.770	415.599	0.010	0.010
36	117.694	976.720	0.154	0.019	64	14.521	382.431	0.010	0.010
37	104.831	889.670	0.148	0.019	65	13.271	349.263	0.010	0.010
38	93.217	839.271	0.142	0.018	66	12.022	316.096	0.010	0.010
39	78.333	768.300	0.136	0.018	67	10.772	282.928	0.010	0.010
40	67.889	749.428	0.130	0.018	68	9.522	249.760	0.010	0.010
41	62.398	723.956	0.124	0.017	69	8.273	216.592	0.010	0.010
42	54.896	709.681	0.118	0.017	70	7.023	183.424	0.010	0.010
43	51.315	676.203	0.112	0.016	71	5.774	150.256	0.010	0.010
44	50.139	654.010	0.106	0.016	72	4.524	117.088	0.010	0.010
45	44.813	641.729	0.100	0.016	73	3.275	83.920	0.010	0.010
46	37.013	652.456	0.094	0.015	74	2.025	50.752	0.010	0.010
47	35.763	652.747	0.088	0.015	75	0.776	17.585	0.010	0.010

* singles; ** couples

6.2. The match between simulated and sample moments

We discuss the match obtained between the simulated and sample moments in the same order in which we conducted the model calibration, as described in Section 4.2. The top two panels of Figure 1 indicate that the model obtains a close match to the age profiles described by survey data for the geometric mean of private non-property (employment) income, for both single adults and couples. Given the discussion provided in Section 4.2, it is reasonable to expect that this aspect of the calibration should obtain a close match to survey data, because the number of associated model parameters is exactly equal to the number of calibration moments. The most obvious anomaly is the jump up in the geometric mean of employment income that is evident for couples at age 65, which is the pensionable age considered for the calibration. This jump up is not generated for any household taken in isolation – indeed, as noted above, household full-time potential wages tend to fall late in the working lifetime – rather, the increase in the geometric mean of employment income later in the working lifetime reflects a mass departure from employment of lower wage households after they gain access to their accrued pension wealth. Although this jump up in the geometric mean of non-property income is not evident in the survey data, it is important not to overstate the importance of this disparity, as relatively few adults choose to be employed after pension age.

Figure 1: Private Non-Property Income Profiles by Age — simulated versus sample moments



Notes: Sample statistics — age profiles calculated from SILC data from 2005

Simulated statistics — age profiles generated from model, using calibrated parameters reported in Table 5

This brings us neatly to the profiles for employment that are displayed in Figure 2, delaying for a moment discussion of the variances of employment income that are reported in the lower panels of Figure 1. The two panels of Figure 2 indicate that the model does a very good job of capturing observed rates of employment participation for both singles and couples, with the most substantial disparity between the simulated and sample statistics being the relatively high rates of full-time employment observed among single adults between ages 35 and 45. This disparity is attributable to the application of taxes and benefits, as the simulation model assumes that single adults without children receive no benefits if they are in full-time employment, but can receive Jobseeker's Allowance if they work part-time. Single adults with no children and low full-time wage potentials can therefore significantly increase their disposable income by electing to work part-time. Single adults with children, however, are eligible to OPFP and Child Benefit irrespective of their employment status, and FIS if they work full-time, so that full-time employment obtains an unambiguous increase in disposable income when a single adult cares for at least one child. The balance between these countervailing incentives switches from part-time to full-time employment during peak child-rearing years.

Two important factors underly the close match between the simulation model and the data that is otherwise reported for employment statistics. First, it was necessary to assume that the wage earned from part-time employment returns a smaller fraction of the full-time wage that the population average statistics imply; without this assumption, the model tended to generate too much part-time employment, relative to the incidence described by the associated sample statistics. A possible explanation for this is that the sample data are affected by selection effects, so that those who take up full-time employment tend to have poorer options if they were to work part-time than current part-time works, and vice versa for current part-time employees. Indeed, qualitative data give some credence to this view. Fagan (2003), for example, reports that approximately 1 in 5 employed people in Europe work full-time when they would prefer to work part-time. The reasons most commonly given for the mis-match include the perception that it would not be possible to do a desired job part-time, that part-time employment is not offered by a desired employer, and that it would damage career prospects.

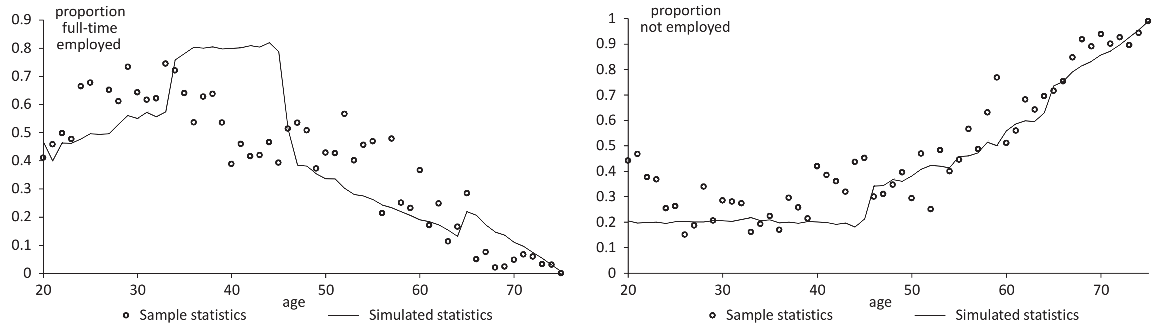
The second factor underlying the match obtained between the model and sample moments of employment is the allowance for an experience effect on future prospects for the latent full-time wage. In the absence of this experience effect, the model tended to generate too little employment participation at the outset of the working lifetime, as is common in the associated literature. Low (2005) points out that a casual inspection of the data shows that young workers tend to command a low wage but have high participation rates, whereas older workers have a higher wage but lower participation rates. It is difficult to reconcile these stylised facts with an intertemporal model of labour supply in which the age-earnings profile is deterministic. Both Low (2005) and French (2005) suggest that a possible explanation for the apparent inconsistency is the self-insurance motive where incomes are stochastic. Individuals work hard when young to accumulate assets, which insure them against wage uncertainty in later life. Yet the careful simulations of Low (2005) suggest that this motive can only partially reconcile a life-cycle model with survey data. We find the same applies here.

One other anomaly that does present itself in Figure 2 is the jump up in the proportions of adults choosing not to be employed at age 65 (pension age), which is particularly evident for couple households, and not as evident in the associated survey data. In this regard, it is important to note that the model assumes that all households access their pension wealth at age 65. In practice, however, many pension schemes make provisions for both early and late retirement, so that the impact of pension eligibility tends to be concentrated in the simulation model in a way that it is not in the survey data.

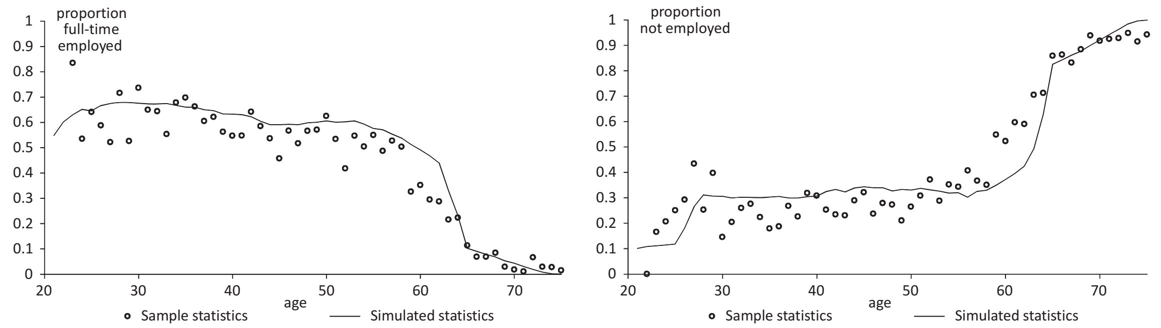
As noted in Section 4.2, the age profiles for the geometric means of consumption generated by the model were amended by adjusting the discount rate δ and the parameter of relative risk aversion $1/\gamma$. Increasing the former of these tends to tilt the consumption profile up with age, and increasing the latter depresses consumption early in the working lifetime (when prospective wage uncertainty is high), and raises consumption toward the end of the working lifetime (as prospective wage uncertainty declines). The top two panels of Figure 3 indicate that the model broadly matches the sample moments for geometric mean consumption by age calculated from survey data. For singles, the sample moments suggest that the age profile of consumption starts out flat, and then falls away in retirement; and for couples, it rises to a discrete peak about age 50. We focused most of our effort here in trying to capture the peak at age 50 described for couples by the sample moments, achieved by increasing both δ and $1/\gamma$. Our scope for increasing δ was limited by our desire not to obtain monotonically increasing consumption profiles with age; in relation to relative risk aversion we were also limited by what is considered 'reasonable' by the wider empirical literature. We return to alternatives that might help to improve this aspect of the calibration below.

The final set of moments considered for the calibration were the age specific measures of the variance of log employment income and log consumption, which are reported respectively in the lower halves of Figures 1 and 3. Note that the same set of parameters were adjusted to match the simulation model to these two separate series of sample statistics; the parameters controlling the variance of (log) latent full-time wages. The lower panels of Figures 1 and 3 indicate that it was not possible to match to both the variances described for employment income and the variances of consumption at the same time. We consequently opted to focus primarily upon the variances for consumption, bearing in mind that these have the most important bearing on household saving and welfare. Hence, while the model substantially overstates age specific variances of employment income described by survey data, it broadly matches variances for household consumption.

Figure 2: Employment Rates — simulated versus sample moments



Panel A: single adults

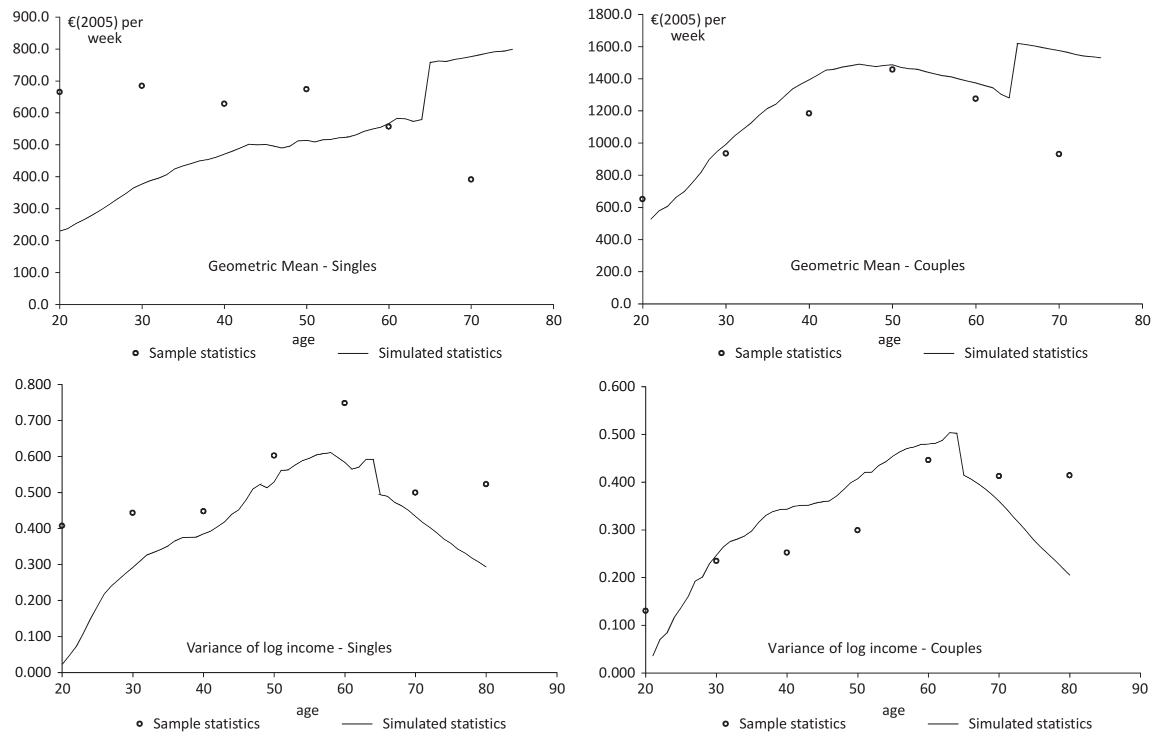


Panel B: adult couples

Notes: Sample statistics — age profiles calculated using data from the Quarterly National Household Survey (April 2005)

Simulated statistics — age profiles generated from model, using calibrated parameters reported in Table 5

Figure 3: Consumption Profiles by Age — simulated versus survey data



Notes: Sample statistics — age profiles calculated using data from the Household Budget Survey (2004/2005)

Simulated statistics — age profiles generated from model, using calibrated parameters reported in Table 5

6.3. Improving the model fit

Three aspects of the model calibration that is reported above appear to warrant further attention. First, the model obtains a very approximate fit to the profile of age specific geometric means for consumption. Second, the model fails to capture the variances of employment income and consumption simultaneously – we can calibrate it only to one or the other of these two sets of statistics. And third, the model generates discrete shocks to labour supply and employment income about the assumed pension age that are not evident in survey data. The last of these appears to be the most straightforward to address, and least concerning of the three; this disparity is likely to disappear after allowance is made for the more flexible timing of pension dispersals that is often possible in practice. We consequently devote the remainder of this section to discussing the other two concerns that are noted above.

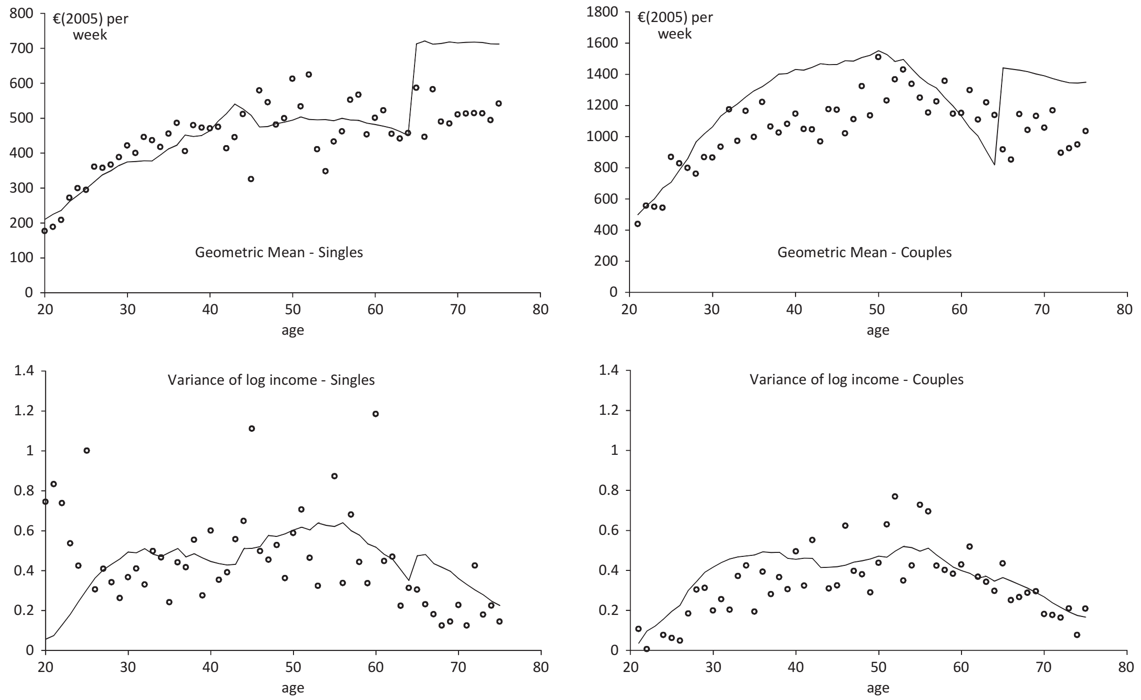
The relationship between employment income and disposable income generated by the model has a strong bearing upon the mismatch between the simulated and sample moments for consumption. Consider, for example, the associated statistics for disposable income that are reported in Figure 4. First, it is encouraging to note that the simulated and sample geometric means are closely aligned to state pension age, suggesting that the way that we have described the tax and benefits function during the working lifetime provides a decent reflection of the practical reality. Two key discrepancies do, however, emerge. First, although a close match is obtained to the geometric means of employment income and disposable income, the variances associated with these two distributions suggest that the model tax function produces greater redistribution than is achieved in practice. And secondly, there is a substantial jump up in disposable income generated by the simulation model at pension age that is not displayed by the sample data. These two disparities between the model and the survey data are clearly consistent with the disparities reported above for consumption, suggesting that a common set of distortional factors is responsible for both.

Disposable income in the model is comprised of employment income, property income, and the influence of taxes and benefits. As the disparity between the dispersion of employment and disposable income is large throughout the simulated lifetime – irrespective of the temporal aspect of property income accrual – the associated departure of the model from the statistical record is likely attributable to the application of taxes and benefits. Indeed, there is good reason to suppose that this is true, given that the stylised nature of the simulation model is ill-adapted to providing a comprehensive description of the Irish tax and benefits system. At the most basic level, the model does not include a very wide range of population characteristics that have an important bearing on the transfer payments to which individuals are eligible in practice. These characteristics include sickness, injury, disability, and the number and age of dependant children in a household.

Furthermore, the focus of the model on annual time increments means that it is not possible to capture heterogeneity that depends on shorter time intervals, such as part year unemployment and so on. Hence, it is to be expected that this population heterogeneity that is unaccounted for in the model should result in greater homogeneity of disposable income than is observed in practice. Addressing this disparity in a way that is computationally feasible is an issue that remains for further research.

In relation to the spike up in disposable income that is generated by the simulation model at pension age, some progress may be made by allowing for the more flexible terms of pension fund dispersals, as discussed in the preceding subsection. Yet, the scale of the jump in disposable income suggests that the model is also generating excessive saving through pension assets (which produce an annuity income stream from retirement). We intend to explore how the model matches to pension fund participation in future work.

Figure 4: Disposable Income Profiles by Age — simulated versus sample moments



Notes: Sample statistics — age profiles calculated from SILC data from 2005

Simulated statistics — age profiles generated from model, using calibrated parameters reported in Table 5

7. Exploring Policy Issues

The model has been constructed in such a way as to allow a range of pension policy issues to be analysed. These include the introduction of mandatory DC pensions, changes in the indexation of State pensions, changes in the State pension age, and changes in the level of State pension benefits. In this section we illustrate the application of the model by exploring trade-offs between changes in the level of State pension benefits and changes in the age at which the State pension becomes payable. Increases in the State pension age are widely viewed as a potential element of a strategy to cope with the demands of demographic ageing. If State Pension Age does not rise to some extent in response to longer life expectancies, fiscal constraints will imply that State pension benefits will be lower than if pension ages do adjust to life expectancy increases.

The model allows this trade off to be identified more precisely, taking account of economic responses to the changed incentives which arise from differing combinations of the level of benefit and the age at which the State Pension becomes payable. Here, we focus on the aggregate impact of a "grid" of policy choices. It should be emphasised that none of these should be regarded as a policy proposal or recommendation. The purpose of this approach is to identify what implications different combinations of benefit levels and State Pension Age have for the exchequer and for society. The level of the State pension payment is allowed to vary between a high of €230 per week – close to the current, 2011 values – and a low of about €170 per week. This "low" figure is about 5% below the value of the State Pension in 2005, the data year, which is taken as the "base case" for the analysis, and about 25% below the "high" value.

Until recently, the State Pension Age had been set at 66 – but with a special "retirement" or "transitional" pension available at age 65, making 65 the effective age at which a State Pension could be obtained. Under legislation implementing aspects of the National Pensions Framework, the State Pension Age is set to rise to 66 in 2014, to 67 in 2021 and to 68 in 2028. Given these pending changes in State Pension Age, we explore combinations of different benefit levels with a State Pension Age between 65 and 68.

The implications of differing combinations of State Pension Age and pension payment levels for the government's budget, for net private saving, for consumption and for employment are set out in Tables 6 to 9 below. It should be noted that the model is geared towards generating the long-term implications of a policy change, and the statistics reported here provide only a qualitative indication of short run incentive effects.

Looking first at the impact on the net budgetary position of the government (Table 6), we see that the net tax take increases with state pension age, and decreases with the generosity the SCP. Increasing state pension age by a year raises the net tax intake by between €180m and €255m per year. The higher are benefit levels, the greater the saving from an increase in the State Pension Age.

Table 6: Impact on Net Government Budget, Relative to Base Policy Scenario (Euro millions, 2005 prices, per annum)

value of State Contributory	*State Pension Age*			
Pension (€ per week)	*65*	*66*	*67*	*68*
170	178.4	363.5	559.0	743.8
190	-179.3	33.3	251.8	459.7
210	-389.7	-177.0	59.1	287.6
230	-614.7	-381.3	-127.1	115.8

Note: Base simulation assumes State Pension Age of 65 and value of contributory pension of 180 per week

Table 7: Impact on Consumption, Relative to Base Policy Scenario (Euro millions, 2005 prices, per annum)

value of State Contributory	*State Pension Age*			
Pension (€ per week)	*65*	*66*	*67*	*68*
170	-139.2	-301.2	-457.6	-610.0
190	139.7	-36.8	-208.7	-381.0
210	428.0	216.1	29.7	-155.3
230	686.6	469.0	268.1	68.2

Note: Base simulation assumes State Pension Age of 65 and value of contributory pension of 180 per week

Increasing the payment rate of the SCP by €10 per week leads to a net increase in exchequer costs of between €85m and €180m per year. The cost increase is naturally lower when the State Pension Age is higher; an equal-valued increase in benefit also turns out to be less expensive, in terms of exchequer cost, at higher levels of benefit.

The broad import of these findings is that, in a steady state situation, a given budgetary envelope for pensions can be compatible with a high pension age and a low payment rate, or a higher payment rate with a low pension age.. For example, a rise from the base case (2005 levels) of €180 per week to €190 per week, combined with an increase in the pension age from 65 to 66, would be broadly neutral for the Exchequer. Thus, raising the pension age by a single year is compatible a higher payment level in a budgetary neutral policy change – or can allow the maintenance of existing levels when public finances are under sustained short and medium term pressure.

Comparing Tables 6 and 7 reveals that the impact of the considered policy counterfactuals on aggregate domestic consumption is an inverted relation of the impact on the government budget. Hence, increased government saving can be interpreted as a form of enforced private saving, and vice versa, an observation that is particularly evident in wake of the 2008 financial crisis.

The effects on aggregate labour supply of the policy counterfactuals, reported in Table 8, have the expected signs, indicating increased employment as the generosity of state pensions is reduced, and as the state pension age is increased. It is noteworthy that the (long-run) effects on the duration of the working lifetime of increasing state pension age that are projected by the model are much smaller than is commonly assumed in the policy debate. The duration of the working lifetime is projected to increase by between 0.1 and 0.2 years for each year that state pension age is increased, with the effect rising with the generosity of state pensions. This is in contrast to the common assumption that a one year increase in state penion age will lead to an equivalent shift in labour market exit rates (implying an equivalent increase in the average duration of the working lifetime).[21]

An important factor underlying this result is that it reflects a long-run effect in which individuals are considered to foresee the higher state pension age from the beginning of their working lifetimes, and adapt their savings behaviour to accommodate the change (returned to below). This highlights the capacity of a dynamic model to reveal trade-offs in behaviour that might not be obvious at first glance, and to provide some quantitative detail around those trade-offs. When interpreting this interesting result, however, a number of additional factors should also be borne in mind:

1. The model does not account for the “signal” effect that the state pension age may have on individual expectations and planning in practice.
2. The model is calibrated to declining wages later in the working lifetime, and this decline is projected on current work profiles, so that these profiles may feed indirectly into work incentives in the policy counterfactual. We have attempted to control for this type of effect, both in the general approach to calibration (which is designed to take endogenous account of selection effects), and by imposing smooth age trends from reasonably early on in the working lifetime (age 45 for singles and 55 for couples).
3. The employment profiles of singles, in particular, do not respond very strongly to the policy environment.

The sensitivity of the model-based results shown here needs to be tested using alternative assumptions about the formation of decisions on retirement, and how they may be influenced by increases in State Pension Age (SPA). There are, however, a number of considerations that argue against the simple assumption that average

21 In an assessment of the impacts of pension reforms enacted in the UK in 2011, for example, the Department for Work and Pensions assumed that the announcement of a one year increase in the state pension age of men would “increase the age at which males would exit the labour market from age 55 onwards; for instance, a 66 year-old man would adopt the exit rate from the labour market currently adopted by a 65-year old” Department for Work & Pensions (2011), p. 11, paragraph 28.

retirement ages will increase 1 for 1 with increases in SPA. Such considerations include:

1. If labour market productivity and/or wages tend to decline later in life.
2. If the desire and/or capacity to undertake work tends to decline later in life.
3. If the system of private (personal and occupational) pensions and alternative retirement saving vehicles provide sufficient funds to meet the expenditure needs of individuals later in life, and may be drawn upon prior to state pension age.

In the long run, these considerations suggest that the burden of an increase in state pension age is likely to be shared between lower consumption and decreased leisure.

Table 8: Impact on Employment, Relative to Base Policy Scenario (average years)

value of State Contributory Pension (€ per week)	*State Pension Age* 65	66	67	68
170	0.09	0.22	0.37	0.50
190	-0.09	0.07	0.24	0.40
210	-0.25	-0.06	0.13	0.30
230	-0.35	-0.16	0.05	0.25

Note: Base simulation assumes State Pension Age of 65 and value of contributory pension of 180 per week

Table 9: Impact on Net Private Saving, Relative to Base Policy Scenario (Euro billions, 2005 prices)

value of State Contributory Pension (€ per week)	*State Pension Age* 65	66	67	68
170	3.9	3.1	1.7	1.0
190	-4.2	-4.7	-5.6	-6.9
210	-11.2	-12.4	-13.5	-14.8
230	-18.6	-19.2	-20.4	-22.2

Note: Base simulation assumes State Pension Age of 65 and value of contributory pension of 180 per week

Private savings responses to the policy counterfactuals (Table 9) are the product of two considerations:

1. The need for private saving is reduced by increases in the generosity of state retirement benefits; in this case state benefits act as a substitute for private saving.
2. The need for private saving is reduced as the age of retirement increases.

These considerations work in opposite directions when increases in state pension age are coupled with higher benefits. Changes in the State Pension Age operate at the margin, while changes in levels of benefit affect all pensioners. As a result, the latter effect tends to dominate.

8. Conclusion

In this paper we describe how the National Institute's NIBAX model – a model well suited to the analysis of issues regarding household savings, including pensions, labour supply and asset allocation – has been adapted and calibrated to Irish circumstances. The model is an advanced tool, which has been tried and tested both in the policy sphere (in work for the UK Revenue authorities) and in top-level academic journals. Given the large infrastructural investment in building such models, adaptation via calibration represents a promising way of making this analytical approach available to a wider policy context.

Dynamic microsimulation models are essential in tracing the impact of changes in pension policy over the life course. The nature of these models is quite different from the more familiar static tax benefit models. The need to model decisions over an individual's lifetime means that the characterisation of the policy and labour market environment needs to be much more streamlined than in simpler "snapshot" or cross-section analyses.

The data and methods used to calibrate the model to Irish circumstances have been described, and the strategic simplifications used in characterising the tax and welfare systems, pension regimes and the labour market have been outlined. Calibration results indicate that the model does now capture many key features of the Irish system, including the patterns of labour market participation and of wage income over the life-course.

A brief policy analysis suggests that increasing the state retirement age in absence of other labour market reforms may deliver a smaller improvement in the government budget than is commonly assumed in the contemporary policy literature. Although the significance of this finding is difficult to overstate in the current policy environment, the analysis reported here only touches upon the subjects of study that are made possible by the model. We look forward to expanding upon this analysis in future work. One of the priorities for future analysis is the impact of changes in the tax treatment of superannuation contributions, along the lines proposed in the National Pensions Framework (Department of Social and Family Affairs, 2010). Analysis using the present model can help to examine the potential impact of such changes on pension coverage at different income levels, taking into account the ways in which both age and income tend to influence decisions regarding pensions.

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A. List of Variables and Parameters

Preference Parameters

$U_{i,t}$	expected lifetime utility of household i at age t
E_t	expectations operator evaluated at age t
$1/\gamma$	coefficient of risk aversion
ϵ	elasticity of substitution between equivalised consumption and leisure
$\beta_{1,2}$	short-run quasi-hyperbolic discount parameters
δ	long-run (exponential) discount rate
$\zeta_{a,b}$	warm-glow bequest parameters

Ages

T	maximum possible duration of life
t_{SPA}	state pension age
t_{ER}	early retirement age
t_D	age at which all debts must be repaid

Consumption and Demographics

$c_{i,t}$	discretionary composite consumption of household i at age t
$l_{i,t}$	proportion of time spent in leisure of household i at age t
$l_{i,t}^{FT}$	leisure time of single adult, full-time employed
$l_{i,t}^{PT}$	leisure time of single adult, part-time employed
$l_{i,t}^{2FT}$	leisure time of adult couple, both full-time employed
$l_{i,t}^{FtPt}$	leisure time of adult couple, one full-time and one part-time employed
$l_{i,t}^{FtNe}$	leisure time of adult couple, one full-time and one not employed
$l_{i,t}^{PtNe}$	leisure time of adult couple, one part-time and one not employed
$\theta_{i,t}$	equivalence scale of household i at age t
$n_{i,t}^{a}$	number of adults in household i at age t
$n_{i,t}^{c}$	number of children in household i at age t
$\varphi_{j-t,t}$	probability of surviving to age j, given survival to age t

Wealth and Pensions

$w_{i,t}$	net liquid wealth of household i at age t
$w_{i,t}^{+}$	non-negative net liquid wealth balance of household i at age t
$w_{i,t}^{s}$	safe liquid assets of household i at age t
$w_{i,t}^{r}$	risky liquid assets of household i at age t
$nu_{i,t}$	proportion of liquid wealth invested in the risky asset by household i at age t
$w_{i,t}^{p/o}$	wealth held in personal / occupational pension of household i at age t
$r_{i,t}^{s}$	return on safe liquid assets of household i at age t
r_{t}^{r}	return on risky assets at age t
$r_{t}^{p/o}$	return to personal / occupational pension wealth at age t
π_{div}	proportion of liquid wealth lost upon marital dissolution prior to t_{SPA}
D_t	credit constraint on liquid net worth at age t
$\pi^{pc/oc}$	private contribution rate to personal / occupational pensions
$\pi_{l}^{p/o}$	lower bound on labour income to contribute to personal / occupational pensions
π_{u}^{p}	upper bound on labour income to contribute to personal pensions
$\pi_{ec}^{p/o}$	employer (and government) contribution rate to personal / occupational pensions
$\pi_{a}^{l/p/o}$	propn of liquid / personal pension / occupational pension wealth annuitised at t_{SPA}
π^{pe}	proportion of pension contributions that is tax exempt
π^{pt}	proportion of pension annuity income that is taxable
$\pi_{penalty\_a}^{p}$	“account opening” cost on first contributions to personal pension
$\pi_{penalty\_b}^{p}$	“investment cost” for choosing a contribution rate different from $\pi_{c\_default}^{p}$

Income

$\tau_{i,t}$	net tax and benefit (disposable) income of household i at age t
$x_{i,t}$	non-property income of household i at age t
$y_{i,t}$	property income of household i at age t
$pc_{i,t}^{p/o}$	private contributions to private / occupational pensions of household i at age t
$g_{i,t}$	labour income of household i at age t
$p_{i,t}$	pension annuity income of household i at age t
$h_{i,t}$	latent wage of household i at age t
$m_{i,t}$	wage growth parameter of household i at age t
$\psi_{i,t}$	intertemporal persistence of earnings of household i at age t
$\kappa_{i,t}$	experience effect on earnings of household i at age t
$wo_{i,t}$	wage offer identifier
$p_{i,t}^{wo}$	probability of household i receiving a wage offer at age t

B. Maximisation of Expected Lifetime Utility

The intertemporal preference relation, as defined by equation (1), is:

$$U_t = \frac{1}{1-1/\gamma}\left\{u_t^{1-1/\gamma} + E_t\left[\beta_1\delta\left(\varphi_t u_{t+1}^{1-1/\gamma} + (1-\varphi_t)\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right) + \right.\right.$$
$$\left.\left. +\beta_1\beta_2\sum_{j=t+2}^{T}\delta^{j-t}\left(\varphi_{j-t,t}u_j^{1-1/\gamma} + (1-\varphi_{j-t,t})\left(\zeta_a + \zeta_b w_j^{+}\right)^{1-1/\gamma}\right)\right]\right\} \quad (16)$$

where the individual subscripts i have been suppressed, $\varphi_t = \varphi_{1,t}$, and $u_t = u\left(\frac{c_{i,t}}{\theta_{i,t}}, l_{i,t}\right)$. Define:

$$W_t = \frac{1}{1-1/\gamma}\left[u_t^{1-1/\gamma} + E_t\sum_{j=t+1}^{T}\delta^{j-t}\left(\varphi_{j-t,t}u_j^{1-1/\gamma} + (1-\varphi_{j-t,t})\left(\zeta_a + \zeta_b w_j^{+}\right)^{1-1/\gamma}\right)\right]$$
$$= \frac{1}{1-1/\gamma}u_t^{1-1/\gamma} + \delta E_t\left(\varphi_t W_{t+1} + \frac{(1-\varphi_t)}{(1-1/\gamma)}\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right)$$

Then:

$$U_t = \frac{1}{1-1/\gamma}u_t^{1-1/\gamma} + E_t\left[\frac{\beta_1\delta}{(1-1/\gamma)}\left(\varphi_t u_{t+1}^{1-1/\gamma} + (1-\varphi_t)\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right) + \right.$$
$$\left. + \beta_1\beta_2\delta^2\left(\varphi_{2,t}W_{t+2} + \frac{(1-\varphi_{2,t})}{(1-1/\gamma)}\left(\zeta_a + \zeta_b w_{t+2}^{+}\right)^{1-1/\gamma}\right)\right]$$

and if $\beta_1 = \beta_2 = 1$, then:

$$U_t = W_t = \frac{1}{1-1/\gamma}u_t^{1-1/\gamma} + \delta E_t\left(\varphi_t U_{t+1} + \frac{(1-\varphi_t)}{(1-1/\gamma)}\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right)$$

The value function describes expected lifetime utility as a function of the state variables at any given time, t, on the assumption that optimal choices are made and conditional on being alive at the start of time t.[22] Define $\widehat{u}_t$ as the value of intra-temporal utility at time t, specified as a function of the state variables in time t, and conditional on the optimising decisions at time t. Similarly, define $\widehat{W}_t$ as the value of W_t, given the state variables at time t, evaluated at the sequence of optimising decisions for all $t \leq j \leq T$. Then the value function at time t is defined by:

22 Hence, the value function is a functional of the optimised decision stream.

$$V_t = \max_{\psi} \left\{ \frac{1}{1-1/\gamma} u_t^{1-1/\gamma} + E_t \left[\frac{\beta_1 \delta}{(1-1/\gamma)} \left(\varphi_t \widehat{u}_{t+1}^{1-1/\gamma} + (1-\varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^{+} \right)^{1-1/\gamma} \right) + \right. \right.$$
$$\left. \left. + \beta_1 \beta_2 \delta^2 \left(\varphi_{2,t} \widehat{W}_{t+2} + \frac{(1-\varphi_{2,t})}{(1-1/\gamma)} \left(\zeta_a + \zeta_b w_{t+2}^{+} \right)^{1-1/\gamma} \right) \right] \right\}$$

where ψ is the set of decision alternatives available at time t.

To ensure that the value function is positive, it is recorded by the model in the form of the following monotonic transformation of equation (16):

$$Z_t = (1 - 1/\gamma)\, V_t^{\frac{1}{1-1/\gamma}} \tag{17}$$

B.1. Final period of life: $t = T$

Variables

In the final period of life, the household's decision is limited to their period specific consumption. As the opportunity to work or to invest in risky assets is not permitted, and as death in the following period is certain, there is no uncertainty associated with the maximisation problem in this period. Here, we have:

state variables t:	w_t, p_t, n_t^a
control variables t:	c_t
state variables $t+1$:	w_{t+1}

Value function

The value function, V_t, is defined by:

$$V_t = \max_{c_t} U_t \text{ subject to:} \tag{18}$$

$$w_{t+1} = w_t + \tau_t - c_t \tag{19}$$

$$c_t \leq c_t^{\max} \tag{20}$$

$$c_t^{\max} = w_t + \tau_t \tag{21}$$

where $c_t^{\max}$ enforces the lower limit of zero considered for net liquid wealth where a household is subject to a certain probability of death.

Euler condition (if $\beta_1 = \beta_2 = 1$)

Euler conditions are only calculated if quasi-hyperbolic discounting is suppressed ($\beta_1 = \beta_2 = 1$). In this case, the Euler condition associated with the period T maximisation problem is:

$$\frac{\partial V_t}{\partial c_t} = \frac{\partial u_t}{\partial c_t} u_t^{-1/\gamma} - \delta \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^+\right)^{-1/\gamma} \geq 0 \tag{22}$$

Backward induction intermediates

If solutions are based upon Euler conditions, then the following differential terms are also calculated for reference by the backward induction procedure that is used to evaluate solutions at $t < T$:

$$\frac{\partial V_t}{\partial w_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial w_t} + \delta \zeta_b \left(\zeta_a + \zeta_b w_{t+1}\right)^{-1/\gamma} \frac{\partial w_{t+1}}{\partial w_t} \tag{23}$$

$$\frac{\partial c_t^{\max}}{\partial w_t} = (1 + ptr_t) \tag{24}$$

$$\frac{\partial w_{t+1}}{\partial w_t} = (1 + ptr_t) \tag{25}$$

$$\frac{\partial V_t}{\partial p_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial p_t} + \delta \zeta_b \left(\zeta_a + \zeta_b w_{t+1}\right)^{-1/\gamma} \frac{\partial w_{t+1}}{\partial p_t} \tag{26}$$

$$\frac{\partial c_t^{\max}}{\partial p_t} = \left(1 - \pi^{pt} + \pi^{pt} mpy_t\right) \tag{27}$$

$$\frac{\partial w_{t+1}}{\partial p_t} = \left(1 - \pi^{pt} + \pi^{pt} mpy_t\right) \tag{28}$$

where ptr_t denotes the post-tax return to savings received by the household in period t, and mpy_t denotes marginal post-tax income $(\partial \tau / \partial x)$.

If quasi-hyperbolic preferences are considered and $\beta_2 \neq 1$, then $\widehat{X}_t = E_t \left(\frac{1}{(1-1/\gamma)} \left(\zeta_a + \zeta_b w_{t+1}^+\right)^{1-1/\gamma} \right)$ and $\widehat{u}_t$ are stored separately to permit evaluation of the value function in period $t = T - 1$. Otherwise, if $\beta_1 \neq 1$ but $\beta_2 = 1$, then $\widehat{Y}_t = \widehat{u}_t + \delta E_t \left(\left(\zeta_a + \zeta_b w_{t+1}^+\right)^{1-1/\gamma} \right)$ is calculated and stored.

B.2. From State Pensionable Age: $t_{SPA} \leq t < T$

Variables

During this period, a household can choose their consumption, labour supply, and the proportion of their liquid wealth that is invested in a risky asset, v_t. Here, we have:[23]

state variables t:	w_t, p_t, h_t, n_t^a
control variables t:	c_t, v_t, l_t
state variables $t+1$:	$w_{t+1}, p_{t+1}, h_{t+1}, n_{t+1}^a$

23 In period T, h_T is omitted from the decision problem.

Value function

$$V_t = \max_{c_t, v_t, l_t} \left\{ \frac{1}{1-1/\gamma} u_t^{1-1/\gamma} + E_t \left[\frac{\beta_1 \delta}{(1-1/\gamma)} \left(\varphi_t \widehat{u}_{t+1}^{1-1/\gamma} + (1-\varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma} \right) + \right. \right.$$
$$\left. \left. + \beta_1 \beta_2 \delta^2 \varphi_t \widehat{X}_{t+1} \right] \right\} \quad (29)$$

$$w_{t+1} = \min \left\{ w_{t+1}^{\max}, \max \left\{ w_{t+1}^{\min}, \hat{w}_{t+1} \right\} \right\} \quad (30)$$

$$p_{t+1} = \min \left\{ p_{t+1}^{\max}, \hat{p}_{t+1} \right\} \quad (31)$$

$$h_{t+1} = \min \left\{ h_{t+1}^{\max}, \max \left\{ h_{t+1}^{\min}, H\left(t, h_t, n_t^a, n_{t+1}^a, l_t, \omega_t\right) \right\} \right\} \quad (32)$$

$$n_{t+1}^a = N^a \left(t, n_t^a, \epsilon_t^a\right) \quad (33)$$

$$0 \leq v \leq 1 \quad (34)$$

$$c_t \leq c_t^{\max} \quad (35)$$

$$\hat{w}_{t+1} = w_t + \tau_t - c_t \quad (36)$$

$$\hat{p}_{t+1} = \left(\frac{\pi^s + (1-\pi^s)\left(n_{t+1}^a - 1\right)}{\pi^s + (1-\pi^s)\left(n_t^a - 1\right)} \right) p_t \quad (37)$$

$$c_t^{\max} = w_t + \tau_t^{\min} - w_{t+1}^{\min} \quad (38)$$

where $H(.)$ denotes the intertemporal evolution of a household's latent wage (as defined by equation (10)), and $N^a(.)$ defines the intertemporal development of relationship status (as defined by equation (11)). We do not impose an upper bound on the loss that may be incurred when investing in the risky asset. Two assumptions ensure that net liquid wealth never falls below the maximum debt that is considered for analysis. First, we assume that the consumption decision is subject to an upper bound, $c_t^{\max}$, to limit the probability that the upper bound on debt will be breached.[24] Second, given the upper limit on consumption, we assume that the government provides an income top-up to enforce the lower bound on net liquid wealth (as is implied by the specification of the intertemporal evolution of wealth defined by equation (30)).

Equation (30) also makes clear that we assume that a 100% wealth tax is levied on any wealth accrued beyond the maximum threshold $w_{t+1}^{\max}$. Similar assumptions are made in relation to the pension annuity and wage state variables, so that the evaluation of expected utility does not require grid extrapolations. We avoid extrapolating outside of the state-space defined by the grids considered for analysis, as we have found this to be an important source of error in previous work. The upper bound on wealth

24 Hence $\tau_t^{\min}$ is set so that the probability of $\tau_t < \tau_t^{\min}$ is small. In practice, we evaluate $\tau_t^{\min}$ on the basis of the worst case scenario implied by the abscissae of the Gaussian quadrature that is used to evaluate expectations in the model.

by age is determined endogenously by the model, based on the grid limits that are assumed for labour income. The user should consequently specify an upper bound on labour income that is sufficiently high to capture extremes observed in practice.

Euler conditions (if $\beta_1 = \beta_2 = 1$)

A local optimum over the decision set (c_t, v_t) is calculated for each discrete labour option, and the decision set (c_t, v_t, l_t) is then selected to maximise the associated value function. Solution for each (c_t, v_t) combination is based upon the Euler conditions defined by:

$$\frac{\partial V_t}{\partial c_t} = \frac{\partial u_t}{\partial c_t} u_t^{-1/\gamma} + \delta E_t \left\{ \left[\varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \right] \frac{\partial w_{t+1}}{\partial c_t} \right\} \geq 0 \tag{39}$$

$$\frac{\partial w_{t+1}}{\partial c_t} = \begin{cases} -1 \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{40}$$

$$\frac{\partial V_t}{\partial v_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial v_t} + \delta E_t \left\{ \left[\varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \right] \frac{\partial w_{t+1}}{\partial v_t} \right\} \gtreqless 0 \tag{41}$$

$$\frac{\partial c_t^{\max}}{\partial v_t} = mpy_t^{\min} \left(r_t^{r,\min} - r_t^s \right) w_t \tag{42}$$

$$\frac{\partial w_{t+1}}{\partial v_t} = \begin{cases} mpy_t \left(r_t^r - r_t^s\right) w_t \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{43}$$

where Φ_{t+1} is a dummy variable that is equal to one when $w_{t+1} \geq 0$, and is zero otherwise. $mpy^{\min}$ and $r^{r,\min}$ define the values of mpy and r^r used to calculate $\tau^{\min}$.[25] Note that the Euler conditions used to identify the (locally) optimal values of c and v make reference to $\partial V_{t+1}/\partial w_{t+1}$; this term is evaluated by interpolation with reference to the model solutions obtained for period $t+1$.

Backward induction intermediates

Where Euler conditions are considered then the following terms are calculated and stored:

$$\frac{\partial V_t}{\partial w_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial w_t} + \delta E_t \left\{ \left(\varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \right) \frac{\partial w_{t+1}}{\partial w_t} \right\} \tag{44}$$

25 Where c_t is not bound, then the evaluation of $\partial c^{\max}/\partial v$ does not influence equation (41), as $\partial V/\partial c = 0$.

$$\frac{\partial c_t^{\max}}{\partial w_t} = \left(1 + ptr_t^{\min}\right) \tag{45}$$

$$\frac{\partial w_{t+1}}{\partial w_t} = \begin{cases} (1 + ptr_t) & \text{if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 & \text{otherwise} \end{cases} \tag{46}$$

$$\begin{aligned} \frac{\partial V_t}{\partial p_t} &= \frac{\partial V_t}{\partial c_t}\frac{\partial c_t^{\max}}{\partial p_t} + \delta E_t \left\{ \left(\varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} + (1 - \varphi_t)\,\zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \right) \frac{\partial w_{t+1}}{\partial p_t} + \right. \\ &\left. + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}} \frac{\partial p_{t+1}}{\partial p_t} \right\} \end{aligned} \tag{47}$$

$$\frac{\partial c_t^{\max}}{\partial p_t} = \left(1 - \pi^{pt} + \pi^{pt} mpy_t^{\min}\right) \tag{48}$$

$$\frac{\partial w_{t+1}}{\partial p_t} = \begin{cases} (1 - \pi^{pt} + \pi^{pt} mpy_t) & \text{if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 & \text{otherwise} \end{cases} \tag{49}$$

$$\frac{\partial p_{t+1}}{\partial p_t} = \begin{cases} \left(\frac{\pi^s + (1-\pi^s)(n_{t+1}^a - 1)}{\pi^s + (1-\pi^s)(n_t^a - 1)} \right) & \text{if } \hat{p}_{t+1} \leq p_{t+1}^{\max} \\ 0 & \text{otherwise} \end{cases} \tag{50}$$

where $ptr^{\min}$ denotes the post-tax rate of return to net liquid wealth used to evaluate the upper bound imposed on c_t.

As above, if quasi-hyperbolic preferences are considered and $\beta_2 \neq 1$, then $\widehat{u}_t$ and

$$\widehat{X}_t = E_t \left(\varphi_t \widehat{W}_{t+1} + \frac{(1 - \varphi_t)}{(1 - 1/\gamma)} \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma} \right)$$

are stored separately to permit evaluation of the value function in period $t - 1$. Otherwise, if $\beta_1 \neq 1$ but $\beta_2 = 1$, then

$$\widehat{Y}_t = \widehat{u}_t + \delta E_t \left((1 - 1/\gamma)\, \varphi_t \widehat{W}_{t+1} + (1 - \varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{1-1/\gamma} \right)$$

is calculated and stored.

B.3. Period prior to State Pensionable Age: $t = t_{SPA} - 1$

Variables

During this period, a household can choose their consumption, labour supply, private pension contribution, and investment in a risky asset. Here, we have:

state variables t:	$w_t, w_t^o, w_t^p, h_t, n_t^a, n_t^k$
control variables t:	$c_t, v_t, \pi_t^{pc}, l_t$
state variables $t+1$:	$w_{t+1}, p_{t+1}, h_{t+1}, n_{t+1}^a$

Value function

$$V_t = \max_{c_t, \nu_t, \pi_t^{pc}, l_t} \left\{ \frac{1}{1-1/\gamma} u_t^{1-1/\gamma} + E_t \left[\frac{\beta_1 \delta}{(1-1/\gamma)} \left(\varphi_t \widehat{u}_{t+1}^{1-1/\gamma} + (1-\varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^{+} \right)^{1-1/\gamma} \right) + \right. \right.$$
$$\left. \left. + \beta_1 \beta_2 \delta^2 \varphi_t \widehat{X}_{t+1} \right] \right\} \quad (51)$$

$$w_{t+1} = \min \left\{ w_{t+1}^{\max}, \max \left\{ w_{t+1}^{\min}, \bar{w}_{t+1} \right\} \right\} \quad (52)$$

$$p_{t+1} = \min \left\{ p_{t+1}^{\max}, \bar{p}_{t+1} \right\} \quad (53)$$

$$h_{t+1} = \min \left\{ h_{t+1}^{\max}, \max \left\{ h_{t+1}^{\min}, H\left(t, h_t, n_t^a, l_t, n_{t+1}^a, \omega_t\right) \right\} \right\} \quad (54)$$

$$n_{t+1}^a = N^a \left(t, n_t^a, \epsilon_t^a\right) \quad (55)$$

$$0 \leq \nu_t \leq 1 \quad (56)$$

$$\pi_l^{pc} \leq \pi_t^{pc} \leq \pi_u^{pc} \quad (57)$$

$$c_t \leq c_t^{\max} \quad (58)$$

$$\hat{w}_{t+1} = w_t + \tau_t - c_t \quad (59)$$

$$\bar{w}_{t+1} = \min \left\{ \hat{w}_{t+1}, 0 \right\} + (1-\pi_a^l) \max \left\{ 0, \hat{w}_{t+1} \right\} + (1-\pi_a^o) w_{t+1}^o + (1-\pi_a^p) w_{t+1}^p \quad (60)$$

$$\bar{p}_{t+1} = \chi(\pi_a^l \max \left\{ 0, \hat{w}_{t+1} \right\} + \pi_a^o w_{t+1}^o + \pi_a^p w_{t+1}^p) \quad (61)$$

$$w_{t+1}^o = \left(1 + r_t^o\right) w_t^o + \left(\pi^{oc} + \pi_{ec}^o\right) g_t \Phi_t'' \quad (62)$$

$$w_{t+1}^p = \left(1 + r_t^p\right) w_t^p + \left(\pi_t^{pc} + \pi_{ec}^p\right) \left(g_t - \pi_l^p\right) \Phi_t' \quad (63)$$

$$c_t^{\max} = w_t + \tau_t^{\min} + \left(1 - \pi_a^o\right) w_{t+1}^{o,\min} + \left(1 - \pi_a^p\right) w_{t+1}^{p,\min} - w_{t+1}^{\min} \quad (64)$$

where Φ_t' is a dummy variable that equals one when $\pi_l^p \leq g_t \leq \pi_u^p$ and zero otherwise, and Φ_t'' is a dummy variable that equals one when $\pi_l^o \leq g_t$ and zero otherwise.

Euler conditions (if $\beta_1 = \beta_2 = 1$)

A local optimum is calculated with respect to the decision set $\left(c_t, \nu_t, \pi_t^{pc}\right)$ for each discrete labour option, and the decision set $\left(c_t, \nu_t, \pi_t^{pc}, l_t\right)$ is selected to maximise the associated value function. Solution for each $\left(c_t, \nu_t, \pi_t^{pc}\right)$ combination is based upon the Euler conditions defined by:

$$\frac{\partial V_t}{\partial c_t} = \frac{\partial u_t}{\partial c_t} u_t^{-1/\gamma} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} \frac{\partial w_{t+1}}{\partial c_t} + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}} \frac{\partial p_{t+1}}{\partial c_t} + \right.$$
$$\left. + \quad (1-\varphi_t) \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \frac{\partial w_{t+1}}{\partial c_t} \right\} \geq 0 \quad (65)$$

$$\frac{\partial w_{t+1}}{\partial c_t} = \begin{cases} 0 & \text{if } \bar{w}_{t+1} < w_{t+1}^{\min} \\ -1 & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ -\left(1-\pi_a^l\right) & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } w_{t+1}^{\max} < \bar{w}_{t+1} \end{cases} \tag{66}$$

$$\frac{\partial p_{t+1}}{\partial c_t} = \begin{cases} 0 & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ -\chi\pi_a^l & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } p_{t+1}^{\max} < \bar{p}_{t+1} \end{cases} \tag{67}$$

$$\begin{aligned} \frac{\partial V_t}{\partial v_t} &= \frac{\partial V_t}{\partial c_t}\frac{\partial c_t^{\max}}{\partial v_t} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}}\frac{\partial w_{t+1}}{\partial v_t} + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}}\frac{\partial p_{t+1}}{\partial v_t} + \right. \\ &+ \left. \left(1-\varphi_t\right)\zeta_b\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma}\Phi_{t+1}\frac{\partial w_{t+1}}{\partial v_t}\right\} \gtreqless 0 \end{aligned} \tag{68}$$

$$\frac{\partial c_t^{\max}}{\partial v_t} = mpy_t^{\min}\left(r_t^{r,\min} - r_t^s\right) w_t \tag{69}$$

$$\frac{\partial w_{t+1}}{\partial v_t} = \begin{cases} 0 & \text{if } \bar{w}_{t+1} < w_{t+1}^{\min} \\ mpy_t\left(r_t^r - r_t^s\right) w_t & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \left(1-\pi_a^l\right) mpy_t\left(r_t^r - r_t^s\right) w_t & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } w_{t+1}^{\max} < \bar{w}_{t+1} \end{cases} \tag{70}$$

$$\frac{\partial p_{t+1}}{\partial v_t} = \begin{cases} 0 & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \chi\pi_a^l mpy_t\left(r_t^r - r_t^s\right) w_t & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } p_{t+1}^{\max} < \bar{p}_{t+1} \end{cases} \tag{71}$$

$$\begin{aligned} \frac{\partial V_t}{\partial \pi_t^{pc}} &= \frac{\partial V_t}{\partial c_t}\frac{\partial c_t^{\max}}{\partial \pi_t^{pc}} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}}\frac{\partial w_{t+1}}{\partial \pi_t^{pc}} + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}}\frac{\partial p_{t+1}}{\partial \pi_t^{pc}} + \right. \\ &+ \left. \left(1-\varphi_t\right)\zeta_b\left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma}\Phi_{t+1}\frac{\partial w_{t+1}}{\partial \pi_t^{pc}}\right\} \gtreqless 0 \end{aligned} \tag{72}$$

$$\frac{\partial c_t^{\max}}{\partial \pi_t^{pc}} = \frac{\partial \tau_t^{\min}}{\partial \pi_t^{pc}} \tag{73}$$

$$\frac{\partial w_{t+1}}{\partial \pi_t^{pc}} = \begin{cases} 0 & \text{if } \bar{w}_{t+1} < w_{t+1}^{\min} \\ \frac{\partial \tau_t}{\partial \pi_t^{pc}} + \left(1-\pi_a^p\right)\left(g_t - \pi_l^p\right)\Phi_t' & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \left(1-\pi_a^l\right)\frac{\partial \tau_t}{\partial \pi_t^{pc}} + \left(1-\pi_a^p\right)\left(g_t - \pi_l^p\right)\Phi_t' & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } w_{t+1}^{\max} < \bar{w}_{t+1} \end{cases} \tag{74}$$

$$\frac{\partial p_{t+1}}{\partial \pi_t^{pc}} = \begin{cases} \chi\pi_a^p\left(g_t - \pi_l^p\right)\Phi_t' & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \chi\left[\pi_a^l\frac{\partial \tau_t}{\partial \pi_t^{pc}} + \pi_a^p\left(g_t - \pi_l^p\right)\Phi_t'\right] & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } p_{t+1}^{\max} < \bar{p}_{t+1} \end{cases} \tag{75}$$

Backward induction intermediates

Where Euler conditions are considered then the following terms are calculated and stored:

$$\frac{\partial V_t}{\partial w_t} = \frac{\partial V_t}{\partial c_t}\frac{\partial c_t^{\max}}{\partial w_t} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}}\frac{\partial w_{t+1}}{\partial w_t} + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}}\frac{\partial p_{t+1}}{\partial w_t} + \right.$$
$$\left. + \left(1-\varphi_t\right)\zeta_b\left(\zeta_a+\zeta_b w_{t+1}^{+}\right)^{-1/\gamma}\Phi_{t+1}\frac{\partial w_{t+1}}{\partial w_t}\right\} \tag{76}$$

$$\frac{\partial c_t^{\max}}{\partial w_t} = \left(1+ptr_t^{\min}\right) \tag{77}$$

$$\frac{\partial w_{t+1}}{\partial w_t} = \begin{cases} 0 & \text{if } \bar{w}_{t+1} < w_{t+1}^{\min} \\ \left(1+ptr_t\right) & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \left(1-\pi_a^l\right)\left(1+ptr_t\right) & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } w_{t+1}^{\max} < \bar{w}_{t+1} \end{cases} \tag{78}$$

$$\frac{\partial p_{t+1}}{\partial w_t} = \begin{cases} 0 & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} < 0 \\ \chi\pi_a^l\left(1+ptr_t\right) & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \text{ and } \hat{w}_{t+1} \ge 0 \\ 0 & \text{if } p_{t+1}^{\max} < \bar{p}_{t+1} \end{cases} \tag{79}$$

$$\frac{\partial V_t}{\partial w_t^p} = \frac{\partial V_t}{\partial c_t}\frac{\partial c_t^{\max}}{\partial w_t^p} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}}\frac{\partial w_{t+1}}{\partial w_t^p} + \varphi_t \frac{\partial V_{t+1}}{\partial p_{t+1}}\frac{\partial p_{t+1}}{\partial w_t^p} + \right.$$
$$\left. + \left(1-\varphi_t\right)\zeta_b\left(\zeta_a+\zeta_b w_{t+1}^{+}\right)^{-1/\gamma}\Phi_{t+1}\frac{\partial w_{t+1}}{\partial w_t^p}\right\} \tag{80}$$

$$\frac{\partial c_t^{\max}}{\partial w_t^p} = \left(1-\pi_a^p\right)\left(1+r_t^{p,\min}\right) \tag{81}$$

$$\frac{\partial w_{t+1}}{\partial w_t^p} = \begin{cases} \left(1-\pi_a^p\right)\left(1+r_t^p\right) & \text{if } w_{t+1}^{\min} \le \bar{w}_{t+1} \le w_{t+1}^{\max} \\ 0 & \text{otherwise} \end{cases} \tag{82}$$

$$\frac{\partial p_{t+1}}{\partial w_t^p} = \begin{cases} \chi\pi_a^p\left(1+r_t^p\right) & \text{if } \bar{p}_{t+1} \le p_{t+1}^{\max} \\ 0 & \text{otherwise} \end{cases} \tag{83}$$

If quasi-hyperbolic preferences are considered and $\beta_2 \neq 1$, then $\widehat{u}_t$ and

$$\widehat{X}_t = E_t\left(\varphi_t\widehat{W}_{t+1} + \frac{\left(1-\varphi_t\right)}{\left(1-1/\gamma\right)}\left(\zeta_a+\zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right)$$

are stored separately to permit evaluation of the value function in period $t-1$. Otherwise, if $\beta_1 \neq 1$ but $\beta_2 = 1$, then

$$\widehat{Y}_t = \widehat{u}_t + \delta E_t\left(\left(1-1/\gamma\right)\varphi_t\widehat{W}_{t+1} + \left(1-\varphi_t\right)\left(\zeta_a+\zeta_b w_{t+1}^{+}\right)^{1-1/\gamma}\right)$$

is calculated and stored.

B.4. Period $t < t_{SPA} - 1$

Variables

Here, we have:

state variables t: $w_t, w_t^o, w_t^p, h_t, n_t^a, n_t^k$

control variables t: $c_t, v_t, \pi_t^{pc}, l_t$

state variables $t+1$: $w_{t+1}, w_{t+1}^o, w_{t+1}^p, h_{t+1}, n_{t+1}^a, n_{t+1}^k$

Value function

$$V_t = \max_{c_t, v_t, \pi_t^{pc}, l_t} \left\{ \frac{1}{1-1/\gamma} u_t^{1-1/\gamma} + E_t \left[\frac{\beta_1 \delta}{(1-1/\gamma)} \left(\varphi_t \widehat{u}_{t+1}^{1-1/\gamma} + (1-\varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^{+} \right)^{1-1/\gamma} \right) + \right.\right.$$

$$\left.\left. + \beta_1 \beta_2 \delta^2 \varphi_t \widehat{X}_{t+1} \right] \right\} \tag{84}$$

$$w_{t+1} = \min \left\{ w_{t+1}^{\max}, \max \left\{ w_{t+1}^{\min}, \hat{w}_{t+1} \right\} \right\} \tag{85}$$

$$w_{t+1}^o = \min \left\{ w_{t+1}^{o,\max}, \hat{w}_{t+1}^o \right\} \tag{86}$$

$$w_{t+1}^p = \min \left\{ w_{t+1}^{p,\max}, \hat{w}_{t+1}^p \right\} \tag{87}$$

$$h_{t+1} = \min \left\{ h_{t+1}^{\max}, \max \left\{ h_{t+1}^{\min}, H\left(t, h_t, n_t^a, l_t, n_{t+1}^a, \omega_t\right) \right\} \right\} \tag{88}$$

$$n_{t+1}^a = N^a \left(t, n_t^a, \epsilon_t^a\right) \tag{89}$$

$$n_{t+1}^k = N^k \left(t, n_{t+1}^a, n_t^k, \epsilon_t^k\right) \tag{90}$$

$$0 \leq v_t \leq 1 \tag{91}$$

$$\pi_l^{pc} \leq \pi_t^{pc} \leq \pi_u^{pc} \tag{92}$$

$$c_t \leq c_t^{\max} \tag{93}$$

$$\hat{w}_{t+1} = w_t + \tau_t - c_t \tag{94}$$

$$\hat{w}_{t+1}^o = \left(1 + r_t^o\right) w_t^o + \left(\pi^{oc} + \pi_{ec}^o\right) g_t \Phi_t'' \tag{95}$$

$$\hat{w}_{t+1}^p = \left(1 + r_t^p\right) w_t^p + \left(\pi_t^{pc} + \pi_{ec}^p\right) \left(g_t - \pi_l^p\right) \Phi_t' \tag{96}$$

$$c_t^{\max} = w_t + \tau_t^{\min} - w_{t+1}^{\min} \tag{97}$$

Euler conditions (if $\beta_1 = \beta_2 = 1$)

A local optimum is calculated with respect to the decision set $\left(c_t, v_t, \pi_t^{pc}\right)$ for each discrete labour option, and the decision set $\left(c_t, v_t, \pi_t^{pc}, l_t\right)$ is selected to maximise the associated value function. Solution for each $\left(c_t, v_t, \pi_t^{pc}\right)$ combination is based upon the Euler conditions defined by:

$$\frac{\partial V_t}{\partial c_t} = \frac{\partial u_t}{\partial c_t} u_t^{-1/\gamma} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} \frac{\partial w_{t+1}}{\partial c_t} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \frac{\partial w_{t+1}}{\partial c_t} \right\} \geq 0 \tag{98}$$

$$\frac{\partial w_{t+1}}{\partial c_t} = \begin{cases} -1 \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{99}$$

$$\frac{\partial V_t}{\partial v_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial v_t} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} \frac{\partial w_{t+1}}{\partial v_t} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \frac{\partial w_{t+1}}{\partial v_t} \right\} \gtreqless 0 \tag{100}$$

$$\frac{\partial c_t^{\max}}{\partial v_t} = mpy_t^{\min} \left(r_t^{r,\min} - r_t^{s} \right) w_t \tag{101}$$

$$\frac{\partial w_{t+1}}{\partial v_t} = \begin{cases} mpy_t \left(r_t^{r} - r_t^{s}\right) w_t \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{102}$$

$$\begin{aligned} \frac{\partial V_t}{\partial \pi_t^{pc}} &= \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial \pi_t^{pc}} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} \frac{\partial w_{t+1}}{\partial \pi_t^{pc}} + \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}^{p}} \frac{\partial w_{t+1}^{p}}{\partial \pi_t^{pc}} + \right. \\ &+ \left. (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \frac{\partial w_{t+1}}{\partial \pi_t^{pc}} \right\} \gtreqless 0 \end{aligned} \tag{103}$$

$$\frac{\partial c_t^{\max}}{\partial \pi_t^{pc}} = \frac{\partial \tau_t^{\min}}{\partial \pi_t^{pc}} \tag{104}$$

$$\frac{\partial w_{t+1}}{\partial \pi_t^{pc}} = \begin{cases} \frac{\partial \tau_t}{\partial \pi_t^{pc}} \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{105}$$

$$\frac{\partial w_{t+1}^{p}}{\partial \pi_t^{pc}} = \begin{cases} \left(g_t - \pi_l^{p}\right) \Phi_t' \text{ if } \hat{w}_{t+1}^{p} \leq w_{t+1}^{p,\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{106}$$

Backward induction intermediates

Where Euler conditions are considered then the following terms are calculated and stored:

$$\frac{\partial V_t}{\partial w_t} = \frac{\partial V_t}{\partial c_t} \frac{\partial c_t^{\max}}{\partial w_t} + \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}} \frac{\partial w_{t+1}}{\partial w_t} + (1-\varphi_t)\, \zeta_b \left(\zeta_a + \zeta_b w_{t+1}^{+}\right)^{-1/\gamma} \Phi_{t+1} \frac{\partial w_{t+1}}{\partial w_t} \right\} \tag{107}$$

$$\frac{\partial c_t^{\max}}{\partial w_t} = \left(1 + ptr_t^{\min}\right) \tag{108}$$

$$\frac{\partial w_{t+1}}{\partial w_t} = \begin{cases} \left(1 + ptr_t\right) \text{ if } w_{t+1}^{\min} \leq \hat{w}_{t+1} \leq w_{t+1}^{\max} \\ 0 \quad \text{otherwise} \end{cases} \tag{109}$$

$$\frac{\partial V_t}{\partial w_t^p} = \delta E_t \left\{ \varphi_t \frac{\partial V_{t+1}}{\partial w_{t+1}^p} \frac{\partial w_{t+1}^p}{\partial w_t^p} \right\} \tag{110}$$

$$\frac{\partial w_{t+1}^p}{\partial w_t^p} = \begin{cases} \left(1 + r_t^p\right) & \text{if } \hat{w}_{t+1}^p \leq w_{t+1}^{p,\max} \\ 0 & \text{otherwise} \end{cases} \tag{111}$$

If quasi-hyperbolic preferences are considered and $\beta_2 \neq 1$, then $\widehat{u}_t$ and

$$\widehat{X}_t = E_t \left(\varphi_t \widehat{W}_{t+1} + \frac{(1 - \varphi_t)}{(1 - 1/\gamma)} \left(\zeta_a + \zeta_b w_{t+1}^+\right)^{1-1/\gamma} \right)$$

are stored separately to permit evaluation of the value function in period $t - 1$. Otherwise, if $\beta_1 \neq 1$ but $\beta_2 = 1$, then

$$\widehat{Y}_t = \widehat{u}_t + \delta E_t \left((1 - 1/\gamma)\, \varphi_t \widehat{W}_{t+1} + (1 - \varphi_t) \left(\zeta_a + \zeta_b w_{t+1}^+\right)^{1-1/\gamma} \right)$$

is calculated and stored.

C. Data Sources

C.1. Household Budget Survey

The Household Budget Survey of 2004/2005 gathered data on the expenditure patterns, and socio-demographic composition, of just under 6,900 households. (A household was defined as a single person or group of people who regularly reside together in the same accommodation and who share the same catering arrangements.).

For the purposes of our model, the composite consumption good of interest is best interpreted as expenditure on all goods and services, including rent and mortgage interest on the family's residence, but excluding any mortgage capital repayment. This variable was constructed using the version of the HBS lodged at the ISSDA archive, and consumption expenditure classified by age group and partnership status (single/couple) was derived and used in calibration.

C.2. CSO Survey on Income and Living Conditions, 2005

The Survey on Income and Living Conditions (SILC) is the Irish element of the EU SILC. It is used both nationally and in an EU context as a tool for monitoring issues related to poverty and social inclusion. At the ESRI, the SILC data is reshaped into family units (single persons or married couples together with their dependent children) in order to provide the database for SWITCH, the ESRI tax-benefit model. In this form the data are well suited to provide a basis for the dynamic microsimulation model. A sub-population, excluding the self-employed and public sector employees, is defined, as explained in Section 1 of the paper. Special analyses of employment and disposable income are then used as part of the calibration process.

C.3. CSO Quarterly National Household Survey, 2005 (Quarter 2)

The QNHS is a very large scale survey (39,000 households) which gathers detailed information on employment and labour market participation. The version lodged at ISSDA was used to define the relevant subpopulation and conduct special analyses of participation in full-time and part-time employment by age, for use in the calibration process.

C.4. Living in Ireland Survey, 2000-2001

In order to estimate probabilities of transition from single to couple status, it was necessary to use data from a panel study. We used data from the last two waves of the Living in Ireland panel study (2000-2001) to estimate a logit regression for this purpose.

Executive Directors' and Employees' Pensions: A Level Playing Field?[1]

Gerard Hughes

1 INTRODUCTION

Following the decision of the Irish government to guarantee the liabilities of the banking system in 2008, the Minister for Finance set up a committee to review the remuneration packages payable to senior management and directors of the institutions covered by the guarantee. The Covered Institution Remuneration Oversight Committee reported that "...In general, top management make little or no employee contribution for their pensions" (see Department of Finance, 2009, par. 5.22). This is in sharp contrast to the pension arrangements for other employees of financial services companies as they are generally required to make contributions towards their pensions throughout their working lives, just as employees in non-financial companies in the private sector and in the public sector are required to do. The Committee went on to recommend that:

> Pension arrangements for senior executives in each institution should, in our view, be at least broadly similar to those applicable to the generality of the staff of the institution. (See Department of Finance, 2009, par. 5.23)

The Committee's findings raise the question: do pension arrangements for senior executives in non-financial companies differ from those of other employees? The purpose of this paper is to try to answer this question by looking at the pension arrangements for executive directors of large Irish companies quoted on the Dublin and London stock exchanges and comparing them, where possible, with pension arrangements for other employees.

The State has a strong interest in this question because it supports occupational pension arrangements through generous tax reliefs on employer and employee pension contributions, on the investment income of pension funds and on the lump sums payable to occupational pensioners on retirement. This favourable tax treatment "...is equivalent to an interest-free loan from the Treasury and significantly reduces the lifetime taxes of those employees who receive part of their

[1] I am grateful to Jim Stewart, Tim Callan and an anonymous referee for comments on an earlier draft.

compensation in wages and part in pensions, as opposed to those who receive all of their compensation in cash wages" as Munnell (1991, p. 393) points out.

Some public finance specialists, for example those who participated in the Mirrlees Review (Mirrlees, 2011), accept that pension saving is subsidised but "...diminish the importance of [the] revenue losses" by contending that "the treatment of pensions is consistent with that of saving under a consumption tax" (Munnell (1991, p. 394). However, a strong preference for a consumption tax is "of little relevance" as Munnell (1991, p. 394) points out when a country is committed to an income tax rather than a consumption tax and the tax treatment of pension saving is classified as a departure from the benchmark tax system, as it has been again recently by Ireland's Commission on Taxation (2009). Moreover, Hashimzade and Myles (2007), responding to the Mirrlees review, point out that the literature on the choice between income and expenditure as bases for personal taxation focuses on efficiency concerns, but is "...almost silent on the relative equity of the two bases". In a stylised model, with inequality in both earned and unearned income, and bequests of assets, and a range of possible levels and inter-correlations of inequality they find that an income tax performed better from an equity perspective.

The Revenue Commissioners estimate that employer contributions to occupational pension schemes amounted to €1.4 billion in 2007. As these contributions are deductible as a business expense, the estimated cost of tax relief for firms amounted to €150 million. In addition, the estimated cost of the exemption of the pension contributions from employee benefit in kind amounted to €540 million.

The remainder of the paper is structured as follows. Section 2 notes how information on executive directors' pensions was drawn from company accounts, and builds a profile of these pensions in terms of the type of scheme and the size and rates of pension contribution made on behalf of executive directors. Executive director's salaries and total remuneration packages are also considered. Section 3 considers related policy issues, including limits on pension contributions and the size of the accumulated pension fund. Section 4 argues for stricter limits on these parameters – known technically as the earnings cap and standard fund threshold. The main findings and conclusions are drawn together in the final section.

2 A Profile of Executive Directors' Pensions

2.1 Source of Pensions Information and Selection of Companies

Information on the pensions of executive directors is available from company accounts. The listing rules of the Irish Stock Exchange (2009) specify that companies must present information in tabular form on each element of each director's remuneration package by name. For defined benefit schemes the value of the increase in pension during the period under review is supposed to be stated together with the accumulated total amount in respect of the accrued benefit to which each director would be entitled on leaving service. For defined contribution schemes information is supposed to be provided on the contributions paid for each director of the company.

As our interest lies in the differences in pension arrangements between senior executives and other employees we focus on pension provision for executive directors in publicly quoted companies. Ideally, we would like to compare their pension arrangements with those for other employees in the same companies. Unfortunately, companies' annual reports do not provide information about the pension arrangements for other employees which is comparable to that for executive directors. Where it is available, therefore, we will use information on occupational pension arrangements for the average employee from a variety of sources (e.g., Pensions Board, Revenue Commissioners, Central Statistics Office (CSO)) to make our comparisons.

In order to gather information on executive directors' remuneration *The Irish Times* list of the Top 1,000 Companies in 2009 was examined in conjunction with the listings of publicly quoted companies on the Dublin and London stock exchanges to find companies with substantial business interests in Ireland whose annual accounts for 2009, or in some cases 2008, were available on the internet. Following the policy adopted in the preparation of *The Irish Times* list we omitted companies registered in Ireland which barely trade here and whose company accounts are filed in jurisdictions outside Ireland or the UK. This search resulted in the identification of 48 financial and non-financial companies from the lists mentioned. These companies had a total of 147 executive directors. All of the companies are listed on the Dublin and London stock exchanges. The list of companies included in our sample is given in Appendix 1.

2.2 Type of Pension Scheme

In recent years many companies have closed defined benefit (DB) schemes to new employees and replaced them with defined contribution schemes (DC). As the risk of underperformance of pension assets is borne by the employer in a DB scheme and by the employee in a DC scheme, it is important to establish if executive directors and employees have the same exposure to these risks.

Of the 48 companies for which we have pension data:

- 4 (8 per cent) have only DB schemes for their employees;
- 33 (69 per cent) have both DB and DC schemes;
- 11 (23 per cent) have only DC schemes.

However, for their executive directors:

- 21 (45 per cent) have only DB schemes;
- 13 (28 per cent) have both DB & DC schemes;
- 13 (28 per cent) have only DC schemes
- 1 company (2 per cent) does not state what type of scheme it provides. Publicly quoted companies are, therefore, far more likely to provide DB schemes for their executive directors than for their other employees.

Nevertheless, the percentage of executive directors covered by a DB scheme is not greatly different from the percentage of other private sector employees covered by such schemes. There are 147 executive directors in the 47 companies for which we have valid data. Of these 54 per cent appear to belong to DB schemes, 44 per cent to DC schemes, and for 1 per cent the type of scheme is not specified.[2] The Pensions Board Annual Report indicates that in 2009 there were 521,234 mainly private sector employees covered by funded DB and DC occupational schemes. Of these 254,325 employees were covered by DB schemes subject to the funding standard and 266,909 employees were covered by DC schemes. The percentage of employees covered by DB schemes was, therefore, just under 49 per cent or five percentage points less than the percentage of executive directors covered by DB schemes.

2.3 Size of Pension Contributions

The Companies Acts specify that information should be provided on the remuneration packages of executive directors. As this information includes annual payments of basic salary, fees or other remuneration, bonuses, benefits in kind, contributions to pension schemes and supplementary cash payments in lieu of a pension contribution, it is possible to identify the level of pension contribution made for executive directors and to estimate what proportion of their salary companies are contributing to a pension fund on their behalf. The Finance Act 2006 put a lifetime cap of €5 million on the size of an individual's pension fund. By 2009 this limit had increased to €5.418 million. There were 17 executive directors for whom no pension contribution was made but 12 of them received a cash contribution instead of a pension contribution ranging from €5,600 to €325,000. The average cash payment was €168,633 while the median payment was €179,500. Our analysis will, therefore, generally use the information available for the 130 executive directors who benefited from a pension contribution by their employer.

The average contribution made to a pension scheme by companies for their executive directors in 2009 amounted to €100,080 and the median contribution was

[2] The phrase "appear to belong" is used as many company accounts do not specify what type of scheme covers their executive directors and the type of scheme has to be inferred from other information in the accounts.

€68,000. For other private sector employees the average contribution was about €2,750 in 2007.[3] On average, therefore, executive directors benefited from pension contributions by their employers which were 36 times greater than the average employer contribution for private sector employees.

If executive directors belonged to a DB scheme it makes a difference to the amount which employers contribute on their behalf. The 64 executive directors in DB schemes had an average pension contribution of €117,457 while the 65 directors in DC schemes had an average contribution of €83,664 or 28 per cent less than those in DB schemes.

The size distribution of pension contributions for the 130 executive directors for which we have valid data is shown in Table 1. There were 4 executive directors, or 3 per cent of the total, for which pension contributions of €300,000 or more were made. There were 9 executive directors, or about 7 per cent of the total, who had pension contributions of €200,000 to €299,999 made on their behalf. Over one-fifth of the directors, or 28 out of 130, benefited from pension contributions of €100,000 to €199,999. Just over a third of the executive directors, or 43, had contributions of €50,000 to €99,999 while one-fifth received contributions of €25,000 to €49,999. One-seventh of the executive directors had pension contributions of up to €24,999 made on their behalf.

The cumulative distribution shows that almost two-thirds of executive directors had pension contributions of €50,000 or more made on their behalf while approaching one-third had contributions amounting to €100,000 or more.

[3] The average employer contribution for other employees is derived from total employer contributions in 2007 of €1.423 billion and membership of funded schemes of 517,684. The figures for executive directors do not include augmented pension contributions which may have been paid on termination of service. A CSO (2011b) survey of pension contributions in 2007 shows that the average employer contribution was €2,753 or 6 per cent of average gross annual earnings.

TABLE 1 Pension Contributions for Executive Directors by Size of Contribution, 2009

Size of Contribution (€)	No. of Executive Directors	Per Cent	Cumulative Per Cent
0 - 24,999	19	14.6	14.6
25,000 - 49,999	27	20.8	35.4
50,000 - 99,999	43	33.1	68.5
100,000 -149,999	14	10.8	79.2
150,000 - 199,999	14	10.8	90.0
200,000 - 299,999	9	6.9	96.9
300,000 or more	4	3.1	100.0
Total	130	100.0	

Note: Cases where companies make both a pension contribution and a cash payment in lieu of pension because the pension fund is in excess of Revenue limits are included.

2.4 Pension Contribution Rates

Table 2 shows the distribution of pension contribution rates for executive directors. The average contribution rate for executive directors in 2009 was 25.8 per cent of salary while the median was 20.8 per cent. The difference between the average and the median is influenced by a small number of contribution rates which exceed 75 per cent of salary. The average employer contribution rate for other private sector employees amounted to 8.5 per cent in 2007 according to a report by Life Strategies Ltd. for the Public Service Benchmarking Body (2007). A CSO (2011b) survey reports a lower figure for 2007 of 6 per cent of average annual gross earnings for all employees excluding those in the public sector. The average contribution rate for executive directors who are members of DB schemes is 24 per cent while for executive directors who belong to DC schemes the average is 27 per cent. These contribution rates for executive directors belonging to DB and DC schemes compare with average employer contribution rates for other employees of about 11 per cent for DB schemes and 7 per cent for DC schemes according to an IAPF (2003) benefits survey and information provided by Kenny (2003).[4] The contribution rates for executive directors for DB schemes are, therefore, twice as great as for other employees in DB schemes. The differential between executive directors and other employees is even greater for DC schemes. The contribution rate for executive directors' DC schemes is nearly four times greater than is being paid into DC schemes for other employees.

[4] The year 2003 is the latest one for which information could be found for employees average DB and DC contribution rates. The Pension Markets Survey carried out by the IAPF (2007) in 2007 does not provide enough information to enable us to estimate what the average employer DB and DC contribution rates are for employees.

TABLE 2 Distribution of Pension Contribution Rates as a Percentage of Salary for Executive Directors, 2009

Contribution Rate (Per cent)	Frequency	Valid Per Cent	Cumulative Per Cent
0 - 4.99	4	3.1	3.1
5 - 9.99	14	10.8	13.8
10 - 14.99	18	13.8	27.7
15 - 19.99	20	15.4	43.1
20 - 24.99	23	17.7	60.8
25 - 29.99	18	13.8	74.6
30 - 34.99	11	8.5	83.1
35 or more	22	16.9	100.0
Total	130	100.0	

Employer contributions of up to 9.99 per cent of salary were made on behalf of about 14 per cent of the executive directors. The same percentage had contribution rates of 10 to 15 per cent while 15 per cent had contribution rates of 15 to 20 per cent. Over 31 per cent had contribution rates of 20 to 30 per cent while 25 per cent had contribution rates in excess of 30 per cent.

The cumulative percentages in Table 2 indicate that 43 per cent of the executive directors benefited from contributions of up to 20 per cent of salary while the remaining 57 per cent benefited from contributions of more than 20 per cent.

2.5 Normal Retirement Age

For the great majority of private sector employees occupational pension schemes specify that the retirement age is 65. Unfortunately, only four companies appear to report the scheme retirement age for their executive directors. The scheme retirement age for the four directors for which information is published is three to five years lower than for the average private sector employee. However, more information would be required before more definite conclusions could be drawn about this aspect of executive directors' pensions.

2.6 Value of Accrued Pension

Companies are supposed to provide information in their annual accounts on the value of the pension which their executive directors have accrued to date and to which they would be entitled if they retired at the end of the reporting year. However, this information is provided in company accounts for 2009 for only 58 of the executive directors in our sample. It shows that the average company pension to which they would have been entitled if they had retired in 2009 was €199,100. The average would, therefore, have been nearly 17 times more than the annual State social insurance pension of €11,976 per annum in 2009 on which most pensioners depend or 11 times more than the average income from all sources of single adults aged 65 and over (€17,985 as reported by the *Survey on Income and Living Conditions 2009* (see CSO, 2010, Table 1.3)).

There is information in the company accounts for 2009 on the transfer value of pension funds for only twelve executive directors. It indicates that if their accrued pension entitlements had to be transferred elsewhere the average value of their accrued pension fund would have been €4.1 million. The largest transfer value amounted to €11.7 million while the smallest amounted to €117,000. Data on the value of funded occupational pension schemes in 2009 and on the number of employees covered by those schemes indicate that the average value of the pension fund for other employees amounted to €120,000.[5] The limited data available on pension transfer values, therefore, suggest that executive directors' pension funds were 35 times greater than the average pension fund of other employees who were covered by an occupational pension fund.

2.7 Executive Directors' Salaries

As already noted company accounts are obliged to provide details of different components of compensation for executive directors. These components enable us to identify the value of the executive directors' annual salaries and total remuneration packages.[6] How then do executive directors' salaries and total remuneration compare with those of other employees?

The average salary for an executive director amounted to €396,100 or more than ten times the average earnings of employees of €36,490 in 2009 as shown by the CSO (2011a) earnings and labour costs survey. The CSO (2011b) estimates that in 2007 the average gross annual earnings of employees in pension schemes provided by their employer was €43,678 or 16 per cent more than average annual earnings of €37,736 for all employees. The average salary for an executive director is influenced by a number of very large salaries amounting to almost €1 million or more payable to the highest paid chief executives. The salary for the five highest paid chief executives ranged from over €900,000 to nearly €1.3 million.

Nevertheless, many executive directors received annual salaries fairly close to the average figure as the median salary of executive directors in 2009 was €335,000 or about 85 per cent of the average executive's salary.

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[5] The transfer value is the amount the company would have to pay if the executive director transferred his pension elsewhere. The average fund value for other employees is derived by dividing the value of all pension funds in 2009 (€72 billion, see *The Irish Times*, 14 April 2010)) by the number of members of funded DB and DC schemes in 2009 (599,072).

[6] Company accounts provide information on the allocation of company shares and share options to executive directors. This component of the total remuneration package amounts to a sizeable part of total compensation for many executive directors but it is difficult to estimate its value on an annual basis. Consequently, it is not included in our table showing total remuneration.

TABLE 3 Distribution of Executive Directors Salaries in 2009

Salary Range (€)	No. of Executive Directors	Per Cent	Cumulative Per Cent
0 - 99,999	3	2.0	2.0
100,000 - 249,999	37	25.2	27.2
250,000 - 499,999	67	45.6	72.8
500,000 -749,999	29	19.7	92.5
750,000 - 999,999	7	4.8	97.3
1,000,000 and over	4	2.7	100.0
Total	147	100.0	

Note: The number of executive directors for which salary information is available is greater than the number for which pension information is available because 17 executive directors did not receive a pension contribution although 12 of them received a cash contribution in lieu of a pension contribution.

The distribution of executive director salaries by salary range is shown in Table 3. Only 2 per cent of executive directors were paid less than €100,000. A quarter of them received between €100,000 and €249,999. Nearly 46 per cent of them had salaries ranging from €$^{1}/_{2}$ million to €$^{3}/_{4}$ million while around 30 per cent received more than €$^{1}/_{2}$ million. The cumulative distribution shows that 72 per cent of executive directors received salaries of €250,000 or more per year.

In addition to their basic salary 47 per cent of the executive directors received a performance bonus. Their average bonus was €251,913. As in the case of salaries this figure is influenced by several bonus payments ranging from €500,000 to nearly €900,000. The median bonus payment was €209,316 or 83 per cent of the average bonus.

2.8 Total Remuneration

Adding the salary, fees, bonus, benefit in kind, pension expense, and cash in lieu of pension yields the total remuneration package of each executive director. The average total remuneration package for executive directors in 2009 amounted to €635,395 while the median package amounted to €555,000, or nearly 90 per cent of the average. A variety of payments, therefore, added around 60 per cent to the mean and median salaries paid to executive directors in 2009.

The CSO earnings and labour costs survey collects information on employee-related payments paid by the employer. It includes statutory employers' PRSI, other social costs (pension fund contributions, life assurance premiums, income continuance insurance), benefits in kind, and redundancy payments. In the second quarter of 2009 these employer payments added nearly 17 per cent to average hourly earnings so the total remuneration package of all employees amounted to €42,565. The executive directors' total remuneration package was, therefore, nearly fifteen times greater than that of the average employee.

Table 4 shows the distribution of total remuneration packages by size category.

TABLE 4 Distribution of Executive Directors Total Remuneration Packages, 2009

Total Remuneration	Frequency	Per Cent	Cumulative Per Cent
0 -99,999	2	1.4	1.4
100,000 - 249,999	20	13.6	15.0
250,000 - 499,999	46	31.3	46.3
500,000 - 749,999	37	25.2	71.4
750,000 - 999,999	21	14.3	85.7
1,000,000 - 1,249,999	7	4.8	90.5
1,250,000 or more	14	9.5	100.0
Total	147	100.0	

Note: See note to previous table.

About 1 in 7 executive directors received total remuneration of more than €1 million per year, and about 3 out of 10 received more than three-quarters of a million euro per year. More than half of the directors received more than half a million euro per year.

3 LIMITS ON PENSION CONTRIBUTIONS AND SIZE OF FUND

As the total remuneration package for the executive directors in our sample amounts on average to about €635,000 per year and the lowest paid director received €53,000 per year, it is clear that nearly all of them are in a position to make their own pension arrangements without any support from the State. Nevertheless, they benefit from very generous tax reliefs from the Exchequer on contributions to their pension funds, the investment earnings of their funds, and lump sums payable on retirement in the same way as other high income earners.

These arrangements confer advantages on executive directors and other high earners in at least two ways. First, the overwhelming majority of executive directors have earnings which place them in the highest income tax bracket. Consequently, they benefit from a subsidy worth twice as much (41 per cent) as the subsidy provided for standard rate taxpayers (20 per cent). Second, the generous cap on pension contributions qualifying for tax relief, and the associated limit on the size of an individual's pension fund, means that the cost to the Exchequer of pension tax reliefs is much greater for high earners than for lower and middle income earners. Indeed, Hughes (2005) and Callan, Keane and Walsh (2009) show that up to 80 per cent of pension tax relief accrues to taxpayers in the top 20 per cent of the income distribution.

The fairest way to deal with the first advantage which high earners have would be to allow pension tax relief only at the standard rate of tax. This policy has been advocated by the TCD Pension Policy Research Group (see Hughes and Stewart,

2007) and other critics of the private pension system such as Social Justice Ireland (2010) and the OECD (2008). Estimates of how much revenue would accrue to the Exchequer by standard rating the tax reliefs vary from around €500 million (see Department of Finance, 2010, p. 93) to about €1 billion per year (see Callan, Keane and Walsh (2009, p.28). A commitment was given by the Fianna Fáil/Green Party coalition government in the EU/IMF programme that standard rating of pension tax reliefs would be phased in by 2013 (see Department of Finance, 2011a) but the Minister for Finance in the current Fine Gael/Labour Party coalition government announced in his Budget 2012 speech that "Although the EU-IMF programme commits us to move to standard rate relief on pension contributions, I do not propose to do this or make changes to the existing marginal rate relief at this time" (see Department of Finance, 2011b).

The second advantage which high earners have could be addressed by further reductions in the caps on the earnings contribution level and the lifetime size of individual pension funds. These limits are the main policy instruments used to contain the cost of pension tax reliefs and to promote greater equity in pension tax relief between high earners and other earners. Are the current limits set at levels that are consistent with the objective of achieving greater equity in pension tax relief? Before answering this question it is necessary to review the context in which caps on earnings contributions and fund sizes were introduced and implemented in order to contain the cost of pension tax reliefs for high earners.

For many years the only limit set was that contributions should not exceed 15 per cent of pensionable salary. In 1996 age-related limits were introduced to provide greater incentives for pension saving by those closer to retirement. They allowed individuals aged less than 55 to contribute 15 per cent of pensionable salary and individuals aged 55 or over to contribute up to 20 per cent. In 1999 these limits were substantially increased in a radical shake up of the pension system by the Minister for Finance, Mr McCreevy. He changed the structure of the age-related limits to increase the incentive to make pension contributions as age increased by retaining the 15 per cent rate for those under 30 and adding five percentage points to it for every decade of age thereafter up to age 50 (see Table 5).

Table 5 Age-Related Maximum Pension Contribution as a Percentage of Earnings Eligible for Tax Relief, 1999-2005 and 2006-2009

Age Band	1996-1999	1999-2005	2006-2009
Under 30	15	15	15
30-40	15	20	20
40-50	15	25	25
50-55	15	30	30
55-60	20	30	35
60+	20	30	40

In a departure from the basic principle that a pension fund should be used to buy an annuity Mr McCreevy also made provision in the Finance Act 1999 for the self-employed and directors who owned 20 per cent of the shares in their company to continue managing their pension fund after retirement in an Approved Retirement Fund (ARF) or in an Approved Minimum Retirement Fund (AMRF). This privilege was extended in 2002 to include proprietary directors and company directors owning 5 per cent of their company shares, and to contributors to Personal Retirement Saving Accounts (PRSA) who were not in the labour force or who were not in pensionable employment.

He also introduced an earnings contribution cap of £200,000 (= €253,947) for contributors to Retirement Annuity Contracts but put no limit on the size of the pension fund which could be accumulated (see Table 6). The maximum pension contribution on which tax relief could be claimed in 1999, therefore, amounted to €76,200 (= €254,000 x 30 per cent). The same limits were applied in 2002 to employee contributions and to contributions to Personal Retirement Saving Accounts (PRSAs) when they were introduced in 2002.

The Minister underlined that he personally was primarily responsible for these changes to the pensions regime when he noted that:

> Some will call these proposals radical. I call them sensible and pro-consumer. I have had a considerable input in forming my views from Members of this House, pension commentators, the pension industry, the experts in the Revenue Commissioners and the advisers in my own Department. In the final analysis, these proposals have my stamp on them and the approval of the Government. (See Dail Debates, 16 February 1999).

The decision to allow the self-employed, and some company directors, to continue managing their pension fund after retirement in an Approved Retirement Fund was reviewed some years later by the Department of Finance (2006). It was found that from 1999 to 2005, 116 individuals accumulated pension funds in ARFs worth more than €5 million each. Two individuals accumulated pension funds worth around €100 million and 6,000 individuals accumulated pension funds worth about €235,000 on average (see Department of Finance, 2006 and Hughes, 2007).

However, the figure for the average size of fund masked a difference between the size of ARFs where the Qualifying Fund Manager was a life office or a stockbroker/bank. The average size of the fund managed by life offices was €148,000 whereas the average size of 484 funds managed by a stockbroker/bank was €661,000. In addition to accumulating large pension funds most of those who owned an ARF did not draw down any income from the fund, The Department of Finance (2006, p. G22) report concluded that:

> The analysis does suggest, however, that for those who have the capacity to survive in retirement without the need to rely on funds invested in an ARF, our 'EET'system of pension taxation is much closer to an 'EEE' system where effectively no tax is paid, or if it is, it is at a low rate and far into the future.

For less wealthy pensioners unlikely to leave their pension fund in an ARF the combination of the tax free lump sum and generous tax emption limits for those aged over 65 led the OECD (2008, p. 90) to reach a similar conclusion in relation to the pension system as a whole when it said that:

> ...few older households will pay any income tax and many of those who do will pay less than younger people with the same income. As a result, a tax system that aims for pension savings, returns and income to be subject to an 'exempt-exempt-tax' (EET) regime is in effect fairly close to being an 'exempt'exempt'exempt' (EEE) system where income channelled through pensions is unlikely to be taxed at any point of the life-cycle.

The revelations that ARFs were being used as a tax avoidance device and that employer contributions could be used by senior executives to get around the cap on the earnings contribution led to the introduction in 2006 of a number of limits on high earners' pension arrangements to create greater equity in pension tax relief. The limits included a cap on the pension contribution out of earnings which would be eligible for tax relief and a limit on the lifetime size of the pension fund which an individual could accumulate, In addition, Approved Retirement Funds to which some high earners could transfer their pension fund on retirement were made subject to taxation as if a specified percentage of the fund is drawn down each year.[7] As the Department of Finance (2006, p. 26) report pointed out these changes were "...aimed at proprietary directors and senior executive staff who are in a position to tailor their remuneration structure and the level of their employer's contributions so as to extract maximum benefits under the current regime."

The Department of Finance (2006) report did not reveal the names of the individuals who had accumulated very large pension funds. However, Murphy and Devlin (2009, p. 287) and Keena (2010) reported subsequently that some chief executives of banks and building societies had accumulated pension funds in excess of €13 million.

[7] The owners of ARFs were taxed in 2006 as if they had drawn down one per cent of the fund. This tax was increased to two per cent in 2007 and to three per cent in 2008 and subsequent years. In 2011 the tax on the assumed draw down was increased to five per cent of the fund.

These developments led the Revenue Commissioners and the Department of Finance (2006) to consider whether greater equity could be created in the arrangements for pension tax relief by including employer contributions within the age-related and annual earnings limits. However, it was decided that the best constraint on employer contributions would be a limit on the maximum allowable tax-relieved pension fund. Hence, a cap of €5 million was imposed in 2006 on the lifetime size of individual pension funds (see Table 6). The introduction of the standard fund threshold had no effect on the overwhelming majority of those covered by pension schemes as their annual contributions and the size of their pension funds are far below the Revenue Commissioners' limits. It did not force the 116 individuals who already had an ARF of more than €5 million to reduce the size of their pension fund although the tax on the assumed draw down may eventually result in some reduction. These owners of ARFs were allowed to apply to the Revenue Commissioners to keep the fund which they had built up and to increase it in line with the indexed value of the standard fund threshold (see Hughes, 2007 for further discussion of this issue).

The threshold did have an effect on executive directors whose pension funds amounted to around €5 million. As we have shown, some of those whose pension funds were in excess of the threshold were given cash payments by their companies in addition to or in lieu of pension contributions.

TABLE 6 Limits on Annual Pension Contributions and the Size of the Pension Fund, 1999-2011

Tax Year	Annual Contribution Earnings Cap	Limit on Size of Pension Fund	Maximum Tax Relieved Employee Contribution
1999	£200,000 (€254,000)	No limit	£60,000 (€76,200)
2006	€254,000	€5 million or value of fund at 7/12/05	€101,600
2007	€262,382	€5.165 million or indexed value of the personal fund threshold (as agreed with Revenue)	€104,953
2008	€275,239	€5.418 million or indexed value of the personal fund threshold (as agreed with Revenue)	€110,095
2009	€150,000	€5.418 million or indexed value of the personal fund threshold (as agreed with Revenue)	€60,000
2011	€115,000	€2.3 million or indexed value of the personal fund threshold (as agreed with Revenue)	€46,000

Note: Marginal tax rates 1999, 46 per cent; 2006, 42 per cent; 2007 to 2011, 41 per cent.

The intention behind the pension caps was made clearer by the Minister for Finance, Mr Lenihan, when he slashed the earnings cap almost in half from €275,239 in 2008 to €150,000 in 2009. He said in his budget speech on 14 October 2008 that this major reduction would "...promote greater equity in tax relief" (see Department of Finance, 2008). On the same day the Tánaiste, Ms. Coughlan, elaborated on this point when she said in the Dail:

> The measure will only affect taxpayers on higher incomes and will save the Exchequer €100 million in a full year. However, for the vast majority of taxpayers who save for retirement through supplementary private pension provision, this change will have no impact.
>
> As the Deputies are aware, the Green Paper on pensions estimated the total cost of tax relief and supplementary pension provision for 2006 was close to €3 billion. Over one-third of this cost is estimated to be accounted for by relief on employee contributions to occupational schemes and individual contributions to personal pension plans.
>
> Over recent years, many individuals and reports have raised the issue of the equity of the current tax relief arrangements given the significant Exchequer costs involved and the fact that the reliefs are skewed significantly towards those on higher incomes. Apart from helping to meet the challenging budgetary circumstances we are now facing, the decision to reduce the earnings limit should also be taken as a signal of the Government's intent to move towards more equitable tax arrangements generally for private pension provision in the context of the development of the long-term policy framework for the pensions.

Nevertheless, as the age-related percentage limits and the annual earnings cap apply only to pension contributions by individuals there is a loophole which may permit senior executives to frustrate efforts to create greater equity in pension tax relief. Employers are left free to contribute whatever amount they wish to employee pensions subject only to the constraint on the lifetime size of the fund.[8] Consequently, as the Minister for Finance (2009) noted in a written reply to a Parliamentary Question by the Labour TD Roísín Shortall on 6 October 2009:

> ...changes could be made to the terms of employment contracts, due to the reduction in the annual earnings cap, to provide for a switch from employee contributions to employer contributions.

The Covered Institution Remuneration Oversight Committee reported that some financial institutions were already doing this and it criticised the practice:

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[8] The Department of Finance (2006) report gives an example of how employer contributions can be used to circumvent the cap on the earnings contribution. Over a nine year period aggregate contributions of almost €14 million were made to two individual occupational pension schemes. These contributions were largely paid by the employer. The maximum contribution eligible for tax relief that an owner of an RAC or a PRSA could have made over the same period would have been €685,800.

> We consider that pension arrangements for top management should be reviewed. We have become aware of a practice in which cash allowances were paid to compensate for the effects of the "pensions cap" imposed by the Finance Act, 2006. Pension schemes should reflect public policy and tax law and it is unacceptable that arrangements should be put in place which would be inconsistent with the intent of the relevant legislation. (See Department of Finance, 2009, par. 5.21)

The reductions in the Finance Act 2009 and the Finance Act 2011 of the annual earnings limit on pension contributions to €150,000 and then to €115,000 are welcome steps toward creating greater equity in the pension system. Unfortunately, the reduction in the earnings limit that occurred in 2009 was not accompanied by any reduction in the standard fund threshold despite the recommendation of the Commission on Taxation (2009, Recommendation 10.8) that:

> There should be a correlation between the annual earnings limit and the standard fund threshold, and the reduction in the annual earnings limit suggests that there should be a corresponding reduction in the standard fund threshold.

However, the National Recovery Plan published in November 2010 pointed out that:

> Equity of the existing tax arrangements could be improved by further downward adjustments to the annual earnings cap for pension contribution purposes and to the maximum allowable lifetime limit for a tax relieved pension fund (the Standard Fund Threshold – SFT), both adjustments would impact on higher earners. (Dept. of Finance, 2010, p. 94)

Subsequently, the standard fund threshold was reduced to €2.3 million in the Finance Act 2011 when the earnings limit was reduced by the Fianna Fáil/Green Party coalition government to €115,000.

4 WHAT SHOULD THE EARNINGS CAP AND STANDARD FUND THRESHOLD BE?

If the standard fund threshold had been based on the amount needed to provide a maximum private pension of half salary for someone earning £115,000 in 2011 (i.e., a pension of €57,500), the lifetime size of the pension fund ought to have been reduced from €5.418 million to €1.32 million (= €57,500 x 20 + €115,000 x 1.5) using a valuation factor of 20:1 to convert a defined benefit pension to a cash equivalent and allowing for payment of a lump sum of $1^1/_2$ times salary out of the fund.[9]

None of the political parties proposed a standard fund threshold very close to this figure in the manifestos issued during the general election in 2011 as Hughes and Stewart (2011) point out. Table 7 shows that the Fine Gael proposal that the threshold should be €1.5 million is closest to the figure of €1.32 million.

TABLE 7 Pre-Budget 2011 Pension Tax Arrangements, Political Party Election 2011 Manifesto Proposals for Pension Tax Reliefs and TCD Pension Policy Research Group Pension Reform Proposals

Pension Component	Pre-Budget 2011	Fianna Fáil & Green Party	Fine Gael	Labour	Sinn Fein	TCD Pension Policy Research Group Proposals
Max. subsidised pension			€60,000			€27,050
Max. tax free lump sum	€1.350 million	€200,000	€250,000			€112,500
Earnings contribution cap	€150,000	€115,000			€100,000	€75,000
Standard fund threshold (€ million)	€5.418	€2.3	€1.5			€0.622
Marginal tax relief	41%	20% in 2014	41%	41%	20%	20%
Temporary levy on pension funds			0.5%			
Estimated reduction in cost of tax exp.		€700 million from 2014	€575* million	€500 million		€1 billion

Source: Hughes and Stewart (2011).

* The temporary levy of 0.6 per cent imposed on pension fund assets by the Fine Gael/Labour government in 2011 is estimated to yield €470 million per year over a four year period.

The proposals for pension caps by the political parties shown in Table 7 and the proposal in the Programme for Government "...to cap taxpayers subsidies for all future pension schemes for politicians (and indeed for everybody) that deliver income in retirement of more than €60,000" (see Department of Taoiseach, 2011) are focused on the private pension system and do not take account of the State contributory pension. The Pensions Board (1998) in the National Pensions Policy Initiative report argued that in retirement income from all sources, including Social Welfare and private pensions, should replace 50 per cent of pre-retirement income subject to the Social Welfare pension replacing 34 per cent of average industrial earnings.[10] Most funded DB schemes integrate their pension benefits with the State

9 The 20:1 rate (capitalisation factor) is given in section 19, of the Finance Act, 2011.

10 The Fine Gael/Labour maximum pension figure of €60,000 is somewhat more than the maximum pension of €57,500 implicit in the cap in the Finance Act 2011 on the earnings contribution of €115,000.

pension to limit the amount they have to pay to the difference between the percentage of earnings replaced by the State pension and 50 per cent of pensionable earnings. The National Pensions Framework (Department of Social and Family Affairs, 2010, p. 14)) endorses the integration of State and private pension benefits when it says that the government "...will seek to ensure that the level of the State Pension is maintained at 35 per cent of average weekly earnings where earnings are calculated by the CSO Earnings, Hours and Employment Costs Survey."

The Fianna Fáil/Green Party coalition set the earnings contribution limit for private pensions at €115,000. Fine Gael did not specify an earnings limit but it proposed that the maximum subsidised private pension should be €60,000 although its spokesman on Finance in 2009, Richard Bruton (2009) had suggested a lower limit of €40,000. Implicitly, therefore, the Fine Gael earnings limit is €120,000. Sinn Fein proposed an earnings limit of €100,000 so its implicit maximum subsidised private pension amounts to €50,000. The Labour Party did not specify either an earnings limit or a maximum subsidised pension in its manifesto but it stated that the amount of tax relief currently being given for private pensions is no longer supportable and that it favoured capping the tax relief on both employer and employee pension contributions and reducing the maximum pension fund and maximum tax-free lump sum payable on retirement. In the Programme for Government the Labour Party agreed with Fine Gael that the maximum subsidised private pension should not exceed €60,000. Implicitly, therefore, the Labour Party earnings cap is €120,000.

The earnings limits proposed by the political parties would allow a combined private pension and State contributory pension to replace more than 50 per cent of pre-retirement earnings up to limits of €100,000 to €120,000. These limits do not serve to target tax reliefs for private pensions at earners at the middle and lower end of the income distribution, as recommended by a number of commentators (Hughes and Stewart (2007), Tasc (2010), OECD (2009), Social Justice Ireland (2010)). The TCD Pension Policy Research Group in conjunction with Tasc (2010) argue that this could be done by using the PRSI ceiling of €75,000, which was about twice average earnings in 2010, as a benchmark to which the earnings contribution ceiling should be reduced.

An earnings contribution ceiling of €75,000 implies that the maximum subsidised pension should be €37,500 and the maximum tax free lump sum should be €112,500. If the State Pension had met the 35 per cent target mentioned in the National Pensions Framework it would have amounted to €12,623. However, it actually amounted to €11,976 or 32 per cent of the target pension. Hence, an integrated private pension would have had to provide an income in retirement of about €25,500 to ensure that the replacement rate target of 50 per cent for the maximum subsidised pension would be met. Applying the 20:1 valuation factor to this sum and allowing for payment of the lump sum out of the fund indicates that a standard fund threshold of €622,500 in 2010 would have been sufficient to achieve the 50 per cent target.

The reduction in the earnings contribution limit from €275,239 in 2008 to €115,000 in 2011 and in the standard fund threshold from €5.4 million in 2009 to €2.3 million in 2011 and the abolition of employee and employer PRSI relief on pension contributions shows that there is a desire to create greater equity in pension tax arrangements. A continuation of the policy of reducing these limits taking account of the contributory State pension in order to target pension tax reliefs at middle and lower income earners could result in a considerable levelling of the playing field between executive directors and other employees.

5 CONCLUSION

The evidence presented above shows that there is not a level playing field for executive directors and employees pensions. The replacement of DB schemes with DC schemes has affected other employees more than executive directors of publicly quoted companies. Proportionately, more executive directors continue to enjoy access to a DB scheme which is generously funded by their employer who bears the risk of poor performance of the fund.

Executive directors have far more favourable pension terms than other employees in terms of the percentage of salary their employer contributes to their pension fund. The average employer contribution rate for an executive director amounted to around 26 per cent compared with 6.9 to 8.5 per cent for private sector employees.

Executive directors benefit from much larger employer pension contributions (€100,000 on average) than other employees (€2,700 on average). The size of the employer contribution to executive pensions is related to the size of their salary (€396,100 on average) which is more than ten times greater than the average earnings of other employees (€36,490) or nine times greater than the average earnings of employees covered by an employer provided pension scheme (€43,678).

Although the data on executive directors' normal retirement age is limited they indicate that executive directors' pension schemes specify a lower retirement age than the schemes to which other employees belong. There are better data on the average pension to which executive directors would be entitled if they had retired in 2009. It shows that the average executive director would have been entitled to a company pension of about €199,100. This compares with an annual income from a State pension of €11,976 for single adults with no occupational pension and with an income from all sources of €17,985 for single adults aged 65 and over (see CSO, 2010, Table 1.4). On average, therefore, if the executive directors in our sample had retired in 2009 they would have been entitled to a pension 17 times more than the State pension which the majority of single pensioners were living on in 2009 or 11 times more than the average income of single adults aged 65 and over from State pensions and other sources.

Consideration of what the earnings cap and standard fund threshold should be to create a more even playing field between executive directors' and employees' pensions indicates that if the objective of public policy were to take account of the State contributory pension and to target pension tax reliefs at middle and lower earners, as the TCD Pension Policy Research Group and others argue, the earnings contribution should be capped at €75,000 and the standard fund threshold should be capped at €622,500.

Although companies are not obliged to provide information on the pension arrangements for other employees they are required to provide detailed information in their annual accounts on the pension arrangements for executive directors. Unfortunately, not all of them do so. It is difficult, therefore, to make detailed comparisons of how the pension arrangements for these two groups differ. The reporting requirements for executive directors' pensions should be enforced and broadened to include information on pension arrangements for other employees.

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Appendix 1

Appendix Table A1: Executive Pension Arrangements in 47 Non-Financial and Financial Companies Quoted on the Irish or UK Stock Exchanges in 2009

IT Rank: Non-Financial	Name of Company	Listed on Irish (ISX) or UK Stock Exchange (UKSX)	Annual Report Year End
1	CRH	ISX	31/12/09
4	Smurfit Kappa Group	ISX	31/12/09
6	DCC	ISX	31/12/09
8	Kerry Group	ISX	31/12/09
12	ESB	NL/Semi-state	31/12/09
15	Ryanair	ISX	31/3/09
16	Grafton Group	ISX	31/12/09
17	Aryzta	ISX	31/7/08
20	Total Produce	ISX	31/12/09
21	Glanbia	ISX	2/1/10
27	Diageo Ireland	ISX	30/6/09
30	United Drug	ISX	30/9/08
31	Kingspan Group	ISX	31/12/08
36	Origin Enterprises	ISX	31/07/09
41	Independent News & Media	ISX	31/12/09
45	Aer Lingus	ISX	31/12/08
47	Bord Gais Eireann	NL/Semi-state	31/12/09
51	Vodafone Ireland	LSX	31/3/09
53	Greencore Group	ISX	25/9/09
59	BT Ireland	LSX	31/3/09
68	An Post	NL/Semi-state	31/12/08
69	National Lottery Company	NL/Semi-state	31/12/08
81	Icon Clinical Research	ISX	31/12/09
84	Tullow Oil	ISX	31/12/08
89	Dublin Airport Authority	NL/Semi-state	31/12/08
92	Fyffes	ISX	31/12/08
106	C & C Group	ISX	29/2/09
115	FBD Holdings Plc	ISX	31/12/09
147	Irish Continental Group	ISX	31/12/09
179	Paddy Power	ISX	31/12/09
181	Eirgrid	NL/Semi-state	30/9/09
236	CPL Resources	ISX	30/6/09
273	Irish Aviation Authority	NL/Semi-state	31/12/09
348	Donegal Creameries	ISX	31/12/09
364	Hilton Food Group	LSX	31/12/09
371	RPS Group	LSX	31/12/09
388	IFG Group	ISX	30/12/09
	Kenmare Resources Plc	ISX	31/12/09
	Merrion Pharmaceutical	ISX	31/12/09
	TVC Holdings Plc	ISX	31/3/2010
	UTV Media	ISX	31/12/09
	Worldspreads Group Plc	ISX	31/12/09
IT Rank: Financial			
F2	Bank of Ireland	ISX	31/3/09
F4	Allied Irish Bank	ISX	31/12/09
F5	Anglo Irish Bank	NL	31/12/09
F7	Irish Life and Permanent	NL	31/12/09
F14	Educational Building Society	NL	31/12/09
F23	Irish Nationwide Building Society	NL	31/12/09

NL = not listed.

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