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ORIGINAL PAPER

Optimizing the Life-Cycle Path of Pension Premium Payments and the Pension Ambition in the Netherlands

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Abstract

We determine the optimal life-cycle path of pension premiums during the working ages and pension benefits during retirement, assuming that households can choose these freely. We calibrate the model on Dutch data. The optimization takes into account the fact that incomes generally rise during the working ages and that children are generally present in young households. Both features lead to an upward sloping path of optimal pension premium rates over the working life, while under the current pension system this is rather flat. The welfare gains from implementing the optimal pension system depend on the specification of the model, but can be sizable. A potentially lower return on pension assets in the future implies a further delay of optimal pension premiums during the working ages and a lower optimal pension benefit after retirement. Differentiating the path of pension premiums and benefits according to the level of educational attainment of the main income earner brings only small additional welfare gains compared to the situation in which pension premium rates are based on the average income profile in the Dutch economy.

Keywords Retirement savings · Optimal pension premiums · Life-cycle model · Netherlands

JEL Classification D15 · E21

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1 Introduction

Approximately 90% of employees participate in a funded occupational pension scheme in the Netherlands.[1] Combined with the first pillar pension (pay as you go financed public pension), this forms the major part of retirement income for the vast majority of the population. The occupational schemes generally feature pension premiums that depend on income: each pension fund typically levies flat premium rates on incomes in excess of a franchise and up to a maximum pensionable income. In general, no additional factors are considered. Furthermore, the pension ambition, the level of pension benefits that the schemes aim at, generally only depends on lifetime labour income. Here too, no further analysis takes place as to whether other circumstances should play a role as well.

The aim of this paper is to determine the influence of a number of factors on the path of optimal pension premiums and benefits. The first factor is the expected income profile of the household. This is usually increasing with age during the working life. The second factor is the change in family size and composition during life that are due to the presence of children in the household. As this paper shows, both factors represent a reason to shift a part of the pension premiums paid from the beginning of the working career to the end, while under the current scheme the pension premium rates are only slightly changing over the working life. This shift increases the age dependency of the ratio of pension premiums to incomes that under the current system results from the combination of rising incomes and the franchise. The third factor that we analyse is the level of educational attainment of the household. As we show in the paper, households in which the main earner has a low level of educational attainment can expect a rather flat income profile over the working life, while households in which the main earner has a medium or high level of educational attainment can expect a steep income profile. Consequently, the profile of optimal pension premium rates can potentially be quite different for the three categories of households.

We determine the path of optimal pension premiums and benefits in a life-cycle model in which the household earns a deterministic age-dependent income. We consider that households can freely choose the desired path of pension premiums and pension benefits and they do so by maximizing lifetime utility from consumption. Because the income is certain, households only save for retirement. That is why throughout this paper we consider that optimal savings of the household are equal to the optimal pension premiums. Since the income and the return on pension assets are deterministic, the model is very tractable and admits an analytical solution. We set the deterministic income path over a household's life-cycle equal to the path of average income in the economy. In reality, people's income is stochastic, but the average income profile in the economy gives people (and pension funds) a reference in terms of what income profile to *expect* when they enter the labor market.

[1] https://www.pensioenfederatie.nl/website/the-dutch-pension-system-highlights-and-characteristics, original source of the information: https://www.rijksoverheid.nl/documenten/publicaties/2020/07/06/aanvalsplan-witte-vlek.

We calibrate the model on Dutch data. Our results show that taking into account the upward sloping income profile and the presence of children in young households leads to two changes in the second pillar pension schemes. First, we show that the optimal path of pension premium rates rises with age. Since people want to smooth consumption over their life, an upward sloping income profile means that people would like to borrow in the beginning of their working life and then repay the debt and save for retirement towards the end of their career. Moreover, households have higher consumption needs while children are present. That is why they would prefer to defer paying premiums to the pension system to older ages when children leave the household. Second, we show that the optimal pension benefit for households with children is lower when the presence of children is taken into consideration.

The welfare gain from implementing the optimal pension premiums and benefits scheme is quantitatively important. Our analysis indicates that, relative to the current pension system, the optimal pension scheme would raise welfare by the equivalent of 3.1% of lifetime consumption in the case that no borrowing constraints are imposed and of 2.5% in the case there are borrowing constraints. We also carry out an analysis in which we acknowledge that households can have different income paths and family compositions over the life-cycle because of different levels of educational attainment of the main household earner. Differentiating optimal premium rates by taking into account the level of educational attainment of the main household earner brings some additional welfare gain for households with a lower level of educational attainment (equivalent to 1% of lifetime consumption) compared with the situation when pension premium rates are based on the profile of average income in the Dutch economy. However, there is almost no additional welfare gain for households with medium and higher educational attainment. We also determine what a lower rate of return on pension assets implies for the optimal pension premiums and benefits. We obtain that households would find it optimal to shift even more of the premiums paid to the pension fund to the end of their working career. Optimal pension benefits are also lower.

It should however be noted that our numerical outcomes are not meant to be imposed on the whole workforce in the Dutch economy. The contribution of the paper is rather methodological: it presents a framework for optimizing the time path of premiums and pensions. The outcomes are rather indicative as we carry out the exercise for the average Dutch household. For the actual implementation, each pension fund should perform the optimization for themselves, using the inputs that apply to their own work force and also choose a level of differentiation between workers that suits them best.

The contribution of this paper is that it determines the optimal level of pension premiums and benefits taking into account simultaneously the upward sloping income profile, the changing family composition and the level of educational attainment of the household. Previous literature has analysed these factors separately. We also show the impact of borrowing constraints and of a lower return on pension assets on the optimal path of pension premiums and benefits.

By calibrating the model on Dutch data we contribute to the pension discussion in the Netherlands. In 2020, a new Pension Agreement was introduced in the Netherlands. One of its properties is that it makes the pension premiums actuarially fair and undoes the system of its implicit intergenerational transfer from the young to the old. It combines a constant (or 'flat') pension premium rate with an actuarially fair build up of pension wealth in individual accounts.[2] Age independent ('flat') pension premiums were an important element in the so called SER-advice of, among others, employers and employees on the new pension contract due to labor market effects (SER 2019, p. 27).

A number of other arguments in favour of a flat contribution rate are summed up in Tweede Kamer (2020). One of these is that it would lead to a more stable time path of contribution payments for employers. While age dependent pension premium rates would not be stable, they would however still be predictable. Another argument is that a flat premium rate elongates the average investment horizon of the pension contributions and leads to a higher pension result. A further argument is that flat rates are standard practice in collective pension systems in other countries.[3] All these arguments must be traded-off against the disadvantage of age independent pension premium rates: households cannot smooth consumption over their life-time optimally. A number of recent papers (Crawford et al. 2021; Scott et al. 2021) actually challenge the optimality of flat pension rates and reach conclusions that support our findings.

The implementation of the upward sloping profile of pension premium rates that we find optimal in our paper may pose some problems in practice. We can think of two ways how to implement this in practice. The first solution is that employers accept that the pension costs related to their employees increase over their career. This may make employers reluctant to hire or keep older workers. The second way of implementing the optimal scheme is by increasing the size of the employee's premiums across the working life. In this case the net wage will increase less (or even decline) with age. If people have different preferences than the ones assumed in this paper, a smaller increase or a decline in their net wage may induce people to retire earlier.

This paper builds on the literature that analyzes the role of the life-cycle income profile and family composition on the optimal time path of consumption and savings. Attanasio and Weber (2010) and Nishiyama and Smetters (2007) use an approach in which the household planner takes account of household size by imputing standardized consumption in the utility concept. Standardized consumption reflects the consumption of each of the individual earners in the household. It is calculated by dividing family consumption by a factor that is larger than 1 for families with more than one member. This factor takes into account the fact that family consumption has to be shared with the other members of the household as well as the fact that multi person households benefit from economies of scale.[4] However, these papers

[2] For current participants in Individual Defined Contribution contracts, employers may opt for continuing the current age-dependent (and age-increasing) pension premium path (Ministry of Social Affairs and Employment 2020, p. 6).

[3] Pension contribution rates show a significant rise with age only in Switzerland, see www.bsv.admin.ch/bsv/en/home/social-insurance/bv/grundlagen-und-gesetze/grundlagen/sinn-und-zweck.html.

[4] For a three person household, for instance, the factor is smaller than 3. Section 3 elaborates on this.

do not include the utility of the other members of the household. In this approach the other members are only a cost factor by reducing the standardized consumption of the household. Other papers do include the consumption of other household members in the utility. Domeij and Klein (2013) do so by including the standardized consumption of all household members and also attach equal weights to them. Fuchs-Schundeln (2008), Scholz et al. (2006) and Laitner and Silverman (2012) also attach equal weights but impute per capita consumption rather than standardized consumption and therefore ignore the economies of scale involved in forming a multiple people household. Bick and Choi (2013) explore the implications of the different ways of taking into account the size and composition of the household. They show that these lead to diverging optimal paths of consumption but express no preference for either of these.

We use two approaches in our paper. Our preference lies with the model developed in Domeij and Klein (2013) that takes into account all members of the household in the utility function. It uses a more comprehensive measure of welfare and thus may be a better way to determine the pension scheme that maximizes welfare from a social perspective. We will call this the *family model*. We also present the results of the model in which the utility concept only takes account of the standardized consumption that accrues to the income earners in the household. It is the same model as in Attanasio and Weber (2010) and Nishiyama and Smetters (2007). We will call this the *earner model*.

Our paper is part of the literature analysing optimal retirement savings. Cui (2008) focuses on the effect of life-cycle earnings on pension premiums in individual defined contribution pension systems and finds that substantial welfare gains can be obtained by making the time path of pension premiums age dependent. Gomes et al. (2009) determine optimal retirement savings and portfolio composition in the presence of tax deferred accounts. They also find that the optimal pension premium rate is increasing with age. Summers (1984) and Elmendorf (1996) have analyzed the role of the return on capital on optimal savings. We follow their methodology, but add a realistic income profile, family composition and borrowing constraints to their analysis. We also look at households with different levels of educational attainment.

Two recent papers study optimal retirement savings in a framework similar to ours. Scott et al. (2021) substantiate the low enrollment of young households in 401(k) plans in the US. They find that for young households that are liquidity constrained and expect an upward sloping income path, it is optimal to pay no pension premiums up until their late 30s. We obtain the same results in the model with borrowing constraints. Additionally, we analyze what the presence of children in the household implies for optimal pension premiums. Crawford et al. (2021) use UK earnings profile to show that households optimally save a greater proportion of their earnings right before the retirement age, while households with children optimally save more after the children leave the household.

Our paper abstracts from a number of specifications in order to keep the model tractable and have an analytical solution for it. We do not take into account relevant features such as the bequest motive of households, income shocks, stochastic returns on assets, other assets and debts or the disutility of labor. We expect that extending the model with these features will change the size of the welfare gain and the slope of the pension premium profile. Hence, policy conclusions from our results should carefully weigh the calculated welfare gain against possible negative and positive effects of non-modelled aspects. However, we do not expect that extensions to the model will eliminate completely the age dependence of the optimal pension premium rate or the welfare gain. These results come from the upward sloping income path and the presence of children in the first part of a household's life. The impact of some features that we abstract from on the optimal pension premium rates has already been investigated in other papers: the presence of income shocks in de Kok (2021) and stochastic returns on assets and the portfolio composition decision in Gomes et al. (2009). In both cases the optimal pension premium rate is upward sloping with age. These papers do not take into account the presence of children in the household, a feature that strengthens the results in our analysis.

An interesting extension would be to include other factors that influence the household's savings pattern, for example the presence of study loans or mortgages. The introduction of mortgages would strengthen our finding that aiming at a lower pension benefit raises lifetime welfare because of the financial alleviation resulting from the disappearance of the mortgage costs at higher ages. The possible future wider adoption of reverse mortgages could add to this argument. The effect of the introduction of mortgages on the upward sloping path of pension premium rates is mixed. In the absence of borrowing constraints it would probably increase the steepness of this path. The costs associated to mortgage repayments are typically constant through the time in nominal terms and therefore, due to inflation and rising incomes, generally weigh most heavily on young households. These would be a reason to defer even more of the pension premium payments towards the end of the career. With borrowing constraints however, there would be very limited room for lowering the premiums for young households as, even without the introduction of mortgages, they turn out to be zero at these ages. The smaller optimal size of the pension ambition might then even require lower premiums for the older households, thus making the time path less steep. A similar reasoning would be applicable in case of the introduction of study loans. Another interesting point to consider is the disutility from supplying labor. In this case the pension premium profile would also take into account the age at which people prefer to retire.

The rest of this paper is structured as follows. Section 2 discusses the life-cycle models that are used to carry out the optimization and Sect. 3 the data we use to calibrate the model. Section 4 presents the results and a sensitivity analysis that explores the robustness of the results with respect to some parameters in the model. We also determine the optimal pension premium path and the welfare gain for different educational levels. Section 5 presents the results in the case that borrowing constraints are imposed. Section 6 concludes the paper.

2 The Models

Firstly, we describe the model we use to find the optimal life-cycle path of consumption by only taking into account the utility of the earners in the household (Sect. 2.1). Secondly, in Sect. 2.2 we present a model in which the utility of all members of the household is considered. Section 2.3 describes how we model the current pension system. In order to measure the welfare gain of the outcomes of these models relative to those of the current pension system, we calculate the equivalent variation of consumption. The formulas with which we do that are presented in Sect. 2.4.

2.1 Earner Model

A household enters the labor market at 25 years of age. She earns a gross income equal to y_t at each age t. Until the age at which the benefit from the public pay-as-you-go pillar (*Algemene Ouderdomswet*—AOW) becomes available (t_{aow}), the variable y_t includes income from labor and other transfers[5] (w_t). Afterwards, the household only earns the benefit from the public pay-as-you-go pension system (aow_t). The probability to survive until age t is equal to ψ_t, with a maximum age of T. We assume that households discount the utility from future consumption with β and that the gross rate of return on wealth equals R. The household insures herself for longevity risk.

The household chooses each period how much to consume (c_t) and implicitly how much wealth to accumulate (a_t) by maximizing the present value of the utility of standardized consumption:

$$\sum_{t=1}^{t=T} \beta^{t-1} \psi_t u\left(\frac{c_t}{eq_t}\right) \tag{1}$$

where $u(\cdot)$ is the utility function and the variable eq_t represents the equivalence factor at time t which adjusts the consumption based on the number of members in the household.

The decision of the household is subject at each age t to a budget constraint:

$$y_t + Ra_{t-1} + tr_t = c_t + tax_t + a_t \tag{2}$$

where tax_t is the amount of tax that the household pays. The per capita transfers tr_t come from the fact that a fraction of the population alive at time $t-1$ dies and the bequests are divided between the members of age t still alive at that age.

Income each period is defined by the following:

$$y_t = \begin{cases} w_t, & \text{if } t < t_{aow} \\ aow_t & \text{if } t \geq t_{aow} \end{cases} \tag{3}$$

We assume that a household starts without wealth and cannot have negative wealth when ceasing to exist:

$$a_0 = a_T = 0 \tag{4}$$

[5] For example social assistance, unemployment benefit, child related transfers.

Preferences are described by a Constant Relative Risk Aversion (CRRA) utility function:

$$u\left(\frac{c_t}{eq_t}\right) = \begin{cases} \frac{(\frac{c_t}{eq_t})^{1-\sigma}}{1-\sigma}, & \text{if } \sigma \neq 1 \\ \log(c_t/eq_t) & \text{if } \sigma = 1 \end{cases} \tag{5}$$

where σ is the inverse of the elasticity of intertemporal substitution.

Since both the income of the household and the return on wealth are deterministic, the household only saves in order to afford consumption during retirement. That is why throughout this paper we equate the savings of households with pension premiums and the wealth accumulated for retirement with pension assets.

In order to determine the amount saved or dis-saved at each age t, we rewrite the budget constraint of the household (2) in the following way:

$$y_t + Ra_{t-1} - a_t + tr_t = c_t + tax_t \tag{6}$$

We denote by p_t the amount saved or dis-saved at each age t:

$$p_t = Ra_{t-1} - a_t \tag{7}$$

As long as the household accumulates assets, the value of p_t is positive. We assimilate this value to the optimal pension premiums paid to the pension fund. When the household starts to draw down the assets she has built, p_t turns negative. We assimilate this value to the optimal pension benefits received from the pension fund.

We must note that the age at which the household starts to draw its assets down, i.e. p_t turns negative, is endogeneous to the model and must not necessarily coincide with the age at which the AOW benefit becomes available (t_{aow}). The household can consume from its assets even before she receives the AOW pension benefit.

We combine the per period budget constraint from Eq. 2 into a lifetime budget constraint (all derivations of the equations can be found in "Appendix 1.3"):

$$\sum_{t=1}^{T} \frac{\psi_t(c_t + tax_t)}{R^{t-1}} = \sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}} \tag{8}$$

Using the first order conditions of the maximization problem, we can derive the solution for consumption at time t:

$$c_t = c_1(\beta R)^{\frac{t-1}{\sigma}} \left(\frac{1-\omega_t}{1-\omega_1}\right)^{\frac{1}{\sigma}} \left(\frac{eq_1}{eq_t}\right)^{\frac{1-\sigma}{\sigma}} \tag{9}$$

where ω_t represents the percentage tax rate at time t. This value of the tax rate differs before and after retirement (see Table 1).

The specification of Eq. 9 shows that the shape of the optimal life-cycle path of family consumption depends on three terms. The first term $(\beta R)^{\frac{t-1}{\sigma}}$ captures the net effect of the time discount factor and the return on wealth. If the return on wealth exceeds the time discount factor ($R\beta > 1$) households save more and delay consumption to older ages. The converse is true if the return on wealth is lower than the time discount factor ($R\beta < 1$).

The second term $\left(\frac{1-\omega_t}{1-\omega_1}\right)^{\frac{1}{\sigma}}$ captures the impact of taxes on relative net incomes before and after retirement: a relatively low level of taxation after retirement forms an incentive to save more during the working years and thus to shift consumption to the retirement phase.[6] The size of the effect for these two terms depends on the value of σ: a high value for this parameter reflects a low valuation of increases in consumption relative to decreases in it and thus a high preference for constancy of consumption levels throughout the life-cycle. This results in a lower impact of these terms. A low value for σ reflects the opposite.

The third term, the ratio of equivalence factors $\left(\frac{eq_1}{eq_t}\right)^{\frac{1-\sigma}{\sigma}}$, captures the impact of changes in family size. It reflects the fact that a high number of children in the household reduces the benefit that each of its individual members, and thus also the earners, has from family consumption. This individual benefit, or standardized consumption, is calculated by dividing family consumption by the equivalence factor. The size of the effect of this term on the optimal life-cycle path of consumption differs from the other two terms because it works through two channels that work in opposite directions. The first is that a high equivalence factor (more children) lowers standardized consumption, and thus also the benefit that earners of the household have from family consumption in these years. This lowers the marginal utility of a unit of family consumption for the earners which, in this model, has a negative effect on optimal family consumption. The second channel is that the lower individual benefit also increases the marginal utility of consumption of its members, entailing that the earner's utility valuation per unit of (standardized) consumption increases. This raises optimal standardized and family consumption and this effect becomes larger the higher the value of σ. If σ is larger than 1 the latter of the two effects dominates and optimal family consumption tends to be high in years with a high equivalence factor. The opposite holds if σ is smaller than 1.

Equation 9 also shows that the shape of the life-cycle path of family consumption is fully independent of the years in which the family earns its income. Incomes only impact on the levels of consumption and it does this via the lifetime budget constraint (Eq. 8). This independence results from the fact that we do not impose borrowing constraints at this point.

2.2 Family Model

The family model can be seen as an extension of the earner model where the consumption of the children is included in the utility function. To implement this variable, we denote the number of members in the household by n_t. The utility function (Eq. 5) is adjusted as follows:

[6] For simplicity, average and marginal tax rates in both phases are set equal. This is further discussed in "Appendix 1.3".

$$u\left(\frac{c_t}{eq_t}\right)=\begin{cases} n_t\frac{\left(\frac{c_t}{eq_t}\right)^{1-\sigma}}{1-\sigma}, & \text{if } \sigma\neq 1\\ n_t\log(c_t/eq_t) & \text{if } \sigma=1\end{cases} \tag{10}$$

The consumption at time t for the family model becomes:

$$c_t=c_1(\beta R)^{\frac{t-1}{\sigma}}\left(\frac{n_t}{n_1}\right)^{\frac{1}{\sigma}}\left(\frac{eq_1}{eq_t}\right)^{\frac{1-\sigma}{\sigma}}\left(\frac{1-\omega_t}{1-\omega_1}\right)^{\frac{1}{\sigma}} \tag{11}$$

The relative number of members in a household at time t has a positive effect on the consumption at time t. Compared to the earner model (Eq. 9), the number of members of the household plays a more important role in determining the consumption at time t.

2.3 The Current Pension System

We model the current system, here referring to the system after the introduction of the new Pension Agreement, by imputing flat (age independent) pension premium rates during the working years as well as flat pension benefits after retirement. In order to enable a pure comparison of welfare effects with the systems derived in the two models above, we assume that there are no intergenerational transfers. Hence the pension premium paid is actuarially fair. The pension premium rate that is levied on gross incomes above the franchise typically averages 21%.[7] Around two-thirds (14%) of it is paid by the employer, while roughly one third (7%) is paid by the employee.[8]

We assume that as a result of general equilibrium effects, both the employee's and employer's part of the pension premiums are effectively borne by the employee. This is based on the perception that the Netherlands are a small open economy and, as a result of international competition on product markets, employers have limited financial room to raise labour costs. This view may be challenged by considering the incidence of taxes under conditions of imperfect competition. Firms might then have the room to pass on part of the cost of the taxes to consumers, allowing them as well to absorb rises of labour costs. This may especially be the case in the more or less sheltered services sector if all firms face the same tax increase. It should however be noted as well that the employee would then be confronted with an increase in consumer prices implying that the initial partial avoidance of the costs of the pension premiums would effectively be largely offset. Moreover, the analysis of the incidence of taxes may be inappropriate for that of pension premiums. As the latter leads to future pension benefits, forward looking agents may in part absorb, rather

[7] The average premium rate of the following five pension funds in 2020 in the Netherlands: ABP, PFZW, PBFbouw, PMT and Shell pension fund.

[8] See for example the split used by the pension fund ABP: https://www.abp.nl/pensioen-bij-abp/pensioenpremie/.

than pass on, rises in pension premiums and these rises may therefore have smaller effects.

The contribution of the employer is included in our income data as well. Therefore, in order to determine the pension savings under the current pension system, we adjust the pensionable income by dividing it by 1.14.

We use the next formula to obtain pension savings under the current pension system:

$$p_t = 0.21 \max \left[\min \left(\frac{y_t - np_t}{1.14}, ptf_t \cdot cap \right) - ptf_t \cdot f, 0 \right], \tag{12}$$

Pension premiums are levied on income y_t minus non-pensionable income np_t up to a maximum level of pensionable income *cap*. Non-pensionable income is comprised in our analysis of childcare benefits, social assistance and unemployment benefits.

Before applying the premium rate of 21%, a franchise *f* is deduced. The franchise is multiplied by the number of hours worked by the household in a week as a percentage of full time working hours *ptf*.

Pension benefits are fixed in real terms and can be seen as annuities. On the year of retirement, we calculate how much pension benefit an individual receives per year based on the pricing definition of a one-dollar fixed premium per year annuity:

$$A = \sum_{t=1}^{T-ra} \frac{\psi_{t|ra}}{(1+R)^t} \tag{13}$$

where A is the amount of wealth required to be able to pay for a one-dollar annuity, ra is the retirement age, $\psi_{t|ra}$ is the probability that a household reaches age t given that he reached the retirement age ra and R is the rate of return. The amount of annual pension benefits (pb) that are paid from the accumulated wealth is equal to:

$$pb_t = \frac{a_{ra-1}}{A} \tag{14}$$

Because of the way it is computed, the pension benefit is always age invariant under the current pension system. However, under the optimal pension system the pension benefit can vary with age.

For simplicity, we will assume that the household starts to draw down its pension assets at the age when the AOW pension benefit becomes available, i.e. $ra = t_{aow}$.[9]

2.4 Deriving the Equivalent Variation and the Effect on Welfare

Besides finding the optimal path of pension savings and the optimal pension ambition, we want to measure its additional value compared to the current pension system. We express the welfare improvement in terms of consumption levels. We

[9] In reality households can draw down her assets earlier. We make this assumption in order to facilitate the comparison with the family model. In the optimum of this model, the household draws down their assets after the age at which the pension benefit becomes available t_{aow}, see Fig. 4c.

calculate the equivalent variation, i.e. the percentage change in annual consumption required by households in order to be indifferent between the current pension system and the optimal pension system:

$$\sum_{t=1}^{T} \beta^t \psi_t u(c_{vp,t}) = \sum_{t=1}^{T} \beta^t \psi_t u((1+\delta)c_{fp,t}) \tag{15}$$

where δ represents the consumption equivalent, c_{vp} is the consumption under the optimal pension system and c_{fp} is the consumption under the current pension system. A positive value for the consumption equivalent δ indicates that the current pension system has a lower welfare: households require a higher level of annual consumption in order to be just as well off as in the economy with an optimal pension system.

Because we are using a CRRA utility function (Eq. 5), the formula above simplifies to:

$$\sum_{t=1}^{T} \beta^t \psi_t u(c_{vp,t}) = (1+\delta)^{1-\sigma} \sum_{t=1}^{T} \beta^t \psi_t u(c_{fp,t}) \tag{16}$$

The formula for the consumption equivalent becomes:

$$\delta = \left(\frac{V(c_{vp})}{V(c_{fp})} \right)^{\frac{1}{1-\sigma}} - 1 \tag{17}$$

$$V(c_{vp}) = \sum_{t=1}^{T} \beta^t \psi_t u(c_{vp,t}) \tag{18}$$

$$V(c_{fp}) = \sum_{t=1}^{T} \beta^t \psi_t u(c_{fp,t}) \tag{19}$$

We compute the consumption equivalent in two distinct ways. In the first case, we simply replace the consumption of households under the age dependent pension premium regime and under the current pension system, respectively, in formula 17. This will be the standard way of computing the consumption equivalent and of assessing welfare gains throughout the paper.

In the second case, we also analyze the impact of a different schedule of pension premiums and benefits on the tax level prevailing in the economy and incorporate it in the welfare quantification. More specifically, we acknowledge in this case the fact that a change in the pension system may also affect the amount of taxes paid throughout a household's life and, hence, the government budget. This is because pension premiums are not taxed. We consider that if tax revenues are higher under the optimal pension system than under the current pension system, the difference in revenues is transferred back to households. We transfer these extra government revenues in such a way that the time varying consumption levels are adjusted across all ages equally in relative terms. To the contrary, if tax revenues are lower under the optimal pension system than under the current system, an extra tax is levied on households in order to re-balance the government budget. As in the rest of the paper, we consider that the extra taxation or transfers have no influence on the amount of labor supplied by households, i.e. labor is inelastic.

We determine the lifetime difference in the present value of the tax paid under the current pension system ($tax(c_{t,fp})$) and under the optimal pension system ($tax(c_{t,vp})$):

$$\zeta = \frac{\sum_{t=1}^{T} \frac{\psi_t tax(c_{t,vp})}{(1+d)^{t-1}} - \sum_{t=1}^{T} \frac{\psi_t tax(c_{t,fp})}{(1+d)^{t-1}}}{\sum_{t=1}^{T} \frac{\psi_t c_{t,vp}}{(1+d)^{t-1}}} \tag{20}$$

where d is the discount factor. The consumption in the model with age dependent premium rates is adjusted at each age t with ζ percent:

$$c_{t,vp}^{adj} = c_{t,vp}(1+\zeta) \tag{21}$$

After correcting for the difference in taxes, we determine the value of the lifetime utilities ($V(c_{fp})$, $V(c_{vp}^{adj})$). We substitute these in Eq. 17 in order to obtain the consumption equivalent.

3 Calibration of the Models

3.1 Household Income

In order to determine the life-cycle income profile of Dutch households, we use the Inkomenspanelonderzoek (IPO) data provided by Statistics Netherlands (CBS). The sample period covers the years 2006–2013. The measure of income that we use is the gross income of households. This comprises the income of Dutch households from all sources, including the pension premiums payed by the employer. For our analysis we deduct from the gross income two types of income: a) financial income (income from bonds and shares holding, interest rate on savings accounts), b) income from pensions either public (AOW) or private (second and third pillar of the Dutch pension system). We model these income sources separately in our model through the variable p_t (see Eqs. 6, 7).

We make the following sample selections. First, we only take into account households with a main earner aged between 25 and 65 years. Second, we eliminate households that earn an income from self-employment because this type of income is very volatile. Finally, we restrict the sample to couples and to households that have the same composition throughout the sample period. Consequently, we are left with a number of 222.330 year-household observations in the sample out of the initial number of 784.854 year-household observations.

We transform the household income to real values by dividing through the Consumer Price Index (CPI) with the base in the year 2010. We eliminate the economy-wide income growth rate from the household income data by regressing household income on year fixed effects.

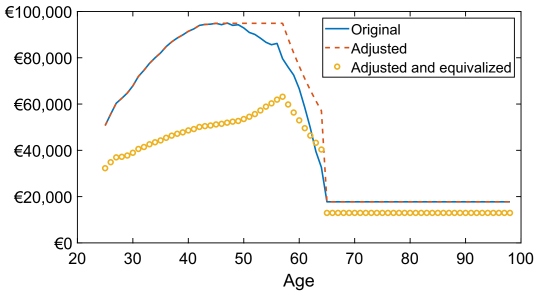

Fig. 1 Average household income over the life-cycle

We present summary statistics of the income data in "Appendix 1.1". Household income is upward sloping with the age of the main earner. Median income is lower than mean income and the gap between the two values increases with age. It is not clear which of the two measures of income is better suited for proxying life-cycle developments in income. On the one hand the income distribution is clearly skewed to the left, signifying more mass towards lower income values, so using the median would capture this phenomenon. On the other hand, it would ignore the upper tail of the distribution. Similar papers use the mean income (Scott et al. 2021) or present results using both the mean and the median income (Crawford et al. 2021).

For our baseline analysis we determine the life-cycle income profile y_t by computing the average income of households with a main earner aged t years, for each t between 25 and 65 years of age. After the age of 65 years, we set y_t equal to the value of the AOW benefit (see Table 1). We also present the results using an income profile obtained by taking the median income of the households with a main earner aged t years.

Figure 1 presents the life-cycle profile of average income. This is upward sloping until the age of 49 years after which it starts to decline. The decline in the average household income is mostly due to the early retirement of the household members.[10] We see a gradual decline in income due to retirement and not an abrupt decline because retirement is sometimes partial (a reduction in the hours worked, retirement of only one of the household members) and also because we are considering the average of Dutch households, with some households retiring later than others.

Since our latest data point corresponds to the year 2013, we try to incorporate the latest developments on the Dutch labor market. More specifically, we try to incorporate the fact that Dutch households have substantially increased the age at which they retire from the labor market.[11] To this end, we extend the peak of the income

[10] In the year 2010, the average labor market participation of men and women aged 50–55 years was 83% dropping to 73% for the age category of 55–60 years and to 39% for the age category of 60–65 years (Statistics Netherlands, CBS).

[11] In the year 2018, the average labor market participation of men and women aged 50–55 years was 85% dropping to 79% for the age category of 55–60 years and to 62% for the age category of 60–65 years (Statistics Netherlands, CBS).

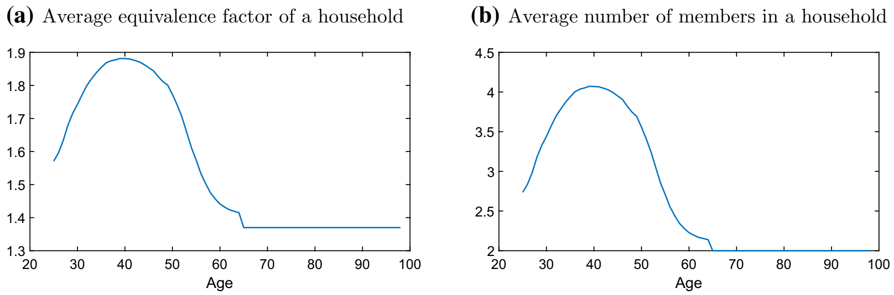

Fig. 2 Average equivalence factor and average number of household members

Table 1 Parameter calibration

Parameter	Explanation	Value
σ	Inverse of elasticity of intertemporal substitution	2
β	Time preference	0.98
R	Gross return on savings	1.02
ω_t	Tax rate until t_{aow}	36%
ω_t	Tax rate after t_{aow}	22%
T+25	Maximum number of years	98
t_{aow}+25	Age when AOW benefit is received	65
d	Discount factor	2%
aow	AOW benefit	17744 EUR
f	Franchise	12674 EUR
Cap	Maximum pensionable income	96183 EUR

path we obtain from the CBS data from the age of 50 years until the age of 57 and let it decrease with 7% per year until the age of 65. This adjustment is based on Van Tilburg et al. (2019). The resulting income profile is presented in Fig. 1 with a dashed line.

For the analysis in Sect. 4.5, we divide the households into three groups based on the educational attainment of the household head: (1) lower education households: BO (basisonderwijs—primary education) and VMBO (voorbereidend middelbaar beroepsonderwijs—pre-vocational education); (2) medium education households: MBO (middelbaar beroepsonderwijs -secondary vocational education), HAVO (hoger algemeen voortgezet onderwijs—higher general secondary education) and VWO (voorbereidend wetenschappelijk onderwijs—university preparatory education); (3) higher education households: HBO (hoger beroepsonderwijs—higher vocational education) and WO (wetenschappelijk onderwijs—university).

3.2 Equivalence Factors and Number of Household Members

The equivalence factors are also derived from the IPO data of the CBS. They reflect the fact that there are economies of scale from forming a family in terms of sharing some of the fixed costs (rent, car etc.). That is why the equivalence factors attach the value of 1 to the first adult in the household, 0.37 to any other adult and a value between 0.15 and 0.33 to every under age child.[12]

For a household aged t years, we set the equivalence factor equal to the mean of all equivalence factors corresponding to households with a head aged t years. We do the same in order to determine the number of household members representative for a household with a head aged t years in the Netherlands.

Figure 2a, b show the profile of the equivalence factor and the number of household members. After the age of 65 years we set the equivalence factor the value corresponding to a household with 2 adults and the number of household member equal to 2. Hence we assume that the two adults of the household die at the same time. This does not accurately reflect reality but it avoids adding another layer of complexity to our analysis by considering the stochastic probability of survival of the partner and whether pension assets will be inherited by the partner or not.

The life-cycle profile of income divided by the equivalence factor (standardized income) is presented in Fig. 1. While the household income profile flattens out around the age of 45 years, standardized income continues to increase until the age of 57 years to due the fact that children gradually leave the household and the equivalence factor declines.

3.3 Values Calibrated for the Parameters of the Model

We use values from the literature to calibrate the parameters of the model as well as characteristics of the Dutch economic environment and the Dutch tax and transfer system.

Table 1 summarizes the parameters used to calibrate the model. We set the gross rate of return on assets R equal to 1.02, based on an expected nominal return on pension assets of 4%[13] and an inflation rate of 2%. In Sect. 4.4.3 we present the results obtained with both a higher rate of return on assets (4%) and a lower rate of return on assets (0%).

We set the parameter σ equal to 2, that corresponds to an elasticity of intertemporal substitution $\frac{1}{\sigma}$ equal to 0.5. This is the mean of the values estimated in the literature (Havranek et al. 2015). The estimations for the time preference parameter β range between 0.93 and 0.99 (Alan and Browning 2010; French 2005; Gourinchas and Parker 2002; Guvenen and Smith 2014; Crawford and O'Dea 2020). We choose

[12] More information regarding how the equivalence factors are set can be found at: https://www.cbs.nl/nl-nl/achtergrond/2004/25/equivalentiefactoren-1995-2000.

[13] https://www.abp.nl/english/investments/, section Investment Results. However, future rates of return are very uncertain.

Table 2 Average hours worked per week

Age category	25–35 years	35–45 years	45–55 years	55–65 years
Average hours worked per week	34	34	34	32
Fraction of maximum hours worked	0.85	0.85	0.85	0.8
Household *ptf*	1.7	1.7	1.7	1.6

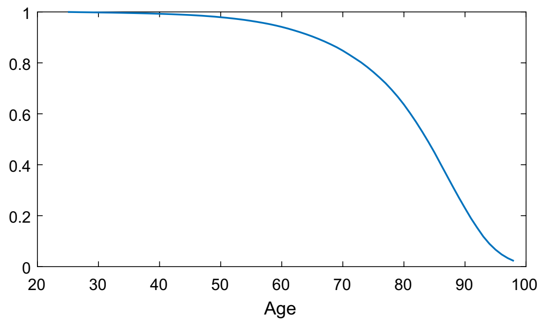

Fig. 3 Survival probability at the age of 20

a value of time preference that corresponds to an annual discount factor that is equal to R, i.e. $\beta = \frac{1}{R} = 0.98$. We present robustness checks of the results for the values of σ and β in Sect. 4.4.

The age at which the households receive the first pillar pension benefit (t_{AOW}) is 65 years. The value of the gross AOW pension benefit is equal to 8872 EUR per person,[14] so 17744 EUR per household, the value in the year 2010.[15]

The maximum level of the pensionable income *cap* is equal to 112189 EUR in 2020. We transform this in the prices of the year 2010 using the CPI index and obtain a value of 96183 EUR. The value of the franchise *f* is set to 12674 EUR,[16] the value from the year 2010. The average number of hours worked by the household in a week corresponds to the year 2018 and is taken from the CBS (see Table 2). We compute the average number of hours worked per week as a fraction of full time work (*pft*) based on a full time equivalent of 40 h/week. We multiply the resulting number by 2 in order to take into account that there are two earners in the household.

The income tax rate is flat, but differs before and after the age when the AOW benefit is received. We fix the tax rate at 36% until the age when the AOW benefit is received and at 22% after this age. These values are equal to the ones used in the

[14] https://centraalaanspreekpuntpensioenen.belastingdienst.nl/publicaties/overzicht-aow-inbouwbedragen-en-aow-franchises/.

[15] The reference to the year 2010 is due to the fact that our income is transformed in real values using the CPI with a base in the year 2010.

[16] https://centraalaanspreekpuntpensioenen.belastingdienst.nl/publicaties/overzicht-aow-inbouwbedragen-en-aow-franchises/.

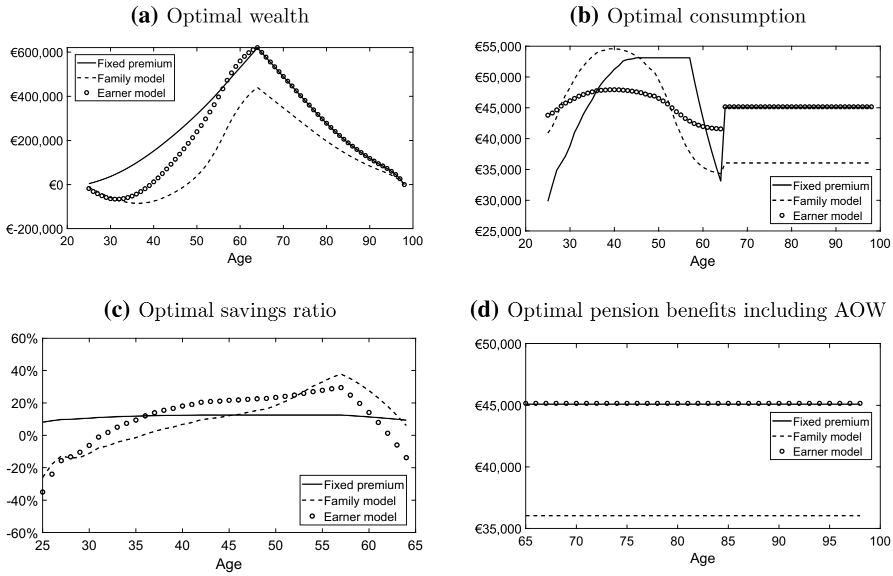

Fig. 4 The current pension system (solid line), the family model (dashed line) and the earner model (circles): optimal wealth, consumption, savings ratio and pension benefits

Gamma model of the Centraal Plabureau (see Van Tilburg et al. 2019). In reality, the Dutch tax system has progessive income tax rates. In "Appendix 1.2" we analyse the implications of progressive income tax rates for the optimal pension premium schedule and we show that the welfare gain of introducing the optimal pension system declines, but remains quantitatively important.

The probability to survive until age t (ψ_t) is obtained from CBS. It corresponds to the year 2010 and represents an average of the survival probabilities of men and women (Fig. 3).

4 Results

In this section we describe the results of the earner and the family model. We ignore borrowing constraints at this point. In Sect. 4.1 we present the optimal path of pension premium rates and pension benefits and we show the welfare effect of the optimization. In Sect. 4.2 we determine the welfare gain that can be achieved by keeping the pension premium rates flat as in the current pension system, but optimizing this flat rate with our model. In the subsequent subsections we analyse the impact of family composition on the outcomes (Sect. 4.3) and we explore the sensitivity of the results to three parameter values: time preference β, the inverse of the elasticity of substitution σ and the return on wealth R (Sect. 4.4). This section concludes by performing the optimization for three different educational levels (Sect. 4.5).

4.1 Optimal Pension Premium and Benefits

Figure 4 presents the results for the family and earner model. Optimal pension premium rates differ substantially from those under the current premium system. These differences largely originate from changes in standardized incomes and, in the family model, household size across the life-cycle (see Fig. 1). The intuition is that this pattern of standardized incomes leads to a continuous decline in the marginal utility of income for each of the family members until the age 57 and a rise afterwards. In both models this in turn leads to an optimal pattern of life-cycle savings ratios (Fig. 4c) that, after being negative in the first decades, rises until this age and declines afterwards. This contrasts markedly with the current pension system in which the pension premium rate is roughly constant. This upward sloping pattern of the pension premium rate is more pronounced in the family model as, other than in the earner model, the utility of all household's members count in the optimization. At the age of 57 savings ratios reach a level of around 30% in the earner model and 35% in the family model. Optimal household wealth in the earner model peaks at around 600 thousand euros (Fig. 4a), roughly the same as under the current pension system, and around 400 thousand in the family model.

The optimal savings ratio declines after the age of 57 years as the income of the households declines as well. As we discussed in Sect. 3, the decline in the household income after the age of 57 years is mainly due to the early retirement of Dutch households. In the model the decline of household income triggers a slower buildup of assets. In the earner model, the savings ratio even turns negative at the age of 62 years indicating that the household starts to draw down her assets at this age.

The life-cycle path of family consumption (Fig. 4b) follows the specifications of Eq. 9 for the earner model and Eq. 11 for the family model. It is highest in the years in which the equivalence factor is highest, especially in the family model. In the earner model this raises family consumption if σ is larger than 1, as is the case in our baseline analysis. As we explain in Sect. 2.1, the relatively high cost of the presence of children at these ages raises the marginal utility of the part of family consumption that accrues to the earners and in turn raises optimal family consumption. In the family model this effect is even larger because the children's utilities are also included in the optimization. The tax incentive on pension savings however increases savings during the working years and curbs consumption. This incentive results from the fact that pension savings can be deducted from income in the working phase and that in this phase marginal tax rates are generally higher than after retirement. This is also the cause of the upward jump in consumption at the age of 65.

Another important finding of this analysis is that in our preferred family model optimal family consumption after retirement and pension benefits (including the AOW) turn out to be substantially lower than under the current system (Fig. 4b, d). This indicates that a lower pension ambition raises lifetime welfare in this model. In the earner model optimal consumption and pension benefits are roughly the same.

The optimal pension benefits turn out to be age invariant exactly as under the current pension system. This is due to our assumption that $R\beta = 1$. In this case the discount factor used by the households to discount future consumption is equal to the return on wealth, so households have no incentive to defer consumption or consume

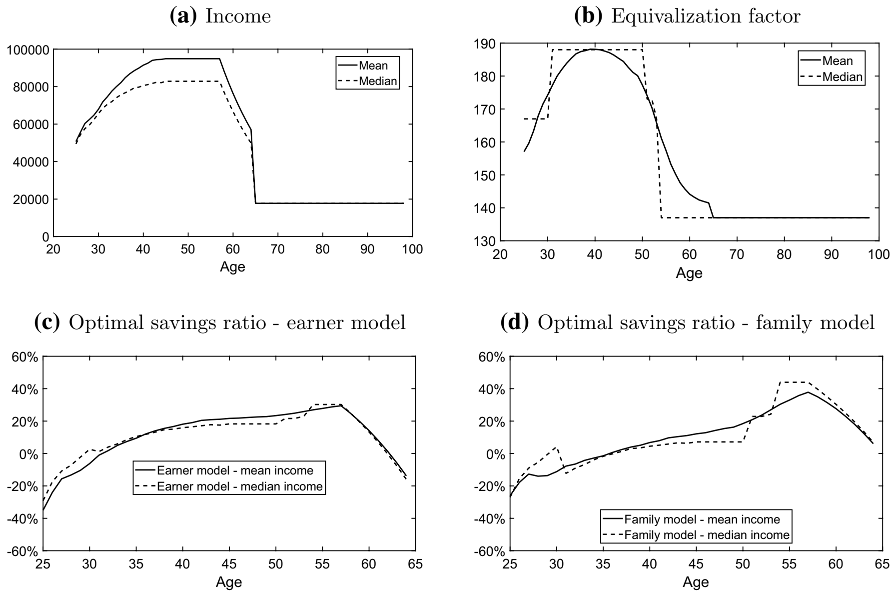

Fig. 5 Median versus mean income, equivalence factor and optimal savings ratio

Table 3 Optimal pension system versus current system—equivalent consumption

	Mean No tax adjustment	Income Tax adjustment	Median No tax adjustment	Income Tax adjustment
Family model	3.1%	3.8 %	2.8%	2.6%
Earner model	2.1%	2.1 %	3.4%	2.4%

in advance during the retirement years. If $R\beta > 1$, households are relatively more patient and prefer to defer consumption to the future. Consequently, the optimal pension benefits are increasing with age. The sensitivity analysis in Sect. 4.4.1 presents this case. If $R\beta < 1$, the reverse is true: households are impatient and prefer to consume more in the beginning of their retirement period. Hence optimal pension benefits decrease with age. The sensitivity analysis in Sect. 4.4.3 presents such a case.

Figure 5 presents the results if the life-cycle profile of income, equivalence factors and household members are based on the median prevailing in each income category rather than the mean.

The profile of optimal savings ratios is similar when using median instead of mean income (Fig. 5c, d) although less smooth due to the jumpy profile of the median equivalization factor (Fig. 5b) and the median number of household members. Optimal pension premium rates are slightly higher until the age of 30 and in the years preceding the partial early retirement of the household (55–60 years).

Table 4 Optimal flat pension system

	Pension premium (% of income)	Pension benefit (EUR)
Family model	15%	28,399
Earner model	21%	40,417
Current system	21%	40,067

Table 5 Welfare gains compared to the current pension system

	Optimal flat pension premium	Optimal variable pension premium rate	Difference in welfare gain
Family model	0.8%	3.1 %	2.3%
Earner model	0.0%	2.1 %	2.1%

The welfare gains from optimizing the pension premiums and the pension ambition are presented in Table 3. Columns 2 and 3 present the consumption equivalent in the baseline scenario where the life-cycle income profile is based on the mean income, while columns 4 and 5 present the consumption equivalent when life-cycle income is based on the median income. Columns 2 and 4 present the consumption equivalent computed using formula 17, while columns 3 and 5 presents the consumption equivalent for the case in which we correct the consumption path with the differences in tax revenues cashed by the government under the current and the optimal pension system, respectively (see Sect. 2.4).

The analysis based on mean incomes shows that, in the family model, households require a 3.1% higher lifetime consumption under the current pension system in order to achieve the same level of lifetime utility as under the optimized pension system. If we apply the tax adjustment as discussed in Sect. 2.4, the welfare gain rises to an equivalent of 3.8% extra consumption. The higher figure results from the tax return obtained by households under the optimal pension system. This is made possible by the higher tax revenues cashed by the government: pension premiums are lowered and taxable income and consumption thus shifted to the working phase of the life-cycle in which tax rates are higher than during the retirement phase. In the earner model, the total welfare gain is smaller and is equivalent to 2.1% extra consumption. With the tax adjustment the welfare gain is the same. If we base the analysis on median incomes, the welfare gains in the family model turn out to be somewhat lower: with no tax adjustment households would require a 2.8% higher consumption under the current pension system, and with the tax adjustment 2.6%. In the earner model however the welfare gain is larger.

4.2 The Optimal Flat Pension Premium

The analysis carried out in Sect. 4.1 allows pension premium rates and benefits to vary with age. We compare the welfare of this optimal pension premium and pension benefit scheme with the current pension system. We find sizeable welfare gains

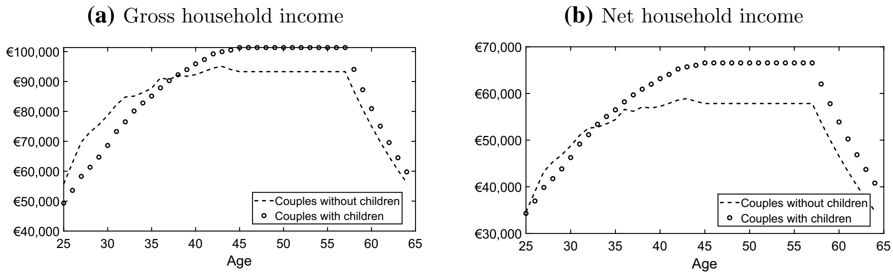

Fig. 6 Household income for couples without children (dashed line) and couples with children (circles)

of 3.1% equivalent consumption in the family model and 2.1% in the earner model. These welfare gains stem from two sources: (a) under the current pension system the pension premium rate is flat, while in the optimal pension system the pension premium rates are increasing with age and (b) the current flat pension premium rate may not be optimal according to our model.

To check what part of the welfare gain that we obtain is due to the upward sloping path of the optimal pension premium rates, we compare in this section the results we presented in Sect. 4.1 with the results of a model in which we search for an optimal flat (age invariant) pension premium rate. To this end, we determine the flat pension premium rate and the corresponding pension ambition that maximizes the lifetime welfare of the household in both the earner and the family model. The computation of the optimal flat premium is done through numerical optimization, because a closed form solution is not available.

Table 4 shows that the optimal flat pension premium rate in the family model is lower than in the current system: an optimal pension premium rate of only 15% versus 21% for the same variable in the current system. In the earner model the optimal flat premium is the same as than under the current pension system.

Table 5 presents the welfare gains from optimizing the flat pension premium rate compared to the current pension system. It shows that in the family model the lower optimal flat pension premium rate increases welfare by the equivalent of a 0.8% increase in lifetime consumption (first column). Comparing this outcome to the 3.1% higher equivalent consumption obtained from allowing pension premiums to vary with age (second column), we see that the upward sloping pension premium rates are responsible for the majority of the welfare gain (third column). In the earner model the welfare gain of 2.1% equivalent consumption we found in Sect. 4.1 is entirely due to the fact that pension premium rates are allowed to depend on age.

4.3 Effects of Family Composition

In this section we analyse the impact of family composition on the optimal pension premium rates. To this end, we compare households with and without children. We first determine the gross income profile of couples that have no children and of households that have at least one child, respectively. The gross income of households with children include child related government transfers, while the net income

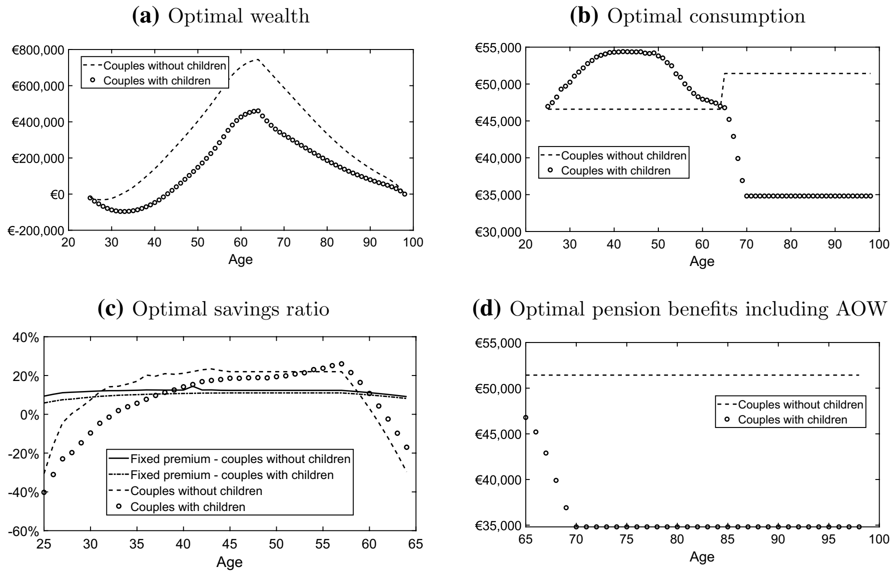

Fig. 7 Couples without children (dashed line) and couples with children (circles): optimal wealth, consumption, savings ratio and pension benefits

takes into account that couples with children benefit from a tax allowance (*Inkomensafhankelijke combinatiekorting*). We fix the size of this to 1859 EUR, the value prevailing in the year 2010.

Figure 6a shows the income profile of the two categories of households. Couples with children have a more upward sloping income profile, both gross and net, than couples without children. On the one hand, couples with children receive child related transfers and child tax allowances that we expect would flatten their income profile. On the other hand, mothers decrease substantially their labor supply in the early years of their family in order to raise their children (Rabaté and Rellstab 2021), hence lowering the income of the household in the early years of the child. Overall the life-cycle income profile of couples with children is more upward sloping than that of households with no children.

Figure 7 shows the result of taking into consideration whether a couple has children or not when establishing pension premiums. Households without children have a much flatter pension premium rate profile than households with children. This is a result of the somewhat less upward sloping income profile, but mostly due to the fact that these households do not have to finance the consumption of children. Hence they accumulate more wealth, start drawing the assets down sooner and have higher pension benefits. The pension benefit is first declining for households with children as children gradually leave the household.

We must note that the pension premium rate is more age dependent in the case of couples with children also under the current pension system (7c). This is because child related government transfers are a part of a household's gross income, but they are not included in the pensionable income (the income measure used to compute

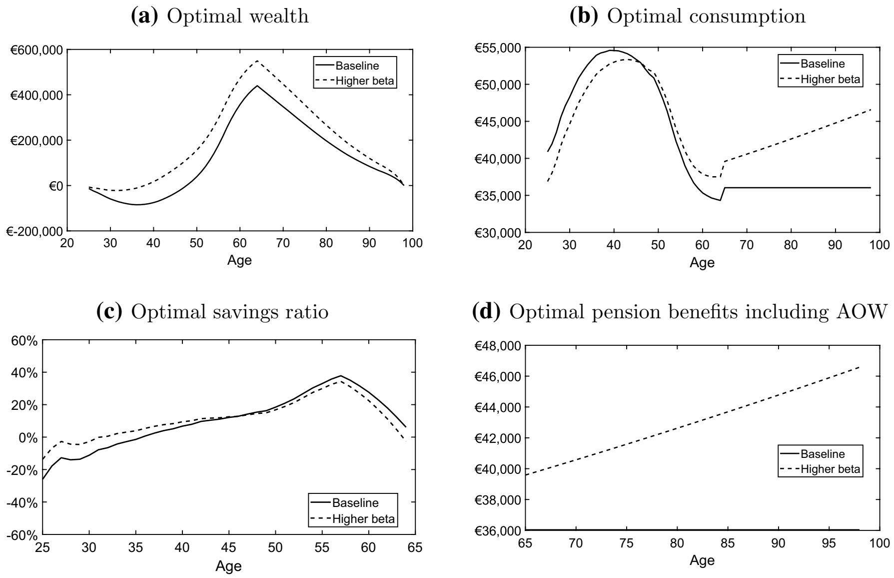

Fig. 8 The family model when the discount factor β equals 0.98 (solid line) and 0.99 (dashed line): optimal wealth, consumption, savings ratio and pension benefits

Table 6 Welfare gain compared to the current system

Parameter	$\beta = 0.99$	$\sigma = 1$	$\sigma = 4$	$R = 1$	$R = 1.04$
Consumption equivalent	1.3%	0.3%	6.3%	6.7%	0.5%

pension premiums). These transfers represent a substantial part of gross income in the early years of a household with children. However, the age dependency is considerably smaller than under the optimal pension premium system.

There are important welfare gains from taking into consideration whether a household has children when setting pension premium rates and benefits instead of setting values that are representative for the average of the population. Households with children obtain a 1.1% higher consumption equivalence and households without children a 4.3% higher consumption equivalence when pension funds differentiate in terms of children being present in the household.

4.4 Sensitivity Analysis

In this section we evaluate the sensitivity of the results of the family model to different values of time preference β, inverse of the elasticity of substitution σ and the gross return on assets R.

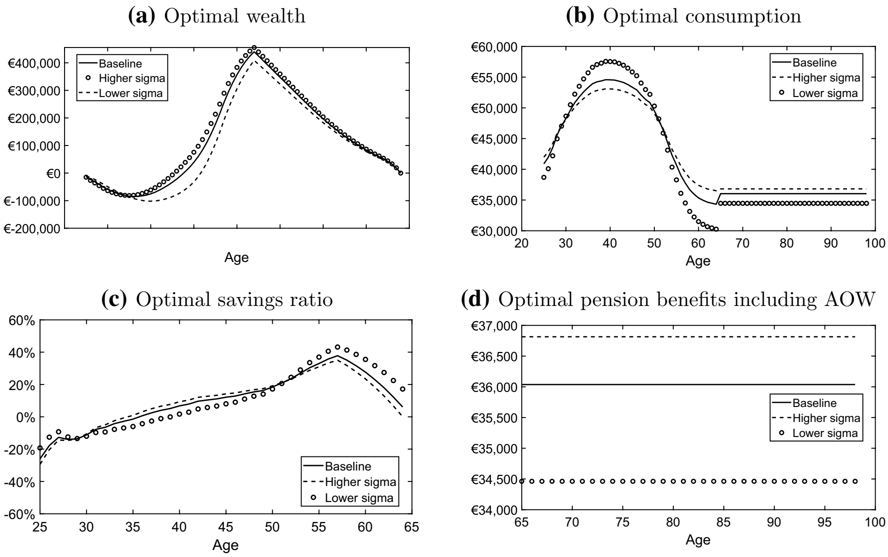

Fig. 9 The family model with values for σ of 1 (circles), 2 (solid line) and 4 (dashed line): optimal wealth, consumption, savings ratio and pension benefits

4.4.1 Sensitivity to the Time Preference Parameter

We first investigate what a higher value for the time preference parameter β (0.99 rather than 0.98) implies for the results of the family model. The value of 0.99 represents the upper bound on the estimated values of β found in the literature, so this is the highest possible value of the time preference that we could use to calibrate our model. Figure 8 presents the differences compared to the baseline calibration.

With a higher value of β, the result that the optimal savings rate is low during the first years of working life and increases until the age of 57 remains unchanged. However, the age-dependency of the optimal savings ratio is less pronounced. Also the welfare gain from introducing the optimal pension system is lower (Table 6).

Optimal wealth now peaks at a slightly higher value than in the baseline. This is a reflection of the higher valuation of future consumption (households are more patient) that leads to higher savings than in the baseline and a shift of consumption to later years. It also leads to pension levels that are higher and rise after retirement due to the fact that the capital return now exceeds the time discounting factor.

4.4.2 Sensitivity to the Elasticity of Intertemporal Substitution

A change in the elasticity of intertemporal substitution, the inverse of σ, changes the curvature of the utility function. A higher σ means that it has a larger bending and this implies a lower positive valuation of increases in consumption relative to the negative valuation of decreases in it. As a result the importance of constancy of standardized consumption during the life-cycle relative to total lifetime consumption

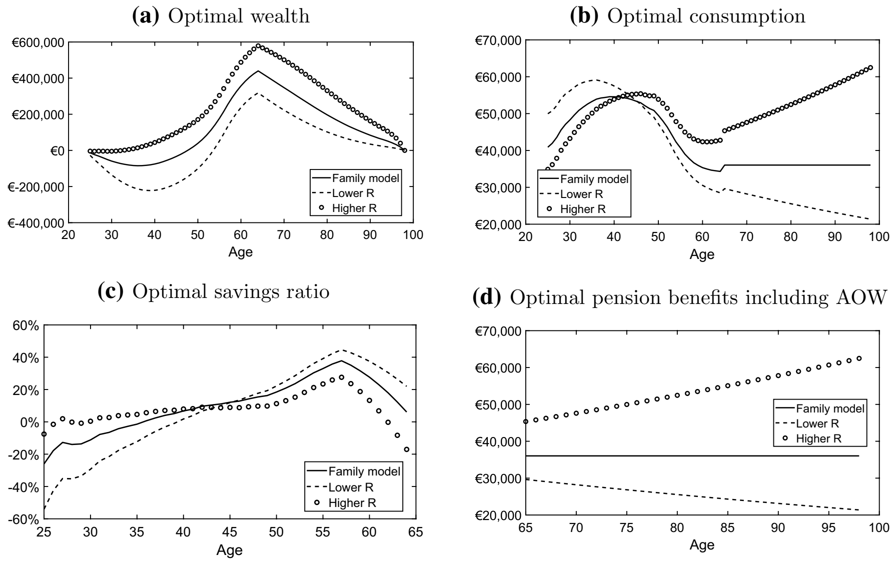

Fig. 10 The family model with a rate of return of 2% (solid line), 0% (dashed line) and 4% (circles): optimal wealth, consumption, savings ratio and pension benefits

shifts in favour of the former. We therefore expect the life-cycle path of standardized and family consumption to flatten and savings to be affected correspondingly. The opposite holds if σ is lower: we then expect differences in standardized and family consumption during the life-cycle to increase.

Figure 9 shows the results if σ is equal to 1 and 4, compared to the value of 2 we assume in the baseline calibration. They are in line with our expectations. Consumption shows a larger variation during the life-cycle in the case of a lower σ (Fig. 9b). It responds stronger to changes in the variables on the right hand side of Eq. (11). Optimal savings ratios (Fig. 9c) are lower than in the baseline until the age of around 50 and higher afterwards. Wealth peaks at approximately the same level. Accordingly optimal consumption (Fig. 9b) after retirement and optimal pension benefits (Fig. 9d) show small differences. Figure 9 also shows that a higher σ leads to the opposite effects. Welfare gains increase with the value of σ (Table 6).

4.4.3 Sensitivity to the Rate of Return

Figure 10 shows the results of the model if we change the rate of return on assets from 2% to a lower value of 0% and to a higher value of 4%. We perform this robustness check because the future rate of return on assets is uncertain.

The results show that in the case of a lower rate of return on assets households accumulate less wealth at the retirement age. Consequently, optimal pension benefits are also lower and households consume less in the second part of their life. Optimal savings ratios are lower in the first part of a household's working life and higher in

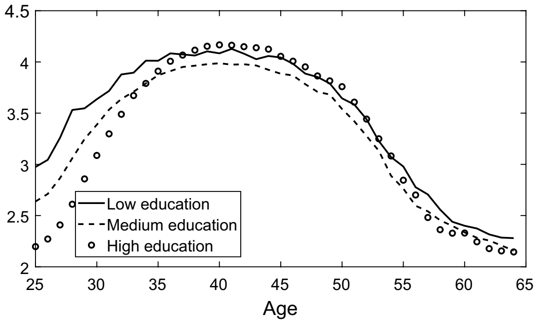

Fig. 11 Average number of household members per education level

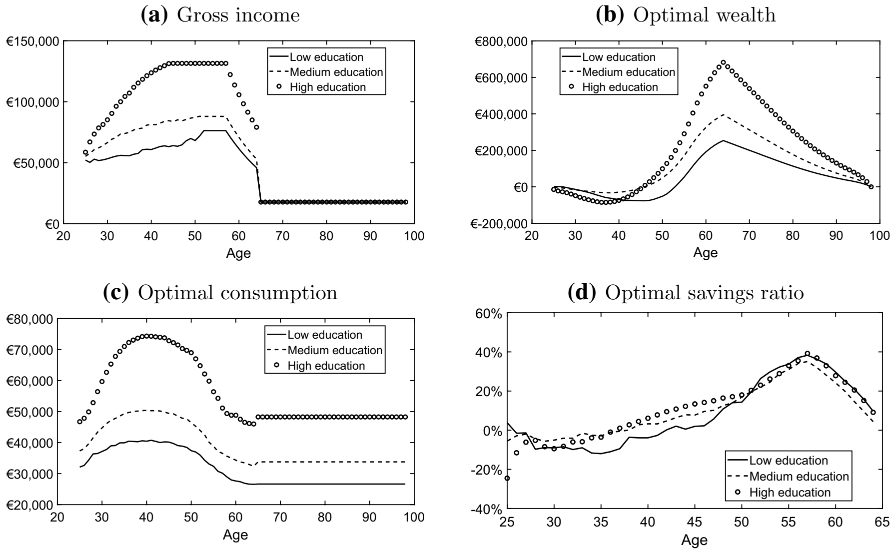

Fig. 12 The family model for a household with a low education level (dashed line), a medium education level (solid line) and a high education level (circles): household income (including gross AOW and employer pension contribution), optimal wealth, consumption and savings ratio

the second part of the working life. This implies that households shift more of their retirement savings from the beginning towards the end of their career when the rate of return on assets is lower. Consequently, the scope of an upward sloping profile of pension premium rates is even higher in a low interest rate environment. The welfare gain from introducing the optimal pension premiums and benefits schedule is also higher in a low interest rate environment, being equivalent to a 6.7% higher lifetime consumption (Table 6).

The reverse is true if the rate of return on assets is higher equal to 4%. The profile of the optimal pension premium rate is flatter and the household accumulates a

Table 7 Welfare gain from differentiating according to the level of educational attainment

Education level	Consumption equivalent
Low educational attainment	1%
Medium educational attainment	0.3 %
High educational attainment	0.1 %

higher level of wealth. The welfare gain is smaller than in the baseline case, equivalent to 0.5% higher lifetime consumption (Table 6).

4.5 Different Education Levels

In this section we determine the optimal savings ratios of households with different education levels. We also investigate the welfare gain that can be obtained by explicitly taking the level of educational attainment into account when setting pension contributions and benefits.

As we mentioned in Sect. 3, we group households in three groups of educational attainment according to the education level of the main income earner: low, medium and high. This splitting of households in different education groups is relevant because education level is observable and it is a rather stable characteristic over the life of a household. It is also determined rather early on in the working life of a household. Hence pension premiums can potentially be set differently based on this characteristic of the household head.

Households with different levels of educational attainment exhibit significant differences in terms of the lifetime income profiles (Fig. 12a). More specifically, households with a higher educational attainment have a steeper increase in income over their working life than households with medium and low educational attainment. They also face a sharper decline in income after retirement. This is a result of the fact that the public pension (AOW) is a flat rate system and does not depend on earnings during the working years. Households with a low educational attainment have a rather flat income profile over their life.

There are also differences between households with different educational attainment in terms of how family composition evolves over the life-cycle, but these are less pronounced than the differences in the income profile (Fig. 11). Households with a low educational attainment have children earlier in their life than households with a medium and high educational attainment.

Figure 12 presents the results of optimizing the family model for the three types of households. Because of the steeper increase in income over the life-cycle, households with a higher level of educational attainment have a profile of optimal savings ratios that is slightly more progressive than the one of the households with low and medium educational attainment (Fig. 12d). Although the income profile of households with a low educational attainment is rather flat, their optimal savings ratio is also progressive, albeit less than in the case of the households with medium and

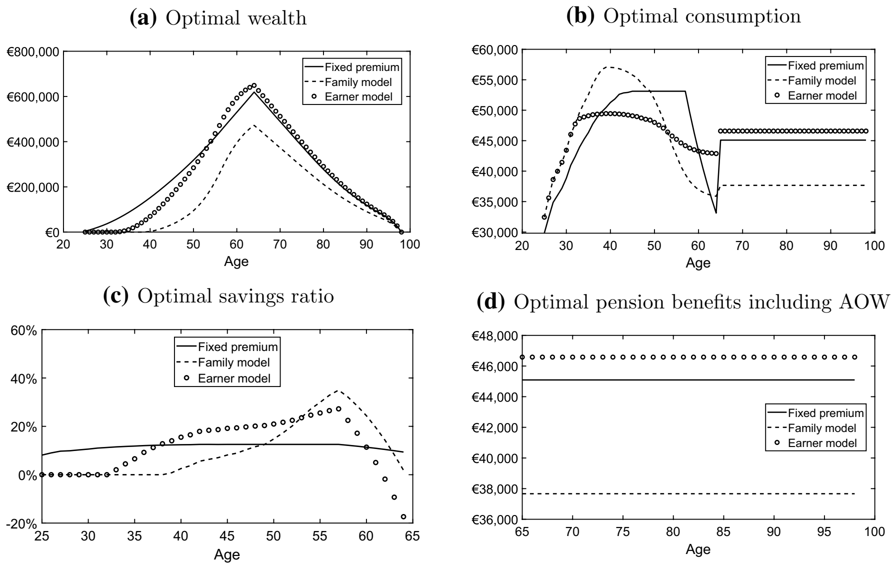

Fig. 13 The model with the current pension system (solid line), family model with borrowing constraints (dashed line) and earner model with borrowing constraints (circles): optimal wealth, consumption, savings ratio and pension benefits

high education levels. This is because of the presence of children in the early life of the household.

We investigate whether differentiating the path of pension contributions and the level of benefits for households with different educational attainments brings important welfare gains. To this end, we compute the consumption level that households with low, medium and high educational attainment would obtain if pension funds (or a social planner) would impose the premium rates derived from the model that uses the average income path of Dutch households and the average number of children present in the household (Sect. 4.1, Fig. 4c). We compare the resulting consumption paths with the optimal consumption profiles for each education level (Fig. 12c). We compute the consumption equivalent, i.e. the annual percentage increase in consumption required by households in the case that pension contributions are based on the average income and average number of children of Dutch households in order to be just as well off as in the case that pension contributions are set at the optimal level corresponding to their education group.

We present the consumption equivalent for each level of educational attainment in Table 7. There is a welfare gain from setting pension premium rates equal to their optimal level in the case of households with a low level of educational attainment (equivalent to a 1% increase in lifetime consumption). However, households with a medium and a high level of educational attainment achieve almost no welfare gain when pension premiums are set according to their income profile and according to the specific developments in household composition.

Table 8 Optimal pension system versus current system—equivalent consumption

	No borrowing constraints	With borrowing constraints
Family model	3.1%	2.5%
Earner model	2.1%	1.5%

5 Imposing Borrowing Constraints

The results of our baseline model (Fig. 4) indicate that people find it optimal to borrow from the pension fund in the first part of their career. In this section we recognize that borrowing from the pension fund can be unfeasible in practice. We solve the same optimal consumption and savings problem described by the models presented in Sect. 2, but now we implicitly impose the constraint that pension premiums cannot be negative. There exists no analytical solution to the model with borrowing constraints, thus we solve the model numerically.

Figure 13 presents the results obtained when we include a borrowing constraint. Households find it optimal to pay no pension contributions in the first part of the career and afterwards pay a pension contribution that increases with age. Optimal savings ratios are zero until the age of 32 years in the earner model and of 38 years in the family model (Fig. 13c). Until these ages the borrowing constraint is binding and consumption is equal to net income. Later on, savings rates increase substantially and reach a level of 30% in the earner model and 37% in the family model.

Overall, we obtain roughly the same wealth accumulation, pension benefits and consumption at older ages as in the case that there are no borrowing constraints. Optimal consumption at younger ages remains substantially higher than under the current fixed premium system even with borrowing constraints (see Fig. 13b).

Table 8 shows that, as expected, the existence of borrowing constraints reduces the welfare gains that can be achieved with the optimization of pension premiums and pension ambition. However, a large part of the welfare gain still remains. Equivalent consumption equals 2.5% of annual consumption in the family model and 1.5% in the earner model, compared to respectively 3.1% and 2.1% without the borrowing constraints.

6 Conclusion

In this paper we present an analytical framework for the optimization of the path of pension premiums and benefits that combines three factors—an income profile that rises over the life-cycle, the presence of children in a household and the level of educational attainment—and calibrates it to Dutch data. The results show that the optimal pension scheme in the Netherlands differs substantially from the current pension scheme. The optimal scheme features premium rates that increase during working life. The level of pension benefits is lower than under the current pension system. This is due to the fact that children leave the household before the retirement age of the household head. Hence, the household needs to consume substantially less during the retirement phase than in the early years of the working life. Our calculations indicate that the optimization would raise welfare levels by an amount that equals that of a 3.1% increase in lifetime consumption if no borrowing constraints are imposed and 2.5% if, more realistically, we do impose these constraints. Taking into account the level of educational attainment of the main earner of the household brings only small changes in the path of optimal pension premium rates. There are modest welfare gains from taking into account the level of educational attainment in the case of households with a low educational attainment.

We do not take into account a number of factors that would quantitatively change our results: for example, stochastic returns on pension assets, bequests, disutility of labor. These would probably change the size of the optimal pension premiums. However, we expect our main result regarding the upward sloping path of optimal pension premium rates to hold even with these extensions. An important extension of our model would be to consider other reasons why people borrow and save: for example study loans and mortgages. The introduction of mortgages would strengthen our finding that aiming at a lower pension benefit raises lifetime welfare because of the financial alleviation resulting from the disappearance of the mortgage costs at higher ages. The effect of the introduction of mortgages on the upward sloping path of pension premium rates is mixed. In the absence of borrowing constraints it would probably increase the steepness of this path. The costs associated to mortgage repayments are typically constant through the time in nominal terms and therefore, due to inflation and rising incomes, generally weigh most heavily on young households. This would be a reason to defer even more of the pension premium payments towards the end of the career. With borrowing constraints however, there would be very limited room for lowering the premiums for young households as, even without the introduction of mortgages, they turn out to be zero at these ages. The smaller optimal size of the pension ambition might then even require lower premiums for the older households, thus making the time path less steep. A similar reasoning would be applicable in case of the introduction of study loans. These extensions are left for future research.

Appendix

Summary Statistics

See Tables 9 and 10.

Table 9 Household income summary statistics

Age	Mean	p25	Median	p75	SD log income	Skewness
25	50,690	35,168	49,438	63,401	0.56	− 1.69
30	67,861	51,214	65,540	82,191	0.46	− 1.42
35	82,101	58,032	75,610	98,347	0.47	− 0.79
40	91,436	61,237	80,539	107,616	0.49	− 0.42
45	94,887	61,389	82,851	111,739	0.53	− 0.35
50	92,882	59,129	82,759	112,374	0.58	− 0.94
55	85,633	53,949	77,132	105,897	0.59	− 1.19
60	66,610	36,836	58,050	84,643	0.91	− 2.48
65	21,355	2963	11,790	27,409	1.72	− 0.96

Table 10 Household composition summary statistics

Age	Mean equiv. factor	Median equiv. factor	Mean no of household members	Median no of household members
25	1.57	1.67	2.74	3
30	1.74	1.67	3.44	3
35	1.85	1.88	3.94	4
40	1.88	1.88	4.07	4
45	1.85	1.88	3.95	4
50	1.77	1.88	3.56	4
55	1.57	1.37	2.71	2
60	1.44	1.37	2.23	2
65	1.42	1.37	2.15	2

Optimal Pension Premium Rates with Progressive Income Tax Rates

In this appendix we check the robustness of the results to the assumption that income tax rates are flat. For simplicity, the baseline scenario makes the assumption of flat tax rates. This assumption may not be innocuous, because a progressive income tax rate will flatten the life-cycle profile of net household income. Consequently, the scope for age dependent pension premium rates declines.

Throughout the paper we use the policy variables (for example the value of the pension franchise and the pension cap) from the year 2010, the middle of the period for which the income data is available (2006–2013). However, in the case of the tax code, we choose to use the average tax rates corresponding to the year 2020. We make this choice because income tax rates have become substantially more progressive since 2010. The relationship between the gross income and the average tax rate we assume is similar to the one estimated in Vrouwerff (2021) (see Fig. 14, left panel). Because information about the average tax rates after the AOW age is missing in Vrouwerff (2021), the income tax is kept flat at 22%, the same as in the baseline scenario. The

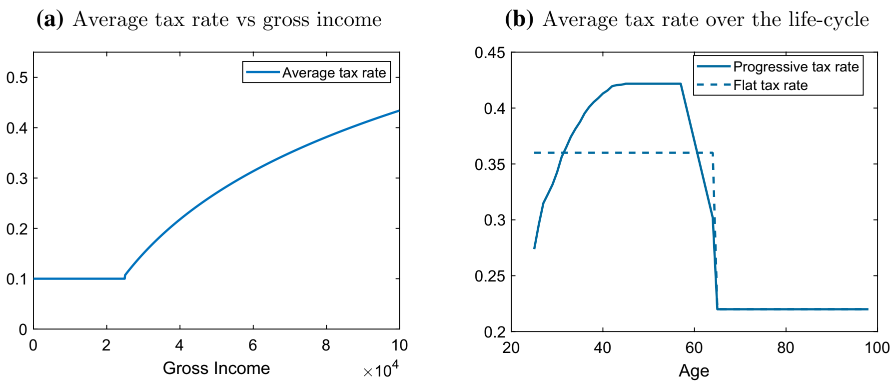

Fig. 14 Progressive average income tax rates

average tax rates corresponding to the life-cycle income profile of the average Dutch household are shown in Fig. 14, right panel.

Using the progressive tax rate depicted in Fig. 14, we compute the optimal consumption and savings schedule. The results are presented in Fig. 15. Comparing these with the results from the baseline scenario (Fig. 4), we see that the life-cycle profile of the savings rates is slightly less upward sloping. Wealth accumulation and pension benefits are also smaller in the case of both the earner and the family model. The differences are however small. The welfare gains from implementing the optimal pension system decline to 2.5% from 3.1% in the case of the family model and

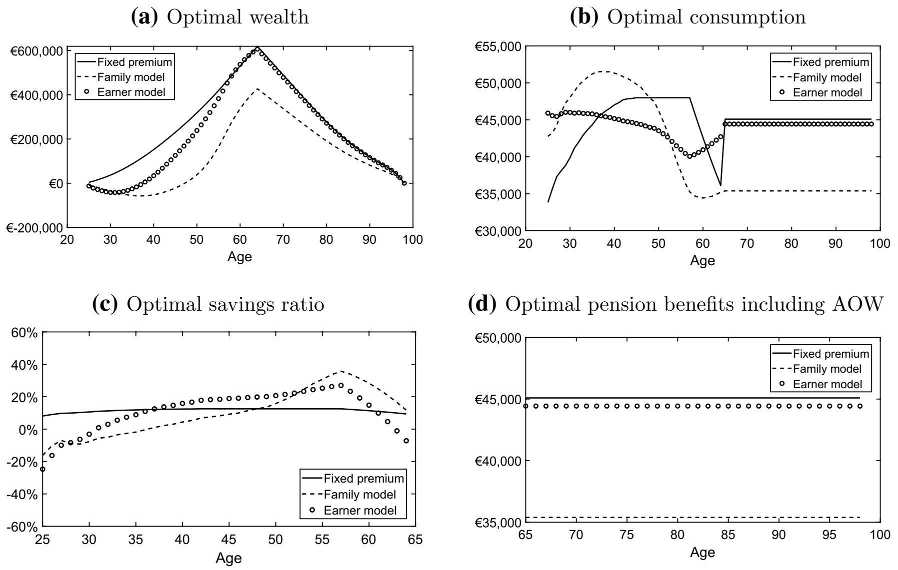

Fig. 15 The current pension system (solid line), the family model (dashed line) and earner model (circles): optimal wealth, consumption, savings ratio and pension benefits

1.3% from 2.6% in the case of the earner model. If we impose borrowing constraints, welfare gains drop to 2.4% and 1%, respectively.

Derivation of the Optimization Problem

Appendix 1.3 contains a step by step derivation of the equations presented in the paper. We start directly with the family model and mention what changes must be implemented in the derivations in order to obtain the earner model.

The household chooses each period how much to consume (c_t) and implicitly how much wealth to accumulate (a_t) by maximizing the present value of the utility of standardized consumption:

$$\sum_{t=1}^{t=T} \beta^{t-1} \psi_t n_t u\left(\frac{c_t}{eq_t}\right) \tag{22}$$

where β is the time preference parameter, ψ_t is the probability to survive until time t, n_t is the number of members in a household, σ is the inverse of the elasticity of intertemporal subsitution and eq_t equals the equivalence factor at time t. In the earner model, the number of household members (n_t) is equal to 2 at every age because the consumption of children is not valued in the utility function. Consequently, this variable drops from the subsequent equations.

The decision of the household is subject at each age t to a budget constraint:

$$y_t + Ra_{t-1} + tr_t = c_t + tax_t + a_t \tag{23}$$

where y_t is the income of the household comprised of labor income until the age when the pay-as-you-go benefit is received (t_{aow}) and the pay-as-you-go pension benefit (AOW) afterwards, R is the rate of return, a_t is the wealth, the per capital transfers tr_t come from the fact that a fraction of the population alive at time $t-1$ dies and the bequests are divided between the members still alive at time t.

The size of the bequests left by the people who die is given by:

$$B_t = Ra_{t-1} l_{t-1}\left(1 - \frac{\psi_t}{\psi_{t-1}}\right) \tag{24}$$

where Ra_{t-1} is the per capita wealth accumulated by people alive at time $t-1$, l_{t-1} is the number of people alive at time $t-1$, $\frac{\psi_t}{\psi_{t-1}}$ is the probability to survive between period $t-1$ and t and $\left(1 - \frac{\psi_t}{\psi_{t-1}}\right)$ is the probability to die between period $t-1$ and t. We divide total bequests among the people that are still alive at time t:

$$\frac{B_t}{l_t} = Ra_{t-1} \frac{l_{t-1}}{l_t}\left(1 - \frac{\psi_t}{\psi_{t-1}}\right) \tag{25}$$

Next we take into account that the ratio of people alive at time t and people alive at time $t-1$ is equal to the probability to survive between periods $t-1$ and t:

$$\frac{l_t}{l_{t-1}} = \frac{\psi_t}{\psi_{t-1}} \tag{26}$$

We substitute relation 26 into 25 and obtain the per capita transfer coming from bequests:

$$\frac{B_t}{l_t} = Ra_{t-1}\frac{\psi_{t-1}}{\psi_t}\left(1 - \frac{\psi_t}{\psi_{t-1}}\right) \tag{27}$$

$$tr_t = \frac{B_t}{l_t} = Ra_{t-1}\left(\frac{\psi_{t-1}}{\psi_t} - 1\right) \tag{28}$$

Finally, we substitute 28 in the period by period per capita budget constraint from relation 23 and obtain:

$$y_t\psi_t + Ra_{t-1}\psi_{t-1} = c_t\psi_t + tax_t\psi_t + a_t\psi_t \tag{29}$$

We use the individual budget constraints to obtain the lifetime budget constraint:

$$\sum_{t=1}^{T} \frac{\psi_t(c_t + tax_t)}{R^{t-1}} = \sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}} \tag{30}$$

The consumption can be described by:

$$c_t = (y_t - p_t)(1 - \omega_t) \tag{31}$$

where p_t equals the amount of pension money (either being saved or dis-saved) and ω_t equals the percentage of tax on income net of pension premiums paid at age t: 36% until the age of 65 and 22% afterwards. For simplicity, average and marginal tax rates in both phases are set equal.[17] The tax paid is equal to $tax_t = (y_t - p_t)\omega_t$, so expenditures (consumption and tax) can be rewritten as[18]:

$$c_t + tax_t = (y_t - p_t)(1 - \omega_t) + (y_t - p_t)\omega_t = \frac{c_t}{1 - \omega_t} \tag{32}$$

Therefore, Eq. 30 can be rewritten as:

$$\sum_{t=1}^{T} \frac{\psi_t c_t}{R^{t-1}(1 - \omega_t)} = \sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}} \tag{33}$$

[17] In reality however average and marginal tax rates differ, both in size and in their impact. A high average tax rate reduces income and thus increases the marginal utility of consumption. As a result it increases the allocation of consumption to years in which the average tax rate is relatively high, reducing saving. A high marginal tax rate has the opposite effect. It reflects that a large part of pension savings goes untaxed and thus stimulates it in these years.

[18] In the Netherlands around 70% of the pension premium is paid by the employer, and 30% by the employee, see for example the premium structure of ABP: https://www.abp.nl/pensioen-bij-abp/pensioenpremie/. Our modelling of the effects on net incomes and consumption nonetheless assumes that the full 100% is effectively paid by the employee. This is explained in the main text in Sect. 2.3.

The problem that the household solves becomes:

$$\max_{\{c_t\}} \sum_{t=1}^{t=T} \beta^{t-1} \psi_t n_t \frac{(\frac{c_t}{eq_t})^{1-\sigma}}{1-\sigma} + \lambda \left(\sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}} - \sum_{t=1}^{T} \frac{\psi_t c_t}{R^{t-1}(1-\omega_t)} \right) \tag{34}$$

The first order conditions of the above maximization problem are:

$$\beta^{t-1} n_t \left(\frac{1}{eq_t} \right)^{1-\sigma} c_t^{-\sigma} = \frac{\lambda}{R^{t-1}(1-\omega_t)} \tag{35}$$

It follows that the relationship between first period consumption (c_1) and the consumption in period t (c_t) is given by:

$$c_t = c_1 (\beta R)^{\frac{t-1}{\sigma}} \left(\frac{n_t}{n_1} \right)^{\frac{1}{\sigma}} \left(\frac{eq_1}{eq_t} \right)^{\frac{1-\sigma}{\sigma}} \left(\frac{1-\omega_t}{1-\omega_1} \right)^{\frac{1}{\sigma}}, \forall t = 2, \dots, T \tag{36}$$

Next, we substitute Eq. 36 in the life-time budget constraint of the household from Eq. 33:

$$\sum_{t=1}^{T} \frac{\psi_t c_1 (\beta R)^{\frac{t-1}{\sigma}} \left(\frac{n_t}{n_1} \right)^{\frac{1}{\sigma}} \left(\frac{eq_1}{eq_t} \right)^{\frac{1-\sigma}{\sigma}} \left(\frac{1-\omega_t}{1-\omega_1} \right)^{\frac{1}{\sigma}}}{R^{t-1}(1-\omega_t)} = \sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}} \tag{37}$$

Now we can derive a closed-form solution for the first period consumption of the household:

$$c_1 = \frac{\sum_{t=1}^{T} \frac{\psi_t y_t}{R^{t-1}}}{\sum_{t=1}^{T} \frac{\psi_t (\beta R)^{\frac{t-1}{\sigma}} \left(\frac{n_t}{n_1} \right)^{\frac{1}{\sigma}} \left(\frac{eq_1}{eq_t} \right)^{\frac{1-\sigma}{\sigma}} \left(\frac{1-\omega_t}{1-\omega_1} \right)^{\frac{1}{\sigma}}}{R^{t-1}(1-\omega_t)}}. \tag{38}$$

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