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Abstract

We investigate numerically how indexation of funded pensions for inflation can be differentiated across the various groups of fund participants. The pension arrangement is modelled after the Dutch situation. While the aggregate welfare consequences are small, group-specific consequences are more substantial with the workers and future born losing and retirees benefitting from a shift away from uniform indexation. Those welfare shifts result from systematic redistribution of welfare rather than shifts in the benefit of risk sharing provided by the system.

JEL-Code: H55, I38, C61.

Keywords: indexation, funded pensions, welfare effects, pension buffers, stochastic simulations.

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1 Introduction

Funded social security systems are vulnerable to financial market shocks as the consequences of the recent financial crisis have shown. These consequences have also alerted both policymakers and academics to the question how risks should be shared among the participants in funded pension systems. It is well known from the literature that non-funded social security can raise welfare through the intergenerational sharing of income risks (Enders and Lapan, 1982, and Merton, 1983). However, there has been less research on how pension funds can affect welfare through intergenerational risk sharing. The literature suggests that income uncertainty is just weakly correlated with the uncertainty on asset returns (Heaton and Lucas, 2000). This makes pension funds a priori suitable vehicles for risk sharing between workers and retirees. This is also the case for the second pension pillar in the Netherlands, which to a certain extent can be characterised as a defined-benefit (DB) system. In this paper we will explore how the indexation of pension rights to price and wage inflation can be adjusted to improve the operation of the system.

The overall Dutch pension system is largely based on an unfunded pay-as-you-go (PAYG) first pillar and a funded second pillar.[1] The Dutch pension system shares features with systems like those in, for example, the US,[2] Germany and Switzerland. The Dutch second pillar is unusually large, though, because it is roughly the size of the first pillar and it is expected to grow further in relative terms. Through their contributions to sectoral or company pension funds workers build up pension rights to a future nominal pension. Both contribution and accumulation *rates* are identical across a fund's participants. Hence, those on higher incomes contribute more and accumulate more rights. Second pillar benefits are of a defined-benefit nature in the sense that accumulated rights guarantee the holder a nominally-fixed benefit in euros as of retirement until death. Accumulated rights are usually once a year heightened up to compensate for the past rate of price inflation, so as to protect the purchasing power of the pension, or wage inflation, so as to have the pension benefit track the general increase in welfare. However, indexation is not required by law and the board of the pension fund may index by less than full or not even at all if this is deemed necessary to maintain a healthy funding ratio as measured by the ratio of pension assets and liabilities.

The pension fund is a vehicle for intergenerational risk sharing. For example, financial market developments affect the size of the pension buffers and may lead to a change in the contribution rate and/or the indexation rate. This way, younger generations share in the financial market risks that tend to be mostly concentrated among the older people. By linking indexation to wages, retirees share in the productivity risk which is mostly born by the workers (Bohn, 2006). Uncertainties in life expectancy can be buffered by both changes in indexation and pension premia.

When the funding ratio falls below a given "long-term" threshold (roughly 125% for a fund with average investment risk), the fund has to submit a "long-term" (15 year) restoration plan to the supervisor, the Dutch central bank (DNB), to return to above this threshold, while when the funding ratio falls below 105%, a situation called "underfunding", it has to submit a "short-term" (3 or 5 year) plan to undo the underfunding. Funds have to rely on a mix of reduced indexation, higher contributions and, in case these instruments provide insufficient restoration power, partially writing off existing pension rights. The latter instrument is considered the last resort and supervision is aimed at avoiding this in all but very exceptional circumstances.

This paper focuses on changes in indexation as the main instrument for the stabilisation of

[1] The system also features a third pillar, which is based on voluntary (tax-facilitated) savings mostly through insurance companies. This pillar is of relatively minor importance, though.

[2] Nowadays, most pension funds in the U.S. are of a defined contribution (DC) type, but pension funds in the public sector are generally of a DB type. Hence, the Dutch second pillar resembles more closely the situation in the U.S. public sector.

pension buffers, because contribution rates in the Netherlands are generally thought to have reached their "natural" maximum. Indexation of pension rights is usually uniform over the entire group of participants in the fund. However, there is a growing discussion whether the policy parameters should be differentiated across the various groups of participants in a pension fund. Specifically, Hurst and Willen (2007) find it typically welfare improving to have pension contributions increase with the worker's age. Indeed in the Netherlands much of the discussion focuses on differentiating contribution and accumulation rates over cohorts. Another, related instrument is the differentiation of indexation across the various groups of participants in a fund. However, to the best of our knowledge there exist no analysis of what would be the best way to differentiate indexation across groups of fund participants. This is exactly what we will analyse in this paper.

Because accumulated pension rights are increasing over a person's working life, retirees and those close to retirement will be hurt most by a uniform reduction in indexation. Moreover, these groups are left with little or no flexibility to make up for any loss of indexation by working more, while, in addition, a given loss of purchasing power has to be absorbed by a consumption reduction over a relatively short remaining lifetime. Hence, these groups are at particular risk under policies that resort to changing the indexation rate in order to keep pension buffers stable. Because financial market risks are a major source of fluctuation in pension buffers, pension income of the elderly is particularly sensitive to financial market shocks even though the younger generations would be best placed to bear this source of risk given the imperfect correlation between the return on human wealth and that on financial wealth. In fact, the seminal analysis in Bodie et al. (1992) shows that the share of total (human plus financial) wealth invested in equity should be constant over one's lifetime, implying that shocks in shock prices have identical proportional effects on consumption at all ages. This would be an argument to shift a disproportionate part of the indexation risk to younger workers, at least to the extent that this risk is primarily linked to the financial market performance of the pension fund's asset portfolio.

We explore the following alternatives to uniform indexation across the participants. One is to have "status-dependent" indexation, in which the retired always receive exactly enough indexation to compensate for price inflation, while the indexation rate of the entire group of workers moves uniformly in response to changes in the pension buffer. We also consider more complicated alternatives to uniform indexation. One is to reduce changes in the indexation rate with age, the idea being that older people hold more rights on average and, hence, are hurt more severely by uncertainty in the indexation rate. A final alternative is to make indexation dependent on income such that higher-income individuals absorb relatitvely more of the uncertainty about indexation than those on lower incomes.

We develop an applied small-open economy overlapping generations model with annual cohorts of heterogeneous agents and a pension system that incorporates the main features of the Dutch system. In our stochastic simulations, calibrated to the situation in the Netherlands, we hit the economy with a variety of unexpected shocks. These may be broadly classified into three categories: demographic uncertainty (the size of newborn generations and survival probabilities that determine life expectancy), economic uncertainty (productivity growth and the inflation rate) and financial uncertainty (bond and equity returns and yield curve).

In spite of all the reasonable arguments that can be put forward in favour of differentiating indexation, we find that at the aggregate level, as measured by the equivalent variation for all groups together, uniform indexation tends to perform better than any of the alternatives. The average difference in terms of compensating initial resources is relatively small, though, and is always less than 0.5% of the initial resources of individuals. At the group level the effects are larger. Initial retirees benefit from a switch away from uniform indexation, while the workers and future born are net payers for the switch. Most of the benefit to the initially retired and the payment by the others is purely redistributional. Only a relatively small part of the welfare effects is the result of a difference in the effectiveness of risk sharing. We also investigate the robustness of these results by varying within reasonable bounds the initial pension buffer and the assumed equity premium. However, the results remain qualitatively unaltered. Under all indexation schemes, the average indexation rate has to decline over time to maintain the fund's sustainability in the wake of increasing longevity. An increase in the retirement age that leaves existing pension rights untouched does little to avoid this decline and leaves our basic results essentially unaltered.

The paper is organised as follows. Section 2 provides a brief discussion of the literature on risk sharing within social security systems. Section 3 lays out the main elements of the model. Section 4 describes the policy rule and the benchmark calibration. Section 5 reports the results of the stochastic simulations for the various forms of indexation under the benchmark calibration. Section 6 presents a robustness analysis varying the initial funding ratio and the equity returns, while Section 7 concludes the main text. Finally, the online appendix provides further details on the basic model, the estimated shock processes, the policy rule followed by the pension funds and the outcomes of some variations on our benchmark. It is available at http://www1.fee.uva.nl/mint/beetsma.shtm.

2 Literature review

Bodie et al. (1992) use a life-cycle model with the possibility to invest in two assets (risk-free and equity). They start with the case of a non-stochastic wage and consider the case of a constant level of labour supply optimally chosen at the start of one's life and the case of flexible labor supply that can respond to the performance of their investment portfolio. In particular, a bad performance induces individuals to increase their labour supply. More importantly, the opportunity to ex post vary the labor supply leads individuals to invest with more risk. The optimal amount invested in equity is proportional to total wealth, i.e. the sum of human and financial wealth. Under flexible labour supply, human wealth is measured as the discounted sum of wage earnings under the assumption that leisure is zero throughout one's life, while under fixed labor supply, it is measured as the discounted sum of wage earnings obtained under the given amount of working time. The main results are the following. The initial amount of investment in equity is likely to substantially exceed financial wealth at the beginning of one's life. Moreover, it is higher under flexible labor supply. Further, the share of financial wealth invested in equity is decreasing over one's working life as human capital gets depleted and becomes constant upon retirement. Bodie et al. (1992) also consider stochastic wages. The processes for the wage rate and the stock price are assumed to be perfectly correlated. The consequence is that human capital can be seen as equivalent to the combination of an investment in equity and an investment in a risk-free asset. Hence, through their human capital individuals already possess an implicit investment in equity and, hence, the explicit investment in the risky asset is the difference between the total desired exposure to equity risk and the implicit exposure already present.

In the view of Teulings and De Vries (2006) the role of pension funds is to take intertemporal consumption decisions on behalf of participants who find it difficult to take such decisions for themselves and to allow for intra-temporal sharing of longevity risks. They build a model in which individuals supply until their exogenous retirement age a given amount of labour against a deterministic wage. Further, they die at a given, known age and they can invest in risk-free bonds and risky equity. The results on the optimal investment allocation are essentially identical to those in Bodie et al. (1992). Gains from intergenerational risk-sharing can be obtained when new pension fund participants absorb upon entry part of the fund's gains or losses made in recent years before the entry. This way new entrants invest over a longer period of their life in equity, thereby further diversifying their risk exposure. This type of risk sharing is effectively applied in the Dutch pension system, as new entrants share in the under- or overfunding of their fund at the moment of entry, thereby sharing in the past investment performance of the fund. The optimal response to a shock to the value of the fund's portfolio is an identical proportional reduction in consumption over the entire future, while the pension contribution rate is raised over the remaining working career. Finally, Teulings and De Vries (2006) also consider a defined-benefit generational accounting structure, in which wealth at the moment of retirement is fixed at a level sufficient to finance the future benefits with certainty. Hence, as of retirement date all wealth is invested in risk-free bonds. This produces a welfare loss, because it would be optimal to hold at least some equity.

Cui et al. (2010) compare intergenerational risk sharing in funded pension schemes with individually-optimal investment schemes. The funded pensions feature DB elements. If assets minus liabilities are positive (negative) then contributions may be reduced (raised) and pension benefits may be raised (reduced). Three types of risk-sharing rules are considered in the case of a mismatch. Under the first rule only contributions are changed and only workers share in the risks. Under the second rule, only benefits are changed and only the retired share in the risk, while under the final rule both contributions and benefits are adjusted. This is the preferred regime, because under this regime the largest number of generations share in the risks. Under this scheme investment in risky assets is largest, while the adjustment parameters in contributions and benefits are small implying that mismatch vanishes only gradually. However, this is still not the optimal regime. Under a social planner adjustment is even slower to spread shocks over even more generations, which allows the fund to take on even more portfolio risk.

Our framework differs in a number of ways from that in the other contributions discussed here. In Teulings and De Vries (2006) there is only uncertainty about the return on the investment portfolio. Also in Bodie et al. (1992) there is only one source of uncertainty. Even when wages are stochastic, they are perfectly correlated with equity returns. We allow for more sources of risk in our model and, in particular, for demographic risk and inflation risk. Specifically, in contrast to Bodie et al. (1992), productivity risks and stock market returns are imperfect correlated. This is important, because under this assumption a pension fund acquires a useful role in reallocating productivity risk from workers to retirees and reallocating stock market risk from retirees to workers. We deviate from the other contributions by allowing for intragenerational inequality and rising life expectancy and by explicitly addressing indexation policy, which plays a crucial role in DB funded pension systems. The additional complications that we introduce in this paper also force us to make some simplications in some directions. In particular, we will assume that the labour supply and the composition of individual investment portfolios are exogenous.[3] This latter assumption has the advantage that we simulate a model with realistic portfolio allocations.[4]

3 The model

There are D overlapping cohorts each period, with a period corresponding to one year. Further, all individuals within a given group earn the same income.

[3] Related works that allow for endogenous labour supply in funded pension systems are Bucciol and Beetsma (2010) and Bonenkamp and Westerhout (2010).

[4] Investment allocations determined through optimisation lead to portfolios with unrealistically high shares of equity. This is problematic for simulations aimed at realistically quantifying the consequences of alternative policy scenarios.

3.1 Cohorts and demography

We assume that individuals enter the labour force at their 25^{th} birthday and we denote by the age of a cohort the amount of time since entry into the labor force. The age is indicated by the index $j = 1, ..., D$. Each period there is an exogenous age-dependent probability that an individual will die. An individual who has entered the labour force at the start of period $t - (j - 1) = t - j + 1$ has an exogenous marginal probability $\psi_{j,t-j+1} \in [0, 1]$ of reaching age j at the end of period t conditional on having reached age $j - 1$ at the end of period $t - 1$. This probability is stochastic and exhibits a downward trend, thereby causing an upward trend in the average age of the population. Further, the cohort of newborns (i.e. new entrants into the labour force) in period t is $1 + n_t$ times larger than the cohort of newborns one period earlier, where n_t is also stochastic.

3.2 Skill groups and the income process

Each individual belongs to some skill group i, with $i = 1, ..., I$, and remains in this skill group during its entire working life. A higher value of i corresponds to a higher skill level. The division into skill groups is such that all groups contain an equal number of individuals. Given the macroeconomic circumstances, an individual's income is uniquely determined by the combination of its age and skill level. In other words, all the individuals of a given age in the same skill-group earn the same hourly wage. We allow for skill-related income differences, because individuals below a certain income level cannot build up claims to a second-pillar pension in the Dutch system and, hence, those individuals will be hardly affected by policy changes in the second pillar. A shift from one scenario to another may have substantially different welfare consequences for an individual depending on its skill level. Hence, assuming away intra-generational heterogeneity would not do justice to this important aspect of the Dutch second-pillar system and would prevent us from making realistic individual welfare comparisons.

Individuals work for R years after which they retire and they live for at most D years after entry into the labour force. During their working life, they receive a labour income $y_{i,j,t}$ given by:

$$y_{i,j,t} = e_i s_j z_t, \tag{1}$$

where e_i, $i = 1, ..., I$ is the efficiency index for skill group i, s_j, $j = 1, ..., R$ is a seniority index to allow income for a given skill level to vary with age, and z_t is the exogenous process

$$z_t = (1 + g_t) z_{t-1}, \tag{2}$$

where g_t is its exogenous, stochastic *nominal* growth rate and $z_0 = 1$.

3.3 Social security and accidental bequests

The social security system consists of two pillars that closely resemble the Dutch pension system. The first pillar is a PAYG arrangement organized by the government, which sets the contribution rate such that this pillar is balanced on a period-by-period basis. This pillar pays out a flat benefit to every retiree and is a given fraction of average income, implying that the contribution rate is adjusted in response to shocks. Although this pillar plays a relatively minor role in our analysis, it is a relevant element of our model, because it provides an important share of the income of large groups of retirees. In particular, given the franchise for the second pillar (as explained below), for low-skilled individuals the first pillar is the only or main source of income in retirement. As a result, changes in the second pillar can only have limited welfare consequences for these individuals. The second pillar consists of private pension funds that provide defined benefit nominal pensions.

3.3.1 The first pillar of the social security system

Each period, an individual of working age pays a mandatory contribution $p^F_{i,j,t}$ to the first pillar of the social security system. This contribution depends on its income $y_{i,j,t}$ relative to certain thresholds $\delta^l y_t$ and $\delta^u y_t$:

$$p^F_{i,j,t} = \left\{ \begin{array}{ll} 0 & \text{if } y_{i,j,t} < \delta^l y_t \\ \theta^F_t \left(y_{i,j,t} - \delta^l y_t \right) & \text{if } y_{i,j,t} \in \left[\delta^l y_t, \delta^u y_t \right] \\ \theta^F_t \left(\delta^u y_t - \delta^l y_t \right) & \text{if } y_{i,j,t} > \delta^u y_t \end{array} \right\}, \quad j \leq R, \tag{3}$$

where δ^l, δ^u and θ^F_t are policy parameters and $y_t = \sum\limits_{j=1}^{R} \frac{N_{j,t}}{I} \sum\limits_{i=1}^{I} y_{i,j,t} / \sum\limits_{j=1}^{R} N_{j,t}$ is average income. In period t the benefit received by an individual retiree is a fraction ρ^F of average income:

$$b^F_t = \rho^F y_t. \tag{4}$$

Each period the contribution rate θ^F_t is adjusted such that aggregate contributions into the first pillar equal aggregate first-pillar benefits. Notice that someone on an income lower than $\delta^l y_t$ pays no contribution, but still receives the same benefit as someone with a high income.

3.3.2 The second pillar of the social security system

Each period, a worker pays a mandatory contribution $p^S_{i,j,t}$ to the second pillar if its income exceeds the franchise income level λy_t, where parameter λ denotes the franchise as a share of average income. Specifically,

$$p^S_{i,j,t} = \theta^S_t \max \left\{ 0, y_{i,j,t} - \lambda y_t \right\}, \quad j \leq R, \tag{5}$$

where θ^S_t is a policy parameter, which we assume to be capped at a maximum value of $\theta^{S,\max} > 0$. The contract underlying a second-pillar pension arrangement in the Netherlands generally imposes a cap on the contribution rate and we include this feature into the model.

An individual from skill group i of cohort j receives a second-pillar pension benefit linked to his entire wage history given by:

$$b^S_{i,j,t} = M_{i,j,t}, \qquad j > R, \tag{6}$$

where $M_{i,j,t}$ is the "stock of nominal pension rights" accumulated by the end of period t. It is the annual benefit in euros that the retiree receives each year during retirement, as long as this number is not revised through indexation or a reduction by writing off existing rights.[5] Variable $M_{i,j,t}$ is a stock variable that increases with each additional year of work the individual has provided. At the end of period t it is given by:

$$M_{i,j,t} = \left\{ \begin{array}{ll} (1 - m_t) \left\{ \begin{array}{c} (1 + \omega_{i,j,t}) M_{i,j-1,t-1} \\ +\mu \max \left\{ 0, y_{i,j,t} - \lambda y_t \right\} \end{array} \right\}, & j \leq R \\ (1 - m_t)(1 + \omega_{i,j,t}) M_{i,j-1,t-1}, & j > R \end{array} \right\}, \tag{7}$$

where parameter μ is the annual accrual rate and parameter $\omega_{i,j,t}$ is the rate of indexation of nominal rights. It will depend on the financial position of the pension fund, as we will detail below, and it is also allowed to be potentially cohort- and skill-group specific . Further, $m_t > 0$ is a

[5] For example, someone of age 35 who has accumulated 2000 euros of nominal rights, would, if he were to stop working now and in the absence of indexation or a reduction, receive 2000 euros each year as of his 65th birthday.

proportional reduction in nominal rights that may be applied when the funding ratio is so low that restoration is no longer possible using other instruments, while $m_t < 0$ when earlier reductions are undone. We assume that $m_t > 0$ only when $\omega_{i,j,t} = 0$. Each individual enters the labour market with zero nominal claims ($M_{i,0,t-j} = 0$ for any i and t). In contrast to the first-pillar pension benefit, the second-pillar benefit depends on both the cohort and skill level of the individual.

Given the accrual rate μ and franchise share λ, the choice of the fund's policy parameters θ_t^S, $\omega_{i,j,t}$ and m_t depends on the level of the nominal funding ratio

$$F_t = \frac{A_t}{L_t}, \tag{8}$$

where A_t and L_t are the values of the fund's assets, respectively liabilities. At the end of period t the fund's assets are aggregate contributions in period t *minus* total benefits paid out in period t *plus* the assets at the end of period $t-1$ grossed up by their return in the financial markets:

$$A_t = \left(\sum_{j=1}^{R} \frac{N_{j,t}}{I} \sum_{i=1}^{I} p_{i,j,t}^S - \sum_{j=R+1}^{D} \frac{N_{j,t}}{I} \sum_{i=1}^{I} b_{i,j,t}^S \right) + \left(1 + r_t^f\right) A_{t-1}, \tag{9}$$

where

$$1 + r_t^f = (1 - z^e)\left(1 + r_t^{lb}\right) + z^e \left(1 + r_t^e\right), \tag{10}$$

where r_t^f is the average nominal return on the fund's assets in period $t-1$, r_t^{lb} is the return on long-term bonds and r_t^e the return on equities. All asset returns are exogenously determined on the international financial markets, in line with the situation of the Netherlands being a small open economy operating under perfect capital mobility. Further, an exogenous share z^e of the fund's value is invested in equities and the remainder in long-term nominal bonds. Actual data for Dutch pension funds show a rather stable composition over the years, which may point to pension funds aiming at stable targets for the various asset categories. For this reason we assume that z^e is constant.

The long-term bonds held by the pension fund always have a 10-year maturity. Therefore, at the end of each year bonds of 9-year maturity are sold for new 10-year bonds. The online appendix shows that

$$r_t^{lb} = \frac{\left(1 + r_{10,t-1}^b\right)^{10}}{\left(1 + r_{9,t}^b\right)^9} - 1,$$

where $r_{10,t-1}^b$ ($r_{9,t}^b$) is the yield on a 10-year (9-year) zero coupon bond in year $t-1$ (year t).

The fund's liabilities are the sum of the present values of current and future rights *already accumulated* by the cohorts currently alive:

$$L_t = \sum_{j=1}^{D} \frac{N_{j,t}}{I} \sum_{i=1}^{I} L_{i,j,t}. \tag{11}$$

where $L_{i,j,t}$ is the liability to the cohort of age j and skill level i, which is computed as the discounted sum of the projected future nominal benefits based on the current stock of nominal rights. Discounting takes place against a term structure of annual nominal interest rates $\{r_{k,t}\}_{k=1}^D$. Hence,

$$L_{i,j,t}=\left\{\begin{array}{ll} E_t\left[\sum_{l=R+1-j}^{D-j}\left(\prod_{k=1}^{l}\psi_{j+k,t-j+1}\right)\frac{1}{(1+r_{l,t})^l}M_{i,j,t}\right], & \text{if } j\leq R \\ E_t\left[\sum_{l=0}^{D-j}\left(\prod_{k=1}^{l}\psi_{j+k,t-j+1}\right)\frac{1}{(1+r_{l,t})^l}M_{i,j,t}\right], & \text{if } j>R \end{array}\right\}. \tag{12}$$

When $j \leq R$, we discount all future benefits to the current year t, but of course they will only be paid out once individuals have retired. Crucially, in the Netherlands the computation of the liabilities excludes any *future* indexation. Hence, pension funds that aim at maintaining the purchasing power of the accumulated rights need to maintain a funding ratio that is substantially above 100%.

3.3.3 Accidental bequests

The only role of accidental bequests in the model is to ensure that resources do not "disappear" because people die. The government collects all the financial assets from those who die and redistributes them through equal transfers to all those who are alive.

3.4 The individual decision problem

Each period individuals choose nominal consumption $c_{i,j,t}$. The state variables are assets $a_{i,j,t}$ and the income process z_t. The individual's value function is:

$$V_{i,j,t}\left(a_{i,j,t}, z_t\right)=\max_{c_{i,j,t}}\left\{u\left(\widetilde{c}_{i,j,t}\right)+\beta\psi_{j+1,t-j+1}E_t\left[V_{i,j+1,t+1}\left(a_{i,j+1,t+1}, z_{t+1}\right)\right]\right\},$$

subject to

$$a_{i,j+1,t+1}=\left(1+r_{j,t+1}\right)\left(a_{i,j,t}-c_{i,j,t}+\widetilde{y}_{i,j,t}\right),$$

where the period utility function $u\left(\widetilde{c}_{i,j,t}\right)$ is given by

$$u\left(\widetilde{c}_{i,j,t}\right)=\frac{1}{1-\gamma}\widetilde{c}_{i,j,t}^{1-\gamma},$$

where γ is the coefficient of relative risk aversion and $\widetilde{c}_{i,j,t}$ is *real* consumption,

$$\widetilde{c}_{i,j,t}=\frac{c_{i,j,t}}{\prod_{s=1}^{t}\left(1+\pi_s\right)},$$

where π_t is the rate of price inflation in period t. Further, $\widetilde{y}_{i,j,t}$ is total income net of contributions:

$$\widetilde{y}_{i,j,t}=\left\{\begin{array}{ll} y_{i,j,t}+h_t-p_{i,j,t}^F-p_{i,j,t}^S, & \text{if } j\leq R \\ b_t^F+b_{i,j,t}^S+h_t, & \text{if } j>R \end{array}\right\},$$

where h_t is the accidental bequest, while the portfolio rate of return depends on the age-specific share invested in equities, x_j:

$$1+r_{j,t+1}=\left(1-x_j\right)\left(1+r_{t+1}^{sb}\right)+x_j\left(1+r_{t+1}^{e}\right),$$

where a share $\left(1-x_j\right)$ is invested in one-year bonds against a return r_{t+1}^{sb}.

3.5 The shocks

The estimation of the shock processes is described in detail in the online appendix. Here, we provide only a brief description. There are only aggregate shocks in the model. The menu of shocks consists of demographic shocks, shocks to the income growth rate and the inflation rate, which together detemine productivity shocks, and financial market shocks. All these shocks are collected in the vector $\zeta_t = \left[\epsilon_t^n, \epsilon_t^\psi, \epsilon_t^g, \epsilon_t^\pi, \epsilon_t^e, \epsilon_t^{sb}, \epsilon_{2,t}^b, ..., \epsilon_{D,t}^b\right]$ with elements

- ϵ_t^n: shock to the newborn cohort growth rate, n_t.
- ϵ_t^ψ: shock to the set of survival probabilities, $\left\{\psi_{j,t-j+1}\right\}_{j=1}^D$.
- ϵ_t^g: shock to the nominal income growth rate, g_t.
- ϵ_t^π: shock to the inflation rate, π_t.
- ϵ_t^e: shock to the nominal equity return, r_t^e.
- ϵ_t^{sb}: shock to the one-year "short-term" bond return, r_t^{sb}.
- $\epsilon_{k,t}^b, k = 2, ..., D$: shock to the nominal bond return at maturity k, $r_{k,t}^b$.

All these shocks affect the funding ratio, while only demographic shocks affect the first-pillar of the pension system. In response to the shocks the parameters of the pension system may need to be adjusted to restore the balance in the first pillar and to maintain sustainability of the second pillar.

Each demographic shock is distributed independently of all the other shocks. The growth rate n_t of the newborn cohort depends on deterministic and random components:

$$n_t = n + \epsilon_t^n,$$

where n is the mean and ϵ_t^n the innovation at time t, which follows an AR(1) process. The survival probabilities evolve according to a Lee-Carter (1992) model. We allow the shocks to the inflation rate, the nominal income growth, the one-year bond return and the equity return to be correlated with each other and over time. These variables feature the following multivariate process:

$$\begin{pmatrix} \pi_t \\ g_t \\ r_t^{sb} \\ r_t^e \end{pmatrix} = \begin{pmatrix} \pi \\ g \\ r^{sb} \\ r^e \end{pmatrix} + \begin{pmatrix} \epsilon_t^\pi \\ \epsilon_t^g \\ \epsilon_t^{sb} \\ \epsilon_t^e \end{pmatrix}, \tag{13}$$

with means $\left(\pi, g, r^{sb}, r^e\right)'$ and innovations $\left(\epsilon_t^\pi, \epsilon_t^g, \epsilon_t^{sb}, \epsilon_t^e\right)'$ for year t that follow a VAR(1) process,

$$\begin{pmatrix} \epsilon_t^\pi \\ \epsilon_t^g \\ \epsilon_t^{sb} \\ \epsilon_t^e \end{pmatrix} = \mathbf{B} \begin{pmatrix} \epsilon_{t-1}^\pi \\ \epsilon_{t-1}^g \\ \epsilon_{t-1}^{sb} \\ \epsilon_{t-1}^e \end{pmatrix} + \begin{pmatrix} \eta_t^\pi \\ \eta_t^g \\ \eta_t^{sb} \\ \eta_t^e \end{pmatrix}, \quad \begin{pmatrix} \eta_t^\pi \\ \eta_t^g \\ \eta_t^{sb} \\ \eta_t^e \end{pmatrix} \tilde{} N\left(\mathbf{0}, \Sigma_f\right). \tag{14}$$

Hence, our shocks consist of a deterministic component, which is a linear combination of previous-year shocks, and a purely random component, given by realizations from i.i.d. innovations.

The yield curve is constructed by setting the return $r_{1,t}^b$ at the one-year maturity at r_t^{sb} and the returns at higher maturities $k \geq 2$ equal to the sum of the one-year return r_t^{sb} plus the excess of the return at maturity k relative to the one-year return, $\widetilde{r}_{k,t}^b$, which is simulated on the basis of an estimated vector autoregressive distributed lag (VADL) process with lag 1 for $\widetilde{r}_{k,t}^b$, $k = 2, ..., D$.

3.6 Welfare comparisons between policy scenarios

We compare welfare between the two scenarios A (our benchmark scenario) and B (the alternative) at the start of period $t = 1$ for individuals alive at that moment and at the start of their first year of life for individuals that are born later. The individual welfare comparison is based on the equivalent variation $EV_{i,j,t}$, which for skill group i of cohort j we define as the amount of wealth that should be added in scenario A to obtain the same utility as in scenario B. That is, for those alive at the start of $t = 1$, we define $EV_{i,j,1}$ by the equation

$$V^A_{i,j,1}\left(a_{i,j,1} + EV_{i,j,1}, z_1\right) = V^B_{i,j,1},$$

where $\left(a_{i,j,1} + EV_{i,j,1}, z_1\right)$ are the arguments of the value function, that is the level of assets plus the equivalent variation and the level of the income process at the start of $t = 1$, while for those born at the start of $t \geq 2$, we define $EV_{i,1,t}$ by the equation

$$V^A_{i,1,t}\left(a_{i,1,t} + EV_{i,1,t}, z_t\right) = V^B_{i,1,t},$$

where $a_{i,1,t} + EV_{i,1,t}$ is the initial level of assets at birth plus the equivalent variation and z_t is the level of the income process at the start of t. The equivalent variations for various groups can be added up to produce an aggregate welfare comparison at $t = 1$:

$$EV = \left(\sum_{j=1}^{D} N_{j,1}\frac{1}{I}\sum_{i=1}^{I} EV_{i,j,1}\right) + \left(\sum_{k=2}^{251}\frac{N_{1,k}}{\left(\left(1+g\right)\left(1+n\right)\right)^{k-1}}\frac{1}{I}\sum_{i=1}^{I} EV_{i,1,k}\right) \tag{15}$$

This expression sums the equivalent variations of all individuals alive at time $t = 1$ and the equivalent variations at birth ($j = 1$) of all future-born individuals discounted at the rate $\left(1+g\right)\left(1+n\right) - 1$. We choose this particular discount rate, because $\frac{1}{I}\sum\limits_{i=1}^{I} EV_{i,1,k}$ grows on average at the same rate g as nominal income and each new generation $N_{1,k}$ in period k is on average $(1 + n)$ times the size of the previous young generation. Hence, the weight of future-born generations in the overall measure EV is made comparable to the weight of the currently-alive generations.

As an alternative aggregate measure we take the percentage of those alive at $t = 1$ in favour of the alternative policy:

$$PER = \sum_{j=1}^{D} N_{j,1}\frac{1}{I}\sum_{i=1}^{I} \mathbf{1}_{\left\{V^B_{i,j,1} > V^A_{i,j,1}\right\}}$$

where $1_{\{.\}}$ is an indicator function that equals unity if the condition within the curly parentheses holds, and 0 otherwise.

4 The policy rule

The government automatically adjusts the contribution rate $\theta^F_t \in (0, 1)$ to maintain a balanced first pillar of the pension system. On average, this contribution rate increases over the years along with the ageing of the population. More policy options are available to affect the funding ratio of the second pillar. There are three key parameters, of which the period $t + 1$ values are determined on the basis of the funding ratio F_t: the contribution rate $\theta^S_{t+1} \in \left[0, \theta^{S,\max}\right]$, the indexation parameter $\kappa_{t+1} \geq 0$ and, as a last resort, a reduction $(m_{t+1} > 0)$ or restoration $(m_{t+1} < 0)$ of the nominal pension rights. Parameter $\kappa_{t+1} \geq 0$ captures the average (across the population) degree of indexation to nominal wage growth. The board of the pension fund selects the contribution rate and the indexation parameter, but can only reduce nominal rights under special circumstances, as described below.

We define three threshold values for the funding ratio, $\xi^l = 1.05 < \xi^m < \xi^u = 1.50$, where $\xi^m = 1.25$.[6] When the funding ratio F_t exceeds ξ^m, after restoring possible earlier cuts in nominal rights, the fund's Board sets the contribution rate θ^S_{t+1} at its initial level θ^S_1 and the indexation parameter to $\kappa_{t+1} = \frac{2}{3} + \frac{1}{3}\frac{F_t - \xi^m}{\xi^u - \xi^m}$. Hence, indexation in $t+1$ increases linearly in F_t and is complete (equal to 1) at ξ^u. Notice that, due to population ageing, the contribution rate θ^S_1 will be increasingly insufficient to finance aggregate benefits. The result is that indexation will on average be falling over time. Moreover, notice that indexation exceeds unity when the funding ratio exceeds ξ^u. This way the funding ratio is stabilised from above.

As mandated by the Dutch Pension Law, when the funding ratio falls below ξ^m, but remains above ξ^l, a long-term restoration plan is started, while when it falls below ξ^l, a short-term restoration plan is started. The latter situation is termed "underfunding". The long-term restoration plan requires a restoration of the funding ratio to at least ξ^m in at most $K^l = 15$ years (ignoring possible future shocks), while the short-term restoration plan requires restoration to at least ξ^l in at most $K^s = 5$ years (ignoring possible future shocks). Hence, policy aims at keeping the funding ratio above ξ^m. This is achieved by following an "indexation policy", of which the primary instrument is the parameter $\kappa_{t+1} \geq 0$. Specifically, within each year of the restoration plan indexation is set as follows:

$$\kappa_{t+1} = \begin{cases} 0, & \text{if } F_t \leq \xi^l \\ \frac{2}{3}\frac{F_t - \xi^l}{\xi^m - \xi^l}, & \text{if } F_t \in \left(\xi^l, \xi^m\right] \end{cases} . \tag{16}$$

The projected funding ratio is then computed (assuming further shocks are absent) and compared with its target prescribed by the restoration plan. If necessary, the contribution rate θ^S_t is raised up to at most the maximum $\theta^{S,\max}$. Conform Dutch Law, when there is underfunding ($F_t < \xi^l$) and the adjustments in the indexation parameter and the contribution rate are jointly insufficient, nominal rights are scaled back by whatever amount is necessary to eliminate the underfunding within the allowed restoration period. In the case of a long-term restoration plan, nominal rights remain untouched.

The indexation parameter κ_t is identical for the entire population, but the actual level of indexation received by each individual may differ with the policy adopted. The growth rate $\omega_{i,j,t}$ of pension rights of an individual with skill level i and age j in period t is given by:

$$\omega_{i,j,t} = g\kappa + \left[\max\{0, g_t\kappa_t\} - g\kappa\right] f(i,j), \tag{17}$$

where $[\max\{0, g_t\kappa_t\} - g\kappa]$ measures the deviation of actual indexation from its target $g\kappa$. We set the target indexation rate at $\kappa = \frac{2}{3}$, implying that the target is to have indexation cover price inflation on average.[7] If nominal income growth is relatively high, such that $g_t\kappa_t > g\kappa$ and $f(i,j) > 0$, then indexation exceeds target indexation. The function $f(i,j)$ allows the pension fund to allocate more of less of the deviation of actual indexation $g_t\kappa_t$ from target indexation $g\kappa$ to specific skill and age groups. The idea is that some groups might have less capacity to bear the risk associated with indexation, while other groups may have more capacity in this regard. Obviously, if the fund is supposed to reduce indexation uncertainty for some groups, then for other groups uncertainty will be raised. Hence, we may have $f(i,j) < 1$ for some groups and $f(i,j) > 1$ for other groups.

[6] The lower threshold is the official one imposed by the supervisors in the Netherlands in order to protect the nominal pension rights. The upper threshold corresponds to the one at which many funds start providing full indexation to nominal wages, hence the one at which the value of the pension rights grows in line with the overall welfare level.

[7] In our calibration average price growth is 2/3 of average nominal wage growth. Of course, shocks may alter this ratio.

We consider a baseline of "uniform" indexation, in which indexation is the same for all the fund participants, and three schemes in which indexation is made contingent. Under "status-contingent" indexation, retirees always receive a certain indexation rate (corresponding to full price indexation on average), while all workers receive an identical, but uncertain indexation rate. Under "age-contingent" indexation, the uncertainty about indexation falls with age. Under "income-contingent" indexation, the uncertainty about indexation is smaller when the present value of second-pillar pension income is larger relative to the present value of income from all sources.

(1) Baseline: uniform indexation

In any given year, indexation is identical for all the individuals. That is,

$$f(i,j) = 1.$$

We take this as the benchmark case. It is also the most common situation in the Netherlands.

(2) Status-contingent indexation

For retirees the indexation rate is constant over time, whatever is the size of the funding ratio. By contrast, all the workers are subject to identical uncertainty about the indexation rate. Specially,

$$f(i,j) = \begin{cases} \alpha^s & j \leq R \\ 0 & j > R \end{cases},$$

where $\alpha^s > 0$. This is the simplest possible variation on the benchmark of uniform indexation. The rationale for this scheme is that retirees have relatively little room for responding to shocks, because their expected remaining life expectancy is relatively low. Fixing the indexation rate may reduce their consumption uncertainty.

(3) Age-contingent indexation

All individuals are subject to uncertainty about actual indexation relative to target indexation. However, the uncertainty shrinks with age. The rationale for this scheme is analogous to that for the previous scheme: the older a person gets, the shorter its expected time to death and the larger will be the effect of a given shock on its yearly consumption flow. Specifically, we impose that

$$f(i,j) = \alpha^a (D-j),$$

where $\alpha^a > 0$.

(4) Income-contingent indexation

Indexation is subject to uncertainty for all individuals, but uncertainty is negatively related to the present value of second-pillar pension income relative to the present value of income from all sources (labour, accidental bequests and first- and second-pillar pension benefits) at time $t = 1$.[8] In particular, for an age j and skill group i individual, the present value of second-pillar pension income (henceforth termed "second-pillar pension wealth") is given by:

$$PV^S_{i,j,1} = E_1\left[\sum_{l=\max\{0,R+1-j\}}^{D-j} \frac{1}{\psi_{j,1-j+1}}\left(\prod_{k=0}^{l}\psi_{j+k,1-j+1}\right)\frac{1}{\left(1+r^b_l\right)^l} b^S_{i,j+l,1+l}\right].$$

[8] We take the values at the beginning of the simulation to avoid the circularity problem of having indexation rates that depend on the rescaling function, which in turn depends on indexation rates. The initial indexation rate is known and is based on the initial funding ratio according to (16).

Notice that this present value takes into account the uncertainty around death age (through the survival probabilities), and discounts future benefits using bond yield returns, as is common practice in this literature (see, e.g., Bodie et al., 1992, or Pelizzon and Weber, 2009). To avoid complicating matters too much we discount expected future benefits against the average yield curve $r_l^b, l = 1, ..., D$ (see the online appendix). We define "first-pillar pension wealth" analogously as:

$$PV_{i,j,1}^{F} = E_1 \left[\sum_{l=\max\{0,R+1-j\}}^{D-j} \frac{1}{\psi_{j,1-j+1}} \left(\prod_{k=0}^{l} \psi_{j+k,1-j+1} \right) \frac{1}{\left(1+r_l^b\right)^l} b_{i,j+l,1+l}^{F} \right]$$

and "labour income wealth" as the present value of future labour income realisations (plus accidental bequests and minus pension contributions):

$$PV_{i,j,1}^{Y} = \begin{cases} E_1 \left[\sum\limits_{l=0}^{R-j} \frac{1}{\psi_{j,1-j+1}} \left(\prod\limits_{k=0}^{l} \psi_{j+k,1-j+1} \right) \frac{1}{\left(1+r_l^b\right)^l} \widetilde{y}_{i,j+l,1+l} \right], & j \leq R \\ 0, & j > R \end{cases} .$$

We define "human wealth" as the sum of labour income wealth, first-pillar pension wealth and second-pillar pension wealth. Finally, we define $PW_{i,j,1}^{S}$ as the ratio between second-pillar wealth and human wealth:

$$PW_{i,j,1}^{S} = \frac{PV_{i,j,1}^{S}}{PV_{i,j,1}^{Y} + PV_{i,j,1}^{F} + PV_{i,j,1}^{S}}.$$

The rescaling function for indexation is:

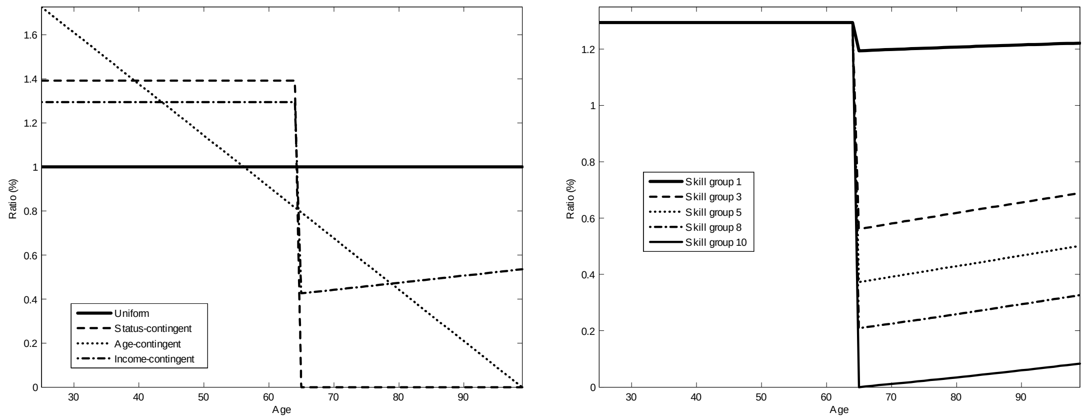
$$f(i,j) = \alpha^{i} \left(\max_{i,j} \left\{ PW_{i,j,1}^{S} \right\} - PW_{i,j,1}^{S} \right),$$

where $\alpha^i > 0$. The idea is that those with a relatively larger share of their human wealth in the second pension pillar face less uncertainty about the deviation of actual indexation of their second-pillar benefits from its target level.

In the above schedules, the rescaling function $f(i,j)$ depends only on one parameter that we calibrate so as to produce a funding ratio similar to that under uniform indexation. In particular, the parameter is always calibrated in such a way that applying the rescaling function does not change the total amount of nominal rights:

$$\sum_{j=1}^{D} \frac{N_{j,1}}{I} \sum_{i=1}^{I} M_{i,j,1} f(i,j) = \sum_{j=1}^{D} \frac{N_{j,1}}{I} \sum_{i=1}^{I} M_{i,j,1}. \tag{18}$$

Figure 1 shows the profile of the indexation schedules. In general, contingent-indexation policies reduce the difference between actual and target indexation rates for older households. For income-contingent indexation, the deviations are also smaller for richer households.



a. All schemes **b.** Income-contingent

Figure 1. Rescaling functions

5 Calibration and simulation details

5.1 Benchmark calibration

The economically active life of an individual starts at his 25^{th} birthday. He then works for $R = 40$ years. Individuals live for at most $D = 75$ years after entry into the labour force. We set the discount factor at $\beta = 0.96$, a rather common number in the macroeconomic literature (e.g., see Imrohoroglu, 1989, or Krebs, 2007), and the coefficient of relative risk aversion at $\gamma = 3$, which accords quite well with the assumed risk aversion in much of the macroeconomic literature (see, e.g., Imrohoroglu *et al.*, 2003) as well as estimates at the individual level (for example, Gertner, 1993, and Beetsma and Schotman, 2001). The efficiency index $\{e_i\}_{i=1}^{I}$ is based on the income deciles for the Netherlands for the year 2000 reported by the World Income Inequality Database (WIID, version 2.0c, May 2008). We normalise the index such that it has an average value of unity. The seniority index $\{s_j\}_{j=1}^{I}$ uses the average of Hansen's (1993) estimation of median wage rates by age group. We take the average between males and females and interpolate the data using the spline method. The composition of individual investment portfolios is exogenous given and the shares $x_j, j = 1, ..., D$ invested in equity are based on the figures reported by age in Table 9 of Alessie et al. (2001).

The social security parameters are based on those for the Dutch pension system. The maximum income assessable for contributions to the first pillar is $3,850.40$ euros per month in 2008, as reported by the Dutch Tax Office ("Belastingdienst"). Therefore, we set $\delta^u = 1.10$, which is roughly equal to $3,850.40 * 12/42,403$, where $42,403$ euros is our imputation for the economy's average income for 2008.[9] Further, we set $\delta^l = 0.4685$, so as to generate an initial contribution rate of $\theta_1^F = 12.77\%$, identical to the initial second-pillar contribution rate, $\theta_1^F = \theta_1^S$, which we calculate on the assumption that aggregate contributions and benefits at time 1 are equal in the absence of shocks. This value of θ_1^S is close to the actual value in the Netherlands. We cap θ_t^S at $\theta^{S,\max} = 25\%$. Finally, we set the benefit scale factor at $\rho^F = 0.2435$.

We assume that the pension fund always invests half of its portfolio in equities, hence we set $z^e = 0.50$ for any level of the funding ratio F_t. This corresponds roughly to the balance sheet

[9] Eurostat's most recent figure on average Dutch income refers to the year 2005. The same source also provides minimum income until the year 2008. Exploiting the correlation between average and minimum income, we run an OLS regression of average income on minimum income. As a result, we predict the average income for year 2008 to be $42,403$ euros.

average for Dutch pension funds over the past 10 years (DNB, 2009). Because realised returns on bond and equity investments will generally differ, at the end of each period the fund reshuffles its portfolio such that at the start of the next period the equity share is again $z^e = 0.50$. We set the pension accrual rate μ to 2% and the franchise parameter λ to 0.381.[10]

We calibrate ρ^F and λ so as to generate realistic replacement rates at retirement date that are on average equal to 30.40% for the first pillar and 37.60% for the second pillar. The first-pillar replacement rate is decreasing in the skill level and ranges from an average of 12.06% for the highest skill group to 63.33% for the lowest skill group. By contrast, the second-pillar replacement rate is higher for more skilled groups and ranges from an average of 3.78% to an average of 56.64%. The overall replacement rate of the two pillars together is higher for more skilled groups, but differences are small and the average replacement rates range from 67.11% to 68.70%.

We choose initial assets so as to generate an initial funding ratio of 1.15.[11] Consistent with (16), we set $\kappa_1 = \frac{1}{3}$.

The deterministic component of the growth rate of the newborn cohort, $n = 0.2063\%$, is the average annual growth rate based on the estimation of an order-one moving-average model of the annual number of births in the Netherlands over the period $1906 - 2005$ (source is the Human Mortality Database, 2009). Our calibration of the survival probabilities is based on the estimation of a Lee and Carter (1992) model using Dutch period survival probabilities.[12] The combination of survival probabilities and birth rates determines the size of each cohort. The starting value of the old-age dependency ratio (i.e., the ratio of retirees over workers) is 20.99%, in line with the OECD (2009) figure for the Netherlands in 2005.

The averages we calibrate for price inflation, nominal income growth and the bond and equity returns are reported in the final four lines of Table 1. We loosely follow the literature (see, e.g., Brennan and Xia, 2002, and van Ewijk et al., 2006) and set average annual inflation at $\pi = 2\%$, average annual nominal income growth at $g = 3\%$ (which corresponds to average real productivity growth of 1% per annum) and the average one-year bond yield at $r^{sb} = 3\%$. Finally, we set the average annual equity return at $r^e = 6\%$ in order to generate a funding ratio that is stable over time in the absence of shocks and policy parameter changes.

[10] The maximum accrual rate that is fiscally facilitated in the Netherlands is 2.25% for pension arrangements based on the average wage over the working life and 2% for arrangements linked to the final wage.

[11] Initial assets A_0 are 1.13 times aggregate income in the economy. This is quite comparable with second-pillar pension assets in the Netherlands which are on the order of $120 - 130\%$ of GDP.

[12] With these probabilities, the average population age is initially set to 48.21 years and the remaining life expectancy to 33.54 years, as opposed to 33.23 years for a 48-year old in 2005 according to the actual data (see Human Mortality Database, 2009).

Table 1. Benchmark calibration of the exogenous parameters

Symbol	Description	Calibration
General setting		
D	Number of cohorts	75
R	Number of working cohorts	40
β	Discount factor	0.96
γ	Relative risk aversion parameter	3
$\{e_i\}_{i=1}^{I}$	Efficiency index	WIID (2008)
$\{s_j\}_{j=1}^{I}$	Seniority index	Hansen (1993)
First pillar pension parameters		
$\left\{\delta^l, \delta^u\right\}$	Income thresholds in the contribution formula	$\{0.469, 1.10\}$
ρ^F	Benefit scale factor	0.2435
Second pillar pension parameters		
z^e	Equity share in fund portfolio	0.5
$\left\{K^S, K^L\right\}$	Restoration periods in years	$\{5, 15\}$
μ	Second-pillar pension accrual rate	0.02
λ	Franchise share	0.381
F_1	Initial funding ratio	1.15
$\theta^{S,\max}$	Upper bound on contribution rate	0.25
Annual averages of the random variables		
π	Inflation rate	2%
g	Nominal income growth rate	3%
r^{sb}	One-year nominal bond return	3%
r^e	Equity return	6%

5.2 Simulation details

We draw $Q = 1,000$ sequences of vectors of unexpected shocks over $2D - 1 + 250 = 399$ years, simulated from the joint distribution of all the shocks. Our welfare calculation is based on the economy as of the D^{th} year in the simulation. Hence, we track only the welfare of the cohorts that are alive in that year, implying that those that die earlier are ignored, and we track the welfare of cohorts born later, the latest one dying in the final period of the simulation. In other words, the total number of years of one simulation run equals the time distance between the birth of the oldest cohort that we track and the complete extinction of the last unborn cohort that we track. In each period there are D overlapping generations. For convenience, in the simulation we relabel the D^{th} year as $t = 1$. The first $D-1$ years of our simulation are needed to generate a distribution of the assets across the various groups at the start of $t = 1$.

In each simulation run, we set the trends in newborn growth rates and in survival probabilities to zero after $t = 40$, thereby stopping the ageing process after $t = 40$, although the shocks to both processes remain. Hence, also mortality rates at any given age are no longer on a falling trend. For several reasons we stop the ageing process after 40 years . First, we find it hard to imagine that mortality rates continue falling indefinitely. Important common mortal diseases have already been eradicated, while it will become increasingly difficult to treat remaining lethal diseases, in particular also because the share of healthcare in total spending will hit its limit at some moment. Second, some important ageing studies, such as those by the Economic Policy Committee and European Commission (2006) and the United Nations (2009), only project ageing (and its associated costs) up to 2050 (hence 40 years from now). Finally, we want to avoid an ever-growing population as a result of the ageing process.

To allow for a proper comparison of the various indexation schedules, we use the same simulated shock series for each schedule both during the initialisation phase and during the remainder of the simulation run. At the start of the initialisation phase the pension rights of all the individuals are set to zero and during this phase they accumulate pension rights according to (7), while indexation is uniform and applied according to the schedule (16) and (17). Hence, the situation at the start of $t = 1$ is identical for each run under the various indexation schedules. At the start of $t = 1$, the process z_t is rescaled to unity ($z_1 = 1$) and both the nominal pension rights and the assets accumulated through voluntary savings of all the individuals are rescaled by the same factor. Using (11) and (12), we can then compute total pension liabilities at the start of $t = 1$. Because welfare depends on the size of the buffer after the initialisation period in the simulation run, we reset the stock of pension fund assets such that the funding ratio at the start of $t = 1$ equals the desired initial funding ratio, that is 1.15 in the benchmark case. In other words, the assets and liabilities of the pension fund at the start of $t = 1$ are identical across the various indexation schedules. The starting assets of the newborns are zero at the start of $t = 1$, $a_{i,1,1} = 0$.

To obtain the optimal consumption rules we solve the individual decision problem recursively by backward induction using the method of "endogenous gridpoints" (Carroll, 2006). To avoid the curse of dimensionality caused by having state variables for our shocks, we determine the optimal consumption profile in year t under the assumption that the shocks in year $t - 1$ are equal to their average, and in t there are innovations following the VAR(1) process of the shocks in (13). While this is an approximation, what matters mostly for agents' decisions are future assets, which in turn are largely determined by current assets and the wage rate. Existing deviations of shocks from their averages play only a relatively minor role, in particular in the case of financial market shocks for which persistence is small. We approximate the random variable distributions by means of a Gauss-Legendre quadrature method (see Tauchen and Hussey, 1991) and discretise the state space using a grid of 100 points with triple exponential growth.[13] For points that lie outside the state space grid, we use linear extrapolation to derive the optimal rule.

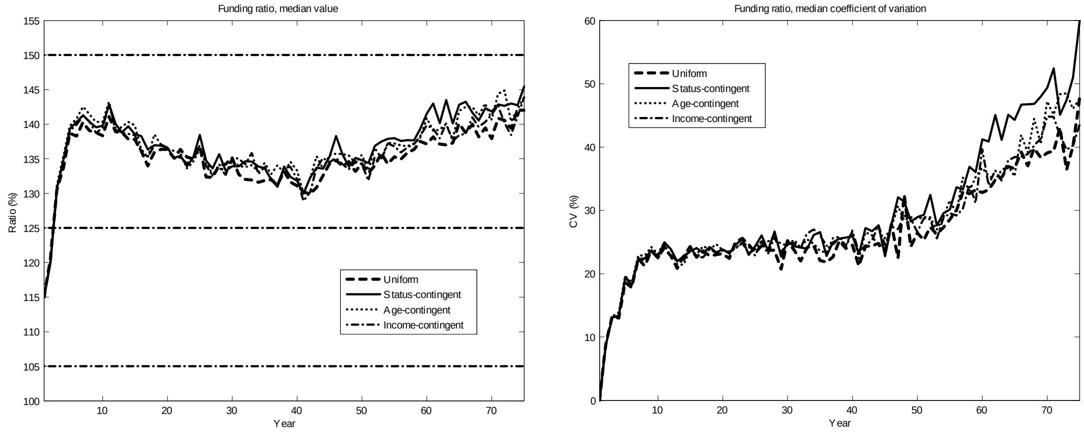
6 Results

6.1 Benchmark analysis

Panel a. of Figure 2 shows the median funding ratio for the various indexation schemes under consideration.[14] In all instances, the median funding ratio is kept well within the $[\xi^m, \xi^u]$ interval and, after the initial couple of years, when the funding ratio restores quickly from a situation of underfunding, there is no clear trend visible. The dispersion in the median funding ratios across the various indexation schemes is rather small. This is also the case for the coefficient of variation of the funding ratio, which is defined as half the interquartile range over its median. It shows an upward trend (see panel b. of Figure 2).

[13] We create an equally-spaced grid of the function $log(1 + log(1 + log(1 + s)))$, where s is the state variable. The grid with "triple exponential growth" applies the transformation $exp(exp(exp(x) - 1) - 1) - 1$ to each point x of the equally-spaced grid. This transformation brings the grid back to the original scale of the state variable, but determines a higher concentration on the low end of possible values. A grid with triple exponential growth is more efficient than an equally-spaced grid as the consumption function is more sensitive to changes at small values of the state variable.

[14] We report the median rather than the average funding ratio, because the former is not affected by the few extreme outcomes in our simulations.



a. Median trend **b.** Coefficient of variation

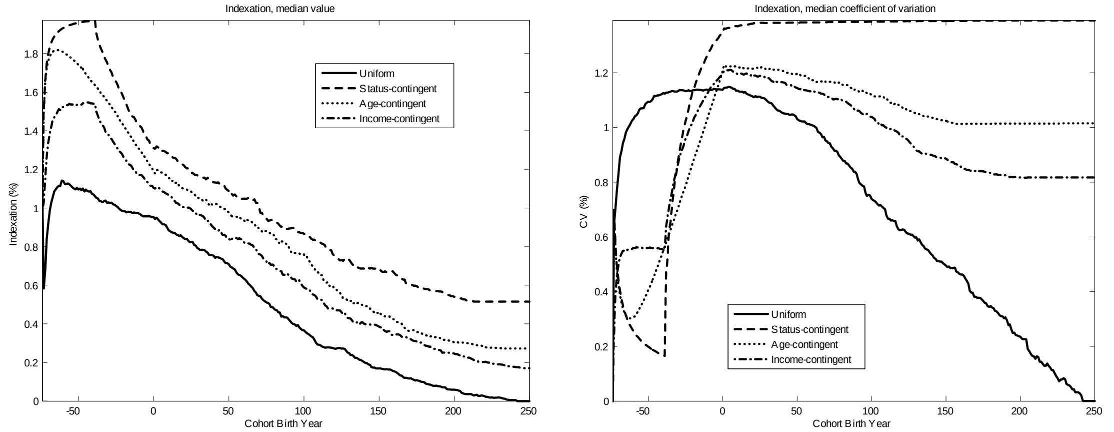
Figure 2. Funding ratio, benchmark case

Table 2 presents summary statistics for the various indexation policies. The statistics associated with the funding ratio and the policy instruments are rather similar across the various cases. The correlations between the value of the assets and liabilities are always rather high, between 60 and 70%, which is a necessity for pension funds that try to limit mismatches between the values of the assets and liabilities. Further, irrespective of the specific indexation scheme, in around 17% of the time the funding ratio lies below $\xi^l = 105\%$. This is substantially more frequent than the 2.5% of time that was foreseen by DNB, but it may quite well be in line with the frequency of underfunding that we have observed over the past decade in the Netherlands. The likelihood that the funding ratio is below $\xi^m = 125\%$ and a long-term restoration plan is needed is always in the range $30 - 35\%$. This likelihood equals the likelihood that one or more of the policy instruments needs to be altered. The likelihood that the indexation rate needs to be adjusted and that this suffices is always around 4%. The likelihood that both the indexation rate and the contribution rate have to be altered and the use of these instruments is sufficient is in the range of $32 - 34\%$. Finally, the likelihood that these instruments are jointly insufficient and pension rights need to be cut is around 0.6%.

Table 2. Funding ratio properties, benchmark case

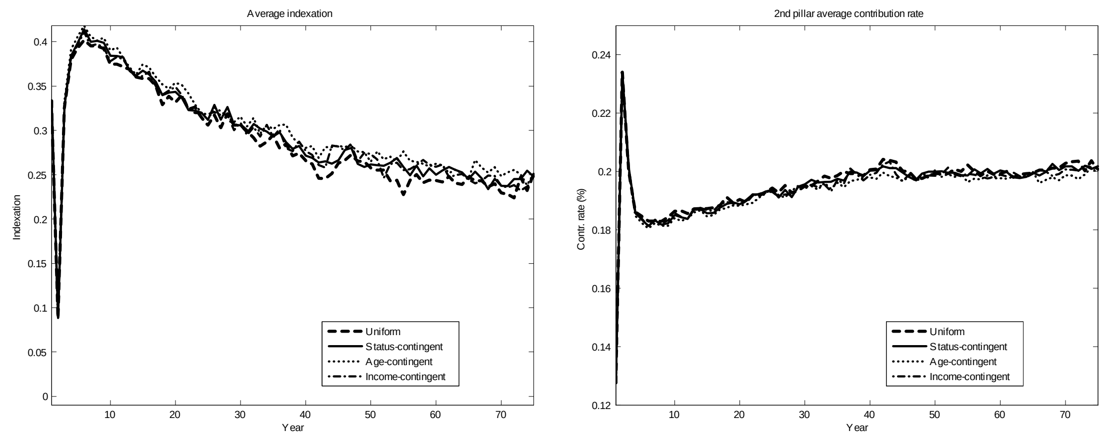
%	Uniform	Status contingent	Age contingent	Income contingent
	Funding ratio volatility (CV=coefficient of variation)			
Median CV	26.534	29.471	28.124	27.415
Median CV, assets	35.254	35.579	35.866	35.337
Median CV, liabilities	47.904	49.534	49.984	48.650
Assets-liabilities correlation	67.051	66.925	63.540	68.963
	Probability of a funding ratio below a given threshold			
Below ξ^l	16.991	16.917	17.131	17.021
Below ξ^m	38.652	37.597	37.669	38.200
Below ξ^u	62.961	61.343	61.547	62.117
Probability of a change in the indexation and contribution rates (with a ratio below ξ^m)				
Only indexation rate	3.839	4.263	4.371	4.192
Both rates is enough	34.176	32.723	32.683	33.365
Both rates is not enough	0.637	0.612	0.616	0.643
	Average policy parameters (standard deviation in parentheses)			
Contribution rate θ_t^S	19.554	19.493	19.360	19.459
	(5.917)	(5.923)	(5.940)	(5.930)
Indexation rate κ_t	28.870	29.601	30.298	29.604
	(31.344)	(31.400)	(31.502)	(31.424)
	% Welfare comparison relative to uniform indexation			
PER	-	34.301	5.278	40.180
EV	-	-0.471	-0.160	-0.489

We observe that the indexation rate on average is around $29 - 30\%$, well below what is needed to preserve the purchasing power of the pension rights. Given the cap on the second-pillar funding rate and the fixed retirement age despite the ageing process, the only way to maintain the long-run sustainability of the second pension pillar is to gradually reduce the indexation rate. Figure 3 shows the average (remaining for those alive at $t = 1$) life-cycle indexation for each cohort in our simulations. On average indexation is around $0.75 - 1\%$, implying that with average inflation of 2%, purchasing power of existing rights shrinks by around $1 - 1.25\%$ on average every year. The average contribution rate (see Figure 4) is always $19\% - 20\%$ of income above franchise, which is about fifty percent above the starting value of the second pillar contribution rate.



a. Median **b.** Coefficient of variation

Figure 3. Average lifetime indexation (% accumulated rights), benchmark



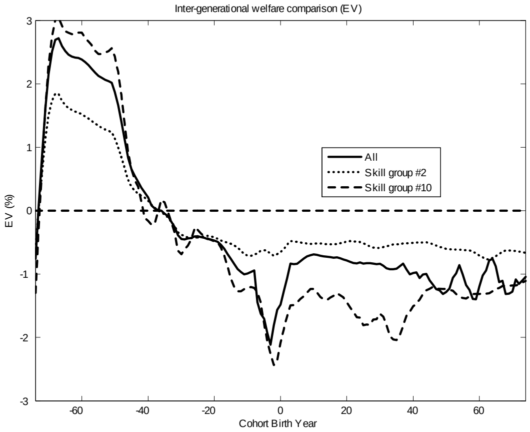
a. Indexation rate **b.** Contribution rate

Figure 4. Average policy parameters, benchmark case

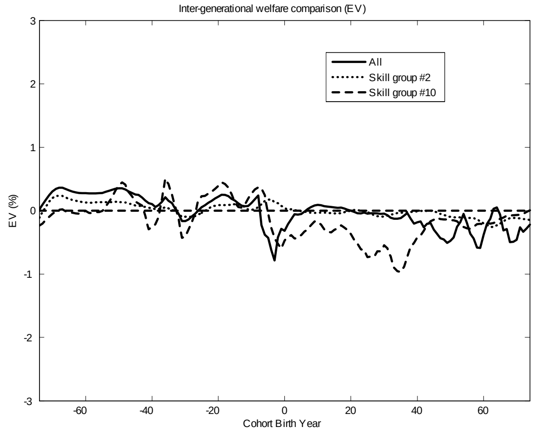
It is of interest to compare the projected increase in the contribution rate with that computed in the Appendix to the Goudswaard-Report (Goudswaard *et al.*, 2010). The Report takes 2009 as the initial year of its simulation and assumes that the initial funding ratio is 105%. Total indexation is a weighted average of nominal wage growth and price inflation with weights 0.65 and 0.35, respectively. Full indexation is given at a funding ratio of 135% or higher and zero indexation at a funding ratio below 100%. If the funding ratio F_t is between 100% and 135%, indexation is proportional with factor $(F_t - 100) / (135 - 100)$. Based on an average nominal portfolio return of 5%, the contribution rate as a share of *total* salary rises from 12.7% in 2009 to 17.2% in 2050 (with a peak of 19.4% in 2025). The increase in the contribution rate is proportionally somewhat less than in our model, in which contribution rates are expressed in terms of income above franchise, while the initial funding ratio in the Goudswaard-Report report is lower than in our benchmark case. The difference is mostly explained by the fact that the return on the pension portfolio is slightly lower in our case (4.5% instead of 5%).

Table 2 also reports a welfare comparison of alternative indexation schemes with the benchmark of uniform indexation. In all instances, uniform indexation is preferred by a majority of those alive in period 1 (as indicated by $PER < 50$). Also, when measured by the aggregate equivalent variation EV, uniform indexation outperforms all the alternatives, although the outperformance is on average relatively small. The value of -0.471% for EV under status-contingent indexation should be interpreted as follows. Status-contingent indexation produces the same welfare as uniform indexation if under status-contingent indexation each generation alive at $t = 1$ gets 0.00471 extra in resources (or 0.471% of their expected initial income), since the income process is normalised to unity at $t = 1$, newborns at $t = 2$ get $0.00471 * (1 + g)$ extra, the newborns at $t = 3$ get $0.00471 * (1 + g)^2$ extra, etcetera.

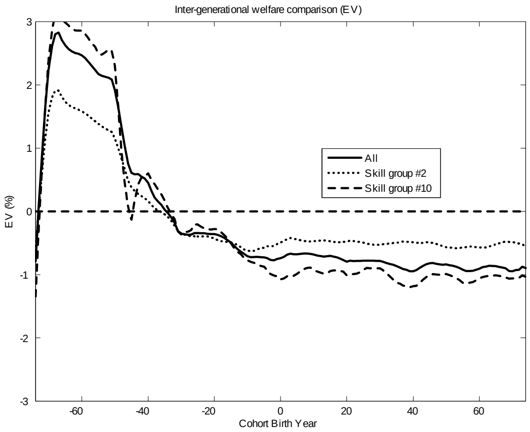
Figure 5 reports the welfare consequences for different cohort-skill combinations of replacing uniform indexation with one of its alternatives. Points above the horizontal axis indicate a welfare gain compared with uniform indexation, and vice versa for points below the horizontal axis. Considering the overall effect of a switch away from uniform indexation, we see that those who are retired at $t = 1$ benefit on average substantially (between 2 and 3% of period $t = 1$ income) from the alternative. For example, with status-contingent indexation, these generations benefit from the higher indexation, aimed at protecting purchasing power, than the indexation they would receive under uniform indexation. The same is the case with age-contingent and income-contingent indexation where the elderly and those for whom second-pillar pension income is relatively important are most protected against a (downward) deviation from target indexation. It is the workers at $t = 1$ and the future born that pay for the benefit enjoyed by the retired. Importantly, by calculating $EV_{i,j,1}^{no\ shocks}$ and $EV_{i,1,t}^{no\ shocks}$ when shocks are absent and subtracting those values from the "overall" effects $EV_{i,j,1}$ and $EV_{i,1,t}$, we obtain the equivalent variations that are purely attributable to the presence of shocks. Hence, these are the gains (or losses, if negative) from better (worse) risk sharing under the alternative to uniform indexation. The risk-sharing effects are relatively small compared to the overall effects, implying that the overall effects are dominated by systematic redistributions among groups of participants. In particular, under any of the alternatives to uniform indexation there is a systematic redistribution from workers and future borns towards those that are retired at $t = 1$.



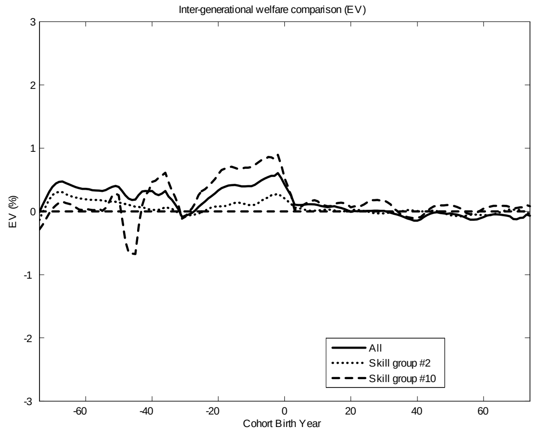
a. Status-contingent, overall effect



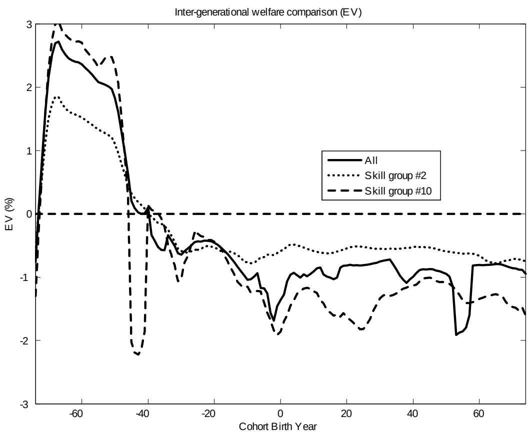
b. Status-contingent, risk sharing effect



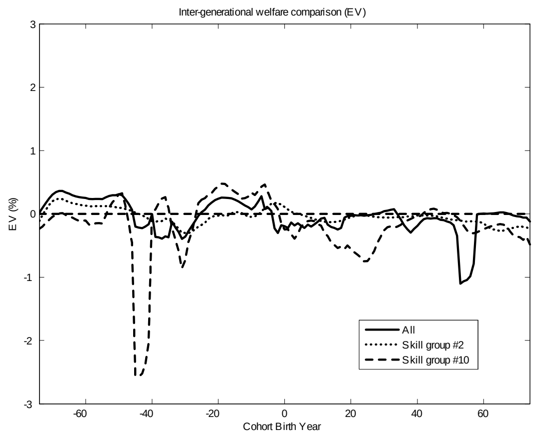
c. Age-contingent, overall effect



d. Age-contingent, risk sharing effect



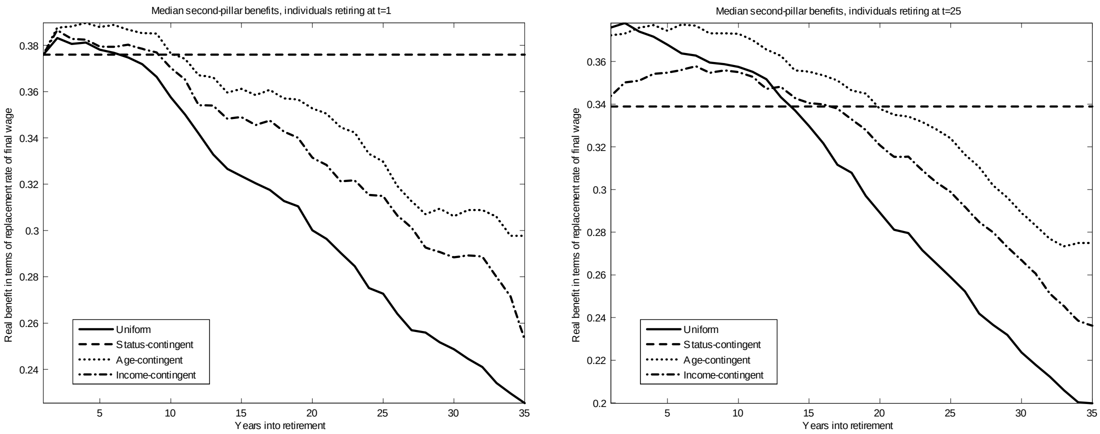
e. Income-contingent, overall effect



f. Income-contingent, risk sharing effect

Figure 5. Welfare comparison (EV), benchmark case

Under any of the arrangements we have considered above, the burden of stabilising the pension buffer is mostly on adjusting the indexation rate. Hence, as we demontrated earlier in Figure 3, the effect of population ageing on the pension buffer is countered by a gradual reduction in the indexation rate. Figure 6 tracks the average real value of the second-pillar pension benefit of someone in skill group 6 who retires at start of period $t = 1$ and someone of the same skill group who retires at the beginning of period $t = 25$. Because individuals in skill group 1 are usually below the franchise level, for most cohorts skill group 6 is the median skill level of those who build build up a pension through the fund. The horizontal axis depicts the number of years into retirement and the vertical axis depicts the replacement rate of the benefit as a share of the final wage. Hence, for someone who retires at the start of period 1 and who has been in retirement for τ years, the real value of the pension benefit expressed in euros of the retirement date is $b^S_{i,j,\tau}/\left[(1+\pi_2)\cdot \ldots \cdot (1+\pi_\tau)\right]$. Obviously, under status contingent indexation, the purchasing power of a given retiree's benefit is expected to remain constant until this person dies. However, due to lagging indexation during working life someone who enters retirement at a later date will receive a lower benefit in terms of the final wage. Hence, the replacement rate falls from 38% for someone who retires at the start of the simulation to slightly more than 34% for someone who enters retirement 24 years later. Under the three other arrangements, uniform, age-contingent and income-contingent indexation, indexation falls short of price inflation and the real value of the benefit decreases during retirement. The largest decrease is under uniform indexation, where after 35 years almost 40% of the benefit's real value has been lost. Not surprisingly, for someone who enters retirement at $t = 25$, the real benefit is higher during first 15-20 years under the alternatives to status-contingent indexation. During working life the accumulation of rights is faster, because there is no need to finance the high indexation given to the retired that would take place under status-contingent indexation.



a. Individuals retiring at $t = 1$ **b.** Individuals retiring at $t = 25$

Figure 6. Real second-pillar benefits (share of latest wage), benchmark

6.2 Robustness: varying the initial funding ratio and the equity return

We perform a robustness check on two important calibration parameters. First, we explore the case of a lower initial funding ratio of 105% and a higher initial funding ratio of 125%. This is a relevant variation, because we have seen recently that, as a result of the turbulence in the financial markets, funding ratios can vary substantially over relative short periods of time. Hence, the starting conditions can change rather dramatically within short periods of time. Nevertheless, the numerical outcomes are very similar to those under the benchmark case. Hence, we report them only in the online appendix. When the funding ratio is initially set to 105%, the likelihood of underfunding and the average contribution rate become slightly higher, while the average indexation rate becomes slightly lower, all this being the result of the deterioration in the starting position. The opposite movements away from the benchmark occur when the initial funding ratio is set at 125%.

Second, we vary the average equity return and consider the case of an average equity return of 4% and an average equity return of 8%. Also this is a relevant variation to consider, because the uncertainty about future equity returns is particularly nowadays and funded pension systems are generally considered to be vulnerable to financial market circumstances. Moreover, the Don *et al.* (2009) "Parameters Commission" failed to agree on the expected equity return Dutch pension funds need to use when calculating the contribution rate. Our simulations show that when the average equity return is set to 4%, the funding ratio is less volatile, the average contribution rate is slightly higher and the average indexation rate is slightly lower than under the benchmark calibration. When the average equity return is set to 8%, the opposite is the case: the funding ratio is more volatile, the average contribution rate is slightly lower and the average indexation rate tends to be slightly higher than under the benchmark calibration.

As far as the welfare consequences of our variations are concerned, in all instances the aggregate welfare effects as measured by EV are small. Only with relatively high average equity returns aggregate welfare is slightly in favor of the alternatives to uniform indexation. However, the welfare effects for individual groups can be quite large due to redistribution of welfare among groups. As under the benchmark calibration, it is always the retirees who benefit from a shift away from uniform indexation, while workers pay for such a shift.

6.3 Sensitivity analysis: raising the retirement age

An increase in the retirement age is usually put forward as one of the main options to increase the financial sustainability of the Dutch second-pillar pension system. In our model, life expectancy at birth rises from 78.7 years for those born at time $t = 1$ to 83.0 years for those born at time $t = 41$, after which it remains stable because we assume no further growth in the survival probabilities. Our simulations up to now have been done under the assumption that the retirement age remains constant. We will now explore how our earlier results are affected if we let the retirement age gradually increase, such that the approximate $1 : 2$ ratio of average retirement life relative to average work life is preserved. Concretely, this implies that we raise the retirement age at three moments, namely from 65 years to 66 years at $t = 11$, from 66 years to 67 years at $t = 26$ and, finally, from 67 years to 68 years at time $t = 41$. After $t = 41$, the retirement age is kept fixed at 68 years. To aim at the same replacement rate after a full working life under the new life expectancy, whenever we raise the retirement age from R^{old} to $R^{new} = R^{old} + 1$, we also reduce the accrual rate μ, from μ^{old} to $\mu^{new} = \mu^{old}\left(R^{old}/R^{new}\right)$. We assume that existing rights remain untouched. Hence, older workers accumulate pension at a slower pace for only a relatively short period. For example, someone who is 60 years at $t = 11$, will accumulate pension rights for next 6 years at a rate of μ^{new}. Obviously, given that $\mu^{new} = \mu^{old}\,(40/41)$, this person will retire with a higher replacement rate than under the old retirement age. Not surprisingly, the numerical outcomes reported in Table 3 are very similar to those under the benchmark. This is the case for the behaviour of the pension buffer and the frequency with which long-term and short-term restoration plans need to be implemented. Also the average values of the policy parameters are very similar. In most instances, the average indexation rate is higher than under the benchmark, but only slightly so. Aggregate welfare effects of a switch away from uniform indexation remain small, while retirees continue to benefit from such a switch at the cost of the workers. The magnitudes of the intergenerational welfare shifts remain of the same orders of magnitude as before (see the online appendix). Overall, these results show that reducing the accumulation rate of pension rights in response to increasing life expectancy without touching upon existing rights will have only little effect on the sustainability of the second pillar and, thus, on the scope for providing sufficient indexation to protect the real value of the retirement benefits.

This finding sheds light on the current discussion about the adjustment of the second pillar in the Netherlands. While all the groups involved in the restructuring agree that with its current generosity the system is unsustainable in the sense of providing future generations with a decent pension, there is substantial disagreement as to what extent old pension rights should be protected. Our results demonstrate that the currently retired would need to substantially contribute to maintain the sustainability of the system.

Table 3. Funding ratio properties, varying retirement age

%	**Uniform**	**Status contingent**	**Age contingent**	**Income contingent**
Funding ratio volatility (CV=coefficient of variation)				
Median CV	24.942	27.201	27.715	27.596
Median CV, assets	35.220	35.431	35.652	35.794
Median CV, liabilities	47.221	48.631	49.420	48.278
Assets-liabilities correlation	65.676	67.307	65.056	68.558
Probability of a funding ratio below a given threshold				
Below ξ^l	16.839	16.736	16.892	16.685
Below ξ^m	38.721	38.023	37.468	37.860
Below ξ^u	63.596	62.251	61.571	61.872
Probability of a change in the indexation and contribution rates (with a ratio below ξ^m)				
Only indexation rate	3.869	4.371	4.391	4.356
Both rates is enough	34.204	33.033	32.444	32.875
Both rates is not enough	0.648	0.619	0.633	0.629
Average policy parameters (standard deviation in parentheses)				
Contribution rate θ_t^S	19.626	19.570	19.339	19.457
	(5.905)	(5.910)	(5.941)	(5.931)
Indexation rate κ_t	29.143	29.666	30.230	29.724
	(31.417)	(31.402)	(31.498)	(31.422)
% Welfare comparison relative to uniform indexation				
PER	-	9.499	2.821	4.207
EV	-	-0.338	-0.140	-0.325

7 Conclusions

We have analysed the consequences of differentiating the indexation of pension rights to nominal price and wage inflation across groups of participants in a funded pension system like that in the Netherlands. Our analysis was based on stochastic simulations of a small-open economy overlapping-generations model subject to demographic, economic and financial shocks. We have compared the usual Dutch practice of uniform indexation across all participants, with status-dependent indexation that protects retirement benefits against price inflation, age-dependent indexation and income-dependent indexation. Pension buffers behave rather similarly under the various alternatives, both in terms of median buffer values and in terms of volatility of those buffers. This may not be so surprising given that the policies to regulate the value of the buffers are identical across the various scenarios. At the aggregate level, as measured by the equivalent variation for all groups together, uniform indexation tends to performs better than any of the alternatives. The average difference in terms of compensating initial resources is relatively small, though. The initial retirees benefit from a shift away from uniform indexation, while the workers and the future born are the net payers for such a shift. Most of the group specific welfare effects are purely redistributional. Finally, an increase in the retirement age without touching the existing pension rights leaves these findings unaffected and does little to offset the secular decline in the indexation of the retirement benefits that is needed to maintain the long-run sustainability of a funded pension arrangement.

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