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Retirement Planning: Portfolio Choice for Long-Term Investors

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To my mother and father

Retirement Planning:
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Abstract

This thesis consists of four papers. Common to the first three papers is the framework for analysis; a life-cycle model of a borrowing-constrained individual's consumption and portfolio choices in the presence of uncertain labour income. The income process, taxes and pension systems are also realistically calibrated.

The first paper investigates some welfare effects of forced saving through a mandatory pension scheme. Pension benefits stem from both a defined benefit and a notionally defined contribution part, the latter indexed to stochastic aggregate labour income. It is shown that, early in life, individuals attribute little value to their pension savings. Furthermore, for individuals in mid-life, the welfare loss associated with the dependency between pension returns and labour income growth is estimated to 1.2% of annual consumption.

The second paper investigates the diversification demand of an individual faced with the alternative, through an individual account in a mandatory pension scheme, of exchanging aggregate labour income risk for equity exposure. It is shown that, depending on age and exchange premium, individuals will be either buyers or sellers of such swaps, and that inter-generational risk sharing can therefore be achieved.

The third paper explores the recent transition from defined benefit to defined contribution for white-collar workers in Sweden. The main result is that individuals with the characteristic of a low expected pre-retirement income relative to average income during working life and high variance in earnings are winners (typically, men with university degree in the private sector), and that those with the opposite characteristic (typically, women with university degree in the public sector) would be losers.

The aim of the fourth and final paper is to determine whether there is a home bias among the newly established Swedish National Pension Funds. Estimation errors in historical estimates of return moments make traditional analysis of the home bias puzzle work poorly. Therefore, this paper takes another approach by using the information available to the fund. The results demonstrate a significant bias towards domestic equities that cannot be explained by informational advantage or any other risk and return based explanation.

Preface

This thesis is concerned with optimal portfolio choice for long-term investors, with a particular focus on retirement savings. My original interest was portfolio theory in general and my first paper at graduate school concentrates on the home bias puzzle. This paper investigates whether or not there is a home bias in the Swedish National Pension Funds. I learned two important insights working on this topic; first and foremost, I recognised the importance of focusing on the utility of the actual client - the individual - when deciding on how to allocate assets in institutional portfolios or when designing policies in general; secondly, I realised that my interest lies in normative economics rather than positive economics. Accordingly, the remaining three papers of this thesis analyse how the design of pension schemes affect individual utility and optimal behaviour.

The investment problems facing individuals have some interesting characteristics. Individuals hold non-traded assets, in particular human capital, social security and defined benefit pensions; they hold illiquid assets, in particular housing and defined contribution pension savings; they have individual preferences; they are usually borrowing constrained; they are subject to non-linear taxation; and they have to plan over long horizons. For this reason, portfolio choice theory has become an exciting and challenging research area for many financial economists over the last decade. This thesis has its origin in the aforementioned literature and also in the general research on pension issues.

There is a global trend away from defined benefit pension plans, in which employees make no decisions about savings and investments, to defined contribution plans, in which they have to make such decisions. Unfortunately, the very same complexity that makes the investment problem interesting to academics, makes it difficult for the individuals who are forced to make these decisions. Many participants in defined contribution pension plans lack the appropriate skills and information to make good decisions and urgently need help. This has motivated a development of advisory systems and financial products that combines scientific knowledge with information technology. It is my hope that my research will be of some help in this development.

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. First, I would like to thank my supervisor, Professor Lennart Flood, for his support and guidance. I am especially grateful for our long discussions about numerous pension issues, which lead me into my current area of research. I was very lucky to have him as my supervisor and without his help with various income definitions and LINDA related problems, none of this work would have been possible.

The support from the Department of Economics & Centre for Finance at Göteborg University is gratefully acknowledged. Furthermore, I am grateful to Stiftelsen Bankforskningsinstitutet for financial support and to Stockholm School of Economics and Chalmers University of Technology for their excellent courses.

This thesis was essentially coauthored by Evert, whose genuine interest and profound knowledge of finance makes him an ideal colleague and discussion partner. In Evert I have found both a close friend and a mentor. For all this, I owe him my deepest gratitude.

Big thanks to all my friends for supporting me and helping me get my mind off research every once in a while - all work and no play makes Kalle a dull boy.

I owe a lot to my family. My mother and father and my sister Fia for always being there for me and for their constant support and encouragement. Their support has been invaluable, and without it this thesis would not exist.

Finally, and most of all, I would like to thank my favorite classmate, Louise, for her continuous love and support during these years. I love you!

Göteborg, April 2008

The Dark Side of Wage Indexed Pensions

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This paper investigates some welfare effects of forced saving through a mandatory pension scheme. The framework for the analysis is a life-cycle model of a borrowing constrained individual's consumption and portfolio choice in the presence of uncertain labour income and realistically calibrated tax and pension systems. Pension benefits stem from both a defined benefit and a notionally defined contribution part, the latter being indexed to stochastic aggregate labour income. We show that agents attribute little value to their pension savings in early life. Furthermore, we estimate the welfare loss for individuals in mid-life associated with the dependency between pension returns and labour income growth to 1.2% of annual consumption.

Key Words: Life-cycle, portfolio choice, pensions.

JEL classification: D91, G11, G23

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1. INTRODUCTION

Mandatory pension schemes is at the very centre of academic and political debates (*cf.* CSSS (2001), Shiller (2003)). Mainly, because of the changes necessary in order to compensate for—too large benefits relative to the contributions of older generations; but also because of how different designs of unfunded pension systems (*eg.* Lindbeck & Persson (2003), Campbell (2005) and Holzmann & Palmer (2006)) will create substantial welfare consequences. Both the contribution profile across age and indexation of pension system liabilities are crucial parts of the design, since it will define the asset that the individual is forced to hold. Intuitively, large contributions at an early age will exacerbate the negative effect of forced savings for young individuals facing a positive income-profile, but postponing contributions too much will make the pays-as-you-go system insolvent. Wage-indexation of pension assets, is an important tool to enable the retireés to participate in the general growth of the resources in society. However, as we will argue in this paper, there are negative consequences associated with such an indexation as it increases the wage exposure during working life.

Sweden was the first country to introduce a Notional Defined Contribution (NDC) system, where contributions are credited to an individual notional account with a return set to aggregate labour income growth. This reform has attracted a lot of interest as a potential blueprint for other countries (*cf.* Schieber & Shoven (1996), Diamond (2002)). To analyse the effects of such a system for the individual, we use a life-cyclel model.

Life-cycle models have generated a lot of interest as a tool for explaining the accumulation and distribution of wealth as well as portfolio choice over the life-cycle. For agents with uncertain income and liquidity constraints, savings serve several purposes, *eg.* precautionary, retirement and bequest. The importance of each of these motives varies over the life-cycle and will consequently affect both the consumption and the allocation between assets. Over the life-cycle, retirement savings will dominate in absolute size and are to a large extent accumulated in mandatory pension schemes. The introduction of such a scheme into a life-cycle model will motivate an optimising agent to respond by adjusting her consumption and portfolio composition over time. Furthermore, the design of the mandatory pension scheme will have important welfare effects.

This paper has its origin in the literature that highlights uncertainty and market incompleteness as important factors in explaining individual choice and welfare. The first papers on this subject came from the consumption literature on buffer-stock saving. The life-cycle / permanent income hypothesis of Modigliani and Brumberg (1954) and Friedman (1957) implies that there should be no correlation between consumption and predictable income change, since agents would borrow against future incomes as a mean to equalise consumption over life. However, data shows a positive correlation between the two (*cf.* Flavin (1981), Hall and Mishkin (1982), Zeldes (1989)).

Deaton (1991), Carroll (1997) and Gourinchas and Parker (2002) created life-cycle models with uncertain wage income and where human capital could not be used as collateral for borrowing and where saving was invested in a risk-free asset. These models could explain the positive correlation between consumption and predictable income change as a rational response to uninsurable income risk in the presence of borrowing constraints[1].

Cocco *et al.* (2005) and others have extended these models by allowing the agents to allocate between risk-free and risky assets. In order to analyse the effects of different retirement savings systems, Campbell, Cocco, Gomes & Maenhout (2001) (henceforth CCGM) augmented the Cocco *et al.* (2005) model by including a mandatory pension scheme. The authors also showed that a lower pension contribution makes younger generations increase their welfare by postponing private savings to a time when their labour incomes are higher.

In this paper we want to analyse some welfare effects of forced saving through mandatory pensions schemes. Our model is set in partial equilibrium, whereas *eg.* Heaton and Lucas (2004) investigate equilibrium effects of alternative pension systems. We restrict our analysis to the problem of an individual who disregards any societal consequences of her choice. The individual welfare effect from forced saving can originate from (at least) four sources. Firstly, it may increase pension savings above the unrestricted level, especially early in life when savings are driven primarily by precautionary motives. Secondly, wealth in retirement accounts cannot be used to accommodate negative income shocks and will therefore incentivise the individual to make additional savings as a precaution. Thirdly,

[1]Deaton (1991) and Gourinchas and Parker (2002) impose borrowing constraints, while Carroll (1997) sets up a model where the agents choose never to borrow.

the risk and return characteristics of the "pension asset" may differ from the optimal choice and, finally, it redistributes income from early to later in life, when different tax rates may apply. In order to analyse these effects, we have chosen a model similar to the life-cycle model of CCGM.

We model individuals rather than households. Our *rationale* is that: female labour participation and divorce rates are high, which together with an age difference between male and spouse can obscure the expected earnings profile if estimated on family data[2] and consequently the "optimal" behaviour in terms of choices will be erroneous; pension contributions and benefits are often based on individual rather than family incomes; taxes are usually progressive and primarily dependent on the individual instead of family incomes.

We have chosen Sweden as a benchmark for the calibration of our model, due to the relative simplicity and transparency of both the tax[3] and pension systems. Since the Swedish pension reform in 1999, pension contributions have been credited to an individual notional account with a return set to aggregate labour income growth. Furthermore, both tax and pension systems are solely dependent on individual rather than on a mixture of individual and family incomes. Finally, the availability of high quality register based data also alleviates some of the quality problems associated with survey data. While calibrated on Swedish data and rules for taxes and pensions, there are several similarities to systems in other countries, *eg.* the US Social Security retirement system. In both Sweden and the US, contributions and benefits are dependent on gross individual income and most importantly, benefits are indexed by average wage growth.

Our model extends the CCGM model by including a realistically calibrated tax and pension system. The main contribution of this paper is that we can attribute a value to mandatory pension savings and analyse the welfare effects of pension returns linked to stochastic labour income growth. Our findings show that young individuals save primarily due to precautionary motives and will therefore attribute little value to savings in retirement accounts. Furthermore, there is a loss of welfare associated with uncertain pension returns indexed by labour income growth. This loss stems primarily from the dependency between labour income and pension returns, rather than from the volatility of pension

[2]When estimating on family data, the educational status, age and retirement date is typically defined by the head of household only.

[3]Most people can file their declaration of their income tax by sending an SMS or e-mail.

returns.

The paper is organised as follows. Section 2 describes the model and the solution algorithm, while Section 3 demonstrates how the model is calibrated. Results are presented in Section 4. Finally, we end with some concluding remarks in Section 5.

2. THE MODEL

2.1. Individual preferences

The individual (rather than the household) maximises the expected utility over a finite life-cycle, which is divided into pre- and post-retirement. Each individual starts her "optimization life" at the age of 20 or 23 (the latter for those with a university degree) τ_0, retires at 65 and dies at a maximum age of 100 T. Individuals have constant relative risk aversion preferences on a single non-durable consumption good.

Individual preferences at time m are defined as

$$\frac{C_m^{1-\gamma}}{1-\gamma} + E_m \sum_{\tau=m+1}^{T} \delta^{\tau-m} \left(\prod_{j=m}^{\tau-2} p_j \right) \left\{ p_{\tau-1} \frac{C_\tau^{1-\gamma}}{1-\gamma} + b(1-p_{\tau-1}) \frac{D_\tau^{1-\gamma}}{1-\gamma} \right\}, \tag{1}$$

where C_τ represent consumption at age τ, γ is the coefficient of relative risk aversion, p_τ is the one year age contingent survival probability, δ is the discount factor, b is the bequest parameter and D_τ is the bequest amount.

2.2. Labour income

The labour income process follows Carroll and Samwick (1997) with the exception that it is based on an individual rather than a household. Individuals were divided into six mutually exclusive groups with respect to sex and education. While in the labour force, the individual experiences idiosyncratic as well as common shocks to gross income. During the pre-retirement period the log labour real income $l_{ik\tau}$ for an individual i belonging to group k is exogenous and given as[4]

$$l_{ik\tau} = f_k(\tau, \mathbf{Z}_{ik\tau}) + v_{ik\tau} + \epsilon_{ik\tau}, \tag{2}$$

where f_k is a function of the individual characteristics[5] $\mathbf{Z}_{ik\tau}$ as well as an average national labour productivity growth μ^l, $\epsilon_{ik\tau}$ is an idiosyncratic temporary shock distributed as $N(0, \sigma_{\varepsilon_k})$ and $v_{ik\tau}$ is a random walk

$$v_{ik\tau} = v_{ik\tau-1} + u_{ik\tau}. \tag{3}$$

The innovation, $u_{ik\tau}$, is divided into a group aggregate $\xi_{k\tau} \sim N(0, \sigma_{\xi_k})$ and an individual uncorrelated component $\omega_{ik\tau} \sim N(0, \sigma_{\omega_k})$ as below

$$u_{ik\tau} = \xi_{k\tau} + \omega_{ik\tau}. \tag{4}$$

2.3. Mandatory savings and retirement benefits

The Swedish mandatory pension system is divided into a notionally defined contribution part, *NDC*, and a funded defined contribution part, *FDC*. Contributions are paid by the employer and are set to 18.5% of gross income, 16% is added to the *NDC* account[6] and 2.5% to the *FDC* (*cf.* RFV (2002)). In our portfolio choice model, each part of the pension system unfortunately requires a separate state variable, adding to the *curse of dimensionality*, *cf.* Bellman (1961). We therefore disregard the smaller *FDC* part of this system.

Contributions to the national pension plan are capped above an income of 300 KSEK[7]. The return on the national pension plan R^l_τ is set to the national labour income growth[8]

[4] Throughout this paper, we discriminate between the future time periods, τ, which belongs to the optimization problem, and the historic time, t, which is used for estimation.

[5] *i.e.* age, martial status, family size, number and age of children.

[6] In the US, benefits are funded through a Social Security tax of 12.4% of the employee´s income up to an amount of $90,000.

[7] In the following, KSEK - thousands of Swedish Kronor will be omitted. The present exchange rate is *circa* 7 SEK / USD.

[8] The National Social Insurance Board (Riksförsäkringsverket) is responsible for the actuarial estimation of liabilities and the appropriate discount rate. In reality, if the assets in terms of estimated future contributions and return from the buffer funds do not support the growth of liabilities, then the actual benefits paid out will be reduced until the assets match the liabilities and *vice versa*. In this paper we will assume that this will not happen.

An important difference between the Swedish and the US system is that there is no real appreciation of benefits after retirement in the US.

$$R_\tau^l = e^{\mu^l + \xi_\tau^A}, \tag{5}$$

$$NDC_{i\tau} = \begin{cases} R_{\tau-1}^l \cdot NDC_{i\tau-1} + 0.16 \min\left[L_{i\tau}, 300\right] & , \tau < 65 \\ R_{\tau-1}^l \cdot NDC_{i\tau-1} - PO_\tau(R_{\tau-1}^l \cdot NDC_{i\tau-1}) & , \tau \geq 65, \end{cases} \tag{6}$$

where PO_τ is the age specific annualised mortality adjusted payout function after retirement, and μ^l is the expected national labour income growth aggregated over all groups with noise, $\xi_\tau^A \sim N(0, \sigma_{\xi^A})$.

Due to the cap on contributions to the NDC plan, the employer partly compensates by paying into a negotiated plan with the individual as the beneficiary. The vast majority of such plans are at present—defined benefit plans, with benefits depending on the wage at retirement. Albeit there is some variation, most of these company defined benefit plans have a payout of 10%, 65% and 32.5% of incomes in the intervals $[0, 320)$, $[320, 850)$, and $[850, 1270)$ respectively at retirement. The return of the company plan is insured to pay a defined benefit depending on the wage at retirement and guaranteed for the remaining life with no real appreciation after retirement. In reality it depends on the wage during the five years prior to retirement. However, modelling this rule correctly would have necessitated additional state variables. We therefore approximate this by only including the permanent income changes until retirement,

$$L_{i64}^P = e^{f_k(\tau, \mathbf{Z}_{ik64}) + v_{ik64}}. \tag{7}$$

Payout from this plan during retirement will be denoted $DBPO_{i\tau}$. Its dynamics are given by

$$\begin{gathered} DBPO_{i\tau} = 0.1 \min\left[L_{i64}^P; 320\right] + \\ 0.65 \min\left[\max\left(L_{i64}^P - 320; 0\right); 850 - 320\right] + \\ 0.325 \min\left[\max\left(L_{i64}^P - 850; 0\right); 1270 - 850\right]. \end{gathered} \tag{8}$$

All payouts from the NDC pension plan are forfeited in the event of death and for simplicity, we assume the same for the defined benefit plan.

2.4. Taxes

Wage and retirement income $L_{i\tau}$ can be defined as

$$L_{i\tau} = \begin{cases} e^{l_{i\tau}} & ,\tau < 65 \\ PO_{\tau}(R^l_{\tau-1} \cdot NDC_{i\tau-1}) + DBPO_{i\tau} & ,\tau \geq 65. \end{cases} \quad (9)$$

According to the present[9] Swedish tax rules, labour income and pension benefit are taxed at the same rate, and separate from capital income. To calculate net income $L^n_{i\tau}$, we first deduct a general allowance of 10, then a municipal tax of 30%, a government tax of 20% on all income above 300 and finally an additional government tax of 5% on income above 450. Net income is bounded below by the social welfare minimum benefit at 60, which also applies to retirees in the form of a government guaranteed pension.

$$\begin{aligned} L^n_{i\tau} = \max[&L_{i\tau} - 0.3\max(L_{i\tau} - 10; 0) - \\ &0.2\max(L_{i\tau} - 300; 0) - 0.05\max(L_{i\tau} - 450; 0); 60]. \end{aligned} \quad (10)$$

All the threshold values that create kinks in tax rates and benefits[10] are appreciated by the expected national labour income growth μ^l, except the social welfare minimum benefit which is constant in real terms.

2.5. Assets

There exist one risky and one risk-free asset with after tax real simple returns equal to R^s_{τ} and R^f respectively. Excess return is defined as

$$R^s_{\tau} - R^f = \mu^s + \eta_{\tau}, \quad (11)$$

[9] We use the tax rules for incomes earned in 2003.

[10] This is the same as in the US since the "bend points" when calculating the primary insurance amount (PIA) are adjusted by average earnings growth.

and correlated with the group aggregate innovation in permanent labour income, ξ_k which allows for a group specific sensitivity to the risky asset,

$$\begin{bmatrix} \boldsymbol{\xi} \\ \eta \end{bmatrix} \sim N\left(\begin{bmatrix} \mathbf{0} \\ 0 \end{bmatrix}, \begin{bmatrix} \boldsymbol{\Sigma} & \boldsymbol{\sigma}_{\xi\eta} \\ \boldsymbol{\sigma}'_{\xi\eta} & \sigma^2_{\eta} \end{bmatrix} \right). \tag{12}$$

2.6. Private savings and consumption

Each individual starts her "optimization life" with initial wealth set to F. In pre-retirement years the individual receives a wage, and in subsequent years the individual will receive retirement benefits. The individual has two control variables: the proportion of cash on hand to consume, θ_τ, and what proportion of savings, α_τ, to allocate to the risky asset. The cash on hand, or disposable wealth, is therefore,

$$X_{i\tau} = \begin{cases} [R^f + \alpha_{i\tau-1}(\mu^s + \eta_\tau)](1 - \theta_{i\tau-1})X_{i\tau-1} + L^n_{i\tau} & , \tau > \tau_0 \\ F_i + L^n_{i\tau} & , \tau = \tau_0 \end{cases} \tag{13}$$

and

$$C_{i\tau} = \theta_{i\tau} X_{i\tau}. \tag{14}$$

Finally, we impose both borrowing and short sales constraints, *i.e.*,

$$0 \leq \theta_{i\tau} \leq 1, \tag{15}$$

$$0 \leq \alpha_{i\tau} \leq 1. \tag{16}$$

2.7. Optimization

The individual's problem can now be characterised as having four state variables (τ, v, X and NDC) and two choice variables (θ and α) as well as four stochastic variables (ϵ, u, ξ^A and η). The value function of the investor's intertemporal consumption and investment problem can be written as

$$V_\tau\left(\Gamma_\tau\right)=\max_{\theta_\tau,\,\alpha_\tau}\left\{\frac{C_\tau^{1-\gamma}}{1-\gamma}+\delta E_\tau\left[p_\tau V_{\tau+1}\left(\Gamma_{\tau+1}\right)+\left(1-p_\tau\right)b\frac{D_{\tau+1}^{1-\gamma}}{1-\gamma}\right]\right\}$$
$$\Gamma_\tau=\left\{X_\tau,v_\tau,NDC_\tau\right\}. \tag{17}$$

The solution to this maximisation problem gives us the state dependent policy rules,

$$\theta_\tau=\theta_{k\tau}(\Gamma_\tau), \tag{18}$$

$$\alpha_\tau=\alpha_{k\tau}(\Gamma_\tau). \tag{19}$$

The problem is solved by backward recursion from the final year - 100. Since there is no analytical solution to this constrained optimization problem, we solve the problem numerically using standard methods. A description of the procedure is found in Appendix A

3. CALIBRATION OF PARAMETERS

3.1. Estimation of labour income process

This section describes the estimation of the labour income process. Appendix B gives a more detailed description of the methodology used.

We estimate the parameters in the labour income process by using LINDA data for the years 1992 to 2002. LINDA covers 3.35% of the Swedish population (more then 300,000 individuals plus their family members) and is described in Edin and Fredriksson (2000). The definition of income includes, in addition to wages, all taxable social benefits, primarily compensation for unemployment, sickness and early retirement. Data was divided into six non-intersecting groups, defined by educational status[11] and sex. The predictable component of labour income was estimated separately for each group and the regressors include dummy variables for marital status and age as well as the number of children in four separate age intervals. Parameter estimates are presented in Table B.1.

We then estimate a polynomial of degree three on the age dummies and the averages of the characteristics to obtain the deterministic component of labour income $\exp\left\{f_k(\tau,\overline{\mathbf{Z}}_{k\tau})\right\}$, *cf.* Table B.2. Two

[11] The three educational groups are: individuals without a gymnasium (high school) degree, individuals with gymnasium degree but no university degree, and finally, individuals with an university degree.

findings are notable. First, individuals with a university degree experience significantly faster income growth in mid-life[12]. This result matches the stylised facts from the US *(cf.* Cocco *et al.* (2005) Gourinchas and Parker (2002) Hubbard *et al.* (1995)). Secondly, within each educational group, men have higher incomes in all stages of the life-cycle than their female counterparts.

The variances of the permanent and transitory components, σ_u^2 and σ_ε^2, of shocks to labour income as specified in Equation (2) were estimated using the methodology of Carroll and Samwick (1997). The results are presented in Table B.3 along with the results by Carroll and Samwick (1997) who based their study on household gross income, and Cocco *et al.* (2005) who used household net income.

Our results show a strikingly lower variation in the transitory component when compared to both of these studies. This was surprising, since we expected a diversification effect within the family and that the lower variation in net *vs* gross income, would reduce the residual variation.

One possible explanation could be that measurement errors are treated in the same way as transitory income shocks and thereby increase the estimated variance. Comparing register based and survey data, Duncan and Hill (1985) and Bound *et al.* (1994) demonstrate that survey data, such as the PSID, can give rise to measurement errors, which may have a large effect on estimated variances.

Our lower estimates can therefore partially be explained by the data in LINDA being based on filed tax reports which are more precise. Gourinchas and Parker (2002), p. 81, state that: "*a reasonable guess might be that roughly a third of the variance of measured income growth is due to mismeasurement and that most of this is transitory*".

3.2. Individual parameters

We use a standard set of assumptions with respect to the individual parameters for the reference case. First, we set the coefficient of relative risk aversion γ to 5 and the discount factor δ to 0.98. The survival probabilities p are sex dependent and taken from the Swedish life insurers (*cf.* Figure 3.1) when underwriting new policies, *i.e.* it is forward looking[13]. The bequest parameter b is set to 1. The importance of the risk aversion parameter γ will be elaborated on when we do the sensitivity

[12] This is probably partly due to a selection bias, since we would expect those with university aptitude to perform better even without a degree, *cf.* Hausmann and Taylor (1981).

[13] The difference from todays realised mortality table is that both sexes are expected to live longer and that the difference in longevity between men and women is increasing.

analysis in Section 4.4.

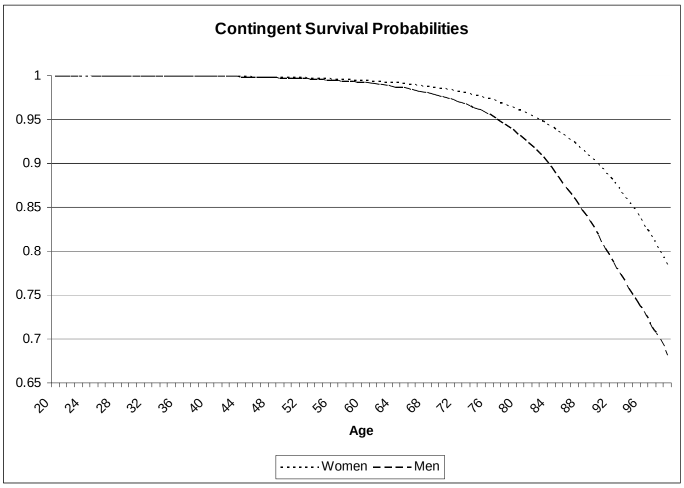

FIG. 3.1 Age contingent survival probabilities

3.3. Assets and correlations

In the optimization, we set the risk-free after tax rate $R^f - 1$ to 1.5%, which fits with the present gross return of less than 2% for long-dated index-linked bonds. The mean after tax equity premium μ^s is set to 3%, which is low when compared with historical average, but corresponds well with forward-looking estimates (*cf.* Claus and Thomas (2001); Fama and French (2002), among others). Volatility σ_η was set to 20% for the risky asset.

Next, we follow the procedure of Cocco *et al.* (2005) to estimate the correlation $\varrho_{\xi_k \eta}$ between group specific permanent labour income shocks $\xi_{k\tau}$ and lagged equity returns $\eta_{\tau-1}$. In Table B.4, we present the estimated correlation using the returns of the Swedish equity index OMX and the 12-month Swedish Treasury Bill as proxies for equity returns and the risk-free rates, respectively. Due to the uncertainty in the equity premium, we analyse the sensitivity in Section 4.4 of our results with respect to an increase in this parameter.

It can be noted that university educated women and men define the range for the correlation, with women having the lowest. One possible explanation could be that women with a university degree are to a larger degree publicly employed. We also set the growth in average labour income μ^l to 1.8%, which is the estimate used by the National Social Insurance Board. Finally, the initial wealth F is set to 47, corresponding to the mean wealth for individuals between the ages of 20 and 23.

4. RESULTS

To study the behaviour of an individual belonging to a specific group, we now use the policy functions in Equations (18) (consumption share) and (19) (risky share) that describe the optimal state dependent behaviour. The contour plots in Figures 4.1 and 4.2 show the policy functions for risky weight and consumption share respectively, with the state variables age and NDC held constant.

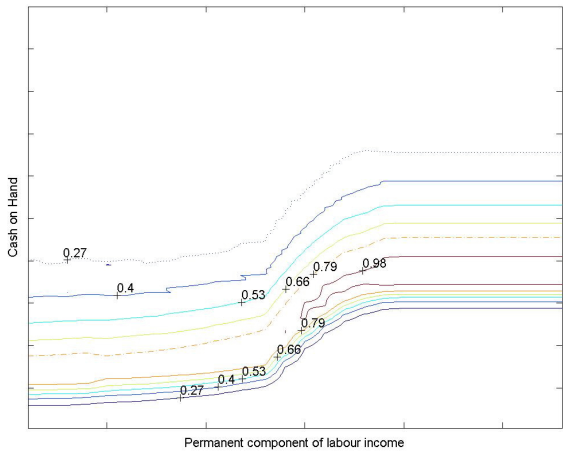

FIG. 4.1 Proportion of savings allocated to the risky asset α at the age of 64 with NDC held constant for men with a high school degree.

At retirement, the permanent component of labour income shock ν decides the defined benefit for the remainder of the life. For large values of cash on hand, the optimal policy in risky weight coincides with the complete market solution[14]. When the ratio of cash on hand to the implicit pension assets (NDC and present-value of future Defined Benefits) decreases, both the consumption and risky share will increase. As the ratio decreases even further, the dominating savings motive is bequest and therefore the risky share is reduced back to the complete market solution. The curvature in policy functions is caused by the defined benefit payout being more sensitive to changes in permanent income (*cf.* Equation (8)). Since defined benefit resembles a risk-free asset, the agent will compensate by increasing both the risky and consumption share.

[14]Where risky share is $\alpha = \frac{\mu^s}{\gamma\sigma_\eta^2}$.

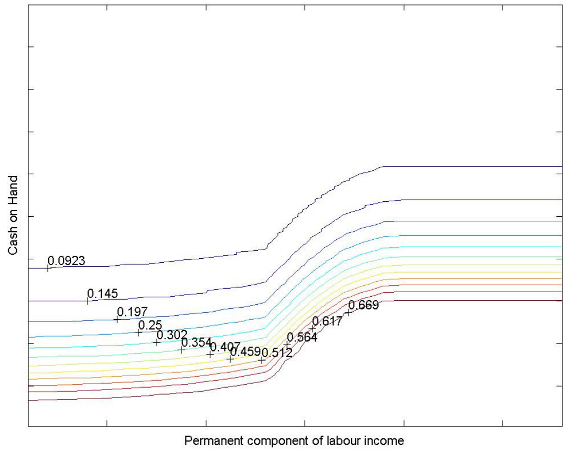

FIG. 4.2 Proportion of cash on hand consumed θ at the age of 64 with NDC held constant for men with a high school degree.

To study the potential outcomes of the model, we simulate the behaviour of an individual (one from each group) by generating 30,000 random trajectories through time. These simulated distributions cannot be directely compared with the actual distributions of today, since the latter are conditional on one realisation for several individuals. In addition, the present population lived under very different conditions in terms of productivity level, pension systems, *etc.* compared to the present and future that we model.

The top and bottom pictures in Figure 4.3 show the simulated individual frequency distribution across age for the risky weight and consumption share, respectively. We note that the short sale constraint is effective for most trajectories in mid-life. Outside this period, there is a wide range of optimal choices dependent on state variables other than age.

4.1. Reference case

In this section, we present the cross-section averages from the simulation. In Figures 4.4 and 4.5 we plot the average of consumption, consumption share, retirement wealth in the NDC account, after tax income, portfolio allocation and cash on hand for an individual from each group.

We note that the individual tries to smooth consumption over life, which can be seen if we compare the wage and consumption profiles. However, an increasing and uncertain labour income together

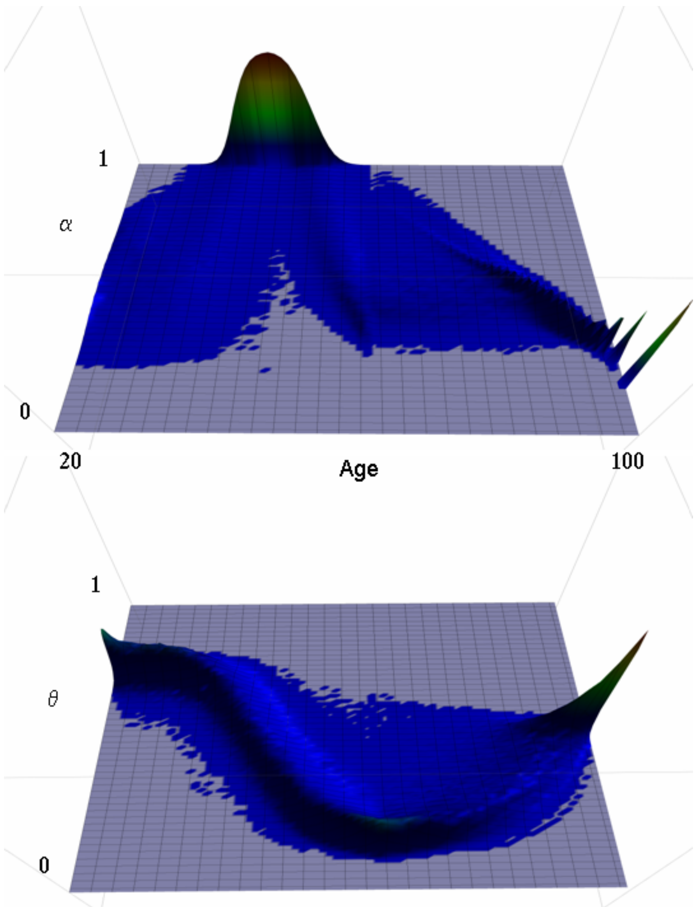

FIG. 4.3 Simulated frequency distributions for the choice variables across ages for men with a high school degree. The upper picture is the proportion of savings allocated to the risky asset α. The lower picture is the proportion of cash on hand consumed θ.

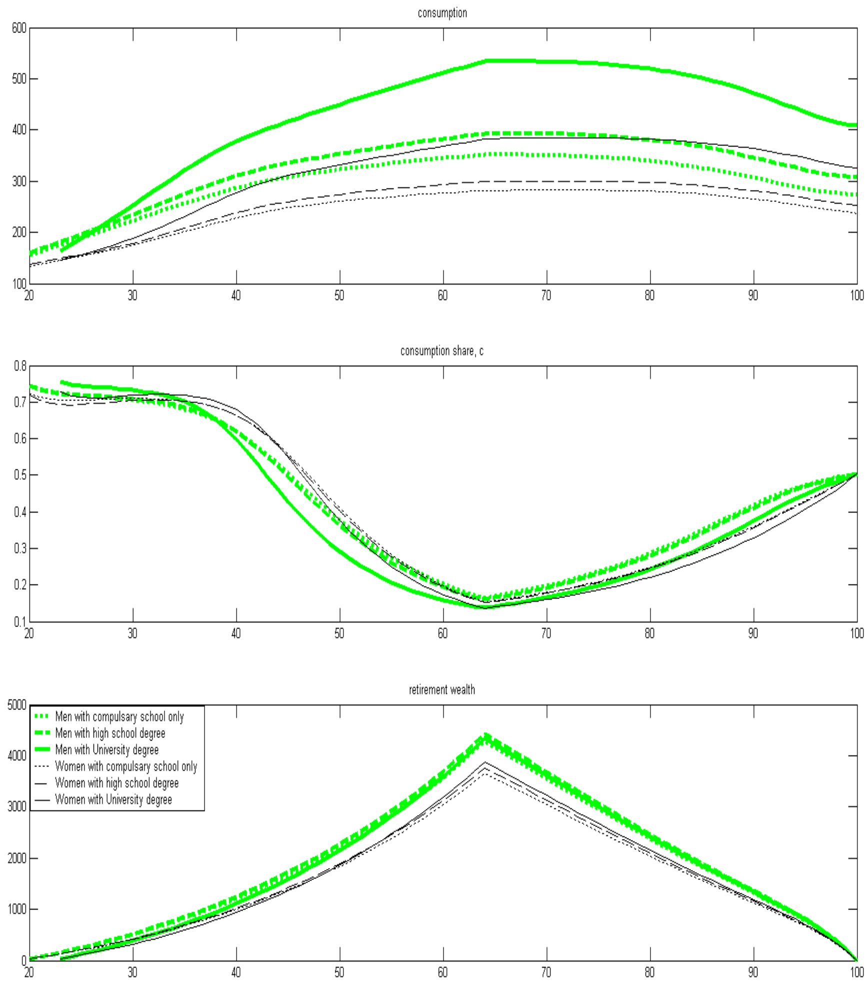

FIG. 4.4 Reference case. Age dependent averages from the simulated distributions for each group.

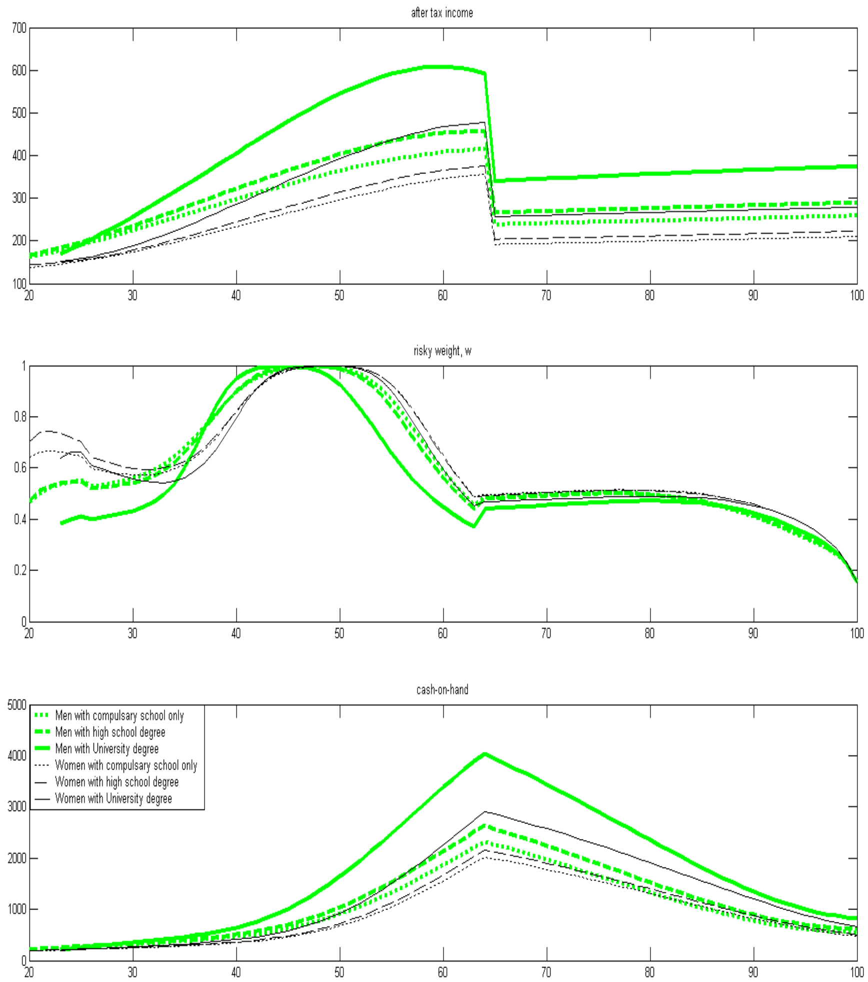

FIG. 4.5 Reference case. Age dependent averages from the simulated distributions for each group.

with the borrowing constraint create a hump-shaped consumption profile, as in *eg.* Gourinchas and Parker (2002). The decline in consumption during retirement is primarily due to mortality risk, which gives rise to a more flat consumption profile for women than for men. It should also be noted that consumption increases with after tax income and peaks close to retirement.

The peak in wages occurs later than in empirical cross-section data since the wage profile is forward looking, *i.e.* it includes the expected increase in wages from the average productivity growth.

The cap on the contribution amount has the effect that there are only small differences in NDC wealth at retirement (*cf.* Figure 4.4), even though wages differ markedly between groups. However, the company sponsored defined benefit plan compensates high income earners for the cap, making the retention rates almost equal across the groups (*cf.* Table 4.1). This result corresponds well with projections from dynamic micro-simulations (*cf.* Flood (2003)).

TABLE 4.1
Retention rates

Median retention rates as a percentage of after tax income at retirement in relation to previous year			
	Total retention rate	Defined Benefit	NDC
Men			
Compulsory school	57	13	44
High school	55	13	42
University	58	29	29
Women			
Compulsory school	54	13	41
High school	55	13	42
University	53	16	37

In order to alleviate the drop in income at retirement, the individual also saves voluntarily to even out consumption over the life-cycle. As can be seen in the consumption share average (Figure 4.4), retirement saving does not start before mid-life. Prior to this, savings are driven by precautionary and bequest motives. Consequentially, the cash on hand during early life is largely invested in the risk-free asset. When private savings for retirement increases during mid-life, wealth is allocated to the risky asset, since the implicit assets in mandatory pension schemes and future wages are closer substitutes to the risk-free asset.

As cash on hand becomes relatively larger in comparison to the implicit assets, the investor compensates by reducing the risky weight. Although the implicit assets are less risky, they are not risk-free. The risk is most pronounced for university-educated men. This group has both a larger relative exposure to the defined benefit asset and a higher correlation between their wages and the stock market.

They will therefore choose a lower risky allocation from mid-life until retirement, when the defined benefit asset becomes risk-free.

The profile for cash on hand (*cf.* Figure 4.5) has the charateristic life-cycle shape that we find in the data[15] (*cf.* Figure 4.6). We also see the effect of the gender difference in longevity on consumption and savings behaviour. During retirement women will decrease their cash on hand at a lower rate than men will, since they expect to distribute their savings for consumption over a longer period.

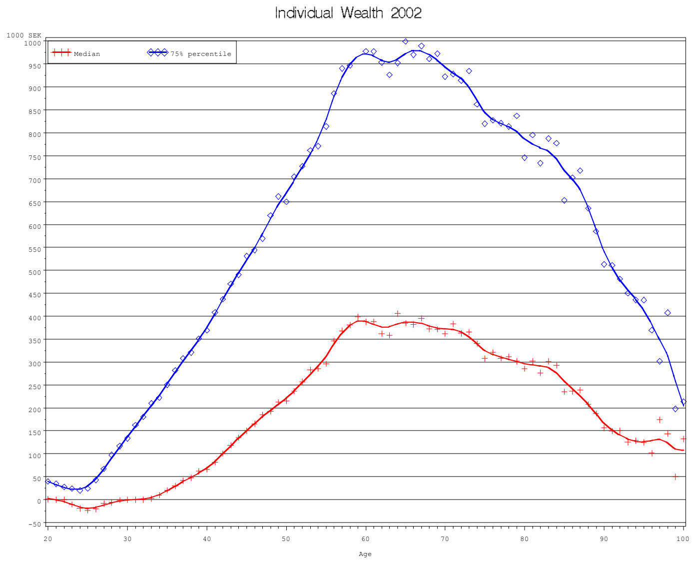

FIG. 4.6 Individual net-wealth. Cross-section LINDA data for 2002 based on 499,241 individuals.

4.2. Valuing the NDC account

Forced saving in early life, when the wage profile is increasing, raises the question of the value of the NDC asset. In Equation (20), we express the value of the NDC asset[16] in terms of cash on hand X, by calculating the expected value of the ratio of the respective derivatives of Equation (17),

$$E_{\tau_0}\left[\frac{\partial V_\tau(\Gamma_\tau)}{\partial NDC}/\frac{\partial V_\tau(\Gamma_\tau)}{\partial X}\right]. \tag{20}$$

We note in Figure 4.7 that the marginal value that an individual attributes to the NDC account

[15] The two profiles are not directely comparable since the simulated profile relates to future wealth whereas the actual data is a cross-section from year 2002. In our simulations, there is a peak at age 65 since we assume a fixed retirement date. In reality, there is a lot of variation in retirement age, making the peak less pronounced. After the age of 80 the number of survivors decreases rapidly in our sample and expected wealth is potentially biased upwards, due to survival probabilities being correlated with wealth (*cf.* Modigliani and Jappelli (1998)).

[16] For comparative purposes, since bequest can only come from cash on hand X, we change the model in two ways. First, we allocate the wealth in the NDC account to bequest in case of death, but taxed with the median tax rate of 30%. Second, we remove the inheritance gains in the NDC system.

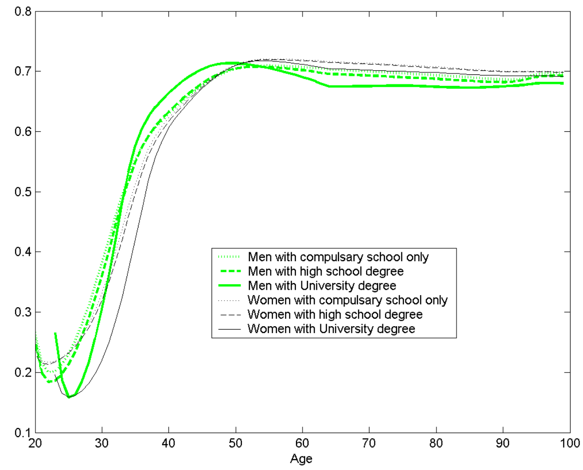

FIG. 4.7 Expected Ratio of Marginal Utilities of NDC and cash on hand. These ratios converge to *cirka* 70% since most retireés will only pay the municipal tax of 30%.

is low in early life. This result is primarily caused by forced retirement saving at a time in life when consumption is preferred. Moreover, since NDC wealth cannot serve the precautionary motive, the agent will make additional savings as a precaution. As the wealth in the NDC account becomes larger in comparison to private wealth (*cf.* Figure 4.8), the marginal value of the NDC asset will decrease even further, since the NDC asset primarily fulfils a small bequest motive. The increase in marginal value until age 40 stems from the retirement savings motive becoming stronger[17].

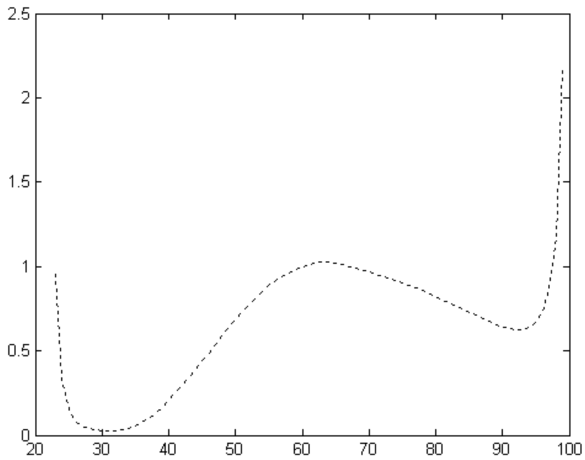

FIG. 4.8 Ratio of private to NDC wealth for university educated men

[17] The ratio has a peak at age 50 for men with an university degree, as their income is often taxed at a higher rate, whereas the bequest of NDC wealth is only taxed at 30 %. As the probability of bequest prior to retirement decreases with age, the ratio falls.

The NDC asset has characteristics similar to a combination[18] of risk-free and risky assets; and the relative value converges to the median after tax value of 70% (*cf.* Equation (10)). As pension benefits are generally lower than wages, only a few trajectories will be in the higher tax brackets during retirement, which is why only the highest income group will experience a slightly smaller value due to higher taxation.

4.3. Risk in the NDC account

This model has five "assets": risk-free, risky, defined benefit, future wages and the NDC asset, of which the last three are non-tradeable. In this section we analyse the diversification properties of the NDC asset. As described in Section 3, the NDC return has a volatility of about 2% and is correlated with both group permanent income shocks and the return of the risky asset. Albeit that the volatility is rather low, the risk in the NDC asset has a major impact on individual utility since this is on average the largest asset at retirement.

The economic importance of the risk in the NDC system can be analysed by computing the utility gains associated with two alternative regimes. The first regime makes the NDC return risk-free, while the second regime makes the return independent of both group permanent income shocks and the return of the risky asset. In both cases, the expected simple return[19] of the NDC account is held constant and equal to that of the reference case.

The utility gains are presented as consumption and bequest equivalent units CBE. A one percent change in CBE represents the same percentage change in consumption and bequest in all possible states for the remainder of life. Equation (17) is solved with the new covariance matrix and the corresponding policy responses, $\theta_{k\tau}(\Gamma_\tau)$ and $\alpha_{k\tau}(\Gamma_\tau)$, are derived. We then compute the value function $V_\tau^a\left(\overline{\Gamma}_\tau^r\right)$ for each age, where $\overline{\Gamma}_\tau^r$ is set equal to the average of each state variable from the reference case. Superindices a and r refer to the alternative and reference case, respectively. The gain in CBE is then defined as

$$G_\tau = \left[\frac{V_\tau^r\left(\overline{\Gamma}_\tau^r\right)}{V_\tau^a\left(\overline{\Gamma}_\tau^r\right)}\right]^{\frac{1}{1-\gamma}} - 1. \tag{21}$$

In Figure 4.9 we have plotted G_τ from making the NDC account independent or risk-free. The groups shown are men with a university degree and women with compulsory school only. These are our extreme groups with respect to earnings, but still depicting a similar pattern.

In the previous section, we showed that the value that a young individual attributes to the NDC

[18] The same Sharpe ratio, the NDC asset is approximately equal to a 10% investment into the risky and the remainder into the risk-free asset.

[19] μ_l is increased by $\frac{1}{2}\sigma^2_{\xi^A}$ in the risk-free regime.

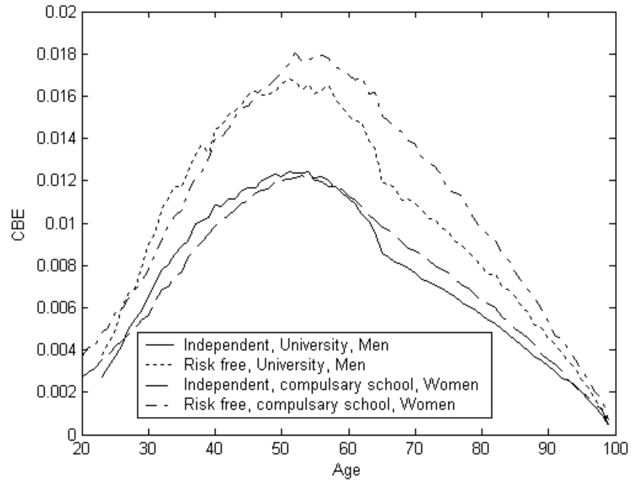

FIG. 4.9 Gain in consumption and bequest equivalent units CBE for the remainder of the life, due to making the NDC account independent or risk free for men with a university degree and women with compulsary school only.

account is very small, since consumption is preferred and savings are primarily driven by precautionary motives. The risk characteristics will therefore be of little importance for a young individual when determining expected lifetime utility.

As the expected ratio of marginal utilities increases (*cf.* Figure 4.7), the sensitivity to changes in risk characteristics increases as well. As one approaches the retirement date, the part of the implicit assets that originates from future wages decreases, making G_τ decline. At retirement, the defined benefit asset will become risk-free, resulting in a more pronounced drop in G_τ for the high-income group. After retirement, the G_τ continues to decrease, as the ratio of private to NDC wealth increases (*cf.* Figure 4.8).

At the peak, the gain in consumption and bequest equivalent units from having a risk-free NDC asset is considerable and ranges from 1.6% to 1.8%. Interestingly, about two-thirds of the gains originate from the elimination of the dependency between NDC asset returns and both group permanent income shocks and risky asset returns. During working life, the NDC asset return is correlated with future wages and defined benefits, as well as with risky asset returns. When in retirement, only the latter correlation remains, but the proportional gain ($\frac{2}{3}$) still holds regardless of age[20]. The existence of a risky asset, correlated with NDC wealth, underlines the risk aspects in NDC during retirement.

[20] Therefore, to the extent that NDC schemes are supported by buffer funds (as in Sweden) to even out differences between contributions and benefits, such funds should actively manage assets with the aim to minimise the correlation with wages. Idiosyncratic risks in such schemes, *eg.* demographic risks, are of less relevance. This is in sharp contrast to how some of these funds interpret their risks. When describing its optimization problem, one fund stated that: "*The optimization of risk-return was done relative to the minimum risk portfolio...This was considered to be the portfolio showing the smallest tracking error relative to the income index*" (Wassum (2002)).

This would have been overlooked if private wealth only could be invested in a risk-free asset.

4.4. Robustness and sensitivity

It is important to note that our parameterisation is conservative with respect to the effects on the valuation of the NDC account analysed in Section 4.2: including the FDC contribution of 2.5% would increase the forced saving; the NDC return is high and the equity premium is low, making these assets approximately equal with respect to Sharpe ratios; and finally the impatience parameter is high which alleviates the negative consequences of forced saving. In order to test to what extent our results are influenced by the parameterisation, we perform two sensitivity tests[21]. Firstly, we decrease the coefficient of relative risk aversion - γ from 5 to 2. This parameter has the property of controling both the elasticity of intertemporal substitution and the risk aversion. Our results, especially in Section 4.2, are driven by the unevenly distributed consumption across ages and are therefore likely to be affected by a change in the elasticity of intertemporal substitution. Furthermore, γ determines the risk aversion and hence the analysis of the risk in the NDC account in Section 4.3.

Secondly, we increase the risk premium to 4%, since our reference case with 3% is low both in comparison with the empirical average and with other studies (*eg.* Cocco (2005); Cocco *et al.* (2005); Gomes and Michaelides (2005); Yao and Zhang (2005)) where 4% was assumed.

Changing the coefficient of relative risk aversion γ from 5 to 2 has a dual effect on the value attributed to the NDC asset. On the one hand, the increase in elasticity of intertemporal substitution raises the value of the NDC asset when the individuals are young and liquidity constrained, since it makes agents more willing to substitute consumption over time. On the other hand, a lower γ induces a higher demand for risky assets and the agent will become constrained by the short sales constraint on the risk-free asset. The NDC asset is a closer substitute for the risk-free asset than for the risky asset and hence an undesirable investment for an agent with relatively low risk aversion.

Early in life the two effects offset each other, making the value attributed to the NDC account approximately equal to that in the reference case (*cf.* Figure 4.11). Later in life as consumption reaches the lifetime average, the effect of a higher elasticity of intertemporal substitution diminishes, resulting in a substantially lower value attributed to the NDC asset than in the reference case. During the last ten years of life, the importance of the non-negativity constraint on the risk-free asset decreases, making the marginal value of the NDC asset equal to the after tax value.

Changing the risk premium, depreciates the relative value of the NDC asset to cash on hand. This

[21] We only present the results for the group Men with a High School Degree, since this group is the most numerous and their wage profile is closest to the average of all groups.

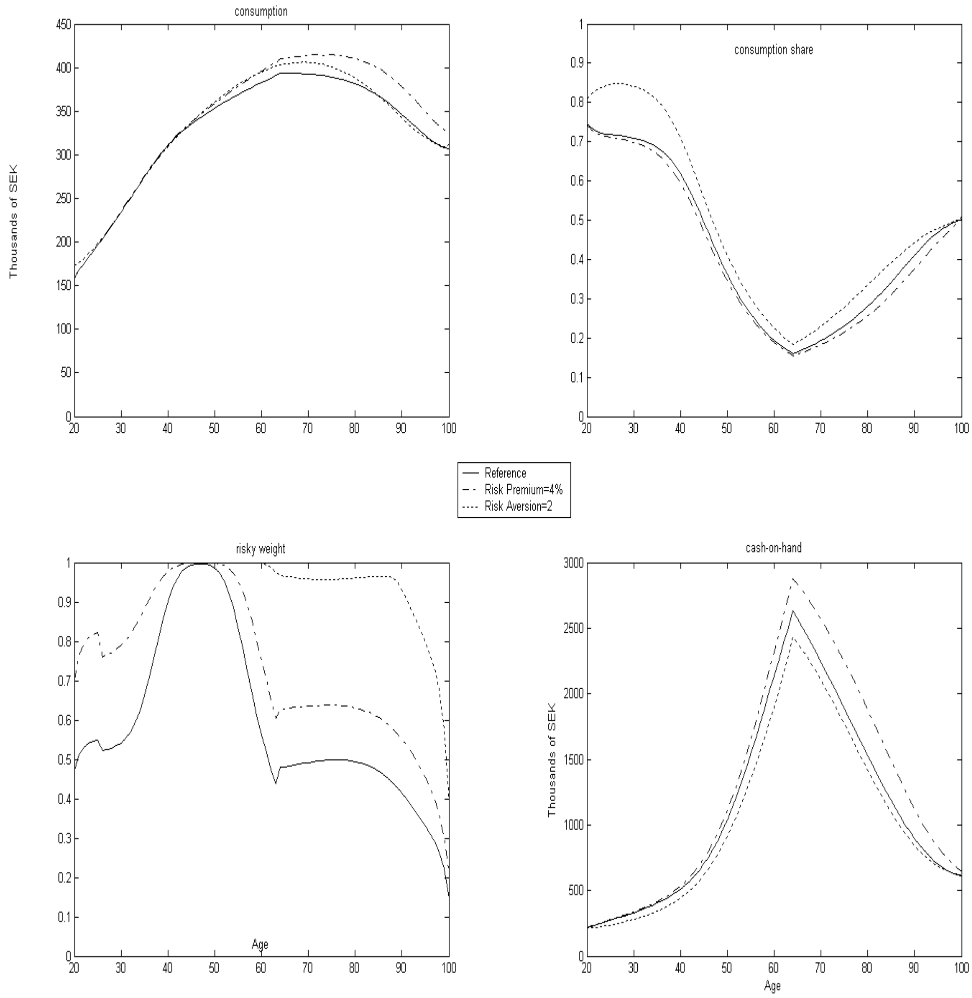

FIG. 4.10 Simulated profiles for men with a high school degree. Effects from changing the risk premium and relative risk aversion.

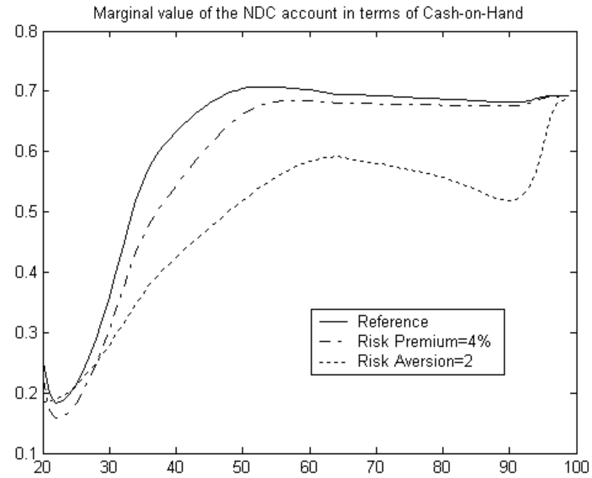

FIG. 4.11 Effects on the marginal value of the NDC from changing the risk premium and risk aversion for men with a high school degree.

effect is most pronounced for a young individual, who is forced to hold this asset for a longer period.

In Figures 4.12 and 4.13, we demonstrate the sensitivity of our results in Section 4.3, with respect to the same changes in risk premium and risk aversion.

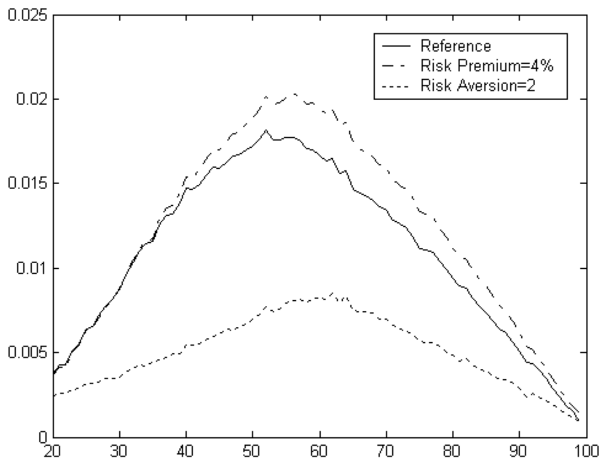

FIG. 4.12 Gain in consumption and bequest equivalent units CBE for the remainder of the life, due to making the NDC account risk free for men with a high school degree.

Lowering the individual risk aversion will reduce the gains from making the NDC asset return independent (*cf.* Figure 4.13) or risk-free (*cf.* Figure 4.12). A higher risk premium relative to the reference case will increase the gains, because the individual will now have a larger proportion of cash on hand in the risky asset. However, the proportion of gains $(\frac{2}{3})$ that stems from independency

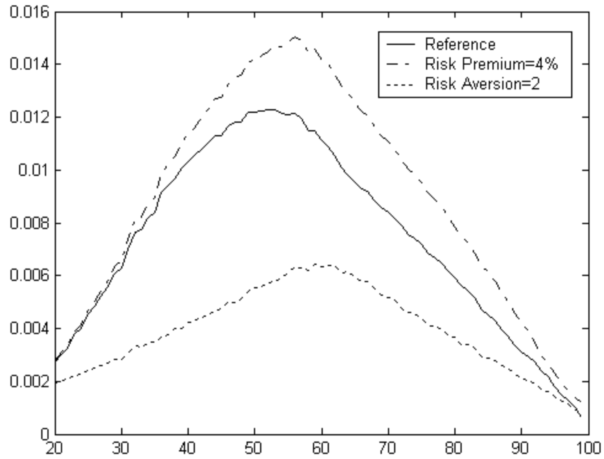

FIG. 4.13 Gain in consumption and bequest equivalent units CBE for the remainder of the life, due to making the NDC account independent for men with a high school degree.

relative to zero risk will be approximately intact.

5. CONCLUSION AND COMMENTS

This paper contributes to the understanding of the risk characteristics and welfare effects of NDC pension systems. We present a life-cycle model of a borrowing constrained individual's consumption and portfolio choice in the presence of uncertain labour income and realistically calibrated tax and pension systems. The pension scheme consists of both a defined benefit and a notionally defined contribution part, the latter being indexed to stochastic aggregate labour income growth.

We investigate the utility effects from forced retirement savings in an asset with returns determined by labour income growth. Firstly, our findings show that individuals attribute little value to their pension savings in early life. We expect this result to hold qualitatively for any pension scheme with a flat contribution rate across ages and therefore to be independent of the country specific calibration. Welfare gains can consequently be achieved by postponing the contribution from early to mid working life, while keeping the duration of the NDC account unchanged. Such a change could also lead to an increase in supply and demand for young labour and thereby encourage an earlier entry into the labour market.

Secondly, we find that it is the dependency between labour income growth and NDC returns rather than the volatility in NDC returns that is the most important source of welfare loss. The reason is that it makes the returns of the NDC asset correlate with individual future wages and defined benefits, as well as with risky asset returns. This effect is essential when analysing the consequences of the proposed change (*cf.* CSSS (2001)) in the US Social Security Benefit indexation that will make retention rates negatively correlated with aggregate wages (*cf.* Munnell and Soto (2005)). The positive welfare effects of this negative correlation will therefore partly compensate for the lower expected retention rate.

Another implication is that to the extent that NDC schemes are supported by buffer funds (as in Sweden) to even out differences between contributions and benefits, such funds should actively manage their assets with the aim to minimise the correlation with wages. Idiosyncratic risks in such schemes, *eg.* demographic risks, are of less relevance. Societal gains could therefore be achieved by reducing dependency between the NDC asset and aggregate income. This topic has been discussed earlier in *eg.* Shiller (2003).

The introduction of a risky asset into a model with these risk characteristics demonstrates the limited inter-generational risk sharing that can be achieved through an NDC asset dependent on average wage growth.

APPENDIX A: OPTIMIZATION

Since no analytical solution to the Equation (17) exists, we solved it numerically by backward recursion. The continuous state variables (cash on hand X, retirement savings account NDC and permanent component of shocks to labour income υ) and choice variables (consumption weight θ and risky weight α) were discretised. The grid of points in X and NDC was distributed exponentially, whereas a uniformly spaced grid was used for υ, θ and α. The introduction of tax and pension systems that are not proportional to wages prohibits us from normalising the problem, *i.e.* we cannot reduce the dimension of the state space, as was done in *eg.* CCGM and Gomes and Michaelides (2005).

Due to zero survival probability in the final year, the value function is simplified since cash on hand is partly consumed and the remainder is bequeathed. Policies and the value of the Bellman equation were therefore easily determined for each combination of state variables. We approximated the value and policy functions for intermediate points with a third degree polynomial B-spline, *cf.* de Boor (1978). The value function in the terminal period was then used to compute the value function in the previous period, where the expectation in Equation (17) was evaluated using a Gaussian-Hermite quadrature approximation (*cf.* Golub and Welsch (1969)). Close to any of the kinks in payout or tax functions, we refined the approximation by using a higher number of nodes. For every combination of states, the optimum was found by a grid search in each choice dimension θ and α. This procedure was then iterated backwardly until the initial year.

APPENDIX B: ESTIMATION

We estimated the parameters in the labour income process by using LINDA data for the years 1992 to 2002. LINDA—a register-based longitudinal data set—consists of a large panel of individuals, which is representative for the population from 1960 and onwards. The data set covers 3.35% of the Swedish population (more then 300,000 individuals plus their household members) and is described in Edin and Fredriksson (2000).

The income data is based on filed tax reports. Our definition of income includes, in addition to wages, all taxable social benefits, primarily compensation for unemployment, sickness and early retirement. We assumed that all individuals with an income less than 100 were voluntarily unemployed, and they were therefore excluded from the estimation. The data was divided into six non-intersecting groups, defined by educational status and sex. The three educational groups were individuals without a gymnasium (high school) degree, individuals with a gymnasium degree but no university degree, and finally individuals with a university degree. Individuals with missing values for educational status (approximately 1.2 percent of the sample) were deleted.

The predictable component of labour income was estimated separately for each group using a balanced panel random effects model with an $AR(1)$ disturbance term,

$$\begin{aligned} l_{ikt} &= \beta_{k0} + \mathbf{Z}_{ikt}\boldsymbol{\beta}_k + \vartheta_{ki} + e_{ikt} \quad &, i = 1, ...N_k \\ e_{ikt} &= \rho e_{ikt-1} + \varkappa_{ikt} \quad &, t = 1, ..., T, \end{aligned} \tag{22}$$

where

$$\vartheta_{ik} \sim NIID(0, \sigma^2_{\vartheta_k}) \tag{23}$$

and

$$\varkappa_{ikt} \sim NIID(0, \sigma^2_{\varkappa_k}), \tag{24}$$

and where l_{ikt} is the logarithm of income adjusted for overall income growth in the economy. $\mathbf{Z}_{ikt}$ includes dummy variables for marital status and age as well as number of children in four separate age intervals. The estimated coefficients are presented in Table $B.1$.

TABLE B.1
Labour Income Process: Coefficients from Regression

	AR(1) Random effects Regression								
Log real income	#Children at age				Status	AR	Std. in	Std. in	R^2
2004 KSEK	0 β_0	1-2 β_1	3-5 β_2	6-17 β_3	Single=1 β_4	ρ	fixed σ_ϑ	overall σ_e	within
Men									
Compulsory school	-.00228	-.00389	-.00056	-.00393	-.00778	.510	.212	.128	.029
High school	.00075	-.00624	-.00364	-.00187	-.01099	.510	.249	.129	.066
University	.006	-.00772	-.0028	.00012	-.00956	.512	.347	.159	.153
Women									
Compulsory school	.04562	-.1064	-.04637	-.01248	.02118	.557	.194	.102	.045
High school	.03433	-.12407	-.0568	-.02393	.02816	.525	.200	.113	.135
University	.03138	-.13274	-.06368	-.02142	.02971	.515	.253	.134	.202

After adjusting the age dummies for expected future labour productivity growth, we estimated a polynomial of degree three on the age dummies and the averages of the characteristics to obtain the forward-looking deterministic income profile, $\exp\left\{f_k(\tau, \overline{\mathbf{Z}}_{k\tau})\right\}$. Table $B.2$ shows the estimated parameters of the income polynomial for each group.

TABLE B.2
Coefficients in the age polynomial of the forward-looking income profile

Income profile, 2004 KSEK, (AGE-18)	Constant	Age	Age^2	Age^3
	a_0	a_1	a_2	a_3
Men				
Compulsory school	211.7	5.960	.2514	-.0048
High school	221.7	4.730	.4363	-.00779
University	190.4	4.283	1.051	-.0188
Women				
Compulsory school	189.5	.758	.3318	-.00473
High school	200.9	-1.108	.4566	-.00645
University	222.1	-6.304	.9188	-.01277

The variances of the permanent and transitory components, σ^2_u and σ^2_ε, of shocks to labour income as specified in Equation (2), were estimated using the methodology of Carroll and Samwick (1997). Define individual residuals from Equation (22), as $l^*_{ikt} = l_{ikt} - f_k(\tau, \mathbf{Z}_{ik\tau})$. The d-year variance is therefore

$$E(l^*_{ikt+d} - l^*_{ikt})^2 = d\sigma^2_{u_k} + 2\sigma^2_{\epsilon_k}. \tag{25}$$

The two parameters in Equation (25) were estimated using OLS on the differences - d and a constant term. We allow for a serial correlation in the transitory term of order $MA(2)$ by only including differences $d > 2$. Furthermore, we exclude the maximum difference $d = 10$ since there is only one observation. This gives us 35 observations for each individual. The results are presented in Table B.3, along with the results by Carroll and Samwick (1997) and Cocco *et al.* (2005).

TABLE B.3
Variance Decomposition

Description	Men	Women	C & S	CGM
Variance of transitory shocks ($\sigma^2_{\epsilon_k}$)				
Compulsory school	.00867	.00623	.0658	.1056
High school (gymnasium)	.00981	.00741	.0431	.0738
University degree	.01208	.01000	.0385	.0584
Variance of permanent shocks ($\sigma^2_{u_k}$)				
Compulsory school	.00462	.00403	.0214	.0105
High school (gymnasium)	.00564	.00460	.0277	.0106
University degree	.00958	.00634	.0146	.0169
Sensitivity to equity returns (β_k)				
Compulsory school	.0291	.0279		.0956
High school (gymnasium)	.0284	.0265		.0627
University degree	.0347	.0205		.0733
Correlation with equity returns ($\rho_{\xi_k\eta}$)				
Compulsory school	.5167	.4767		.3280
High school (gymnasium)	.5136	.4436		.3709
University degree	.5393	.2899		.5155

C & S refers to Carroll and Samwick (1997) and CGM to Cocco *et al.* (2005).

We then follow the procedure of Cocco *et al.* (2005) to estimate the correlation between labour income shocks and stock returns. Using Equation (2), the first difference in l^*_{ikt} can be written as

$$\triangle\, l^*_{ikt} = \xi_{kt} + \omega_{ikt} + \triangle\, \epsilon_{ikt}. \tag{26}$$

Taking the average over individuals in each group gives us the group aggregate component:

$$\overline{\triangle\, l^*_{kt}} = \xi_{kt}. \tag{27}$$

Finally, we estimate the correlations $\varrho_{\xi_k\eta}$ by running the following OLS regression:

$$\overline{\triangle\, l^*_{kt}} = \beta_k(R^s_{t-1} - R^f_{t-1} - \mu_s) + \phi_t. \tag{28}$$

In Table B.4 we present the result from Equation (28), using the return of the Swedish equity index OMX as a proxy for equity returns and the 12-month Swedish Treasury Bill as the risk-free rate.

TABLE B.4
Variance decomposition and estimated return covariances

Group	Number of individuals	Estimated variance of the permanent component, $\sigma^2_{u_k}$	Estimated variance of the transitory component, $\sigma^2_{\varepsilon_k}$	Std. of the permanent aggregate component, σ_{ξ_k}	Correlations with Swedish equity returns, $\varrho_{\xi_k \eta}$
Full sample	55 532			.01989	.482
Men	31540				
Compulsory school	6878	.00462 (.000137)	.00867 (.000379)	.02008	.517
High school (gymnasium)	14978	.00564 (.000112)	.00981 (.000313)	.02020	.514
University degree	9684	.00958 (.000226)	.01208 (.000625)	.02187	.539
Women	23992				
Compulsory school	3485	.00403 (.000140)	.00623 (.000386)	.02014	.477
High school (gymnasium)	11119	.00460 (.000085)	.00741 (.000235)	.01943	.444
University degree	9388	.00634 (.000126)	.01000 (.000348)	.02269	.290

Standard errors in parentheses

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The Bright Side of Shiller-Swaps: A Solution to Inter-generational Risk-sharing

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This paper investigates the diversification-demand of an agent faced with the alternative to swap aggregate labour-income risk for equity-exposure, through her individual account in a mandatory-pension scheme. The framework for the analysis is a life-cycle model of a borrowing-constrained individual's consumption- and portfolio-choices in the presence of uncertain labour-income and realistically calibrated tax- and pension-systems. Pension benefits stem from both defined benefit and notionally defined contributions parts, the latter indexed to stochastic aggregate labour-income. We show that depending on age and swap premium, agents will be either buyers or sellers of such a swap, and that inter-generational risk-sharing can therefore be achieved.

Key Words: Life-cycle, portfolio choice, pensions, Shiller-swap.

JEL classification: D91, G11, G23

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1. INTRODUCTION

Politicians and academics (*cf.* Commission to Strengthen Social Security (2001), Shiller (2003a)) have recently put focus on mandatory pension schemes. Although, this debate has arisen largely due to the legacy cost for future generations; it has also demonstrated the need for management of individual and inter-generational risks, associated with mandatory pensions. New and more cost effective techniques for administrating individual accounts and recent important insights into the risk management of large societal risks (*cf.* Shiller (2003a)) has created new opportunities to address the inter-generational risk-sharing problem. In this paper we propose, a technique for using individual accounts within mandatory pension schemes to increase societal risk-sharing.

Shiller (2003b) argues that: *"the time when we redesign social security ought to be the time when we carefully consider the fundamental intergenerational risk-management problem and define choices in individual accounts".* The inter-generational risk-management problem, can simplistically be thought of as: how to transfer the risks and the benefits between two groups of agents—young and old; where the first group disproportionately have human capital and benefits from labour productivity; whereas the other is primarily a beneficiary of owning real capital and receives return from securities, either directly through private savings or indirectly *via* mandatory pensions. Albeit, individual accounts are important as a vehicle for creating the appropriate incentives, by connecting contributions with benefits; individual accounts, are also motivated by the need to tailor exposure and diversify risks that originate from individual differences; in age, wage uncertainty, implicit insurances, preferences, and assets that the individual may have.

When reforming their pension systems, some countries have introduced a notional—or non-funded—defined contribution system (NDC), with individual accounts, and return indexed to wage growth. This indexation, has the benefit to the retireés of giving them a share of future labour productivity, while distributing the volatility in wages to the entire society. The problem with this type of indexation is that it exacerbates the wage-related risk for younger generations who are already exposed to too much of this risk in their human capital.

Campbell (2005) discusses a risk-sharing system, where contributions are negatively correlated with capital returns, which effectively creates a swap-contract between owners of real and human capital. Campbell and Nosbusch (2006) found that a social security system that optimally shares risks across generations exposes future generations to a share of the risk in physical capital returns. Shiller have in numerous articles (*cf.* Shiller (1993), Shiller (2003a)) advocated the introduction of a swap, that pays the domestic aggregate labour income growth in exchange for risk-free or a global labour income growth.

In this paper we propose an NDC system, which allow the individual some freedom of choice in the allocation of the mandatory savings, while keeping the system for contributions intact. We do this by introducing a swap-contract; where the individual, can choose to enter into a swap, that swaps—aggregate labour income growth in exchange for equity return (henceforth—a Shiller-swap), and thereby addressing the inter-generational risk-management problem. Net positions within the NDC system could be zero, leaving assets and liabilities in the system unchanged. Allowing the individual to enter into specific positions of the Shiller-swap, would assuage the consequences of forcing all individuals into one-size-fits-all, in terms of risk and return characteristics of some of their pension assets. To demonstrate the properties of our proposal, we use a model similar to the life-cycle model of Campbell *et al*(2001), (henceforth—CCGM) and Carlsson and Erlandzon (2005).

In the complete market solution; an individual would equalise consumption over life, while keeping the residual savings in assets (including human capital) optimally diversified. However, restricting the individual from capitalising future income has the consequence that; young individuals will attribute little value to their mandatory pension-savings, since they face a positive earnings profile, (*cf.* CCGM, Carlsson and Erlandzon (2005)). Furthermore, young adults will also have a disproportionate exposure to human capital; which is the *rationale* for our proposal—to use the mandatory savings account in order to create a more balanced portfolio.

Not surprisingly, the largest welfare gains would be achieved by allowing the individual to freely determine, when to save and how to allocate the savings. However, we cannot expect "the market", to solve this problem. The fact that most societies require a system with mandatory savings for pensions among consenting adults, and that such systems have existed in many countries for more than a century; is maybe a tribute to the insights of past politicians into individual behaviour—modern societies will not permit people to consume too much of their income, and then allow the same individuals to rely on society to care for their pension. The individual preferences and perceived insurances that made it necessary for society to introduce the restriction of mandatory savings, will most likely, also reduce the likelihood of these individuals making spontaneously good choices among various investment alternatives. Government has therefore a rôle to play as an administrator of mandatory pensions, but the design of such systems, should minimize the distortions.

We use the Swedish NDC system as a benchmark against which to measure the potential of our proposal. Sweden was the first country to introduce an NDC system, where contributions are credited to an individual notional account with a return set to aggregate labour income growth. This reform—initiated 1999; has attracted a lot of interest as a potential blueprint for other countries (*cf.* Schieber & Shoven (1996), Diamond (2002), Holzmann & Palmer (2006)). Furthermore, the relative simplicity and transparency of both the tax and pension systems also facilitates a realistically calibrated model. While calibrated on Swedish data and rules for taxes and pensions, there are several similarities to systems in other countries, *e.g.* Italy.

This paper has its origin in the life-cycle models that highlights uncertainty and market incompleteness as important factors in explaining individual choice and welfare. Deaton (1991), Carroll (1997) and Gourinchas and Parker (2002) created life-cycle models with uncertain wages and borrowing constraints. Cocco *et al.* (2005) and others extended these models with a portfolio choice between a risk-free and a risky asset. In order to analyse the effects of different pension systems, CCGM added a mandatory pension scheme to the model. They demonstrated a positive welfare effect from a lower pension contribution; due to a postponement of savings until a time when labour incomes are higher. Carlsson and Erlandzon (2005), showed that wage-indexation of mandatory savings, exacerbates the negative welfare effects.

Our model extends the CCGM-model by including realistically calibrated tax- and pension-systems and Carlsson and Erlandzon (2005) by an additional choice; *i.e.* we allow the individual to swap some of the aggregate income exposure within the mandatory pension system for equity exposure. The main contribution of this paper is that: we can identify the age, when the individual would be a buyer or seller of a Shiller-swap and estimate the required risk premium to attract both buyers and sellers. We find that the young would be buyers—and then sellers when older—and that this pattern is invariant to individual risk-aversion. Therefore, the objective of societal risk-sharing can be achieved by allowing the individuals to take positions in Shiller-swaps.

The rest of this paper is organised as follows. Section 2 describes the model, while Section 3 demonstrates how the model is calibrated. The results are presented in Section 4. Finally, we end with some concluding remarks in Section 5.

2. THE MODEL

2.1. Individual preferences

The individual maximises the expected utility over the adult life-cycle, which is divided into pre- and post-retirement. "Optimization", starts at the age[1] of $\tau_0(20)$, retires at a fixed age $K(65)$, and dies at a maximum age of $T(100)$. We assume that the individual has constant relative risk aversion preferences, on a single non-durable consumption good, C_τ.

Individual preferences at time m are defined as

$$\frac{C_m^{1-\gamma}}{1-\gamma} + E_m \sum_{\tau=m+1}^{T} \delta^{\tau-m} \left(\prod_{j=m}^{\tau-2} p_j \right) \left\{ p_{\tau-1} \frac{C_\tau^{1-\gamma}}{1-\gamma} + b(1-p_{\tau-1}) \frac{D_\tau^{1-\gamma}}{1-\gamma} \right\}, \tag{2.1}$$

where C_τ represent consumption at age τ, γ is the coefficient of relative risk aversion, p_τ is the one year age contingent survival probability, δ is the discount factor, b is the bequest parameter and D_τ is the bequest amount.

2.2. Labour income

The labour income process follows Carroll and Samwick (1997). During working life, the individual experiences idiosyncratic as well as common shocks to gross income. The log labour real income $l_{ik\tau}$ prior to retirement, for an individual i belonging to group k is exogenous; *i.e.* the individual cannot

[1] Or at the age of 23, for those with a university degree.

change her labour supply or education to *e.g.* accomodate income shocks, and given as

$$l_{ik\tau} = f_k(\tau, \mathbf{Z}_{ik\tau}) + v_{ik\tau} + \epsilon_{ik\tau}, \tag{2.2}$$

where f_k is a function of the individual characteristics[2] $\mathbf{Z}_{ik\tau}$ as well as an average national labour productivity growth μ^l, $\epsilon_{ik\tau}$ is an idiosyncratic temporary shock distributed as $N(0, \sigma_{\varepsilon_k})$ and $v_{ik\tau}$ is a random walk

$$v_{ik\tau} = v_{ik\tau-1} + u_{ik\tau}. \tag{2.3}$$

The innovation, $u_{ik\tau}$, is divided into a group aggregate $\xi_{k\tau} \sim N(0, \sigma_{\xi_k})$, which we allow to be correlated with excess returns in the risky asset, and an individual uncorrelated component $\omega_{ik\tau} \sim N(0, \sigma_{\omega_k})$ as

$$u_{ik\tau} = \xi_{k\tau} + \omega_{ik\tau}. \tag{2.4}$$

2.3. Present mandatory savings and retirement benefits

Mandatory pension-savings and retirement benefits are part of an NDC-system in which 16% of gross pre-retirement income[3] is contributed by the employer and accounted for in individual accounts. Contributions are capped above an income of 300 KSEK[4]. The return on the accounts—R^l_τ is set equal to the national labour income growth, (*cf.* RFV (2002)).

$$R^l_\tau = e^{\mu^l + \xi^A_\tau}, \tag{2.5}$$

$$NDC_{i\tau} = \begin{cases} R^l_{\tau-1} \cdot NDC_{i\tau-1} + 0.16 \min\left[L_{i\tau}, 300\right] & , \tau < 65 \\ R^l_{\tau-1} \cdot NDC_{i\tau-1} - PO_\tau(R^l_{\tau-1} \cdot NDC_{i\tau-1}) & , \tau \geq 65, \end{cases} \tag{2.6}$$

where PO_τ is the age specific annualised mortality-adjusted payout-function after retirement, and $\xi^A_\tau \sim N(-\frac{1}{2}\sigma^2_{\xi^A}, \sigma_{\xi^A})$.

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[2] *i.e.* age, martial status, family size, number and age of children.

[3] An additional contribution of 2.5% can be managed by the individual in a funded account. For simplicity, we disregard this account.

[4] In the following, KSEK—thousands of Swedish Kronor will be omitted. The present exchange rate is *circa* 7 SEK / USD.

Most individuals also have a negotiated supplementary defined benefit plan, where the employer partly compensates for the cap on NDC contributions. The benefits are constant in real terms, guaranteed for the remainder of life, and depend on the wage at retirement[5]. These company defined benefit plans have a payout of 10%, 65% and 32.5% of incomes in the intervals $[0, 320)$, $[320, 850)$, and $[850, 1270)$ respectively at retirement.

Payout from this plan during retirement will be denoted $DBPO_{i\tau}$, and its dynamics is

$$\begin{aligned} DBPO_{i\tau} &= 0.1 \min \left[L^P_{i64}; 320 \right] + \\ &0.65 \min \left[\max \left(L^P_{i64} - 320; 0 \right); 850 - 320 \right] + \\ &0.325 \min \left[\max \left(L^P_{i64} - 850; 0 \right); 1270 - 850 \right], \end{aligned} \tag{2.7}$$

with

$$L^P_{i64} = e^{f_k(\tau, \mathbf{Z}_{ik64}) + v_{ik64}}. \tag{2.8}$$

All payouts from the NDC pension plan are forfeited in the event of death and for simplicity, we assume the same for the defined benefit plan.

2.4. Taxes

Wage and retirement income $L_{i\tau}$ can be defined as

$$L_{i\tau} = \begin{cases} e^{l_{i\tau}} & , \tau < 65 \\ PO_\tau (R^l_{\tau-1} \cdot NDC_{i\tau-1}) + DBPO_{i\tau} & , \tau \geq 65. \end{cases} \tag{2.9}$$

According to current Swedish tax rules, labour income and pension benefit are taxed at the same rate, and separate from capital income[6]. To calculate net income—$L^n_{i\tau}$, first, we deduct a general allowance of 10; second, a municipal tax of 30%; third, a government tax of 20% on all income above 300; and finally, an additional government tax of 5% on income above 450. Net income is bounded

[5] In reality it depends on the wage during the five years prior to retirement. However, modelling this rule correctly would have necessitated additional state variables. We therefore approximate this by only including the permanent income changes until retirement.

[6] We use the tax rules for incomes earned in 2003.

below at 60 by the social welfare minimum-benefit, which also applies to retirees in the form of a government-guaranteed minimum pension.

$$L_{i\tau}^{n} = \max[L_{i\tau} - 0.3\max\left(L_{i\tau} - 10;0\right) - \\ 0.2\max\left(L_{i\tau} - 300;0\right) - 0.05\max(L_{i\tau} - 450;0);60]. \tag{2.10}$$

All the threshold-values that create kinks in tax-rates and benefits[7] are indexed to the expected national labour income growth—μ^{l}, except the social welfare minimum benefit which is kept constant in real terms.

2.5. Assets

There is one risky and one risk-free asset with after-tax real log-returns equal to r_{τ}^{e} and r^{f} respectively. Excess return is defined as

$$r_{\tau}^{e} - r^{f} = \mu^{e} + \eta_{\tau}, \tag{2.11}$$

where the noise—η, is correlated with the group aggregate innovation in permanent labour income ξ_k, which allows for a group specific sensitivity to the risky asset,

$$\begin{bmatrix} \boldsymbol{\xi} \\ \eta \end{bmatrix} \sim N\left(\begin{bmatrix} -\frac{1}{2}\boldsymbol{\sigma}_{\xi}^{2} \\ -\frac{1}{2}\sigma_{\eta}^{2} \end{bmatrix}, \begin{bmatrix} \boldsymbol{\Sigma} & \boldsymbol{\sigma}_{\xi\eta} \\ \boldsymbol{\sigma}_{\xi\eta}' & \sigma_{\eta}^{2} \end{bmatrix}\right). \tag{2.12}$$

2.6. Private savings and consumption

Each individual starts her "optimization life" with initial wealth set to F. In pre-retirement years the individual receives a wage, and in subsequent years the individual will receive retirement benefits. The individual have two control variables: the proportion of cash on hand to consume—θ_{τ}, and what proportion of savings—α_{τ}, to allocate to the risky asset. The cash on hand, or disposable wealth, is therefore,

[7] This is the same as in the US since the "bend points" when calculating the primary insurance amount (PIA) are adjusted by average earnings growth.

$$X_{i\tau} = \begin{cases} e^{r^f}\left[1+\alpha_{i\tau-1}(e^{\mu^e+\eta_\tau}-1)\right]\left[1-\theta_{i\tau-1}\right]X_{i\tau-1}+L^n_{i\tau} & ,\tau > \tau_0 \\ F_i + L^n_{i\tau} & ,\tau = \tau_0 \end{cases} \tag{2.13}$$

of which consumption is,

$$C_{i\tau} = \theta_{i\tau}X_{i\tau}. \tag{2.14}$$

There is also constraints for both borrowing and short-sales,

$$\begin{aligned} 0 \leq \theta_{i\tau} \leq 1, \\ 0 \leq \alpha_{i\tau} \leq 1. \end{aligned} \tag{2.15}$$

2.7. Mandatory savings with Shiller-swaps

With our proposal, the agent can exchange (buy the contract) the risk and return in their NDC account for equity exposure, through a Shiller-swap. The design of this contract is as follows: first, we define the premium—s, to the seller of the contract; in such a way, that if a Shiller-bond existed, with log-return—$(\mu^l + \xi^A_\tau + s)$, (equal to labour income growth plus premium) it would be a non-redundant asset; *i.e.* attracting an unrestricted (international) investor with power utility,

$$\begin{gathered} \mu^l + s = r^f - \frac{\sigma^2_{\xi^A}}{2} + \beta(\mu^e + \frac{\sigma^2_\eta}{2}), \\ \text{where } \beta = \frac{Cov(\eta,\xi^A)}{Var(\eta)}. \end{gathered} \tag{2.16}$$

We then create a zero-investment portfolio with zero expected payoff,

$$E\left[e^{r^f}(e^{\mu^e+\eta_\tau}+\Lambda-1)-\Lambda e^{\mu^l+\xi^A_\tau+s}\right]=0, \tag{2.17}$$

which determines the exchange multiple—Λ; the ratio by which returns are swapped in a Shiller-swap. We do this since, we are primarily interested in the demand for Shiller-swaps because of their different risk-characteristics, not due to different expected returns.

In Figure 2.1, we show the cash-flows and returns from the constituent securities of the zero-investment portfolio. The portfolio combination of securities is equivalent to the Shiller-swap.

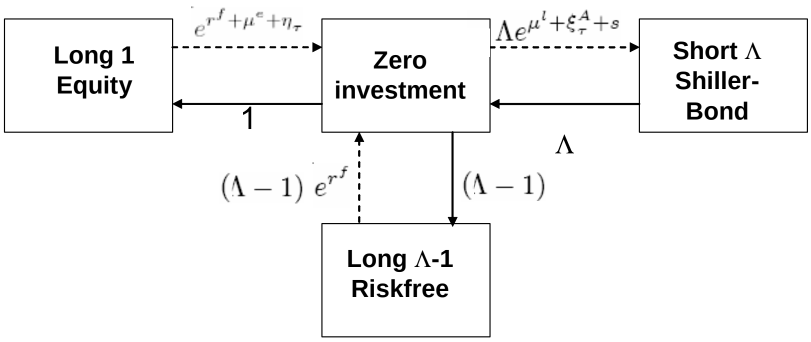

FIG. 2.1 Zero investment portfolio. The dashed lines represent the returns and the the solid lines the investments.

The individuals can now choose—λ, the proportion of their NDC account they wish to swap. Consequently the overall return on the NDC account (Equation (2.5)) changes to

$$R_\tau^l = e^{\mu^l+\xi_\tau^A} + \lambda\left[e^{r^f}\left(e^{\mu^e+\eta_\tau}+\Lambda-1\right)-\Lambda e^{\mu^l+\xi_\tau^A+s}\right]. \tag{2.18}$$

2.8. Optimization

The optimization problem has four state-variables (τ, v, X and NDC) and three choice-variables (θ, α and λ), as well as four stochastic variables (ϵ, u, ξ^A and η). The value function of the individual intertemporal consumption and investment problem can then be written as

$$\begin{aligned} V_\tau(\Gamma_\tau) &= \max_{\theta_\tau,\,\lambda_\tau,\,\alpha_\tau}\left\{\frac{C_\tau^{1-\gamma}}{1-\gamma}+\delta E_\tau\left[p_\tau V_{\tau+1}(\Gamma_{\tau+1})+(1-p_\tau)\,b\frac{D_{\tau+1}^{1-\gamma}}{1-\gamma}\right]\right\}, \\ \Gamma_\tau &= \{X_\tau, v_\tau, NDC_\tau\}. \end{aligned} \tag{2.19}$$

The solution to this problem determines the state-dependent policy-rules

$$\begin{aligned} \theta_\tau &= \theta_{k\tau}(\Gamma_\tau), \\ \alpha_\tau &= \alpha_{k\tau}(\Gamma_\tau), \\ \lambda_\tau &= \lambda_{k\tau}(\Gamma_\tau). \end{aligned} \tag{2.20}$$

We solve the problem numerically by backward recursion from the final year—T, using by-now standard methods, *cf.* Cocco *et al.* (2005) and *Judd*(1998).

3. CALIBRATION OF PARAMETERS

3.1. Labour income process

We use the same parameter estimates of the labour income process as in Carlsson and Erlandzon (2005). The definition of income includes, in addition to wages, all taxable social benefits, primarily compensation for unemployment, sickness and disability retirement. Data was calculated from the LINDA data set for the years 1992 to 2002. LINDA is a register-based longitudinal data set, which consists of a large panel of individuals, and representative of the population from 1960 and onwards. The data set covers 3.35% of the Swedish population (more then 300,000 individuals plus their household members) and is described in Edin and Fredriksson (2000) and this data augmented with wealth information, has recently received attention in *cf.* Calvet *et al* (2006), Campbell (2006) and Flood (2003).

The data was divided into six non-intersecting groups defined by educational attainment and sex. The predictable component of labour income was estimated separately for each group. Table 3.1 shows the estimated parameters of the income polynomial or the most numerous group—Men with High-school degree. The results from the other groups are similar, and income in this group was closest to the national average.

TABLE 3.1
Coefficients in the age polynomial of the forward-looking income profile

Income profile, 2004 KSEK, (AGE-18)				
	Constant	Age	Age^2	Age^3
	a_0	a_1	a_2	a_3
Men with a High school degree	221.7	4.730	.4363	-.00779

Table 3.2 presents result from the variance decomposition.

3.2. Individual parameters

For the reference case we used a standard set of assumptions regarding the individual parameters. First, we set the coefficient of relative risk aversion—γ to 5, the discount factor—δ to 0.98, and the bequest parameter—b is set to 1, making consumption and bequest equally important in the final year. The survival probabilities p are sex dependent and taken from the Swedish life insurers when

TABLE 3.2
Variance decomposition

Group	Estimated variance of the permanent component, $\sigma^2_{u_k}$	Estimated variance of the transitory component, $\sigma^2_{\varepsilon_k}$	Std. of the permanent aggregate component, σ_{ξ_k}
Full sample			.01989
Men with a High school degree	.00564	.00981	.02020

underwriting new policies, *i.e.* they are forward looking.

3.3. Assets and correlations

In Table 3.3, we present the asset and correlation parameters. The mean after tax equity premium μ^e was set to 3%, which is low when compared with the historical average, but corresponds well to some forward-looking estimates (*cf.* Claus and Thomas (2001), Fama and French (2002)). We set the risk-free after-tax rate—r^f to 1.5%, consistent with the present gross return of less than 2% for long-dated index-linked bonds. Volatility σ_η was set to 17% for the risky asset. Following Cocco *et al.* (2005), we then estimated the correlations between aggregate permanent labour income shocks and lagged equity returns $\eta_{\tau-1}$.

TABLE 3.3
Asset and correlation parameters

r^f	.015
μ^e	.03
σ_η	.17
$\varrho_{\xi_k \eta}$	.51
$\varrho_{\xi^A \eta}$	.47

To keep the risk level of the NDC account[8] at approximately the same level as the current system, we restricted the Shiller-swap exposure in the NDC account to ±20% of the account. We also set the growth in average labour income μ^l to 1.8%, which is the estimate used by the Swedish National Social Insurance Board. Finally, initial wealth F was set to 47, the mean wealth for individuals between the ages of 20 and 23.

4. RESULTS

To study the potential outcomes generated by the model; we simulated individual behaviour from age 20, by generating 30,000 random trajectories through time. Subject to the stochastic experience,

[8]Standard Deviation in the value of the NDC account at retirement. The risk in a single year is of course higher.

the individual will choose a response, defined by the policy functions in Equation (2.20) (shares of consumption, risky assets and Shiller swaps), that describe the optimal state dependent behaviour.

4.1. International pricing of Shiller-swaps

As a reference, we plot the averages of the simulated trajectories for cash on hand (Figure 4.1), risky weight (Figure 4.2) and consumption (Figure 4.3) for two scenarios; with and without the existence of an internationally priced Shiller-swap.

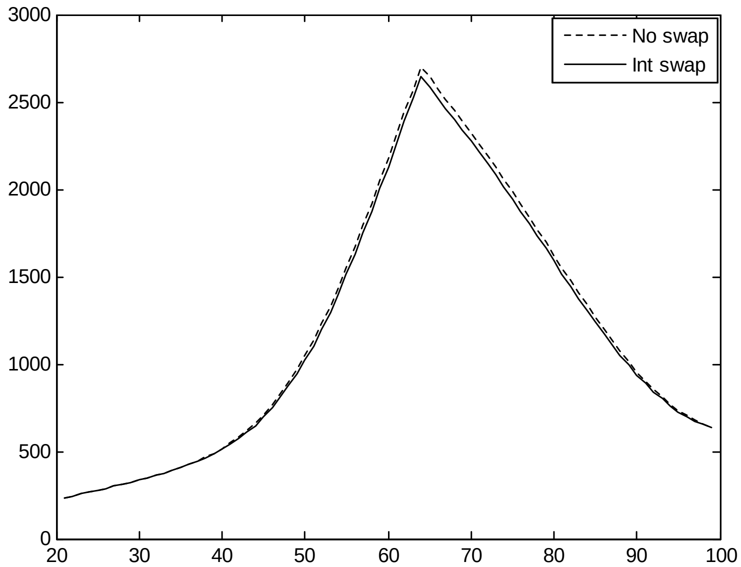

FIG. 4.1 Cash on hand—X, patterns when swap premium is set for international investors and wihout Shiller-swaps.

Since the swap was priced with zero expected return, we do not expect these profiles to be more than marginally different. However, the risk exposure of the NDC account is completely changed. In Figure 4.4, we plot the profile for the average size of the NDC account together with the hedged amount of aggregate wage risk ($-\lambda_\tau \Lambda NDC_\tau$) for an internationally priced swap and the total wage exposure within the NDC account.

Prior to mid-life the agent is constrained by our arbitrary rule of a maximum Shiller-swap share—λ_τ in the NDC account of 0.2 (*cf.* Figure 4.10).

Before retirement, the individual hedge not only the NDC account, but also the discounted expected value of both the defined benefit contract and future wages. When the defined benefit pension is fixed at retirement and future wages are zero, the agent still continues to hedge the discounted

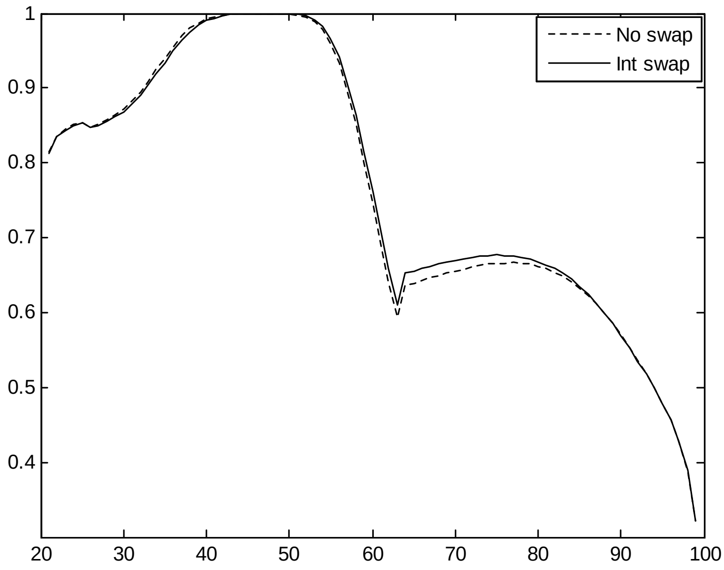

FIG. 4.2 Risky weight—α_τ when swap premium is set for international investors and without Shiller-swaps.

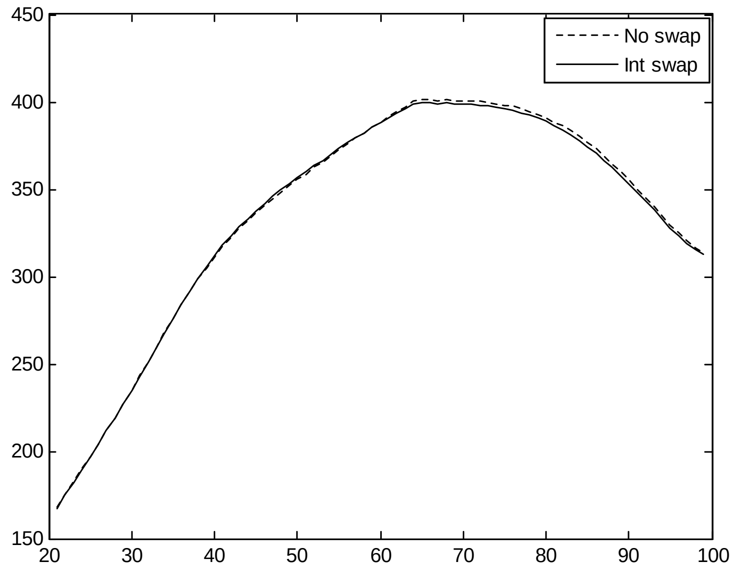

FIG. 4.3 Consumption—C, patterns when swap premium is set for international investors and without Shiller-swaps.

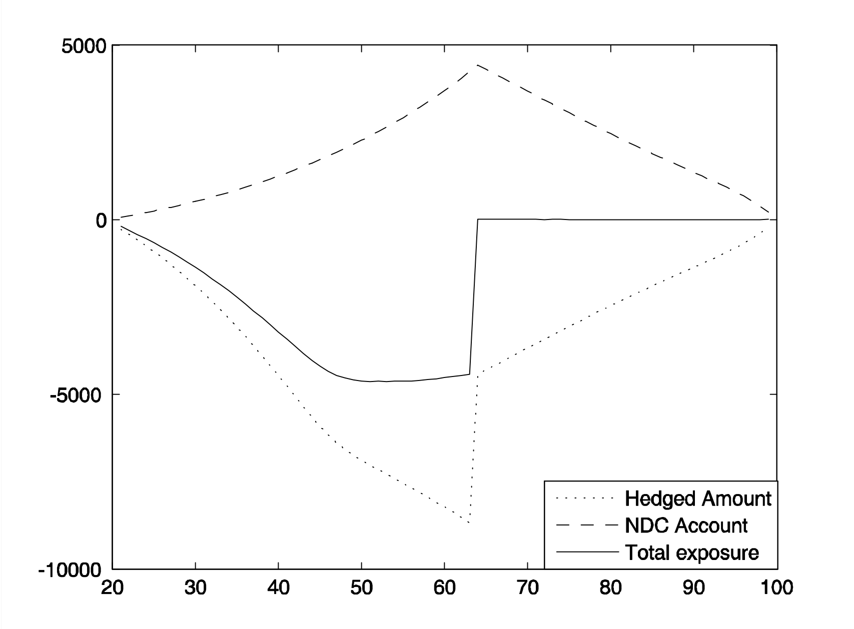

FIG. 4.4 Hedged wage exposure—$\Lambda\lambda_\tau NDC$, value of NDC account and total exposure to wage risk in the NDC account when the swap premium is set for international investors.

expected value of the NDC account.

4.2. Inter-generational pricing of Shiller-swaps

To investigate the potential demand for Shiller-swaps from domestic investors only, without resorting to an international market for Shiller-bonds, we increased the swap premium—s (Equation (2.16)) with $10, 15$ and $25bp$ (basis points) respectively, in addition to what an international investor requires. Figure 4.5 shows the simulated profiles for Shiller-swap share—λ_τ, while Figure 4.6 and Figure 4.7 demonstrates the avarage exposure to equity risk ($\lambda_\tau NDC_\tau$) and wage risk $NDC_\tau(1 - \lambda_\tau\Lambda)$, respectively.

The additional premium will encourage the agent to be both a buyer and seller of such a swap, but at different ages. Before retirement, the individual will on average be a buyer of the Shiller-swap and afterwards a seller; thereby creating a voluntary inter-generational transfer of wage-growth risk. Selling the contract implies a negative equity exposure in the NDC account, that is partly compensated for by a higher risky share—α in private savings (*cf.* Figure 4.8).

The higher risky share in cash on hand does not fully compensate for the negative equity-exposure in the NDC account, as is demonstrated in Figure 4.9, which shows total equity exposure from both private savings and the NDC account.

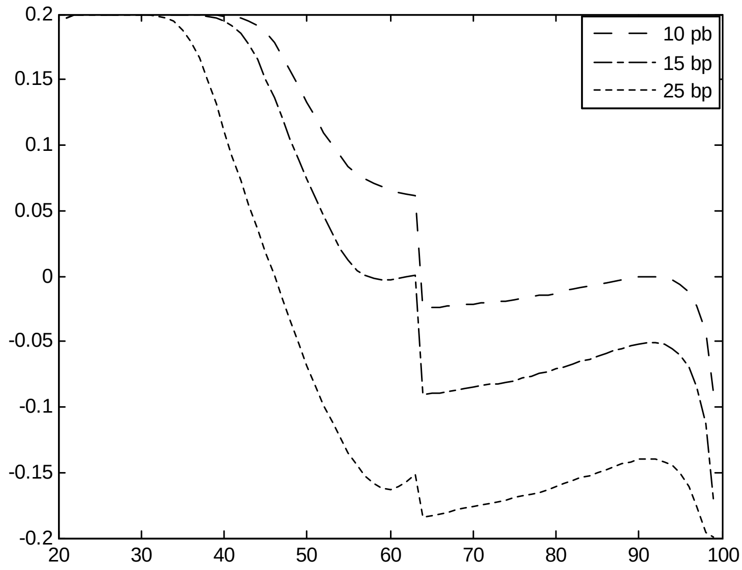

FIG. 4.5 Shiller-swap weights—λ with different swap premia in addition to the international requirement—s.

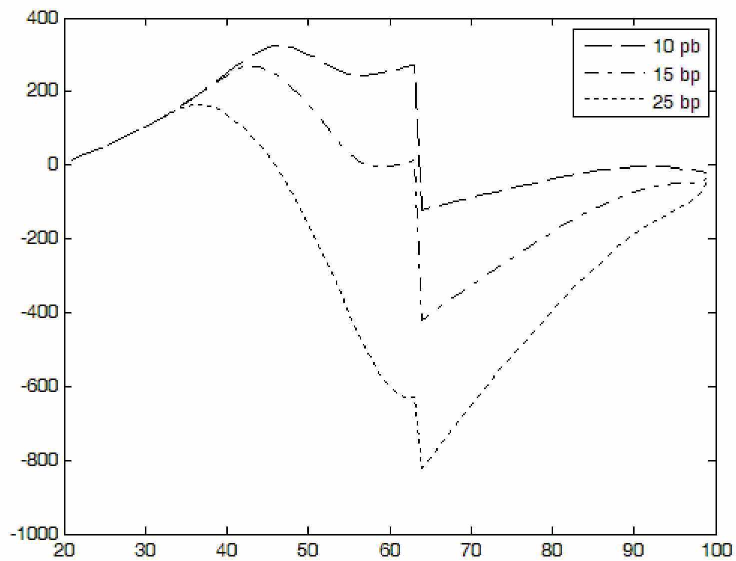

FIG. 4.6 Average equity exposure λNDC in the NDC account.

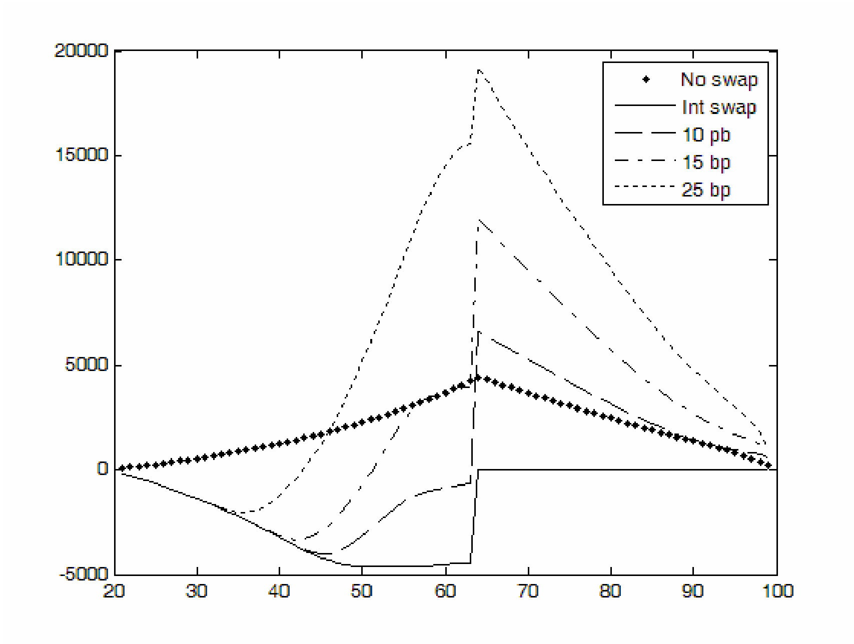

FIG. 4.7 Average exposure to wage risk—$NDC(1 - \lambda\Lambda)$ in the NDC account.

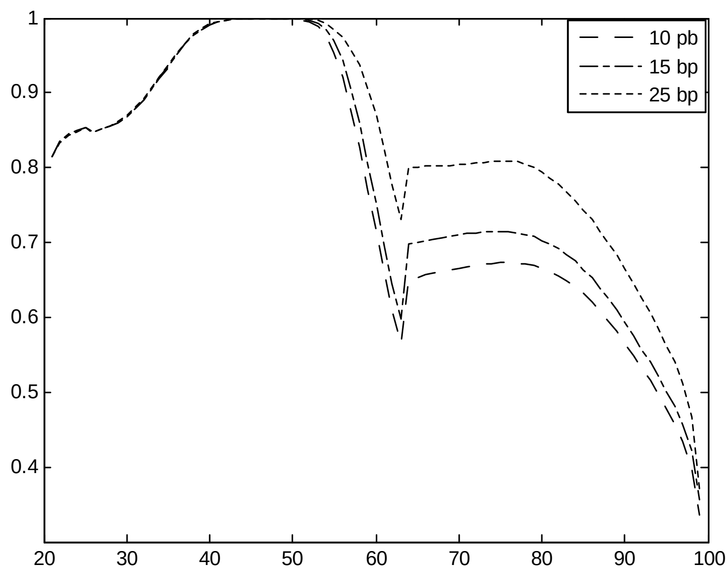

FIG. 4.8 Risky weights of cash on hand—α_τ with different Shiller-swap premia in addition to the international requirement—s.

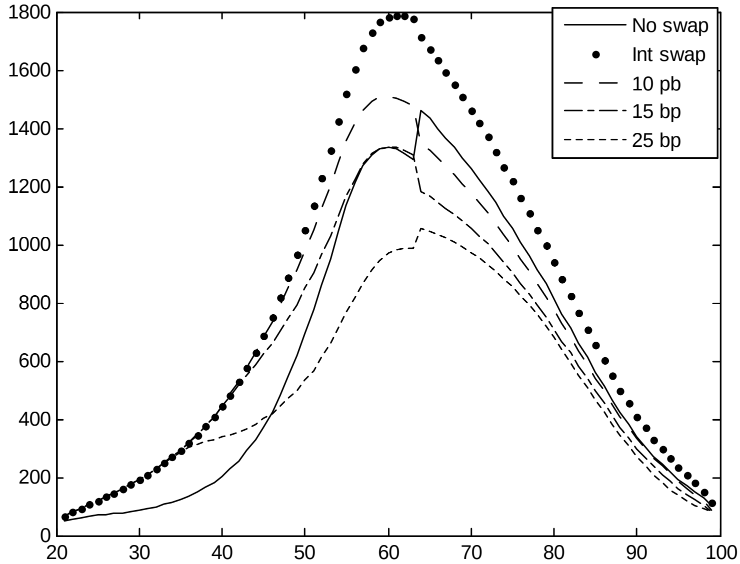

FIG. 4.9 Total exposure to risky assets from private savings and the NDC account—$\alpha X + \lambda NDC$.

In early life, the agent tries to maximise the equity exposure (subject to our constraint of 20%), irrespective of the premium. Later in life and as private savings increase, the increased swap-premium make the agent more inclined to sell the Shiller-swap.

For the single agent belonging to this group and with these preferences (risk aversion); the 15*bp* additional swap premium would approximately "clear" the demand and supply across the individuals age; increasing the premium further would create excess supply. We can therefore expect that—if overall demand and supply is unaffected by individual differences in risk-aversion—a Shiller-swap market could be established within the NDC framework without resorting to an international market.

Changing the relative risk aversion from 5 to 2 or to 10 has only a minor effect on preference for Shiller-swap exposure (*cf.* Figure 4.10), whereas the same changes in risk aversion have a dramatic impact on the risky weight (*cf.* Figure 4.11).

The reason is: as long as individuals are risk-averse, and with the expected risk premium—s and multiple—Λ, set so that the Shiller-swap has zero expected return (*cf.* Equation (2.17)), there will still be demand for the Shiller-swap, but for an hedging purpose; whereas the demand for risky assets are primarily motivated by higher expected returns.

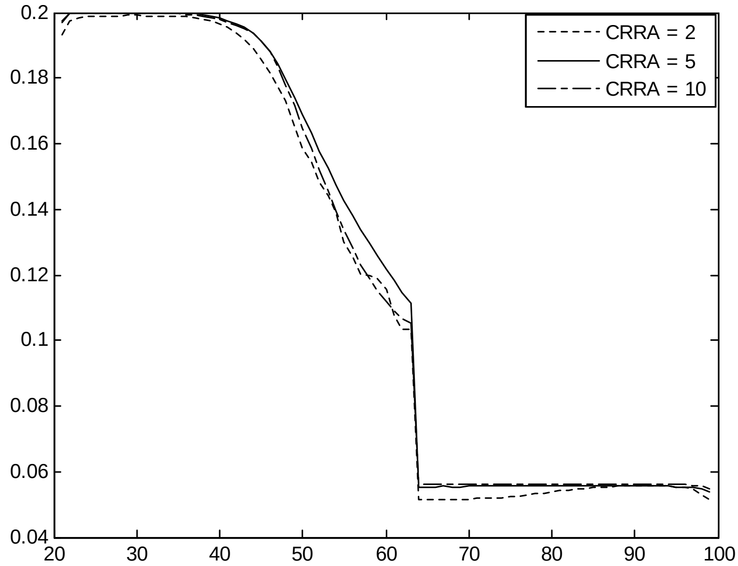

FIG. 4.10 Shiller-swap weights—λ when swap premium is set for international investors, but with different constant relative risk aversions(CRRA)—γ.

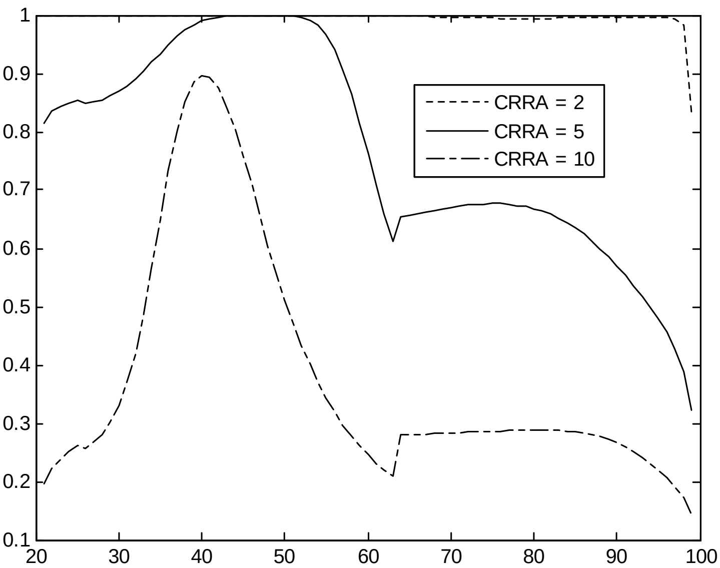

FIG. 4.11 Risky weights when swap premium—s is set for international investors, but with different constant relative risk aversions(CRRA)—γ.

5. CONCLUSION AND COMMENTS

This paper proposes the introduction of a Shiller-swap to mandatory individual pension accounts in order to allow the agents to swap wage-risk for equity-risk. We present a life-cycle model of a borrowing constrained individual's consumption- and portfolio-choice in the presence of uncertain labour income and realistically calibrated tax and pension systems. The pension scheme consists of both a defined benefit and a notionally defined contribution part, the latter being indexed to stochastic aggregate labour income growth.

Our result show that, an internationally priced swap premium, suffices to create large domestic demand for Shiller-swaps across age. However, the swap premium was derived from an international market for Shiller-bonds, which is yet to be established. We therefore show that a "minor" increase of the premium by 15*bp* will create both demand and supply for this swap, but at different ages. It would therefore be possible to create a Shiller-swap market within the pension system, thereby allowing a voluntary inter-generational sharing of wage-risk.

With the implementation of our proposal; forced saving in mandatory pension schemes can be maintained, but with substantially reduced distortions.

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A Tale of Two Systems: Winners and Losers when moving from Defined Benefit to Defined Contribution Pensions

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There is a trend among employers to prefer Defined Contribution instead of Defined Benefit pension plans, since the former transfer all risks associated with investment return, longevity, *etc* from the employer to the employeé. However, Defined Contribution plans also allow the individual to enter into positions contingent on the individual situation. This paper investigates the individual welfare consequences of different plans. We used the recent transition from defined benefit to defined contribution for white-collar workers in Sweden as the benchmark for our analysis. The framework for our analysis is a life cycle model of a borrowing-constrained individual's consumption- and portfolio choices in the presence of uncertain labour income. The main result is that individuals with the characteristic of a low expected pre-retirement income relative to average income during working life and high variance in earnings are winners (men with university degree in the private sector), and that those with the opposite characteristic (women with university degree in the public sector) would be losers.

Key Words: Life-cycle, portfolio choice, defined contribution, defined benefit, income process.

JEL classification: D31, D91, G11, G23, H24, J31

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1. INTRODUCTION

Defined Contribution—DC pension plans[1] are now often the preferred pension system among employers. This is not very surprising since the shift from Defined Benefit—DB[2], transfers all the risks associated with investment return and longevity from the employer to the employeé. However, there are also several advantages for the individual with a DC plan: it allows the individual to enter into specific positions, which reduces the consequences of forcing all individuals into one-size-fits-all, in terms of risk and return characteristics; it facilitates portability when the agent transfers from one employer to another; and not the least it assuages the risks of lower wages in the final years of employment. Which of these systems that are beneficial to the individual is very state dependent and merits this research.

In this paper we have analysed the welfare consequences for the individual when transferring from a DB to a DC system. As a benchmark for this analysis, we have chosen the recently negotiated transfer from a DB to a DC plan between private white-collar workers union and their employers in Sweden, *cf.* Svenskt Näringsliv (2006). This analysis is even more pertinent, since this transfer will most likely be the blueprint for a similar future settlement for the public employeés.

The main result is that individuals with the characteristic of a low expected pre-retirement income relative to average income during working life and high variance in earnings are winners (men with university degree in the private sector), and that those with the opposite characteristic (women with university degree in the public sector) are losers.

Our analysis draws heavily on the literature highlighting: life-cycle saving and consumption, Modigliani and Brumberg (1954) and Friedman (1957); and portfolio-choice, Samuelson (1969) and Merton (1971). Deaton (1991), Carroll (1997) and Gourinchas and Parker (2002) created life-cycle models with uncertain wages and borrowing constraints; which showed that market-incompleteness is important when explaining individual choice and welfare effects. Cocco *et al.* (2005) and others extended the model with portfolio-choice between a risk-free and a risky asset. Campbell *et al* (2001) added a mandatory pension scheme to the model.

[1] A DC plan accumulates a proportion of every salary as a contribution.
[2] A DB plan pays a proportion of final salary as a pension.

The introduction of non-tradeable human capital into the intertemporal life cycle model with portfolio choice and consumption, creates an asset that will influence—how much the individual saves and the optimal portfolio choice in savings. These choices depend on the expected individual dividend profile from human capital and associated uncertainties, but also on the characteristics of other assets; primarily private savings, pension savings and housing.

Labour generates two types of dividends: wages and pension contributions. In this paper we estimated the income process that should be used as the underlying for calculating the derivatives—net wages and pension contributions; keeping the "dividends" from human capital separate from other types of asset-income.

Carroll and Samwick (1997), Gourinchas and Parker (2002), Cocco *et al.* (2005), and other similar earlier studies generally treated returns from human capital as equal to earned income net of return from private savings. Such a wide definition lead to some double-counting, for those who retire early or receive pension benefits dependent on contributions during their working life. In our definition of returns from human capital, we only included income that stem from individual productivity and insurances against, *e.g.* disability, parental leave, unemployment *etc.*—not from early withdrawals from retirement savings.

We are interested in the expected income profile as the underlying for pension contributions and taxes, which influence the individuals future choices in terms of saving and portfolio allocation. It is therefore natural to model individuals rather than households[3], since pension contributions and taxes are primarily dependent on the individual instead of family incomes.

The remainder of the paper is organised as follows: Section 2 describes the model, while Section 3 describes the optimisation problem, and Section 4 the calibration of the model. Section 5 discusses the results, and the final Section 6 summarizes and draws some conclusions.

[3]Furthermore, female labour-participation and divorce rates are high, which—together with an age-difference between man and wife—could have obscured the expected-wage profile if estimated on family data. When estimating on family data, the educational status, age and retirement date is typically defined by the head of household only.

2. THE MODEL

2.1. Individual preferences

We assume that an individual maximise the expected utility over their adult life-cycle, which starts at the age of τ_0, and dies no later than at the age of T. We assume that an individual has constant relative-risk-aversion preferences for a single non-durable consumption good—C_τ.

Individual preferences at time—m are defined as

$$\frac{C_m^{1-\gamma}}{1-\gamma} + E_m \sum_{\tau=m+1}^{T} \delta^{\tau-m} \left(\prod_{j=m}^{\tau-2} p_j \right) \left\{ p_{\tau-1} \frac{C_\tau^{1-\gamma}}{1-\gamma} + b(1-p_{\tau-1}) \frac{D_\tau^{1-\gamma}}{1-\gamma} \right\}, \tag{2.1}$$

γ is the coefficient of relative risk aversion, p_τ is the one-year age-contingent survival-probability, δ is the discount factor, b is the bequest parameter and D_τ is the bequest amount.

2.2. The labour-income process

Following Carroll and Samwick (1997), we assume that the individual income process during working life—L_{it}, is exogenously given by

$$\log(L_{it}) = l_{i\tau} = f(\tau, \mathbf{Z}_{i\tau}) + v_{i\tau} + \varepsilon_{i\tau}, \quad \tau \leq K, \tag{2.2}$$

where—$f(\tau, Z_{i\tau})$ is a deterministic function of individual $i's$ age—τ, and a vector of the individual characteristics[4]—$\mathbf{Z}$, where—K is the retirement age, and—$v_{i\tau}$ is given by

$$v_{i\tau} = v_{i\tau-1} + u_{i\tau}, \tag{2.3}$$

where the permanent shock—$u_{i\tau} \sim N(0, \sigma_u^2)$ is independent from the idiosyncratic temporary shock—$\varepsilon_{i\tau} \sim N(0, \sigma_{\varepsilon_k}^2)$. The permanent shock—$u_{i\tau}$, consists of a group aggregate component—$\xi_{k\tau} \sim N(0, \sigma_{\xi_k}^2)$

[4] *i.e.* age, martial status, family size, and number and age of children.

as well as an idiosyncratic component—$\omega_{i\tau} \sim N(0, \sigma^2_{\omega_k})$,

$$u_{i\tau} = \xi_{k\tau} + \omega_{i\tau}. \tag{2.4}$$

2.3. Assets

There are two assets, one risky and one risk-free asset with after-tax real log-returns equal of r^e_τ and r^f respectively. Excess return is defined as

$$r^e_\tau - r^f = \mu^e + \eta_\tau, \tag{2.5}$$

where the noise—η is correlated with the group-aggregate innovation in permanent labour-income—ξ_k, which allows for a group specific sensitivity to the risky asset,

$$\begin{bmatrix} \boldsymbol{\xi} \\ \eta \end{bmatrix} \sim N\left(\begin{bmatrix} -\frac{1}{2}\boldsymbol{\sigma}^2_\xi \\ -\frac{1}{2}\sigma^2_\eta \end{bmatrix}, \begin{bmatrix} \boldsymbol{\Sigma} & \boldsymbol{\sigma}_{\xi\eta} \\ \boldsymbol{\sigma}'_{\xi\eta} & \sigma^2_\eta \end{bmatrix}\right). \tag{2.6}$$

2.4. Past and present mandatory savings and retirement benefits

In the old system[5], individuals have a defined-benefit and a defined contribution plan. The defined benefit plan has a payout of 10%, 65% and 32.5% of incomes at retirement[6] in the intervals $[0, 320)$, $[320, 850)$, and $[850, 1270)$ respectively[7].

Payout from this plan is constant in real terms, and guaranteed for the remainder of life, $PODB_{i\tau}$,

$$\begin{aligned} PODB_{i\tau} = 0.1 \min\left[L^P_{i64}; 320\right] + \\ 0.65 \min\left[\max\left(L^P_{i64} - 320; 0\right); 850 - 320\right] + \\ 0.325 \min\left[\max\left(L^P_{i64} - 850; 0\right); 1270 - 850\right]. \end{aligned} \tag{2.7}$$

The defined contribution plan has contributions at 4.5% of annual labour income up to 320. Pre-

[5] Individuals born before 1979.

[6] In reality it depends on the wage during the five years prior to retirement. However, modelling this rule correctly would have necessitated additional state variables. We therefore approximate this by only including the permanent income changes until retirement.

[7] In the following, we express all amounts in thousands of SEK. The present exchange rate is *circa* 6 SEK / USD.

retirement labour income—L^P_{i64}, is defined as,

$$L^P_{i64} = e^{f_k(\tau,\mathbf{Z}_{i64})+v_{i64}}. \tag{2.8}$$

The new system is only based defined contributions (*cf.* Svenskt Näringsliv (2006)), with contributions set to: 7% for annual incomes up to 320 and 30% for incomes above this limit. Contributions to the defined contribution plans—DC are therefore,

$$DC_{i\tau} = \begin{cases} 0.045 \min\left[L_{i\tau}; 320\right], & \text{if in old system,} \\ 0.07 \min\left[L_{i\tau}; 320\right] + 0.3 \max\left(L_{i\tau} - 320; 0\right), & \text{if in new system.} \end{cases} \tag{2.9}$$

Individuals can choose the fraction, λ of the defined contribution wealth, DCW to allocate to the risky asset,

$$DCW_{i\tau} = \begin{cases} e^{r^f}\left[1 + \lambda_{i\tau-1}(e^{\mu^e+\eta_\tau} - 1)\right] DCW_{i\tau-1} + DC_{i\tau}, & \tau < 65, \\ e^{r^f}\left[1 + \lambda_{i\tau-1}(e^{\mu^e+\eta_\tau} - 1)\right] DCW_{i\tau-1} - PODC_{i\tau}, & \tau \geq 65, \end{cases} \tag{2.10}$$

where, $PODC$, is the mortality-adjusted annuity from the defined contribution plan.

Irrespective of system, all individuals also receive social security pension benefits—SS, which depend on the individual's labour-income trajectory during working life. In Carlsson and Erlandzon (2005), we modelled this system as state dependent and from the simulated trajectories we have estimated a piece-wise linear retention-rate,

$$SS_{i\tau} = 0.4 \min\left[L^P_{i64}; 320\right] + 0.1 \min\left[\max\left(L^P_{i64} - 320; 0\right); 850 - 320\right]. \tag{2.11}$$

All payouts from these pension plans are assumed to be forfeited in the event of death.

2.5. Labour income and taxes

Wage and retirement income—L can now be defined as

$$L_{i\tau} = \begin{cases} e^{l_{i\tau}}, & \tau < 65, \\ PODC_{i\tau} + PODB_{i\tau} + SS_{i\tau}, & \tau \geq 65 \text{ if in old system,} \\ PODC_{i\tau} + SS_{i\tau}, & \tau \geq 65 \text{ if in new system,} \end{cases} \tag{2.12}$$

According to Swedish tax rules[8], labour income and pension benefits are taxed at a common rate, separate from capital income. To calculate net income—$L^n_{i\tau}$, we first deduct a general allowance of 10; then a municipal tax of 30%; then national tax of 20% on all income above 300; and finally, an additional national tax of 5% on income above 450. Net income is bounded below by the social welfare minimum-benefit and government-guaranteed minimum pension at 60. Therefore

$$\begin{aligned} L^n_{i\tau} = \max[&L_{i\tau} - 0.3\max(L_{i\tau} - 10; 0) - \\ &0.2\max(L_{i\tau} - 300; 0) - 0.05\max(L_{i\tau} - 450; 0); 60]. \end{aligned} \tag{2.13}$$

All the threshold-values that create kinks in tax-rates and benefits[9] are indexed to the expected growth in national labour income—μ^l, except the social welfare minimum benefit which is kept constant in real terms.

2.6. Private savings and consumption

An individual starts her optimisation life with initial wealth set to F. In the following pre-retirement years they receive wages, and in subsequent years retirement benefits. The individual has two control variables: the proportion of cash on hand to consume—θ_τ, and what proportion of savings—α_τ, to allocate to the risky asset. The cash on hand—disposable wealth, is therefore,

$$X_{i\tau} = \begin{cases} e^{r^f}\left[1 + \alpha_{i\tau-1}(e^{\mu^e + \eta_\tau} - 1)\right]\left[1 - \theta_{i\tau-1}\right] X_{i\tau-1} + L^n_{i\tau}, & \tau > \tau_0, \\ F_i + L^n_{i\tau}, & \tau = \tau_0, \end{cases} \tag{2.14}$$

[8] We use the tax rules for incomes earned in 2003.

[9] This is similar to the US since the "bend points" when calculating the primary insurance amounts (PIA) are adjusted by average earnings growth.

of which consumption is,

$$C_{i\tau} = \theta_{i\tau} X_{i\tau}. \tag{2.15}$$

There are also constraints on both borrowing and short-sales,

$$\begin{aligned} &0 \leq \theta_{i\tau} \leq 1, \\ &0 \leq \alpha_{i\tau} \leq 1. \end{aligned} \tag{2.16}$$

3. OPTIMISATION

To simplify the calculation[10], we introduce a decision rule that defines the asset allocation in the defined contribution account. This rule originates from Merton (1971) and states that; in complete markets—the allocation to risky assets—λ, is dependent on the relative size of investable assets to total wealth. In our model, total wealth is the sum of: present value of human capital, cash on hand and expected after-tax[11] DC wealth—DCW^{at}. The present value of human capital is the sum of: income plus defined benefits and defined contributions, net of taxes and adjusted for survival probabilities. Prior to retirement, the human capital is discounted with the complete market rate—s,

$$\begin{gathered} s = r^f - \tfrac{\sigma_\xi^2}{2} + \beta_k(\mu^e + \tfrac{\sigma_\eta^2}{2}), \\ \text{where } \beta_k = \tfrac{Cov(\eta, \xi_k)}{Var(\eta)}, \end{gathered} \tag{3.1}$$

and with the risk-free rate after retirement. Our decision rule is adjusted for the implicit equity exposure through the present value of human capital—$\beta_k \Delta$,

$$\lambda = \min \left\{ \frac{\mu^e \left[DCW^{at} + (1-\theta)X + PV(HC)\right]}{\gamma \sigma_\eta^2 \left[DCW^{at} + (1-\theta)X\right]} - \frac{\beta_k \Delta PV(HC)}{DCW^{at} + (1-\theta)X}; 1 \right\}, \tag{3.2}$$

where Δ is the change in present value of human capital from a group specific permanent income shock—ξ_k.

The individual's problem therefore has four state variables (τ, v, X and DCW) and two choice

[10] The portfolio choice in the DC-account and for private savings is highly interdependent, making a simultaneous choice very complicated numerically.

[11] The after-tax rate is set to the municipal-tax only, since this is typically the only tax that an agent pays when in retirement.

variables (θ and α) as well as four stochastic variables (ϵ, ω, ξ and η). The value function of their intertemporal consumption and investment problem can then be written as

$$\begin{aligned} V_\tau\left(\Gamma_\tau\right) = \max_{\theta_\tau,\ \alpha_\tau} \left\{ \tfrac{C_\tau^{1-\gamma}}{1-\gamma} + \delta E_\tau \left[p_\tau V_{\tau+1}\left(\Gamma_{\tau+1}\right) + \left(1-p_\tau\right) b \tfrac{D_{\tau+1}^{1-\gamma}}{1-\gamma} \right] \right\} \\ \Gamma_\tau = \left\{ X_\tau, v_\tau, DCW_\tau \right\}. \end{aligned} \tag{3.3}$$

The solution to this maximisation problem together with our decision-rule from (3.2) gives us the state dependent policy rules,

$$\begin{aligned} \theta_\tau &= \theta_{k\tau}(\Gamma_\tau), \\ \alpha_\tau &= \alpha_{k\tau}(\Gamma_\tau), \\ \lambda_\tau &= \lambda_{k\tau}(\Gamma_\tau). \end{aligned} \tag{3.4}$$

We solved the problem numerically by backward recursion from the final year—T, using by-now standard methods, *cf.* Judd (1998) and Cocco *et al.* (2005).

4. CALIBRATION OF PARAMETERS

4.1. Estimation of labour income process

Follwing Carroll and Samwick (1997), we modelled the log of real income as deterministic part with both permanent and temporary shocks. Their description of the income-process has been used in several life cycle models, *cf.* Campbell *et al* (2001), Cocco *et al.* (2005), Carlsson and Erlandzon (2005), Cocco (2005), Carlsson and Erlandzon (2006) and Zhou (2006). The deterministic part of Equation (2.2) was estimated (*cf.* Appendix A.1 for details) using a longitudinal panel of data—LINDA, (*cf.* Edin and Fredriksson (2000) for details), that covers the Swedish population in the age interval $[28, 64]$ for fourteen years during $1992 - 2005$, resulting in more than 1.4 million observations.

The data set augmented with wealth information, has recently received attention in *cf.* Calvet *et al* (2006), Campbell (2006) and Flood (2003). The data-set was divided into twelve non-intersecting groups, depending on sex, education and sector (private and public). Using the methodology of Carroll and Samwick (1997), we estimated the variances of the permanent σ_u^2 and transitory σ_ε^2 components of shocks to income as specified in Equation (2.2) (*cf.* Appendix A.2).

4.2. Individual parameters

We used a standard set of assumptions with respect to the individual parameters for the reference case. First, we set the coefficient of relative risk aversion—γ to 5 and the discount factor—δ to 0.98. The gender specific survival probabilities—p were taken from the Swedish life-insurers when underwriting new policies,*i.e.* they are forward looking. The bequest parameter—b was set to 1. Adult life is divided into two intervals: working life $[28, 64]$ and retirement $[65, 100]$. The importance of the risk aversion parameter—γ will be elaborated on when we report on the sensitivity analysis in Section 5.4.

4.3. Assets and correlations

In the optimisation, we set the risk-free after-tax rate—r^f to 1.5%, which is consistent with the present gross return of less than 2% for long-dated index-linked bonds. The mean after-tax equity premium—μ^e was set to 3%, which is lower than the historical average, but corresponds well with forward-looking estimates (*cf.* Claus and Thomas (2001), Fama and French (2002)). Because of uncertainty about the equity-premium, we analysed its sensitivity in Section 5.4. Volatility σ_η was set to 17% for the risky asset.

Next, we followed the procedure of Cocco *et al.* (2005) to estimate the correlation—$\varrho_{k\eta}$ between group specific permanent labour income shocks—$\xi_{k\tau}$ and lagged equity returns—$\eta_{\tau-1}$. Table A.3, shows the estimated correlation, using the returns on the Swedish equity-index—OMX and on the 12-month Swedish Treasury Bills as proxies for risky returns and the risk-free rate respectively.

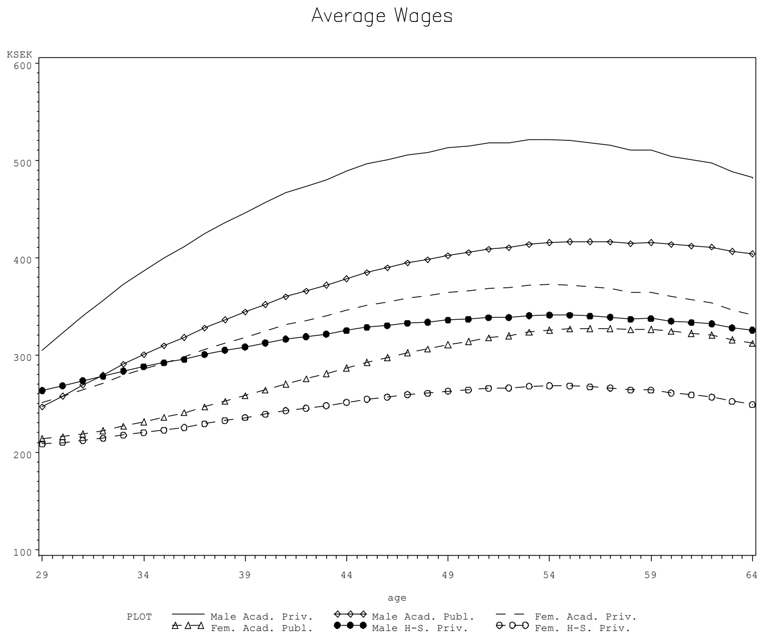
We also set the growth in average labour income—μ^l to 1.8%, which is the estimate used by the National Social Insurance Board. Finally, the initial wealth—F is set to 40, corresponding to the mean wealth for individuals at the age of 28.

5. RESULTS

5.1. Labour income process

For reference, we plotted the average of the simulated income profiles for some[12] of the groups, *cf.* Figure 5.1.

FIG. 5.1 Income profiles for different groups



Simulated real gross wages—L without productivity change.

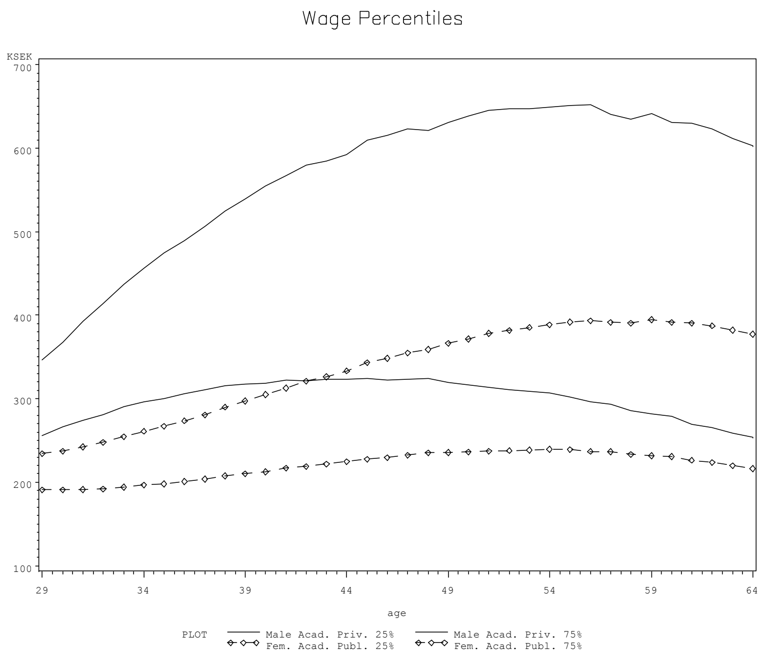
Three findings are notable: First, individuals with a university degree experienced a significantly faster income growth in mid-life than did the other groups, a result which matches stylised facts from the US, *cf.* Hubbard *et al* (1995), Gourinchas and Parker (2002) and Cocco *et al.* (2005). Secondly, at each level of education, men had higher income than did women, at all stages of the life-cycle. Thirdly, that remunerations in the private sector was typically higher than in the public sector.

Our results also show a strikingly lower permanent variance if the agent is employed by a public *vs.* a private entity, whereas the temporary variance was similar, except for those with university degrees. After controlling for private *vs.* public sector, most of the gender differences in variance, that we found in our previous study, Carlsson and Erlandzon (2005) disappeared.

[12] In order to increase readablity, we omitted the groups with similar profiles to the group with the lowest income.

We also note that the permanent shocks to income has the highest correlation with the equity market for the privately employed with an university degree, and that gender is less of an importance. Figure 5.2 shows the large effect that a higher variance in the permanent component for Men in Private sector will have on labour income variation during life, when compared to Females in Public sector, albeit both groups have a University degree.

FIG. 5.2 Income variation



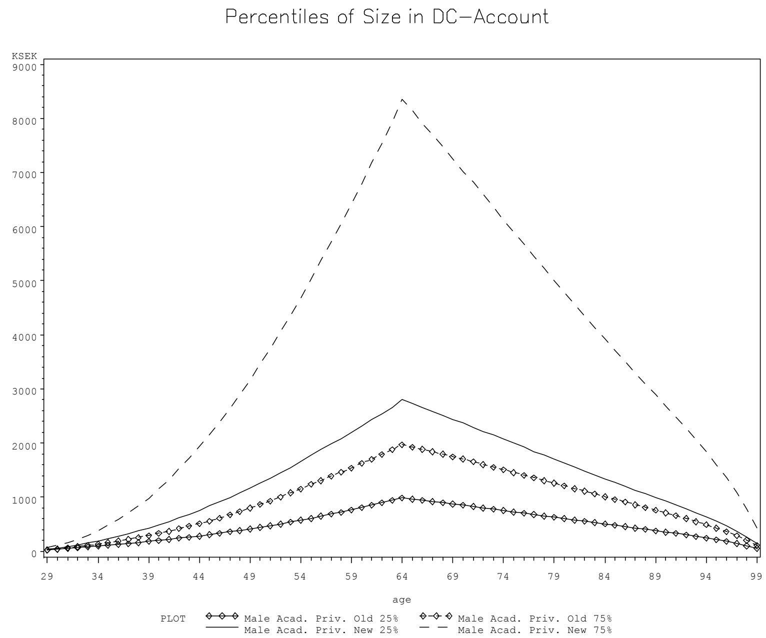
25^{th} and 75^{th} percentiles for simulated real gross wages—L without productivity for Men and Females with University degrees employed in the Private and Public sector.

5.2. Winners & Losers

We simulated the individual behaviour from age—28 until 100 with 10000 trajectories. Contingent on their random experience, individuals choose responses determined by the policy rules in Equation (3.4).

Since the change of pension system was negotiated by consenting adults—we would expect that on average the two systems would generate similar benefits. However, under the new system, individuals have a much larger responsibility for the appropriate management of the DC-account, since the outcome rests solely with the employeé. In Figure 5.3 we show (for the highest income group—Men with University degree in the private sector), the variation in size of the DC-accounts.

FIG. 5.3 DC-account variation



25^{th} and 75^{th} percentiles of the DC-account in the Old and the New pension system for Males with a University degree in the Private sector.

In order to discover to what extent this new pension system generated winners and losers, we evaluated the value function (Equation (3.3)), for the different groups in the first period; using both the old and the new pension system. For each group, we equalised the value of the value functions associated with the two pension systems; by adding an initial amount to the DC-account that was associated with the lowest value of the value function. The results for a subset of the groups are presented in Table 5.1.

Intuitively, we would expect the group with the highest expected final pre-retirement income relative to average income, to lose from the transition and *vice versa*. Another factor, is that high uncertainty in final pre-retirement income will decrease the expected utility of a defined benefit pension. Men with an university degree in the private sector has an early earnings career and a more pronounced decline in income prior to retirement. They are therefore the winners from a transition. The gain for this group is increased, as they also have a higher variance in income, which makes their

TABLE 5.1
Initial amount in Old or New DC-account necessary to equalise the value to the individual of the pension systems

Amount in KSEK		Pension System	
		Old	New
Private	Men		
	High school		19
	University	101	
	Women		
	High school		32
	University	12	
Public	Men		
	University		40
	Women		
	University		80

expected final income less certain.

The defined-contribution system recently negotiated in the private sector is a likely blueprint for a potential change of system for those in the public sector as well. Our analysis shows (*cf.* Table 5.1) that publicly employed would on average lose and that this loss is most pronounced for women. Women typically have their earnings-career later in life (*cf.* Figure 5.1), and therefore have less benefits from early contributions; and secondly that, the lower variance in earnings among publicly employed and will make the Defined Benefit pension closer to a risk-free asset.

5.3. Effects on portfolio choice

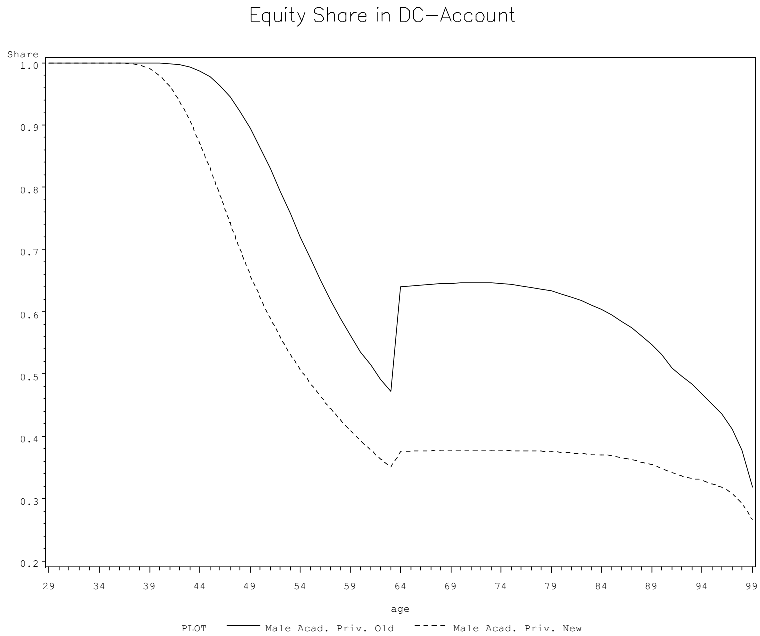
The positive labour income profile and short-sales constraints will typically make younger individuals "more" constrained, *i.e.* with an equity allocation quite different from the complete market solution.

Figure 5.4, shows the average equity proportion of the DC-account. For young individuals is cash on hand very small in comparison to the human capital and since their DC-account cannot be used for precaution or bequest, we get a maximum allocation to equities in the DC-account.

With increasing age, the combined effect of: the DC-account being a much larger proportion of total wealth in the new system and the old Defined Benefit pensions being less risky; will lead to a more conservative behaviour for an agent in the new system. After retirement, when the Defined Benefit benefits become risk-free and hence $\Delta = 0$ in Equation (3.2), we can identify a large increase in the equity exposure for an individual in the old system.

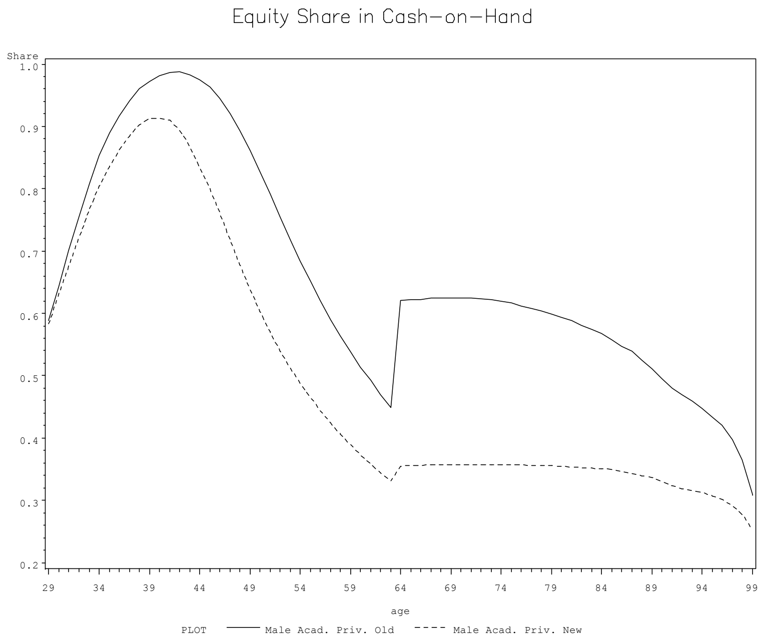
In Figure 5.5, we show the same profile, but now for risky weight in cash on hand. There is a large difference between the risky weight in cash on hand *vs.* DC-account in early life, for precautionary and bequest reasons. After retirement, with decreasing present value of human capital, there is a gradual decline in equity-exposure towards the complete-market solution.

FIG. 5.4 Simulated Average Equity Exposure in DC-Account



Simulated average equity share—λ in the DC-account for Males with University degree in the Private sector, for the old and new pension system.

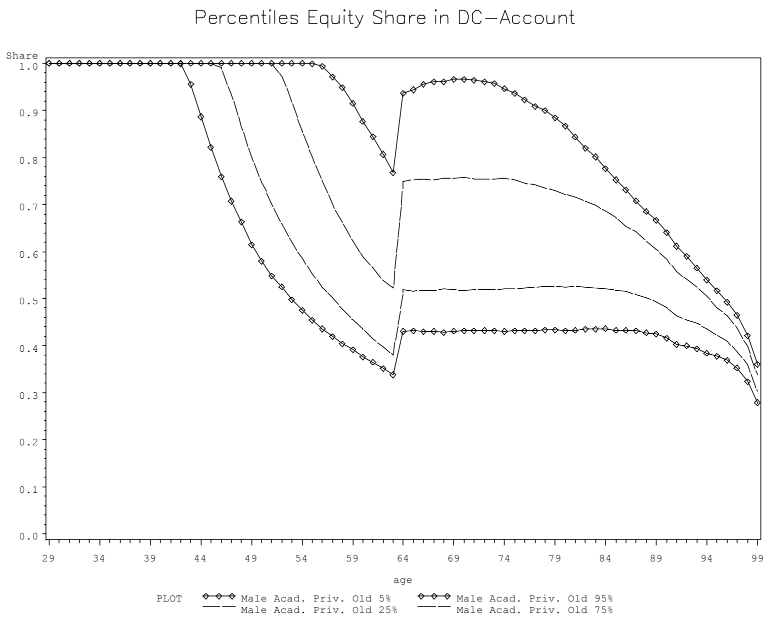
FIG. 5.5 Simulated Average Equity Exposure in Cash-on-Hand



Simulated average equity share—α in the cash on hand-X for Males with University degree in the Private sector, for the old and new pension system.

It is important to note that; the profiles reflect the simulated averages for one individual. Figure 5.6 shows some percentiles of equity exposure for an agent in the old pension system. The large variation is solely due to the accumulated effect of individual experiences. If we in addition, also could account for differences among individuals in: *e.g.* risk aversion, discounting or expected equity premia; then the variation would most likely be even larger.

FIG. 5.6 Variation in equity exposure in DC-Account

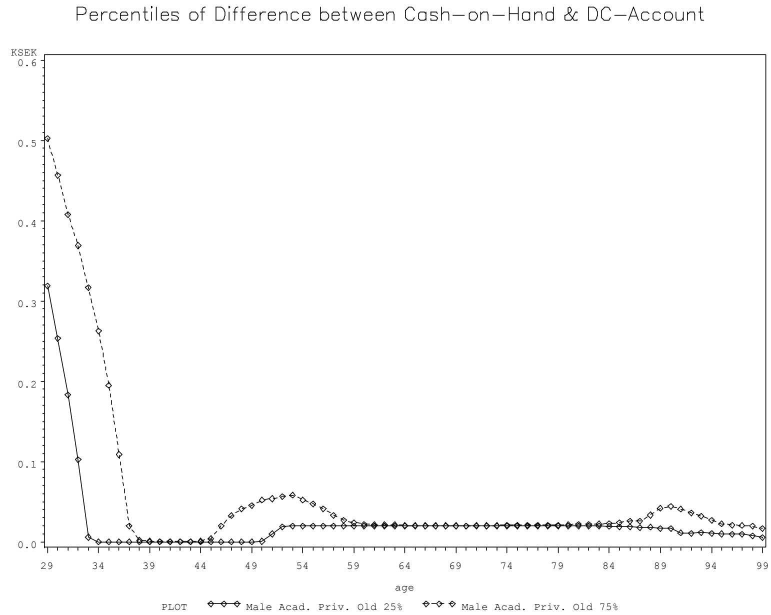


Simulated 5^{th}, 25^{th}, 75^{th} and 95^{th} percentiles percentiles for the equity share—λ in the $DC-$account for Males with University degree in the Private sector in the Old pension system.

In Equation (3.2), we created a decision-rule for the equity share in the DC-account. If this rule is too crude, we would expect individuals to compensate for any such errors in the allocation of their private savings. We therefore "tested" this rule by calculating the difference between the equity share in DC-account and in cash on hand—$(\lambda_{i\tau} - \alpha_{i\tau})$.

A priori, we would expect this difference to be small and show little variance for unconstrained individuals when the precautionary motive is weak, *e.g.*, after retirement. Early in life, however, when individuals are borrowing-constrained, we know that differences between trajectories can be large. Figure 5.7 plots this difference and the variation after retirement is not very large, which indicates that our rule seems to work.

FIG. 5.7 Variation in the difference in equity exposure between DC-Account and cash on hand



Simulated $25^{th}$and 75^{th} percentiles for the difference in equity share between $DC-$account—DCW and cash-on-hand—X for Males with University degree in the Private sector in the Old pension system—$(\lambda - \alpha)$

5.4. Sensitivity analysis

In order to analyse to what extent our results are parameter-dependent, we performed a sensitivity analysis using the group whose benefits are most affected by the change in pension systems—men with a university degree in the private sector. Table 5.2 shows the initial amounts that the DC-account must be increased with, in order to equalise the value of the two pension systems, with respect to changing risk-aversion and a higher equity-premium.

TABLE 5.2
Initial amount in the Old DC-account necessary to equalise the value of the pension systems to the individual, with respect to equity and risk premia for Men with University degree in the Private sector

	μ^e	γ	KSEK
Reference	3	5	101
Low risk aversion	3	2	179
High risk aversion	3	8	70
High equity premium	4	5	106

In all cases, it was beneficial for this group to move into the new system. The result show that changes in the equity premium—μ^e does not have a large impact, whereas the benefit to the less risk-averse was increased substantially.

6. CONCLUSIONS

This paper aims to contribute to the understanding of the welfare effects of moving from primarily a defined-benefit to a defined-contribution pension system, and the changes in optimal individual behaviour required by such a change. The setting is a borrowing-constrained individual's consumption- and portfolio-choice in the presence of uncertain labour-income, with group-dependent labour-income processes and realistically-calibrated tax- and pension-systems. We found that those employed in the private sector had higher income-variance than those in the public sector, while gender differences (after controlling for private *vs.* public employment) were small.

We have used the recently negotiated change from defined benefit to defined contribution pension systems as a benchmark for our analysis. The finding was that agents with low expected final income relative to average income during working life and those with high income variance are set to gain from this transfer. Winners are men with an university degree within in the private sector, and losers would be women in the public sector with an university degree. The value of the different systems to the individual are dependent on the risk preferences, but will not change the preference of system.

Introducing a defined contribution system will necessitate that the individual has to manage the assets differently in private and pension savings; and that the differences in portfolio choice between agents due to individual situations are relatively large, even if we do not account for differences in terms of risk-aversion, *etc*, between individuals. One-size-fits-all kind of life-cycle funds, where the equity allocation depend on age alone, will therefore not solve the asset allocation problem for the individual.

APPENDIX A: DATA AND ESTIMATIONS

A.1. Estimation of the labour-income process

The data set was divided into twelve non-intersecting groups, depending on sex (Male, Female), education (Compulsory school-, High-school- or University-degree) and employer (Public, Private). The matrix of individual characteristics—$\mathbf{Z}$, includes variables for the number of children in different age-intervals as wells as a dummies for maritial status, age. Income was adjusted to real values by deflating with the official consumer price-index. Measured income is an aggregate including gross wages, also all social security benefits (primarily income-compensation for unemployment, disability and childcare) and pension benefits.

To avoid double-counting, we deleted all observations where income included voluntary pension benefits, *i.e.*, individuals above the age of 55 receiving pension pay-outs at their own request. Pension benefits paid prior to age 55 can be considered as insurance payouts and were therefore included. Progressive taxation will induce most agents to make these early withdrawals only if the individual has simultaneously reduced the ordinary wage income. Finally, we exclude an observation if income is less than 100.000 SEK. Individuals with income lower than this level are assumed to be voluntarily unemployed.

The following random-effects linear model was used to estimate the deterministic function for each group,

$$\begin{aligned} l_{it} &= \beta_0 + \mathbf{Z}_{it}\boldsymbol{\beta} + \vartheta_i + e_{it}, \\ e_{it} &= \rho e_{it-1} + \varkappa_{it}, \\ \vartheta_i &\sim N(0, \sigma_\vartheta^2), \\ \varkappa_{it} &\sim N(0, \sigma_\varkappa^2), \end{aligned} \tag{A.1}$$

where—$\mathbf{Z}_{it}$ are the nonstochastic regressors and $\boldsymbol{\beta}$ is the vector of regression coefficients. Estimation results are presented in Table A.1.

TABLE A.1
Labour Income Process: Coefficients from Regression

AR(1) Random effects Regression										
Log real income 2004 KSEK			#Children at age 1-2	3–5	6-17	Married=0 Single=1	AR ρ	Std. in fixed σ_ϑ	Std. in overall σ_e	R^2 within
Private	Men									
		Compulsory	-.00599	.00076	-.00284	-.02846	.5305	.2378	.2378	.185
		High school	-.00762	-.00242	.000027	-.02957	.5356	.2688	.1644	.235
		University	-.00786	.00077	.00035	-.03185	.5469	.3784	.2096	.317
	Women									
		Compulsory	-.08666	-.04532	-.02430	.03215	.5433	.2223	.1338	.271
		High school	-.12572	-.06728	-.03316	.03444	.5116	.2306	.1625	.300
		University	-.17466	-.10077	-.05480	.01108	.4645	.3194	.2085	.328
Public	Men									
		Compulsory	-.02575	-.00889	-.00838	-.04473	.4857	.2462	.1214	.213
		High school	-.01951	-.01389	-.00617	-.03341	.5076	.2642	.1296	.267
		University	-.00655	.00014	.00201	-.01905	.5394	.3190	.1449	.381
	Women									
		Compulsory	-.06417	-.03328	-.01257	.02817	.5480	.2018	.1152	.270
		High school	-.10207	-.04860	-.02063	.03488	.5274	.1699	.1224	.376
		University	-.13186	-.06781	-.02867	.03442	.5038	.2368	.1455	.443

We then calculate the deterministic component of labour income—$\exp\left\{f_k(\tau, \overline{\mathbf{Z}}_{k\tau})\right\}$, adjusted for age dummies with the averages of the characteristics. This was then used to estimate a third-degree polynomial with respect to age, *cf.* Equation (A.2) Table A.2, and Figure 5.1,

$$\exp\left\{f_k(\tau, \overline{\mathbf{Z}}_{k\tau})\right\} = \sum_{m=0}^{3} a_{km}(AGE_\tau - 18)^m. \tag{A.2}$$

A.2. Variance Decomposition

We followed Carroll and Samwick (1997) in decomposing permanent and temporary variances. By combining the error terms from Equation (2.2)—$v_{it} + \varepsilon_{it}$ with the estimated residual—e_{it} from Equation (A.1), we get:

$$\Delta e_{it}(d) = e_{it+d} - e_{it} = (v_{it+d} + \varepsilon_{it+d}) - (v_{it} + \varepsilon_{it}) = (u_{it+d} + ... + u_{it}) + (\varepsilon_{it+d} - \varepsilon_{it}) \tag{A.3}$$

and consequentially the variance is,

$$Var(\Delta e_{it}(d)) = d \cdot \sigma_u^2 + 2 \cdot \sigma_\varepsilon^2. \tag{A.4}$$

Following Carroll and Samwick (1997), we allowed for serial correlation in the transitory shock of the order $MA(2)$, and therefore excluded observations with a time distance less than 3. OLS on

TABLE A.2
Coefficients in the age polynomial of the forward-looking income profile

		Income profile, 2004 KSEK, (AGE-18)	Constant a_0	Age a_1	Age^2 a_2	Age^3 a_3
Private	Men					
		Compulsory	187.4410	3.7553	-0.0149	-0.0009
		High school	192.5214	5.4665	-0.0449	-0.0008
		University	50.6314	26.8242	-0.5615	0.0028
	Women					
		Compulsory	170.8340	0.0714	0.0986	-0.0020
		High school	200.2780	-2.5127	0.2277	-0.0037
		University	170.6430	5.3380	0.0553	-0.0027
Public	Men					
		Compulsory	150.9325	3.0467	0.0011	-0.0008
		High school	176.5778	2.5334	0.0325	-0.0013
		University	91.3953	14.9683	-0.2048	0.0000
	Women					
		Compulsory	154.1382	0.4386	0.0563	-0.0012
		High school	181.6734	-2.1792	0.1781	-0.0027
		University	217.9771	-5.5608	0.4423	-0.0065

Equation (A.4) was then used to estimate σ_u^2 and σ_ε^2.

A.3. Income correlation with the equities

We followed Cocco *et al.* (2005) in estimating the correlation between labour-income shocks and equity–returns. Using Equation (2.2), the first difference in $l^*_{ikt} = l_{ikt} - f_k(\tau, \mathbf{Z}_{ik\tau})$ can be written as

$$\triangle\, l^*_{ikt} = \xi_{kt} + \omega_{ikt} + \triangle\, \epsilon_{ikt}. \tag{A.5}$$

Taking the average over individuals in each group gives us the group-aggregate component,

$$\overline{\triangle\, l^*_{kt}} = \xi_{kt}. \tag{A.6}$$

Finally, we estimated the correlations—$\varrho_{\xi_k \eta}$, by applying OLS to,

$$\overline{\triangle\, l^*_{kt}} = \beta_k (r^e_{t-1} - r^f_{t-1}) + \phi_t. \tag{A.7}$$

Table A.3 presents the result from this regression using the real return of the Swedish equity index OMX as a proxy for equity-returns—r^e and the real return on 12-month Swedish Treasury Bill as the risk-free rate—r^f.

TABLE A.3
Variance decomposition and equity correlations

			Number of observations	Estimated variance of the permanent component $\sigma^2_{u_k}$	Estimated variance of the transitory component $\sigma^2_{\varepsilon_k}$	Std. of the permanent aggregate component σ_{ξ_k}	Correlations with Swedish equity returns $\varrho_{\xi_k \eta}$
Full sample			1 423 930			0.0211	0.40
Private	Men		585 446				
		Compulsory	140 413	0.0042	0.0152	0.0222	0.39
		High school	310 835	0.0054	0.0183	0.0229	0.40
		University	134 198	0.0098	0.0284	0.0270	0.61
	Women		290 776				
		Compulsory	67 364	0.0048	0.0104	0.0187	0.45
		High school	152 254	0.0054	0.0182	0.0173	0.45
		University	71 158	0.0079	0.0306	0.0258	0.51
Public	Men		152 243				
		Compulsory	17 039	0.0021	0.0083	0.0249	0.25
		High school	47 543	0.0029	0.0096	0.0219	0.23
		University	87 661	0.0044	0.0115	0.0216	0.24
	Women		395 465				
		Compulsory	41 921	0.0034	0.0082	0.0236	0.30
		High school	176 607	0.0030	0.0103	0.0207	0.25
		University	176 937	0.0038	0.0138	0.0233	0.22

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Home Bias in the Swedish National Pension Funds

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The aim of this study was to determine whether there is a home bias among the newly established Swedish National Pension Funds. Estimation errors in historical estimates of return moments make traditional analysis of the home bias puzzle work poorly. Therefore, this paper takes another approach by using the information available to the fund. In addition, this study performs a sensitivity analysis by resampling the data at hand under different assumptions about the estimation procedure underlying the return distribution. The results demonstrate a significant bias towards domestic equities that cannot be explained by an informational advantage or any other risk and return based explanation.

Key Words: Home Bias, Pensions.

JEL classification: G11, G23

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1. INTRODUCTION

In 1998 the Swedish parliament approved legislation on a new and reformed pension system. As an integrated part of the new pension system, it is the role of the five Swedish National Pension Funds to act as a buffer when contributions and disbursements do not match. The funds have new guidelines, specifying that only risk and return on investments are to be considered when deciding on an asset allocation, and flexible investment rules allowing the funds to be fully diversified into international assets. It is therefore puzzling that the funds have a bias towards domestic assets.

Traditional analysis of the home bias puzzle used historically estimated means and variances of international asset returns in a mean-variance framework. This approach has since then been criticized for the reason that it neglects several important aspects, such as the costs of international diversification, deviations from purchasing power parity and in particular the statistical uncertainty embedded in historical data. Later papers considered these aspects, however the results were diverse due to the uncertainty in the estimated parameters (see Bekaert and Urias, 1996, Britten-Jones, 1999, and Gorman and Jorgensen, 2002, among others).

This paper takes the aspects omitted in the early papers into consideration and investigates if there is a home bias in the Swedish National Pension Funds. The approach in this paper differs from that used in earlier studies, by directly analyzing the decision procedure leading to the selected asset allocation. Information on the asset allocation decision of the Swedish National Pension Funds is publicly available, making this a rare opportunity since similar information from the private fund industry is restricted. This paper presents evidence of a significant bias towards Swedish equities that cannot be explained in terms of risk and return.

The pension reform was spurred by the fact that the ratio of the elderly non-active population to the working force is rising due to increased longevity and low birth rates. Within a decade the post-war baby boom generation starts retiring, making the problem even worse. This should be managed by the new pension system, which is divided into a notional defined contribution pay-as-you-go (NDC PAYG) part and an advance-funded defined contribution (DC) part. Both the NDC PAYG and the DC systems are self-financing and independent from the government budget. However, the state budget finances contributions to cover additional pension rights for activities such as child care, higher education and military service, as well as a minimum guarantee benefit for low-income earners and for lifetime poor[1].

The idea of the PAYG system is that current pensions ought to be financed by 16 percent of current

[1] See www.rfv.se for further details.

salaries and wages. The size of the contributions and disbursements varies over time, depending on factors such as mortality, birth rates, migration and the rate of income growth. The buffer funds will cover the deficit during the forthcoming decades, when the disbursements are expected to exceed the contributions. This makes the actions of the buffer funds an important issue for the majority of the Swedish people, for whom the pension from the PAYG system will form the largest part of their total pension (see Flood, 2003).

At the beginning of January, 2001, all four large Swedish National Pension Funds (AP1, AP2, AP3 and AP4) started out with SEK 134 billion each, and so altogether exceeding the total holdings by Swedish households in both equities, SEK 484 billion, and mutual funds, SEK 472 billion (Statistics Sweden, 2004). The four funds all have identical investment rules and goals according to the government bill (1999/2000:46) concerning AP1-4:

"The goal shall be to maximize the long-term return on investments relative to the degree of risk exposure. Assets shall be managed to ensure exposure to risk is well diversified. [...] The funds shall be independent of business and other economic and/or political interests."

The unique guidelines for the AP-funds, with the flexible investment rules allowing the AP-funds to be fully diversified into international assets and the clearly specified goals, make it obvious that the funds should be able to justify the selected asset allocations only in terms of risk and return.

For some time, financial economists have argued that international portfolio diversification can enhance the risk-return relationship of investment portfolios, among them Grubel (1968), Levy and Sarnat (1970), Solnik (1974), Grauer and Hakansson (1987) and more recently Kaplanis and Schaefer (1991) and Baxter and Jermann (1997). Nevertheless, the four AP-funds invest a disproportional large part of their portfolio investments in Swedish assets. One example is AP2, which invests one third of its equity portfolio in Sweden, even though Swedish equities represent less then 1 percent of the worlds total equities. There are several possible reasons behind the home bias puzzle. Ziemba and Schwartz (1991) mentions reasons such as regulations, fear, familiarity, transaction costs, lack of knowledge and currency risk, while Lewis (1999) discusses "hedging home risks with home equity", "diversification costs exceeding the gains" and "empirical mismeasurement of home bias" as three possible rational reasons.

Any analysis of the home bias puzzle is sensitive to the estimated return distribution and as numerous authors have shown, the results are usually inconclusive when using historical data (see Bekaert and Urias, 1996, Britten-Jones, 1999, and Gorman and Jorgensen, 2002). An illustrative example is Britten-Jones (1999), who cannot reject the hypothesis that the global tangency portfolio has no exposure to US stocks nor can he reject the hypothesis that the portfolio has no exposure to non-US stocks. This clearly demonstrates the lack of information in historical data when testing for portfolio home bias. Instead, this paper uses the information available to the funds and studies the decision procedure to investigate if the asset allocation decision[2] was made in accordance with the legislated goals (return versus risk) and, if not, it investigates which portfolio would have been selected if the legislation were followed. This study can therefore analyze any deviation from the legislated goals and its implication on the selected asset allocation. More specifically, while considering the possible reasons for the home bias puzzle discussed in the literature, this paper investigates whether the investments in Swedish assets by AP1 can be justified in terms of risk and return. The reason for choosing AP1 is that the data needed was fairly easy to access. Furthermore, AP1 is the fund with the lowest part (12 percent) of its assets invested in Swedish equities. Therefore, if a home bias is found in AP1's asset allocation, then it is reasonable to believe that the other funds, with an even higher exposure to Swedish equities, also have a home bias.

The rest of the paper is organised as follows. The next section presents the theoretical framework, while Section 3 describes the limitations of the study. The data is described in Section 4, the methodology in Section 5 and the results are presented in Section 6. Finally, Section 7 concludes.

2. THEORETICAL FRAMEWORK

2.1. Estimation Error

In the traditional mean-variance (M-V) framework, introduced by Markowitz (1952), the investor chooses a portfolio depending on the return distribution of the assets considered. The vector of expected returns and the covariance matrix are often measured solely from historical data. One alternative, recognized by Markowitz himself, is that security analysts participate in the process of estimating the probability beliefs (see Markowitz, 1952). Either way, the estimates are measured with some degree of error. Because of the errors in the estimates, the parameters used in an M-V optimization will not be the true values of the parameters. Jobson and Korkie (1980, 1981) showed that estimation errors can have a large effect on optimal portfolio weights. Michaud (1989) argues that reason for this is that M-V optimization overweights (underweights) assets with large (small) estimated returns and negative (positive) correlations. He indicates that these assets are the ones most likely to have large estimation errors and that M-V optimized portfolios are "estimation-error maximizers". Since optimal weights are computed based on statistically estimated parameters, the optimal weights are also estimates with a statistical distribution.

[2] Information on the asset allocation decision of the Swedish National Pension Funds is public information.

Estimation risk can, however, be incorporated into the portfolio problem within a Bayesian framework. In Bayesian portfolio analysis, efficient portfolios are selected by maximizing the expected utility conditioned on the predictive density of asset returns. One approach is to use a noninformative diffuse prior as in Stambaugh (1997). The alternative is to use an informative prior. Examples of informative priors are to assume that all assets have identical expected returns, variances and pair wise covariances as in Frost and Savarino (1986) or to assume some prior degree of belief in an asset pricing model as in Pástor (2000). See Bawa et al. (1979) for an extensive treatment of portfolio choice under estimation risk.

2.2. Home Bias

The disproportionately large shares of wealth invested in domestic assets by individuals and institutions around the world are not consistent with theory of portfolio choice. Among the first to recognize this was Grubel (1968). Since then there have been numerous papers written on the subject. Lewis (1999) discusses three main reasons that could explain the equity home bias puzzle:

I. Hedging home risks with home equity: If investors are able to hedge risks that are specific to the home country with home equity it can explain the large positions in domestic equities. Three types of hedge demands are discussed. The first source of country specific risk is domestic inflation. With inflation risk and deviations from purchasing power parity, investors may demand assets designed to hedge this risk. However, the conclusion in Lewis (1999) and in Cooper and Kaplanis (1994) is that inflation hedging cannot explain the home bias. The second type of hedging demand discussed is hedging against wealth that is non-tradable, such as human capital. Does the existence of non-tradable assets provide an explanation for the home bias phenomenon? This question is relevant for the AP-funds since most of the assets and liabilities of the pension system are non-tradable. Baxter and Jermann (1997) include non-tradable human capital into the portfolio problem. They show that the returns to human capital and physical capital are highly correlated within countries, while growth rates of labor and capital income are not highly correlated. Their conclusion is that hedging human capital risk involves a short position in domestic assets. Hence, taking non-tradable assets into consideration only makes the puzzle worse. The demand for hedging with foreign returns implicit in equities of domestic firms that have operations in foreign countries is the third demand discussed. The idea is that holding equities in multinational firms, listed in the home country, provides the investor with returns that depend on foreign economies. This way diversification can be achieved without investing abroad. Lewis (1999) argues that, even though the argument seems plausible, it does not hold up empirically. Hence, the benefits of international diversification can only be gained by holding foreign assets that are not a part of the domestic index. Lewis (1999) comes to the conclusion that the hedge properties of domestic equities cannot explain the home bias puzzle. On the contrary, she argues that since foreign assets are better hedges against some country specific risks, this type of explanation can actually deepen the home bias puzzle.

II. Diversification costs exceed the gains: This explanation for home bias is based upon the costs of international investment, such as information costs, taxes and transaction costs. If the costs are significant they could offset the potential gains from international diversification. However, the gains estimated by several authors seem to be large. Lewis (2000) estimates the welfare gains to be at least 20 percent of permanent consumption and sometimes near 100 percent. While playing an important role historically, governmental capital controls, such as regulations and taxes, has become much less important as capital markets deregulated during the 1990s. Transaction and information costs of investing internationally may be large for individuals but not for institutional investors. Lewis (1999) argues that the increased competition in the mutual fund industry has reduced these costs for individuals as well. The conclusion is that the costs do not appear to exceed the gains, at least not for diversification into developed countries.

III. Empirical mismeasurement of home bias: An alternative explanation for equity home bias comes from incorporating estimation error into the analysis. Generally, papers investigating the gains from international diversification in finance use historical means and variances of returns without considering the uncertainty embedded in the data. The question is whether the gains from international diversification are statistically significant. Bekaert and Urias (1996) examine whether there are gains from foreign investments for investors from the US and the UK. They can reject the hypothesis of no gains for UK investors, but not for US investors. Furthermore, neither Britten-Jones (1999) nor Gorman and Jorgensen (2002) find a significant difference between a 100 percent US portfolio and the M-V frontier tangency portfolio. Lewis (1999) concludes that since international diversification does not lead to a statistically significant improvement of portfolio performance in some cases, there may be no home bias.

Ziemba and Schwartz (1991) state some other, less rational, reasons for the home bias. Individuals, pension boards and investment companies feel more comfortable with what they think they know—their home market. Another reason is that some pension trustees perceive investment abroad as giving help to a competitor.

The review of investment strategy in the AP-funds by Wassum (2002) reports a few reasons put forward by the AP-funds to rationalize their large exposure to Swedish assets. Some funds believe that they have an informational advantage that will make them outperform the Swedish market. The large allocations in Swedish assets are also justified by higher expected returns for the Swedish market.

3. LIMITATIONS

I start by describing the process followed by AP1 when selecting their final portfolio. This makes it easier to understand the limitations of the paper. I continue by describing the limitations of this study and their implications on the results.

When determining their long-term portfolio, it is important for the funds to take the liability structure and all assets (including future contributions) into consideration. By the end of 2001, the assets of the buffer funds (SEK 566 billion) represented about 10 percent of the total book value of the PAYG pension system (RFV, 2002). The remaining 90 percent of assets is the book value of future contributions.

The government bill (1999/2000:46) recommends the AP-funds to conduct an Asset Liability Modeling (ALM) study in order to capture the relationships between assets and liabilities. All four funds used Asset Liability Modeling based on Monte-Carlo simulations. In these models, a large number of projections of the assets and liabilities relating to the funds are simulated for a certain number of years into the future. The outcomes are analyzed through several different key measures of the AP-funds, for example the probability that the funds become insolvent within 40 years[3].

In order to determine the long-term asset allocation, AP1 consulted Morgan Stanley Dean Witter (MSDW) and Wilshire Associates[4]. MSDW included four equity markets and two bond markets in their study. However, the MSDW study did not include Swedish bonds explicitly, since MSDW assumed that Europe and not Sweden was the domestic investment zone of AP1. The study conducted by Wilshire included Swedish equities and Swedish bonds as well as six other asset classes. When deciding on a target portfolio, AP1 focused on the analysis of Wilshire.

The AP-funds found that ALM studies based on Monte-Carlo simulations are very time consuming and there are a vast number[5] of possible portfolios to analyze. For that reason, both studies conducted on the behalf of AP1 (as well as separate studies conducted by AP3 and AP4) started with an M-V optimization in order to select portfolios for further analysis. Generally, only feasible M-V efficient

[3] See Wassum (2002) for a more detailed description of the ALM-studies carried out on the behalf of the AP-funds.

[4] See www.msdw.com and www.wilshire.com for further information on the companies.

[5] There are $\binom{107}{7}$ =26 075 972 546 possible portfolios to test if testing every nonnegative integer-percent-value for 8 asset classes.

frontier asset allocations relative to fund liabilities are of interest (see Michaud, 1998). However, the liabilities are not easy to capture by any benchmark. Wilshire did not include any benchmark in their M-V optimization and the optimization performed by MSDW was done against a 100 percent European bonds benchmark. The efficient frontier portfolios were then analyzed in more detail in the ALM-studies. Finally, focusing on the analysis by Wilshire, AP1 decided on a target portfolio. A separate study was conducted to set the currency hedging strategy.

AP1 and Wilshire constrained the M-V optimizations such that the portfolios would fit the regulatory investment guidelines[6], which apply to all four funds. In addition to the regulatory constraints, Swedish equities and emerging markets equities were constrained to be minimum 20 percent and maximum 10 percent of the equity portfolio, respectively. Furthermore, Swedish bonds were constrained to be minimum $\frac{1}{2}$ of the fixed income portfolio. The inducement for the constraint on Swedish bonds is explained in the report by Wassum (2002): "...this is in particular due to AP1's knowledge of the market, which helps them assess credit ratings."

This paper follows Wilshire's approach to select optimal portfolios by assuming that only M-V efficient portfolios are of interest and by using the same assets, data and regulatory constraints as Wilshire. This way the results from this paper will not depend on my choice of asset classes, historical estimation periods and so on.

It is beyond the scope of this paper to investigate the implications of using M-V preferences when the time horizon is long and the problem is as complex as the Swedish pension system. However, when investigating the home bias in AP1, this paper intends to take the possible home bias explanations discussed by Lewis (1999) into consideration.

The first explanation is that investors hedge home risks with home equity. In the real world AP1 has to consider the non-tradable assets (future contributions) and liabilities (future disbursements) of the pension system when selecting an optimal portfolio. This is the most obvious and probably the most serious violation of the assumptions made. However, taking these non-tradable assets into consideration would most likely lower the optimal weight for Swedish equities[7] (see Baxter and Jermann, 1997, and Coën, 2001). This implies that omitting non-tradable assets will bias the optimal portfolio towards Swedish equities. Hence, any results in this study indicating a home bias are prone to be understated. Other violations of the assumptions made, such as deviations from purchasing power parity, are not likely to have a significant effect on the portfolio allocation since the return

[6] The relevant regulatory constraints are; no short selling allowed, a minimum of 30 percent of assets shall be invested in fixed income securities, and after a gradual increase, no more than 40 percent of assets shall be exposed to currency risk.

[7] This fact was also recognized by the AP-funds. In a report by Wassum (2002) AP2 states: "one of the objectives of the strategic asset allocation is to avoid a weak return when the Swedish economy is weak; therefore, those portfolios showing a low exposure to Swedish equities should be favoured".

assumptions are hedged and expressed in SEK.

The second possible explanations mentioned by Lewis (1999) is that diversification costs might exceed the gains. This is taken into consideratin since Wilshire's return assumptions include diversification costs (including the costs of exchange rate hedging).

The third explanation comes from the fact that traditional analysis of the home bias puzzle use historically estimated return assumptions that are subject to estimation errors. Several studies have shown that international diversification does not lead to a statistically significant improvement in portfolio performance. Therefore, there might be no home bias. This paper investigates if the asset allocation decision is coherent based on the information available to the fund. Consequently, no formal statistical analysis is needed. As a sensitivity analysis, however, this paper examines the effect of estimation error on the optimal weights for Swedish assets by resampling the data at hand under different assumptions about the estimation procedure underlying the return distribution.

4. DATA

This study uses the same asset classes and the same data as Wilshire did in their report. Table 4.1 reports the expected returns, correlations and standard deviations used by Wilshire[8]. Wilshire's starting point for all return forecasts was the expected returns on US stocks and bonds, since it is Wilshire's strong belief that the expected returns on non-US stocks and bonds should be based on the expected returns on their US counterparts. Wilshire estimated the expected returns on US stocks and bonds by combining historical returns with prospective returns. There is, however, limited information available on the estimation procedure used. Wilshire used historical data on US stock and bond returns going back to December 31, 1925. The expected returns on non-US stocks and bonds were based on the expected returns on US stocks and bonds and adjusted for different risk levels and custodial costs. Wilshire's assumptions about future correlations and standard deviations rely, with some judgmental modifications, on historical measurements using 29 years of data. See Wilshire (1999) for further details on the methodology underlying the return assumptions.

The estimation procedure used by Wilshire is analogous to Bayesian estimation of the predictive density, in that Wilshire has prior views about the distribution of asset returns and updates those views as they observe the data. The resulting return distribution is, however, an outcome of insightful analysis by Wilshire rather than a statistical analysis. It is beyond the scope of this paper to use any alternative estimation procedure, even though Wilshire's estimation procedure may seem crude, since

[8]The data comes from the report by Wassum (2002).

TABLE 4.1
Return Assumptions

Asset Class	Exp.Return	Std.Dev.	Correlations							
			1	2	3	4	5	6	7	8
1 Swedish equities	9	23.5	1	0.73	0.5	0.53	0.54	0.39	0.08	-0.02
2 Europe equities (hedged)	8.75	15.2		1	0.68	0.55	0.65	0.42	0.31	0.15
3 US equities (hedged)	8.75	16.6			1	0.43	0.43	0.33	0.22	0.4
4 Pacific equities (hedged)	8.75	20.6				1	0.43	0.25	0.1	0.11
5 Emerging M. eq. (unh.)	10	27.5					1	0.2	0.11	-0.12
6 Swedish bonds (nom.)	5.5	6						1	0.57	0.39
7 Euro bonds (hedged)	5.25	5.1							1	0.53
8 US bonds (hedged)	5.25	5.7								1

it is the very point of this paper to use the same assumptions and methodology as AP1 and Wilshire used to decide on AP1's asset allocation.

Emerging markets equities was considered to be unhedged since Wilshire regarded their hedging to be difficult in practice. Bond exposure relates to both government and non-government investment grade bonds. The asset classes defined by Wilshire were used by AP1 in their final portfolio, with a few exceptions. US bonds and Euro bonds were merged into one global bond asset class and Europe equities, US equities and Pacific equities were merged into one global equity asset class by AP1 because the proposed allocations did not differ substantially from their weights within the benchmarks. Furthermore, Wilshire modeled neither inflation-linked bonds nor real estate due to data insufficiency. AP1 decided to invest 3 percent of total assets in real estate[9]. 20 percent of total assets were allocated to Swedish bonds, of which 2 percent in cash and 8 percent in index-linked bonds. These decisions were made ad hoc by AP1. Table 4.2 presents AP1's final portfolio.

TABLE 4.2
AP1's Final Portfolio

Asset Class	Weight (%)
Real estate	3
Swedish equities	12
Global equities (hedged)	40
Emerging markets eq. (unhedged)	5
Cash	2
Swedish bonds (nom.)	10
Swedish bonds (indexed linked)	8
Global bonds (hedged)	20

In order to compare the final portfolio of AP1 with the optimal portfolios, AP1's portfolio must be expressed in terms of the asset classes used by Wilshire. When converting global bonds into US bonds and Euro bonds, their respective weights at the time within the benchmark[10] were used. The same procedure was used to convert global equities into US equities, European equities and Pacific

[9] An investment that corresponds to their current ownership of 25% in the Swedish company AP Fastigheter AB.
[10] The benchmark used by AP1 is Lehman Brothers Global Fixed Income Index.

equities[11]. This is a straightforward approach since AP1's rational for merging these asset classes was that the proposed asset allocations did not differ materially from their benchmarks. Swedish index-linked bonds are included in Swedish nominal bonds. Real estate and cash do not necessarily fit into any of the asset classes. The main approach (portfolio alternative 1) is to exclude these asset classes from the analysis and to renormalize the portfolio by expressing the weights for the remaining asset classes as percentages of the remaining portfolio. Alternatively, one can consider cash as Swedish bonds and/or consider real estate as Swedish equities. All four alternative portfolios are presented in Table 4.3.

TABLE 4.3
AP1's Final Portfolio expressed in the Asset Classes used by Wilshire

	Portfolio Alternative			
Asset Class	1	2	3	4
Swedish equities	12.63	15.31	12.37	15.00
Europe equities (hedged)	14.00	13.57	13.71	13.30
US equities(hedged)	22.14	21.46	21.68	21.03
Pacific equities(hedged)	5.97	5.79	5.85	5.67
Emerging markets eq. (unhedged)	5.26	5.10	5.15	5.00
Swedish bonds (nom.)	18.95	18.37	20.62	20.00
Euro bonds (hedged)	8.69	8.42	8.51	8.25
US bonds (hedged)	12.37	11.99	12.11	11.75

All computations and simulations described in the next section are performed for each one of the four alternative portfolios and the results are all analyzed in the same maner. However, the main focus is on portfolio alternative 1, which from here on forward will be referred to as AP1's portfolio. Note that this is the portfolio with the smallest bias towards domestic assets. The next section describes the method in detail.

5. METHODOLOGY

5.1. Mean-Variance Efficient Portfolios

This section describes the optimization method and how the optimal portfolio was chosen. The efficient frontier portfolios were selected through parametric quadratic programming[12].

[11] The benchmark used by AP1 is MSCI.

[12] The objective function may be regarded as a primitive utility function or as an approximation of an investor's expected utility in the sense of von Neumann and Morgenstern (1947), as described in Sharpe (1991). The approximation is exact if returns are jointly normally distributed and the investor has negative exponential utility defined over wealth. As shown by Levy and Markowitz (1979), the objective function may provide a good approximation even if returns are not jointly normally distributed and/or the investor has some other utility function.

$$
\begin{aligned}
&\min_{\mathbf{w}} \mathbf{w}'\boldsymbol{\Sigma}\mathbf{w} - \lambda\boldsymbol{\mu}'\mathbf{w},\ s.t. \\
&\mathbf{w}'\mathbf{1} = 1, \\
&\mathbf{w} \geq \mathbf{0}, \\
&w_{SB} + w_{EB} + w_{UB} \geq 0.3, \\
&w_{EM} \leq 0.4,
\end{aligned}
\tag{5.1}
$$

where $\mathbf{w}$ is the portfolio weight vector, $\boldsymbol{\Sigma}$ the covariance matrix, λ the risk tolerance parameter and $\boldsymbol{\mu}$ the vector of expected returns. w_{SB}, w_{EB} and w_{UB} are the portfolio weights for Swedish, Euro and US bonds, respectively. w_{EM} denotes the portfolio weight for Emerging Markets equities. The regulatory constraints facing the AP-funds are all included in the optimization problem: at least 30 percent of the assets shall be invested in fixed income securities, no more than 40 percent of the assets shall be exposed to currency risk, and no short selling is allowed. The reason for not allowing more than 40 percent of the assets to be invested in emerging market equities is that this asset class is unhedged. Varying the risk tolerance parameter, λ, from zero to infinity, spans the M-V efficient frontier. High (low) risk aversion corresponds to low (high) values of λ, and hence a zero (infinitely large) λ gives the minimum variance (maximum return) portfolio.

In this paper 50 portfolios span each M-V efficient frontier. Using Michaud's (1998) terminology, each one of the 50 portfolios is identified by its relative return rank. Each rank corresponds to a specific λ in the optimization[13]. Minimizing the objective function in Equation 5.1 rather than simply minimizing the variance subject to an expected return constraint makes it straightforward to associate the simulated efficient portfolios (in Section 5.2) with the original efficient portfolios. The simulated portfolios will differ with respect to expected return and variance but will have the same risk tolerance level, or marginal rate of substitution of expected return for variance, as the corresponding original efficient portfolios.

A specific M-V efficient frontier portfolio must be chosen in order to compare the weights of AP1's portfolio with the optimal portfolio weights. The portfolio chosen for comparison is denoted the closest optimal portfolio and is defined in Equation 5.2 as the one with the lowest relative variance (see Michaud, 1998) relative to AP1's portfolio,

[13] $$\lambda = \left\{ \begin{array}{cc} rank - 1 & if\ rank = 1, 2, ..., 21 \\ 2 * rank - 22 & if\ rank = 22, 23, ..., 40 \\ 60 + 2^{\mathbf{rank-40}} & if\ rank = 41, 42, ..., 50 \end{array} \right\}$$

The λ are chosen such that the portfolios are almost equally spaced through the frontier and all relevant portfolios are captured.

$$
\begin{gathered}
\arg\min_i (\mathbf{w}_{AP1} - \mathbf{w}_i)'\mathbf{\Sigma}(\mathbf{w}_{AP1} - \mathbf{w}_i) \\
where \\
\mathbf{w}_{AP1} = \text{AP1's portfolio} \\
\mathbf{w}_i = \text{optimal portfolio rank i, i=1,2,...,50.}
\end{gathered}
\tag{5.2}
$$

5.2. Simulation Procedure

Here, I follow Jorion's (1992) data simulation approach to estimate the distribution of the optimal portfolio weights under various assumptions about Wilshire's estimation procedure. I use this parametric resampling approach since the sample used by Wilshire to estimate the expected returns and covariances is unknown. Data resampling, or bootstrapping, methods was first introduced by Efron in 1979. Jobson and Korkie (1981) used a similar method to emphasize the effect of estimation risk on actual portfolio returns.

The data simulation proceeds as follows:

I. Wilshires estimates of asset returns and covariances are assumed to be the true parameters for the return distribution.

II. T random samples of 8 joint returns are drawn from a multivariate normal distribution[14] with these parameters.

III. A new set of means and a new covariance matrix are estimated using these simulated returns.

IV. From these estimates, λ-associated optimal portfolios are calculated as described in Section 5.1. Each λ-associated simulated optimal portfolio provides one observation of the original λ-associated optimal portfolio.

V. Steps 2-4 are repeated 1000 times.

The 1000 resampled efficient frontiers represent the statistical distribution of the original efficient frontier.

[14] It is a reasonable and convenient assumption to assume normally distributed serially independent returns when simulating monthly returns on large indices. However, deviations from normality of monthly returns have been documented in Fama (1965, 1976), Blattberg and Gonedes (1974), Affleck-Graves and McDonald (1989) and Campbell et al. (1997).

6. RESULTS

Figure 6.1 shows the efficient frontiers using the original return distribution as input. The upper frontier includes the regulatory constraints, while the lower frontier includes the constraints used by AP1 and Wilshire. Both frontiers bend sharply at 8 percent return because this is where the fixed income constraint[15] becomes binding. The dot in the figure denotes the portfolio chosen by AP1[16]. The portfolio on the efficient frontier with the lowest relative variance relative to AP1's portfolio is presented in Table 6.1 and Table 6.2. This closest optimal portfolio has rank 28 and is denoted with a cross in Figure 6.1. The closest optimal portfolio seems to be a good choice of optimal portfolio for comparison since it is close in mean-standard deviation space and has the lowest relative variance. Furthermore, it has a higher expected return and a lower standard deviation than AP1's portfolio.

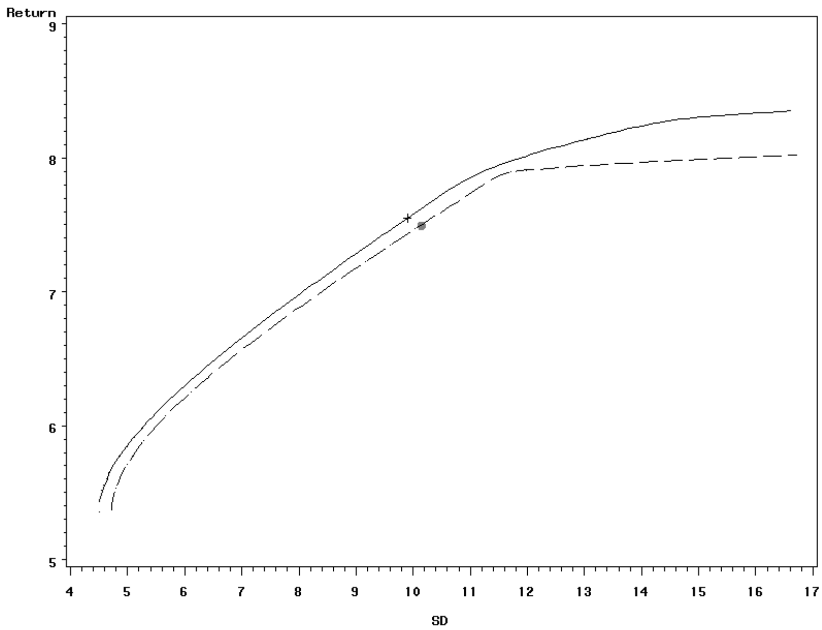

FIG. 6.1 The solid frontier includes the regulatory constraints only, while the dashed frontier includes the constraints used by AP1 and Wilshire. The dot denotes the portfolio chosen by AP1. The closest optimal portfolio is represented by a cross.

Table 6.2 demonstrates considerable differences in the composition of the two portfolios. The differences are, of course, a consequence of the additional constraints imposed by AP1. The constraint allowing emerging markets equities to be a maximum of 10 percent of the equity portfolio is not binding

[15] A minimum of 30 percent of assets should be invested in fixed income.

[16] As described in Section 4 Data, this is portfolio alternative 1. The results for the three remaining alternative portfolios were essentially the same.

TABLE 6.1
Closest Optimal Portfolio

	Closest optimal portfolio	AP1
Rank	28	-
λ	34	-
Expected Return	7.6 %	7.5 %
Standard Deviation	9.9 %	10.2 %

TABLE 6.2
Optimal Portfolio Composition

Asset Class	Rank 28	AP1
Swedish equities	0.00	12.63
Europe equities (hedged)	28.58	14.00
US equities (hedged)	19.66	22.14
Pacific equities (hedged)	10.17	5.97
Emerging markets eq. (unhedged)	5.30	5.26
Swedish bonds (nom.)	2.35	18.95
Euro bonds (hedged)	17.18	8.69
US bonds (hedged)	16.76	12.37

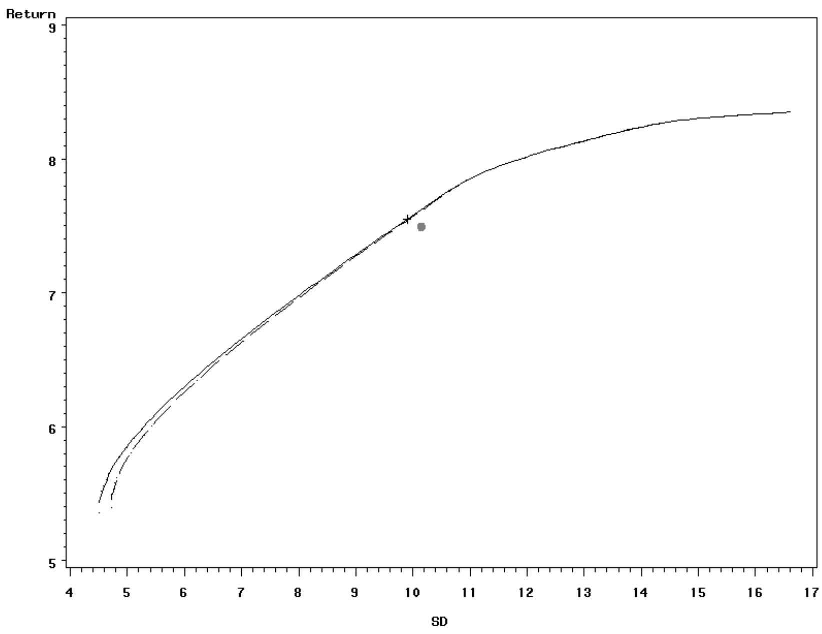

FIG. 6.2 The solid frontier includes the regulatory constraints only, while the dashed frontier includes the additional constraint on Swedish bonds used by AP1 and Wilshire. The dot denotes the portfolio chosen by AP1. The closest optimal portfolio is represented by a cross.

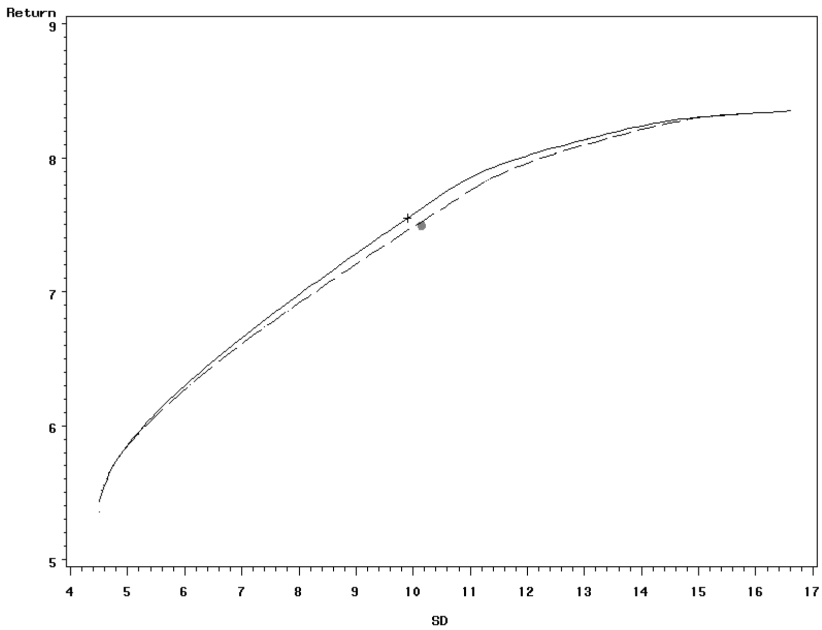

FIG. 6.3 The solid frontier includes the regulatory constraints only, while the dashed frontier includes the additional constraint on Swedish equities used by AP1 and Wilshire. The dot denotes the portfolio chosen by AP1. The closest optimal portfolio is represented by a cross.

and hence has no effect on the selected asset allocation. The second constraint imposed allocates 1/2 of the fixed income portfolio to Swedish bonds[17]. This constraint considerably increases the weight for Swedish bonds and simultaneously decreases the weights for Euro bonds and US bonds. However, when imposed without the other additional constraints it has no noteworthy effect on the efficient frontier in the mean-standard deviation segment relevant for AP1 (see Figure 6.2).

The rationale behind the constraint on Swedish bonds is that AP1 believe they can outperform the Swedish market due to their knowledge of the market. In order to optimally select the exposure to Swedish bonds matching AP1's portfolio, an investor with risk aversion corresponding to the closest optimal portfolio requires a 5.61 percent expected return on the Swedish bond investment, if all other expected returns and all variances and covariances are unchanged. This corresponds to an excess return of 0.11 percent over the return on the benchmark expected by Wilshire. The assumption that AP1 can outperform the market and earn a 0.11 percent excess return is not obviously erroneous and may, thus, explain the home bias towards Swedish bonds.

AP1 constrained Swedish equities to be a minimum of 1/5 of the equity portfolio. As a consequence, AP1's portfolio has a 12.63 percent exposure to Swedish equities while there is no exposure

[17]The weights in AP1's portfolio only approximately conform to the constraints since AP1 made ad hoc decisions to invest in real estate and Swedish cash. The weights conform exactly to the constraints if Swedish cash is treated as Swedish bonds and real estate as non-Swedish equity.

in the closest optimal portfolio[18]. Furthermore, the increased allocation in Swedish equities has substantially decreased the investment in European equities, from 28.58 percent to 14.00 percent. As shown in Figure 6.3, the constraint on Swedish equities have a major effect on the efficient frontier. An investor with risk aversion corresponding to the closest optimal portfolio requires a 10.23 percent expected return on Swedish equities, if all other expected returns and all variances and covariances are unchanged, in order to optimally select 12.63 percent Swedish equities. This corresponds to an additional 1.23 percent risk free return over the return on the benchmark expected by Wilshire[19]. It is highly unlikely that any fund manager will persistently perform such high excess returns on the Swedish market (see Engstrom et al., 2000). Hence, informational advantage cannot explain the equity home bias.

The above analysis clearly shows that AP1's high exposure to Swedish equities is inconsistent with their own assumptions and expectations. This raises the question of how precise the assumptions are. The estimated parameters of the return distribution are measured with some degree of error and hence are not the true values of the parameters. As a sensitivity analysis, I therefore estimate the distributions of optimal portfolio weights under different assumptions about Wilshire's estimation procedure. I start by assuming that Wilshire's estimation of the return distribution was based exclusively on historical data. Two different sample sizes, corresponding to different historical periods used by Wilshire, are simulated 1000 times each; first by using 29 years of monthly returns (see Table 6.3); and secondly by using 73 years of monthly returns[20] (see Table 6.4).

It is evident that there are wide variations in optimal portfolio weights for both sample sizes, even though the variations decrease as the estimation period increase. The resampled Swedish equity weights varies the least but still 177 out of the 1000 resampled weights are at least as high as in AP1's portfolio when simulating 73 years of monthly returns. This indicates that if the return distribution were estimated using simply historical data, the weight for Swedish equities is not statistically significantly different from the exposure in AP1's portfolio, and hence I cannot reject the hypothesis that AP1's exposure is optimal. However, it does not provide any support for the decision to alter the portfolio towards Swedish equities.

AP1 imposed three constraints in addition to the regulatory constraints. Swedish bonds were constrained to be minimum $\frac{1}{2}$ of the fixed income portfolio and Swedish equities and emerging markets equities were constrained to be minimum 20 percent and maximum 10 percent of the equity portfolio,

[18] It is to be noted that there was no exposure to Swedish equities in the portfolios recommended by MSDW.

[19] The excess returns required making AP1's allocation to both Swedish equities and Swedish bonds optimal simultaneously are even higher, since these two assets crowed each other out.

[20] More specifically, following Wilshire, 73 years of monthly returns are simulated and used to estimate the expected returns while the covariance matrix is estimated using the last 29 years of simulated data.

respectively. When simulating 29 and 73 years of monthly returns, all three additional constraints were non-binding in 53 and 33 out of the 1000 resampled portfolios, respectively. Consequently, if the simultaneous constraints on Swedish and emerging markets equities and Swedish bonds imposed by AP1 are defined as the familiarity constraint, this constraint is significantly binding.

The previous analysis was based on the assumption that Wilshire simply used historical means and variances when selecting the optimal portfolio. This is an appropriate assumption for the estimation of the covariance matrix (see Section 4, Data). It is not, however, a good description of the procedure used by Wilshire to estimate the expected returns. This procedure is better described by letting the expected returns on US stocks and bonds be based on historical data and by letting the expected returns on non-US stocks and bonds be based on their US counterparts and adjusted for different risk levels and custodial costs.

Wilshire assumed a premium for Swedish equities and emerging markets equities. The premium assumed over US equities was 0.25 and 1.25 percent, respectively. Wilshire assumed expected returns for the remaining equity markets identical to that of the US. Furthermore, Wilshire assumed equal expected returns for Euro bonds and US bonds, while assuming a 0.25 percent premium for Swedish bonds. It is to be noticed that the premiums for non-US assets are non-stochastic since Wilshire put a 100 percent confidence in these assumptions.

I simulate new resample portfolios under the assumption that Wilshire used the above procedure[21]. More specifically, the expected returns for US stocks and bonds are estimated using 73 years of monthly returns and the expected returns of non-US assets are based on their US counterparts and adjusted through the premiums specified above. The covariance matrix is estimated using 29 years of monthly returns.

Table 6.5 presents the distribution of resampled asset weights. Once again, there are large variations in nearly all asset weights, with Swedish equities being the only exception. There is no exposure to Swedish equities in 930 out of the 1000 resampled portfolios. Furthermore, the maximum exposure to Swedish equities is 5.26 percent. Hence, the approach used by Wilshire implies that AP1's exposure towards Swedish equities is significantly different from the optimal exposure.

[21] The omission of the prospective return estimates for US stocks and bonds is the main difference between this approach and the actual procedure used by Wilshire. The prospective returns were excluded since they are difficult to model.

TABLE 6.3
Weight distribution for 29 years of simulated monthly returns

Asset Class	AP1	Mean	Median	Percentiles 75^{th}	90^{th}	95^{th}
Swedish equities	12.6	7.1	0.00	8.9	27.1	40.2
Europe equities (hedged)	14.0	10.8	0.00	16.2	43.0	54.8
US equities (hedged)	22.1	15.0	1.52	28.0	48.3	58.7
Pacific equities (hedged)	6.0	11.3	0.00	19.7	36.5	47.3
Emerging markets eq. (unh.)	5.3	9.8	1.64	18.1	32.2	40.0
Swedish bonds (nom.)	19.0	13.0	0.00	30.0	40.6	57.2
Euro bonds (hedged)	8.7	14.2	0.00	30.0	48.2	65.6
US bonds (hedged)	12.4	18.8	0.00	30.0	56.0	71.4

TABLE 6.4
Weight distribution for 73 years of simulated monthly returns

Asset Class	AP1	Mean	Median	Percentiles 75^{th}	90^{th}	95^{th}
Swedish equities	12.6	5.3	0.00	7.0	20.3	26.8
Europe equities (hedged)	14.0	14.8	2.5	27.3	45.8	56.5
US equities (hedged)	22.1	16.9	10.8	29.8	46.9	55.6
Pacific equities (hedged)	6.0	11.0	3.9	19.2	33.0	40.8
Emerging markets eq. (unh.)	5.3	8.6	2.9	15.3	25.6	31.9
Swedish bonds (nom.)	19.0	11.2	0.0	23.1	35.3	49.5
Euro bonds (hedged)	8.7	14.2	0.0	30.0	46.2	56.5
US bonds (hedged)	12.4	18.2	7.0	30.0	49.9	61.2

TABLE 6.5
Weight distribution when using Wilshires priors for non-US stock and bond premiums and 73 years of simulated monthly returns for US stocks and bonds

Asset Class	AP1	Mean	Median	Percentiles 75^{th}	90^{th}	95^{th}
Swedish equities	12.6	0.0	0.0	0.0	0.0	0.6
Europe equities (hedged)	14.0	22.5	25.6	32.5	37.7	40.1
US equities (hedged)	22.1	16.1	17.5	22.7	26.2	28.8
Pacific equities (hedged)	6.0	8.4	8.8	11.7	14.0	15.7
Emerging markets eq. (unh.)	5.3	6.1	6.0	8.5	10.3	11.4
Swedish bonds (nom.)	19.0	13.7	8.0	23.6	39.8	47.5
Euro bonds (hedged)	8.7	13.8	13.1	20.9	28.4	30.0
US bonds (hedged)	12.4	19.4	19.8	28.6	34.9	39.1

7. CONCLUSIONS

This paper examines whether AP1's selected asset allocation is coherent given its investment guidelines and the information available to the fund. The conclusion is that the home bias in Swedish bonds can be explained by AP1's belief in that their superior knowledge of the market enables the fund to earn excess returns on the Swedish bond market. On the other hand, this paper presents evidence of a significant bias towards Swedish equities that cannot be explained in terms of risk and return. The high excess return on Swedish equities required making the large allocation in Swedish equities optimal is not in line with empirical research. Hence, informational advantage cannot explain the equity home bias.

The Swedish parliament clearly specified that only risk and return on investments were to be considered when deciding on an asset allocation. Nevertheless, the equity home bias in AP1 can only be explained by non risk-return arguments. When presented with these results, Mr. Ossian Ekdahl, Head of Strategic Analysis at AP1, acknowledges that other factors did have a significant effect on the asset allocation decision (personal communication, April 23, 2004). Mr. Ekdahl states that there is a long held tradition within the investment community to have a home bias and that any fund manager deviating from this norm might be criticized by the media and the public. This is the reason for the home bias in AP1. If tradition is the basis for the home bias in general is an issue for further investigation. However, it could explain the gradual transition from the regulated domestic assets only portfolios of the 1980s to current levels of domestic assets held by Swedish investors (Fondbolagen, 2004).

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