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Return, risk, and the preferred mix of PAYG and funded pensions

Marcel Lever
Thomas Michielsen
Sander Muns

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Affiliations
Marcel Lever – CPB Netherlands Bureau for Economic Policy Analysis
Thomas Michielsen – CPB Netherlands Bureau for Economic Policy Analysis
Sander Muns – CPB Netherlands Bureau for Economic Policy Analysis

Abstract

Population aging depresses returns on PAYG financed pensions, while low interest rates depress the return on funded pensions. This paper explores return, risk, and the preferred long-run mix of PAYG and funded pensions. On the one hand, the expected return on funded assets is substantially higher than the expected return of the PAYG pillar, partially due to aging of the population. On the other hand, PAYG pensions are less volatile than funded pensions, as the growth of the wage sum is less uncertain than asset returns if a 50-50 asset mix in fixed income and equity is assumed. To diversify risks stemming from demography and asset markets, a mix of PAYG and funded pensions is socially preferable. In the absence of within-cohort heterogeneity and transition effects, a transition from a 50-50 mix towards a larger PAYG pillar is only warranted at high levels of risk aversion.

Samenvatting

De vergrijzing van de bevolking vermindert het rendement op omslagfinanciering, terwijl de lage rente het rendement op kapitaaldekking drukt. Dit paper onderzoekt rendement, risico en de meest aantrekkelijke mix van omslagfinanciering en kapitaaldekking. Enerzijds is het verwachte rendement op kapitaaldekking hoger dan op omslagfinanciering, mede door de vergrijzing van de bevolking. Anderzijds zijn omslaggefinancierde pensioenen stabieler dan kapitaalgedekte pensioenen, want de groei van de loonsom is minder onzeker dan het rendement op basis van 50% belegging in vastrentende waarden en 50% in zakelijke waarden. Een combinatie van omslagfinanciering en kapitaaldekking is maatschappelijk gewenst vanwege de diversificatie van demografische en financiële risico's. Bij een gemiddelde afkeer van risico is een verschuiving naar meer omslagfinanciering alleen aantrekkelijk bij een hoge mate van risico-aversie. Hierbij is geen rekening gehouden met inkomensherverdeling binnen generaties of met overgangseffecten bij aanpassing van de mix.

1. Introduction

The mix of pay-as-you-go (PAYG) and funded pension schemes is a hot topic in many countries. In the U.S. a debate has evolved about privatization of the social security system.[1] The PAYG pillar provides more certainty, which particularly benefits low-wage earners. Proponents of privatization of social security, thus of a larger funded pillar, argue that, with population aging (Figure 1), the expected rate of return of a funded scheme is substantially higher than that of the social security system, which is largely financed on the basis of PAYG. In light of the current low interest rates (Figure 2), it has been proposed to expand the Dutch PAYG pillar[2], possibly at the expense of the relatively large Dutch funded pillar.[3] To address the underlying risks from demographic changes and asset markets, the OECD supports the trend to diversify the financing of retirement provisions (OECD Pensions Outlook 2016, p.32).

It is not easy to determine which pillar mix would be most beneficial for any specific country. Even seemingly similar countries such as Belgium, Denmark, the Netherlands and Sweden differ widely in the size of the two pension pillars (Figure 3). As an example, the funded pillar is relatively large in Denmark and the Netherlands. In the Netherlands, the population is not expected to grow much. This results in an increasing dependency ratio (bottom plot in Figure A.1 in the Appendix) and lowers the return in the PAYG pillar, which is the sum of the rates of growth of employment and wages. The return in the funded pillar equals the return on investments, which generally exceeds the growth of the wage sum (Aaron, 1966). This suggests that the funded pillar provides a more attractive long-run pension benefit than the PAYG pillar. However, this is based on an expected return on both single pillar mixes. For instance, it does not account for uncertainty in returns, heterogeneity in risk appetite among individuals, and diversification effects. A simulation study enables us to evaluate pillar mixes across different scenarios, at different levels of risk appetite, and with different assumptions.

1 *https://www.wsj.com/articles/should-social-security-be-privatized-1490582138*, *http://socialsecurity.procon.org/#arguments*.

2 The Dutch PAYG pillar can be considered as the zero pillar in the World Bank conceptual design (Holzmann, Hinz, and Dorfman, 2008).

3 J. Frijns, *https://fd.nl/economie-politiek/1145655/we-moeten-pensioen-meer-via-omslagstel-sel-gaan-regelen*.

Figure 1: Old-age dependency ratio.
Ratio of population aged 65+ per 25–64 years
Source: United Nations World Population Prospects: The 2017 Revision. *https://esa.un.org/unpd/wpp/Download/Standard/Population/*, medium variant

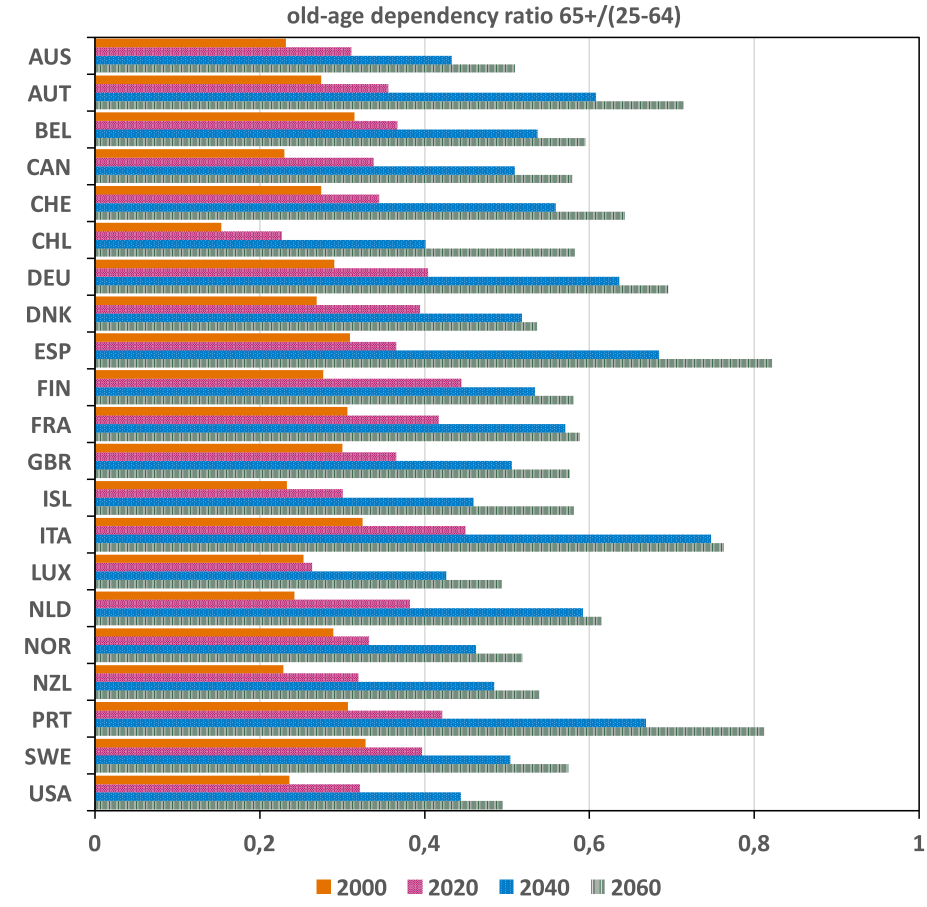


Figure 2: 10 year government yields by G7 country.
Source: OECD (2017), Long-term interest rates (indicator). *dx.doi.org/10.1787/662d712c-en*

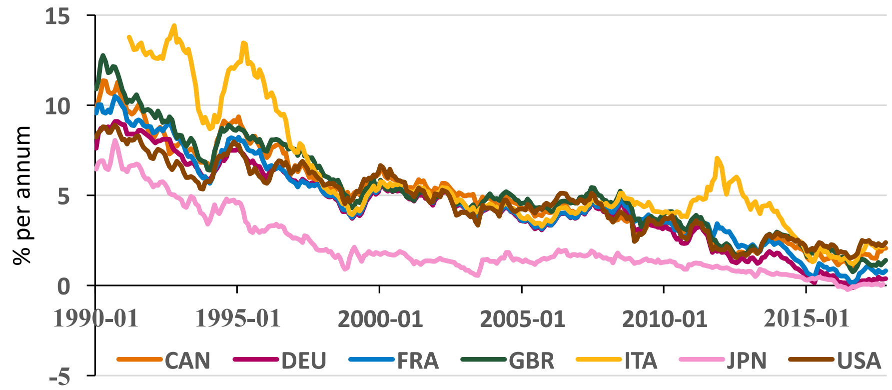
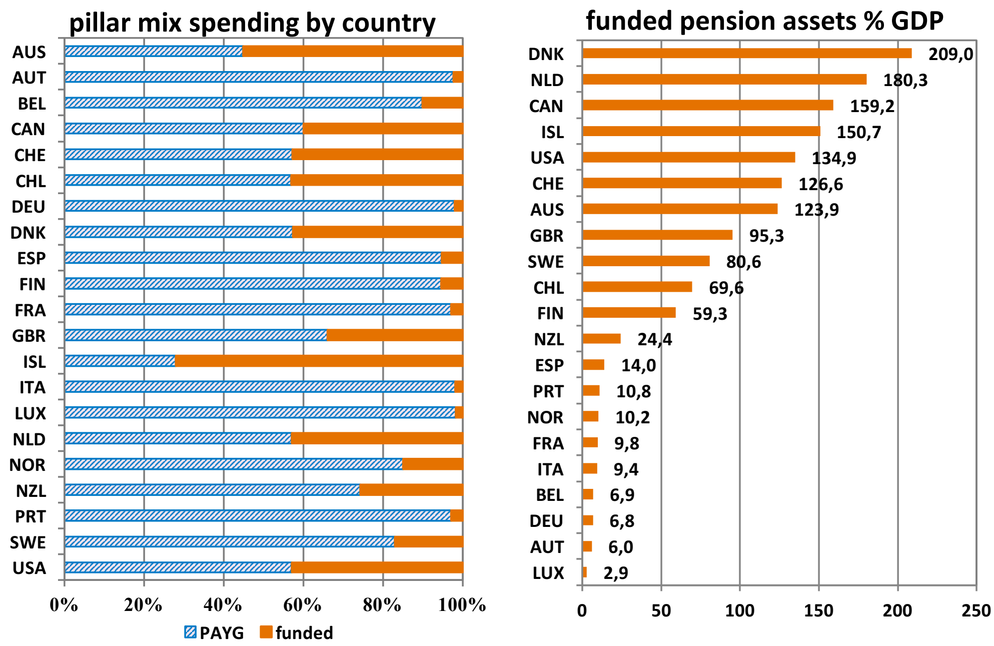


Figure 3: Pensions by country

Left: Pension mix spending by country, 2013. Right: funded pension assets as % of GDP, 2016. Source: OECD Factbook, *data.oecd.org/chart/4Yuq* and OECD Pension Markets in Focus, 2017 edition



Let us assume a PAYG system with a fixed contribution rate. All other factors being equal, an increasing life expectancy will gradually lead to lower PAYG benefits since the dependency ratio increases slowly after a decrease in mortality probabilities. Thus, PAYG-tilted mixes are sensitive to such shocks, particularly in the long run. The funded pillar responds more instantly to a change in (period) life expectancy. The annuity that might be financed from the same contributions – given financial market returns – decreases if life expectancy increases while the retirement age remains constant. Therefore, a change in life expectancy will immediately affect the funding ratio and thereby the funded pillar benefits of retirees as well as the funded pillar accruals of current workers. Our simulations shed light on the long-run impact in both the PAYG pillar and the funded pillar.

In both pillars the long-run impact of a shock in life expectancy depends on the response of the retirement age to such a shock. Suppose the retirement age increases one-to-one with life expectancy, as will be the case in the Netherlands from 2021 onwards. The pension period expressed as a fraction of the working period decreases when life expectancy increases. As a consequence, the replacement rate will increase for cohorts that experience a higher pension age. The opposite applies when the retirement age is constant over time.

Our intergenerational simulation analysis is a first step towards a more comprehensive empirical analysis of the pillar mix. Future empirical research can involve transition, intragenerational redistribution and general equilibrium effects (Barr and Diamond, 2009).

In this study we consider long-run effects by focusing on young cohorts since they are less affected by a transition. This focus can bias our results towards the funded pillar because of a generational conflict of interest in the choice of pillar mix. Since historic contributions are a sunk cost, a higher PAYG contribution rate increases the pension benefits of current retirees without imposing any cost on them. Younger cohorts may on the other hand have a stronger preference for the funded pillar because their PAYG contribution is subject to changes in the pillar mix and thus does not constitute a fully sunk cost. In addition, young cohorts have more time to recover from adverse shocks in asset markets because of their longer investment horizon. Unlike the Dutch practice, in our model the PAYG benefit is related to historic PAYG contributions at the aggregate level. This setup is thus comparable to a notional defined contribution system. This omits trivial outcomes where old generations want young generations to pay a higher PAYG contribution. In practice, a further extension of the Dutch PAYG pillar can be related to historic wage income and thus to historic PAYG contributions. The results hold for representative individuals in the steady state. An analysis of intragenerational distributional effects is beyond the scope of this paper.

A larger funded pillar may affect labor supply decisions (Disney, 2004) and the expected return on assets (Gompers and Metrick, 2001). We abstract from both general equilibrium effects. First, our PAYG pillar is a labor-dependent notional defined contribution scheme. This setup decreases the difference between both pillars in terms of the marginal pension benefit by labor unit. Second, the asset management policy of pension funds tends to have a global scope. As such, investment decisions have a relatively small impact on expected returns. Third, the effect of pension savings on expected returns and economic growth is not trivial because mandatory savings may substitute for voluntary savings, and additional savings do not necessarily increase productive capacity (Barr and Diamond, 2006). From an empirical perspective, Zandberg and Spierdijk (2013) find no significant effects of the growth in funded pension systems on economic growth in the 2001–2010 period for 54 OECD and non-OECD countries. Results are mixed for longer-term effects.

In a simulation study, we examine how the utility of a representative individual varies by cohort and pillar mix. The simulation setup of demographics and financial variables is closer to the real-world Dutch economy than calibrated stylized models encountered in the literature (see Section 2).

Our simulation of several financial variables and Dutch demographics indicates an intuitive trade-off. On the one hand, PAYG pillar benefits are less volatile than funded pillar benefits, as population growth and productivity growth are less uncertain than financial market returns. On the other hand, the PAYG pillar has some disadvantages compared to funded pensions. In the coming decades, the aging population is expected to result in a substantially lower return for the PAYG pillar. Diversification effects suggest that a steady state mix of PAYG and funded pillar pensions is preferable. Our results support this argument to some extent. A transition from a 50-50 mix towards a larger PAYG pillar is only warranted at high levels of risk aversion. The lower uncertainty afforded by a PAYG component compensates for the lower expected return from a smaller funded part. A transition to a more PAYG-oriented system by shifting contributions from the funded to the PAYG pillar leads to higher expected benefits in the short run, but to a substantially lower expected return in the long run.

We perform six sensitivity analyses to indicate how the results are affected by different parameters. The sensitivity tests include permanent changes in birth rates, mortality probabilities, financial returns, interest rates, nominal wage growth, and a one-to-one increase of the retirement age with life expectancy. None of these shocks changes our long-run observations in qualitative terms.

The paper proceeds as follows. Section 2 discusses the relevant literature. Section 3 describes the methodology and data. Section 4 reports the results. Section 5 contains a discussion and conclusions.

2. Literature

Policy reform of the pension system involves complex evaluations (Barr and Diamond, 2009). As such, our paper is connected to several strands of literature. The first strand considers the welfare gains of PAYG and funded pension systems. Krueger and Kubler (2006) found that the American PAYG system for Social Security does not result in an ex ante Pareto improvement. While the system facilitates intergenerational risk sharing by protecting the old from volatile capital markets, it depresses savings and capital accumulation. The lower capital stock in turn decreases future wages, which makes future cohorts worse off. Sánchez-Marcos and Sánchez-Martín (2006) also found that this general equilibrium effect quantitatively dominates the benefits from improved risk sharing. Thus, the added value of PAYG pensions is limited according to their model.

Whereas the above-mentioned papers focus on the negative impact of a PAYG system on capital market returns, Matsen and Thøgersen (2004) argued that a PAYG system can be viewed as an asset whose implicit return equals the growth of the wage bill, and that some exposure to this asset can be welfare-enhancing if the correlation between its return and the stock market return is not too high. Nishiyama and Smetters (2007) found that more funding will result in an efficiency loss when individuals cannot insure themselves against wage shocks.

The second strand involves papers that quantify the welfare gains from intergenerational risk sharing in funded pension schemes (Teulings and De Vries, 2006; Bovenberg et al., 2007; Gollier, 2008; Cui, De Jong and Ponds, 2011; Mehlkopf, 2011; Lever and Michielsen, 2016). Potential gains, according to these papers, arise from the exposure to stock returns realized before individuals join a pension fund. Empirical estimates of these gains in terms of certainty-equivalent pension benefits range from close to zero (Mehlkopf, 2011) to 25% (Gollier, 2008). The welfare gains are limited if regulation forces pension funds to absorb shocks during a limited period of time.

The estimated welfare gains are sensitive to whether labor supply is exogenous to the ad-interim performance of the pension fund, the correlation between wage growth and stock market returns, and how much stock market risk generations can assume before they participate in the labor market. Funded pension systems are limited in the possibility of intergenerational risk sharing if younger workers cannot be forced to join the pension system after negative shocks (Mehlkopf, 2011; Beetsma, Romp and Vos, 2013). The welfare gains depend positively on the equity premium and show an inverted U-shape in risk perception: if individuals are very risk-tolerant, the time diversification of stock exposure before participation in the labor market has limited added value, whereas very risk-averse individuals would not want to hold stocks at all, even if they can extend their investment horizon through a funded pension scheme.

A third body of literature integrates the insights from the welfare gains of the two systems and addresses the optimal relative sizes of PAYG and funded pension pillars. Beetsma and Bovenberg (2009) and Beetsma, Romp and Vos (2013) studied an overlapping generations model with wage and depreciation risk. The second paper added endogenous labor supply to the first paper. Both models are two-period models with a constant size of generations, which may miss demographic risk. A multi-pillar pension system can implement the social optimum, namely by having a defined-benefit funded pillar so that the young can share in the equity risk of the old, and by linking either the PAYG or funded pillar benefits to wages so that the old share in the wage risk of the young. With endogenous labor supply, the marginal return on the contribution rate is identical in both pillars.

Rather than determining the optimal mix of the two pillars from a theoretical model, Bohn (2009) investigated whether real-world pension policies can be rationalized by calibrated standard preference structures. Under constant relative risk aversion, real-world systems have a suboptimal low exposure to productivity risk for the elderly. The observed safe transfers to retirees can be better explained by age-declining risk tolerance such as habit formation.

Auerbach and Lee (2011) presented a comparison of PAYG systems based on the existing systems in Sweden, the US and Germany. Comparing the three systems, they found that shocks are best smoothed in the non-funded Swedish NDC system. Nonetheless, in terms of social welfare, the lower average rate of return more than offsets the benefits of risk reduction. The differences between the systems may disappear when transition generations are taken into account.

A fourth strand of literature addresses the transition from PAYG to funded systems in response to population aging. The PAYG system is a zero sum redistribution from later generations to introductory generations (Sinn, 2000). Although the lower PAYG return disadvantages later generations, there may be no way to eliminate this disadvantage, unless existing pension claims are ignored. However, the funded pillar may have positive impact on labor supply and child rearing (through smoothing across generations).

Miles and Černý (2006) simulated a calibrated model of the Japanese welfare system to determine the welfare effects of a reform that reduces the generosity of the PAYG system. The reform generates a potential Pareto improvement, but there are nontrivial losses for early generations. A less generous PAYG system increases aggregate savings and decreases the risky-asset share of private savings. An important part of the long-run welfare gain of a less generous PAYG system stems from allowing individuals to delay pension savings, provided that participation in a funded pension system is voluntary. This is particularly valuable when young individuals are credit-constrained.

Ludwig and Reiter (2010) performed a similar exercise for the German pension system. They determined the generational welfare weights that rationalize the current arrangements, and asked how a social planner would respond to a fertility shock. The social planner would reduce per-capita benefits, if the labor market distortions from higher PAYG contributions are severe. Kitao (2014) compared four options to restore the sustainability of US Social Security system, given projected demographic trends: an increase in payroll taxes, a decrease in benefits, a higher retirement age, and means-tested benefits. Compared to a decrease in benefits or a higher retirement age, increasing payroll taxes results in a decrease of labor supply and savings. Means-testing benefits has such an effect even more so since that constitutes an additional disincentive to accumulate private wealth.

The last strand of papers looks at the political sustainability of PAYG and funded pension systems. Political support for PAYG systems by the elderly is stronger than opposition against it by younger cohorts (Cooley and Soares, 1999; Gonzalez-Eiras and Niepelt, 2008; D'Amato and Galasso, 2010). Two main factors dampen the resistance of the young to the PAYG system. Firstly, the young treat their past contributions (though still low) to the PAYG system as a sunk cost, so they evaluate the PAYG system more positively than the implicit return on their current contributions would suggest. Secondly, the young can shift part of the costs of the PAYG system to future generations because it lowers aggregate savings, which increases their return on capital in a closed economy.

Within-cohort inequality further increases support for the PAYG system (Song, 2011). Particularly poor individuals are disinclined to save because of the within-cohort redistribution through PAYG pensions. In turn, the increase in inequality due to differences in savings increases the political support for an even more extensive PAYG system.

3. Methodology and data

Economy

Some assumptions enable us to isolate the effects of different configurations of the pension system. We abstract from within-cohort differences in income during the working period by considering a representative agent for each cohort. We disregard the effects of migration and assume that individuals participate in the pension system during their entire life. Each year, the wage and the pension contribution mix are the same for all working individuals.

If alive, each individual starts to work at the age of 25, retires at 70, and has a maximum age of 120. A fixed retirement age differs from the current Dutch pension system, where the retirement age increases roughly one-to-one with an increase in life expectancy. As our sensitivity analysis confirms, a fixed retirement age has no substantial effect on our results. The intuition is that pension benefits, both in the PAYG and the funded pillar, are higher when the retirement age increases with life expectancy.

The contribution rate of each pillar is fixed over time and labor dependent. The latter assumption suggests that a change in the pillar mix would have little impact on labor incentives. This leads us to assume that an adjustment of labor-related pension accrual rates will not affect the labor supply decision of our representative agent. Transition effects towards a different mix are not considered. We focus on the youngest cohorts, which face relatively small potential transition effects.

Pension system

We evaluate the pension result (PAYG plus funded pension benefits) for different pension systems. The pension system is a weighted combination of PAYG and funded pensions, or a boundary case where the system is fully PAYG or fully funded.
In each pension system, the PAYG and funded pillars both have a contribution rate that is constant during the simulation period and identical across working individuals. We fix the total contribution rate per capita for all mixes of PAYG and funded pillars. That is, the total contribution rate to both pillars is 17.24% of the wage irrespective of the interest rate and the relative size of the two pillars.[4] Because

4 With a 50-50 mix of the two pillars, the median PAYG pillar contribution per capita in 2015 amounted to €3,212 in our model. The PAYG pillar expenditure in the Netherlands in 2015 (€35.8 billion, Statline *link*) per capita between 18 and 65 years old (10.7 million individuals, *link*) amounted to €3,360.

the PAYG contribution rate is fixed over time, the PAYG benefit per capita is inversely proportional to the old-age dependency ratio.

The funded pillar that we consider is a collective defined contribution system with a fixed contribution rate. This system is more straightforward to implement than a defined benefit system and it enables sharing of equity risk, interest rate risk, and demographic risk among current and future generations.[5] We calculate a funding ratio, defined as the assets over the nominal present value of the liabilities of the fund. The liabilities are discounted using the nominal term structure of interest rates. Each year, the claim of any worker or retiree is adjusted by one-tenth of the difference between the current funding ratio and 100 percent. The funded pension scheme invests half of its assets in equities and the other half in fixed income whose maturity matches that of the liabilities. We subtract a yearly portfolio cost of 0.5% from the investment return. The best estimate of mortality probabilities is adjusted each year with Bayesian updating, using the realized mortality probabilities in the corresponding scenario.

Initial rights are determined using a 50-50 pillar mix of historic contributions. The initial rights in the funded pillar are determined using the term structure of year-end 2015 and the wage level of 2015. Initially, the sum of assets amounts to €1,580 billion and the funding ratio equals 100 percent. Initial rights in the PAYG pillar are a weighted combination of historic PAYG contributions. The idea behind this setup is similar to a notional defined contribution pension scheme and omits trivial outcomes where old generations want young generations to pay a higher PAYG contribution. A cohort paying a 50-50 contribution to both pillars during the first half of working life, and a 0-100 contribution during the second half, has a PAYG benefit equal to 25% (= 50% × 50% + 50% × 0%) of *current* total pension contributions. For this cohort, pension contributions are, in the second half of the working career, only for the funded pillar, which means that the PAYG pillar runs a deficit in this example. More general, total PAYG contributions and total PAYG benefits may differ during the transition. A deficit can be charged to current pensioners, or it can be financed by raising current or future taxes. That being said, we abstract from a surplus or deficit on an imaginary public PAYG account and the potential effect on public finances. For instance, investing a surplus on a PAYG account blurs the distinction between PAYG financing and funding. In the long run, the pillar mix is stable in our simulations such that PAYG contributions and PAYG benefits are balanced each year.

5 A generic description of the pension model can be found in Michielsen (2015).

Simulation

We simulate each considered pillar mix for 2,000 scenarios. The scenarios are generated by means of the models in Muns (2015; 2017). Each scenario has a different annual time series for demographic factors (birth and mortality) and financial markets (equity returns, interest rates, and inflation rates). The mortality model is based on the mortality of a group of Western European countries (Lee and Li, 2005). The data run from 1960 to 2013 and are from the Human Mortality Database if available, otherwise from Eurostat. We adjust the otherwise low uncertainty in mortality rates to the somewhat larger uncertainty of the World Prospects of the United Nations (UN, 2015). The fertility model is similar to the model in Lee and Tuljapurkar (1994). This model is estimated using data from Statistics Netherlands for the period from 1960 to 2014. The financial model is based on the term structure model in Wu and Xia (2016). This zero lower bound model is estimated using monthly financial data starting from 1990. The submodels are subject to certain restrictions, for example on long-run medians; see Muns (2015; 2017) for more details.

The aggregate model allows for contemporaneous dependence between the annual shocks in the demographic and financial submodels. However, this dependence turned out to be low (Muns, 2015), which may indicate diversification benefits between the PAYG and the funded pillar. Correlations at longer intervals than one year are expected to be nontrivial. For instance, a low birth rate may affect future interest rates through the saving rate. It is a well-known econometric problem that such relations are difficult, if not impossible, to estimate empirically (Poterba, 2004). The empirically observed negative one-year correlation between the inflation rate and stock returns is unlikely to hold at longer intervals (Muns, 2017, footnote 6). This motivates us to set such correlations at zero. If the long-run correlation between inflation and stock returns is positive instead of zero, our results overstate the diversification benefits of mixing the pillars. In this sense, the results of our representative individual are a lower bound for the preferred size of the funded pillar mix. This is counterbalanced by the omission of within-cohort effects, which would increase the preferred size of the PAYG pillar mix.

Each simulated time series starts with the value at year-end 2016 and ends at year-end 2115. Thus, each simulated series reflects a period of 100 annual observations. Appendix A contains descriptive statistics of the scenario set.

Utility functions

We evaluate pension mixes using two different utility functions. One such function considers the replacement rate during the life cycle. This function accounts for fluctuations during the lifecycle. The other utility function considers the nominal lifetime return on contributions in the PAYG and funded pillar. This function can consider a continuum of pillar mixes and fits in a Markowicz framework. Both utility functions are cohort-specific. Possible initial PAYG transfers to non-contributing pensioned cohorts or to an imaginary public fund are not included in the utility functions.

Utility based on replacement rate

For each birth cohort, we evaluate the pillar mixes using the time series of replacement rates in different scenarios. One cohort-specific utility function is the following CRRA Von Neumann-Morgenstern utility function

$$U(r;\gamma) = \mathbb{E}\left[\sum_{t=0}^{\infty} 1(\text{alive and pensioned in } t)\ \frac{r_t^{1-\gamma} - 1}{1-\gamma}\right]$$

with 1(.) the indicator function, the replacement rates $r = \{r_0, r_1, r_2, \ldots\}$ expressed as the series of pension benefits relative to the wage level in the same year, and risk aversion parameter γ.

The denominator of the replacement rate r_t, the wage level in year t, corrects for differences in wage levels across scenarios. In other words, the utility function evaluates a pension mix in real terms. The utility function rewards consumption smoothing since a stable replacement rate is preferred to a more volatile rate around the same mean replacement rate.

Utility based on internal rate of return

The alternative utility function evaluates the internal rate of return by pillar (Disney, 2004), which is in fact the actual annual nominal return by pillar. The internal rate of return (IRR) of each (pillar, cohort) combination follows implicitly from

$$\sum_{a \in \text{ages}} \frac{\text{contribution}_a - \text{benefit}_a}{(1+IRR)^t} = 0.$$

We denote the IRR of the PAYG pillar as IRR_1 and the IRR of the funded pillar as IRR_2. The simulations produce a pair (IRR_1, IRR_2) for each simulation run and each cohort, and thus for each cohort a single correlation coefficient ρ between IRR_1 and IRR_2.

In the Markowicz framework, the return on an asset is completely characterized by the expected return and the level of risk as proxied by the standard deviation. Given a certain level of risk, a higher return increases utility, while a lower return decreases utility. This principle generates the efficient frontier that limits the available expected returns for each level of risk. The optimal (risk, expected return) pair on the efficient frontier depends on the return of a risk-free asset if available, or the risk appetite if a risk-free asset is unavailable. We stress that this optimality is conditional on several assumptions, such as a given asset mix in the funded pillar and absence of transition costs.

In the absence of transition effects, we can assess which pillar mix $(x, 1 - x)$ is preferred in the Markowicz framework. Consider two assets that randomly generate the stochastic internal rate of return on the PAYG pillar (IRR_1) and the funded pillar (IRR_2). Both internal rates of return pertain to the same cohort. The correlation coefficient ρ between the returns of both assets is known. We construct from the two assets a portfolio with weights x (IRR_1) and $1 - x$ (IRR_2) with random return

$$X_x = x\, IRR_1 + (1 - x)\, IRR_2.$$

In the absence of a risk-free asset, the preferred mix maximizes the utility function

$$V(x; \gamma) = \frac{\mathbb{E}\left[X_x^{1-\gamma}\right] - 1}{1 - \gamma}.$$

This approach evaluates each pension mix in nominal terms since the measure V neglects inflation of wages and prices. The expectation operator $\mathbb{E}[.]$ applies to different scenarios, which reflects the fact that fluctuations in pension benefits over the lifecycle have no effect on V as long as the return X_x is unaffected.

A pillar mix with a high return on X (and thus a high V) does not necessarily imply that the economy is more efficient. Instead, it means that participants face a higher nominal return on their pension contributions. This return depends, for the PAYG pillar (IRR_1), on the exogenous growth of the wage sum and, for the funded pillar (IRR_2), on the return of financial assets.

Sensitivity

We performed six sensitivity tests on our long-run outcomes. Firstly, we decreased all future mortality rates such that the time path of the period life expectancy would correspond to the 95th quantile best scenario of the Statistics Netherlands 2014 forecast. Appendix B contains details. Secondly, we evaluated the effect of a twenty percent lower birth rate. The lower birth rate lowers the PAYG benefit of the current generations. Thirdly, we lowered the equity premium from the first simulation year onwards. This does not affect the replacement rate of pure PAYG pension systems.

However, funded pensions will be smaller. Fourthly, the interest rates were 1%-point lower than in the baseline setup. Again, this has an adverse impact only on the funded pillar. Fifthly, the wage growth was 1%-point above the price inflation instead of 0.5%-point. This makes the PAYG pillar more attractive because PAYG benefits are directly linked to instantaneous wage growth. Finally, we considered the effect of a one-on-one increase of the retirement age with life expectancy. This adjustment mechanism is current practice in the Dutch pension system.

4. Results

Figure 4 depicts the replacement rate on a log scale for three different pillar mixes and three different percentiles (median, 1%, and 99%) using the baseline model. An intuitive principle follows from this figure. A full PAYG pension scheme (100-0) gives the lowest median replacement rate, but also the most narrow confidence bands. At the other extreme, a fully funded pension scheme (0-100) gives the highest median replacement rate at the expense of more uncertainty. A mix of both pillars results in an intermediate replacement rate in terms of median and risk. Young cohorts face a higher 1% percentile using a 50-50 mix compared to either 100-0 or 0-100. Hence, a mix may result in diversification benefits (Matsen and Thøgersen, 2004). When enlarging the funded pillar, both utility functions *U(r; γ)* and *V(IRR; γ)* weigh a higher 'good' (replacement rate or return) against the 'bad' of a higher risk.

Figure 4: Replacement rate by cohort birth year.
Median (solid) and 1% and 99% percentile (dashed) of PAYG-only mix (100-0), equal contributions mix (50-50) and funded pillar-only mix (0-100). Mix $m_1 - m_2$ indicates a share m_1 and m_2 of contributions to PAYG and funded pillars, respectively. Initial rights based on corresponding mix. A replacement rate is calculated for each cohort in each of 2,000 simulations. Each scenario-specific replacement rate is based on the replacement rates weighted by the (cohort, scenario) specific probability of survival at each age.

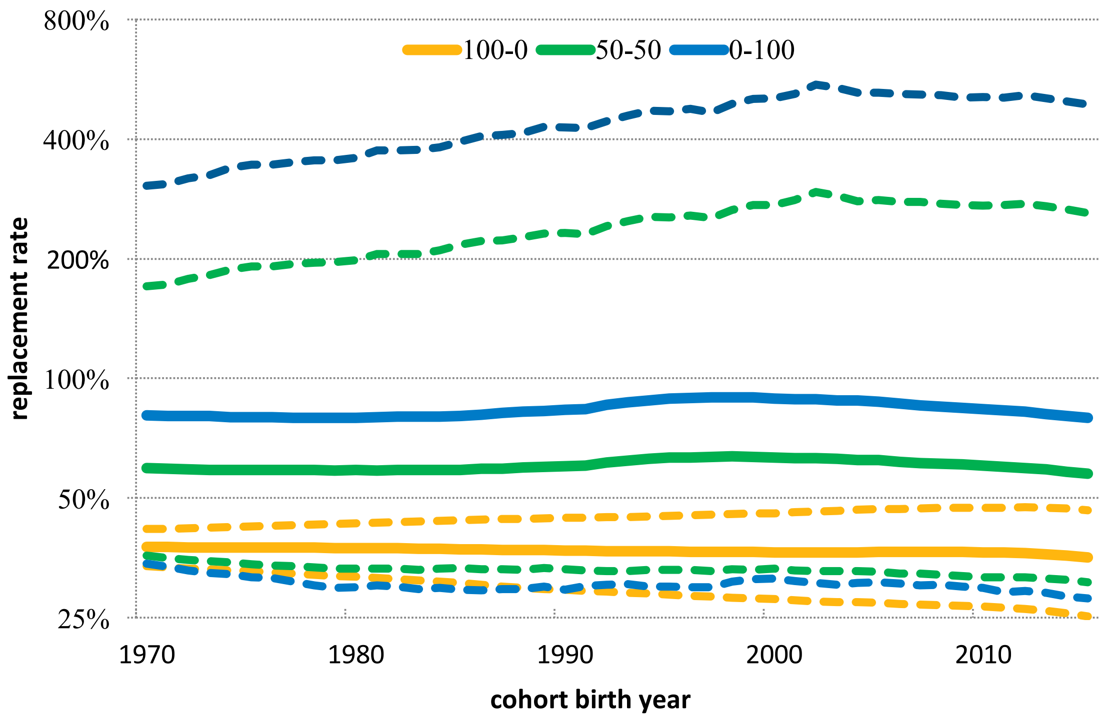


Figure 5 presents the results for the replacement rate based measure $U(r;\gamma)$, where initial rights are based on the 50-50 mix. A larger PAYG pillar is preferred in case of more risk aversion, a result that is in line with Figure 4. Let us focus on the youngest cohorts, for whom initialization and transition are less important. The youngest cohorts prefer a mix tilted to the funded pillar (75% at γ=5). For somewhat older cohorts, investment losses are harder to compensate because of lower human capital and a shorter investment horizon in combination with the assumed mean reversion in asset returns. Nonetheless, the doubling of the dependency ratio in the coming decades will lower the replacement rate from the PAYG pillar over the next 25 years, especially if the pension age were to be fixed (Figure 6). This makes the PAYG pillar unattractive, particularly when older cohorts are not very risk-averse.

A higher dependency ratio has two counterbalancing effects on the stability of funded pillar pensions. The higher the annual payout and the lower the annual contributions, both relative to the size of the fund, the greater is the ultimate impact

Figure 5: Preferred mix by cohort for different levels of risk aversion γ.
Mix m_1 – m_2 indicates a share m_1 and m_2 of contributions to PAYG and funded pillar, respectively. Preferences based on $U(r;\gamma)$. Initial rights based on 50-50 mix.

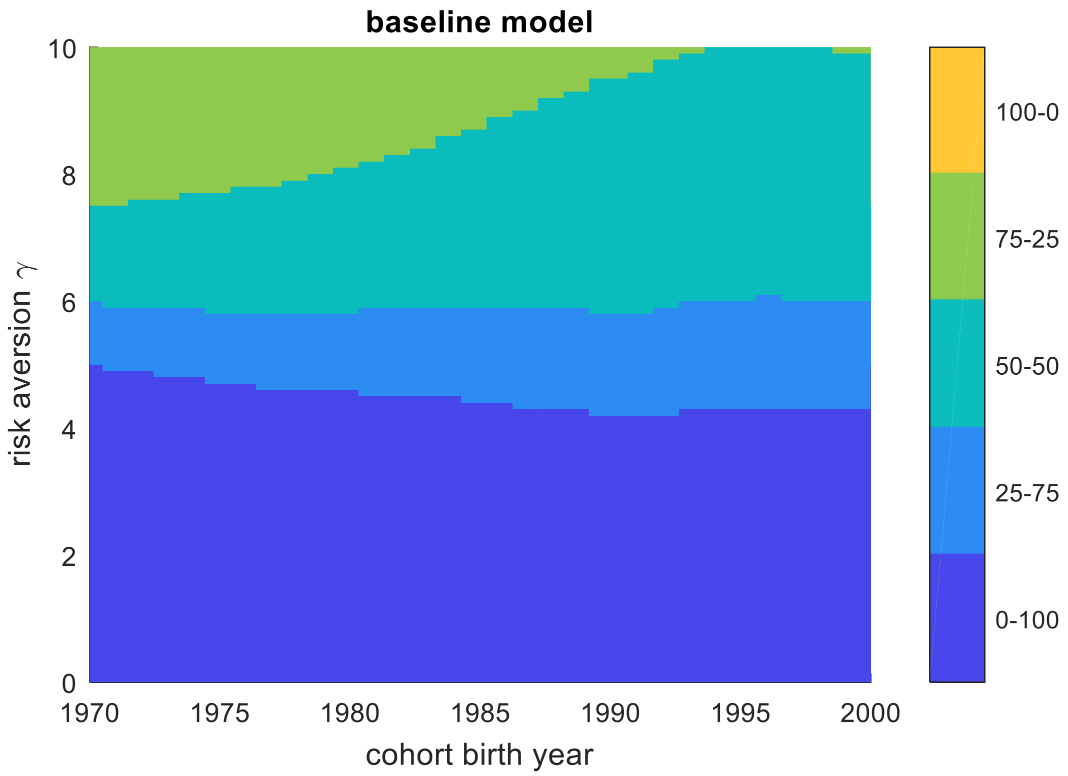
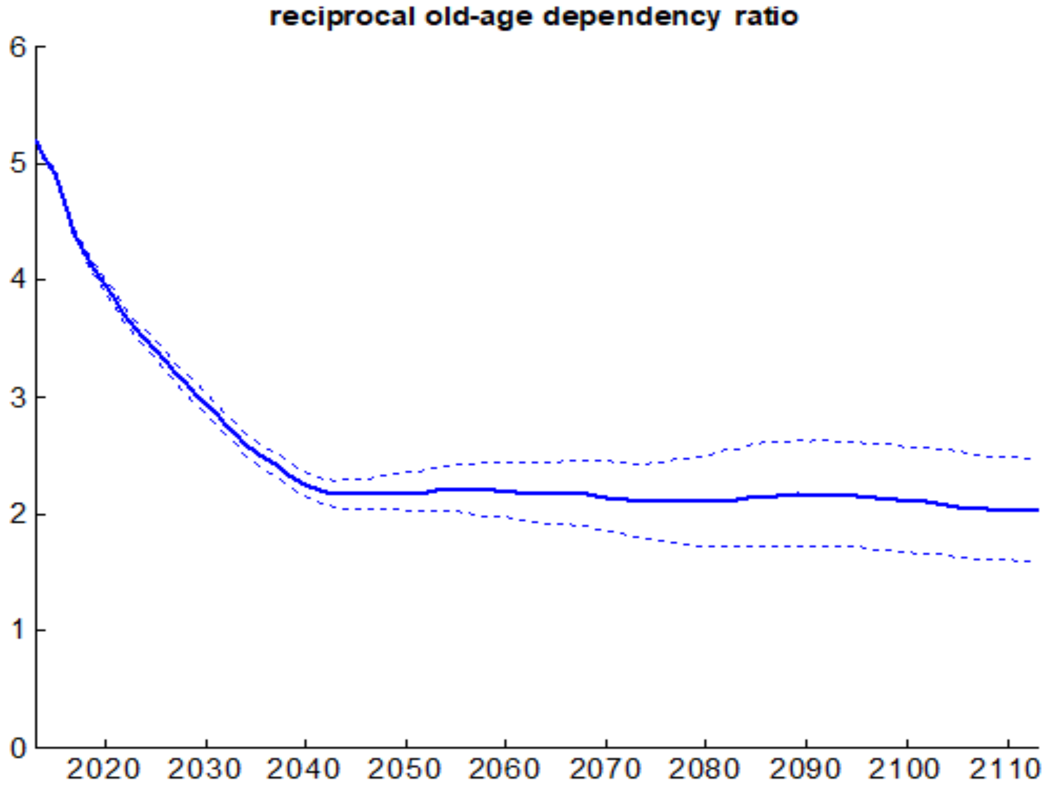


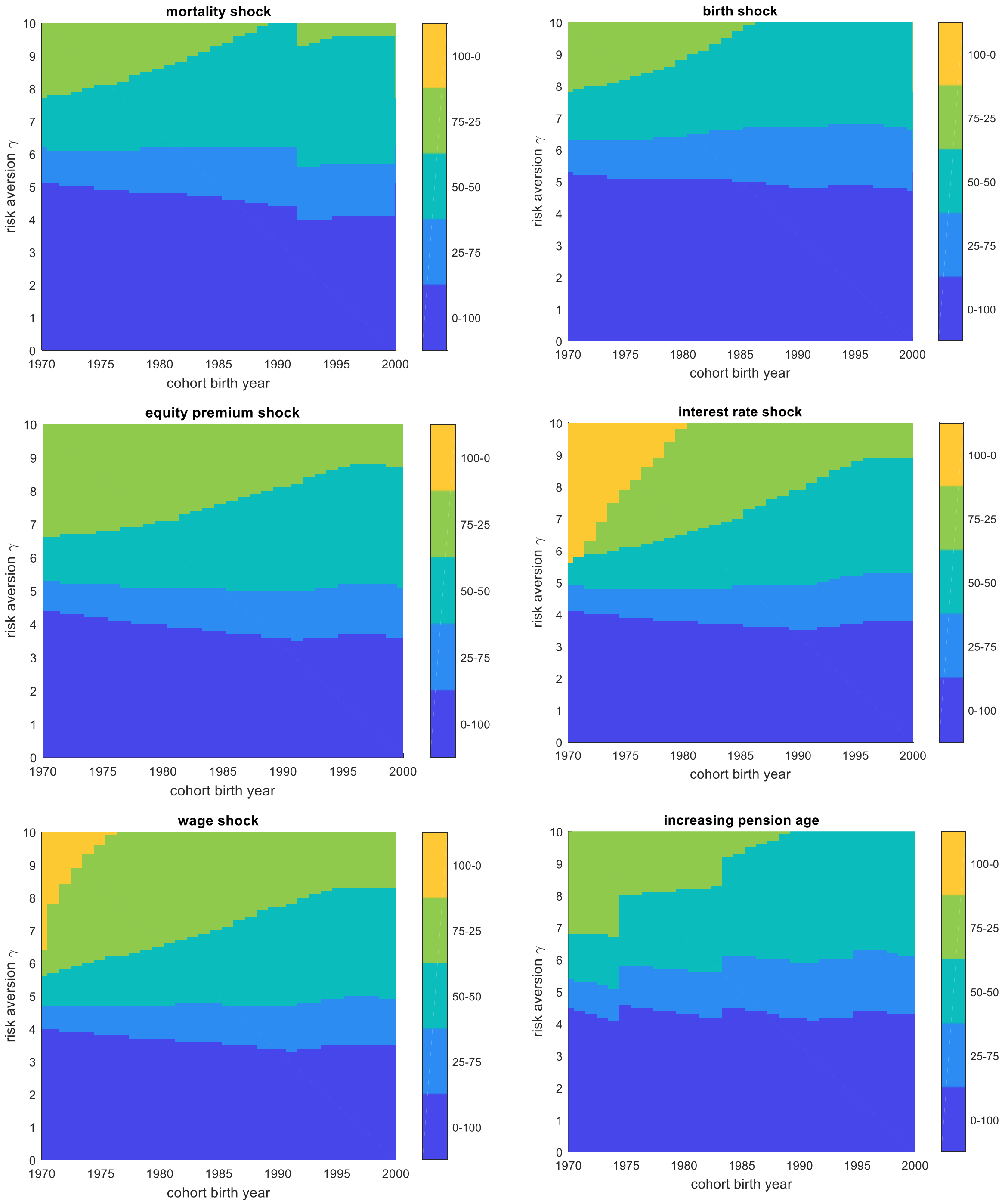
Figure 6: Reciprocal old-age dependency ratio.
Number of people aged between 25 and 69 years relative to people aged 70 years and older. Solid lines are means over 2,000 simulations, medians are qualitatively the same. Dotted lines are 5% and 95% percentiles of the simulations.



of shocks that are absorbed gradually. However, the duration of liabilities decreases, resulting in less exposure to interest rate risk.

Various sensitivity plots are shown in Figure 7. A lower mortality rate has no profound impact on the preferred mix (top left). In the long run, both pillars are hit about equally by the higher life expectancy. A lower birth rate by 20% makes the PAYG pillar somewhat less attractive (top right). As such, the preference moves somewhat towards the funded pillar. The opposite holds when equity returns are 1%-point lower (middle left) as only the funded pillar is affected by the equity premium. A decrease of 1%-point in interest rates has a more profound impact (middle right): asset returns become lower and the funding ratio drops immediately. This makes the funded pillar less attractive for the middle and older cohorts. Still, it cannot support proposals for a pronounced change towards a larger PAYG pillar. An increase in wage growth makes the PAYG pillar more attractive since PAYG benefits are directly linked to PAYG contributions (bottom left). Linking the increase in retirement age to the

Figure 7: Preferred mix by cohort for different levels of risk aversion γ.
Top left: mortality shock (5%-percentile highest life expectancy), top right: birth shock (20% less births). Middle left: equity premium shock (1%-point lower return on equity), middle right: interest rate shock (1%-point lower interest rate). Bottom left: wage shock (0.5%-point higher wage growth), bottom right: retirement age one-on-one coupled to initially expected life expectancy. Mix $m_1 - m_2$ indicates a share *m1* and *m2* of contributions to the PAYG and funded pillars, respectively. Preferences based on $U(r; \gamma)$. Initial rights based on 50-50 mix.



initially expected increase in life expectancy has no profound impact on the pillar mix (bottom right). Cohorts faced with a relatively long working period can benefit from a longer accrual period in the funded pillar. Due to the effect of compounding returns, the length of the accrual period is more important in the funded pillar than in the PAYG pillar. Nonetheless, the qualitative result is not significantly different from the baseline result in Figure 5.

In general, the results for the sensitivity tests presented in Figure 7 are quite robust. In particular, a mix tilted to the funded pillar is preferred by the youngest cohorts. However, shocks can be more extreme. We ignored within-cohort heterogeneity and the compensation needed for the older cohorts who otherwise face a lower PAYG benefit. The evaluation of these topics is beyond the scope of this paper.

Internal rate of return

Using 2,000 simulations, the internal rates of return (IRR) of the two pillars can be calculated for each simulation and each cohort. Because of our long-run focus, we present results for the cohort born in 2000. This cohort has no initial historic rights at the start of the simulation. As a consequence, transition effects do not directly pertain to this cohort.

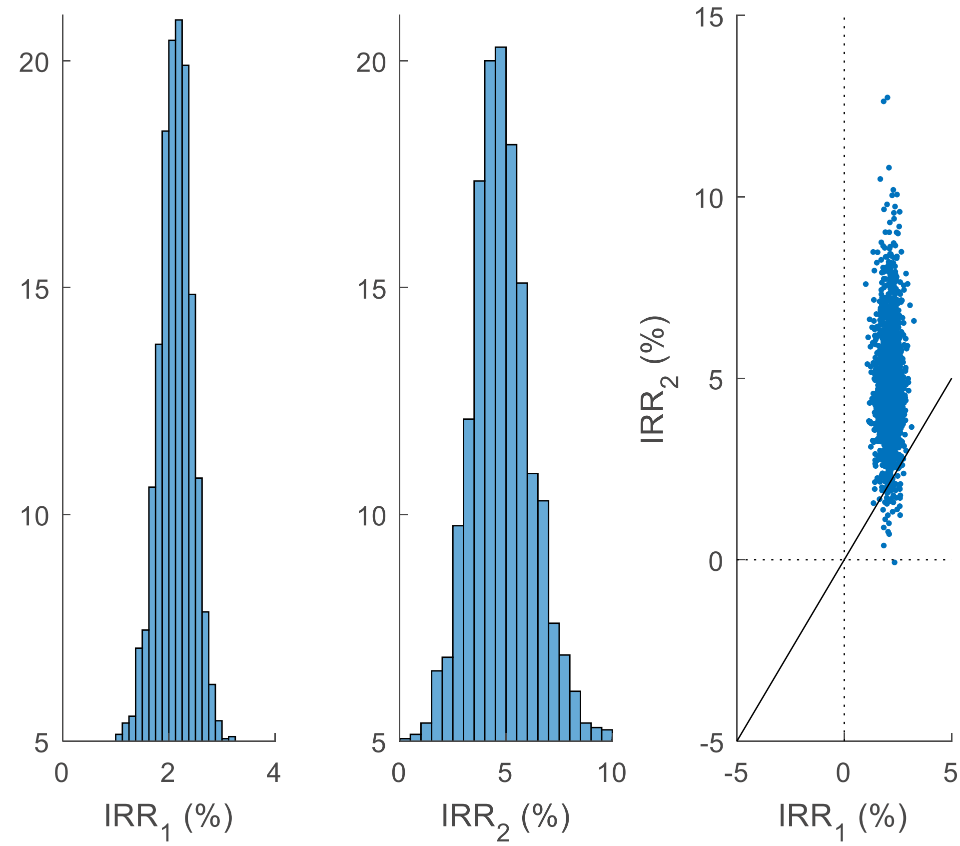
Figure 8 shows the probability density function of the IRR of the PAYG pillar (left), the IRR of the funded pillar (middle), and a scatter plot of the IRR of both pillars (right). On average, the IRR of the funded pillar exceeds the IRR of the PAYG pillar by about 2.6%-points since the medians are 2.1% and 4.7% for IRR_1 and IRR_2, respectively. The correlation between IRR_1 and IRR_2 is very small ($|\rho| < 0.01$), due to the low correlation in the scenarios between demographic variables and asset returns (section 3). A lower correlation enhances the diversification benefits of the pillar mixes.

The left panel in Figure 9 shows the possible (risk, expected return) pair for each pillar mix. Indifference curves are based on the utility measure V. A number x in this panel indicates the PAYG share, the complement $1 - x$ is the share of the funded pillar. Short-selling is excluded. In line with Figure 4, a higher PAYG share corresponds to a lower expected IRR and tends to decrease risk. Again, the difference between the IRR of both pillars is about 2.6%-points. At a low level of risk aversion ($\gamma = 2$), a funded pillar-only mix is preferred, while a largely PAYG pension is preferred at a high level of risk aversion.

The middle panel in Figure 9 confirms that the preferred PAYG share increases with the level of risk aversion. A level of risk aversion at $\gamma = 3.71$ corresponds to an equally weighted mix of the two assets. The PAYG weight increases to 65% at $\gamma = 5$. The right panel shows the preferred PAYG share if a risk-free asset is available. The preferred

Figure 8: Internal rate of return (IRR) of both pillars of cohort 2000 in 2,000 simulations.

Left: Probability density IRR of PAYG pillar. Middle: Probability density IRR of funded pillar. Right: Scatter plot of both internal rates of return.



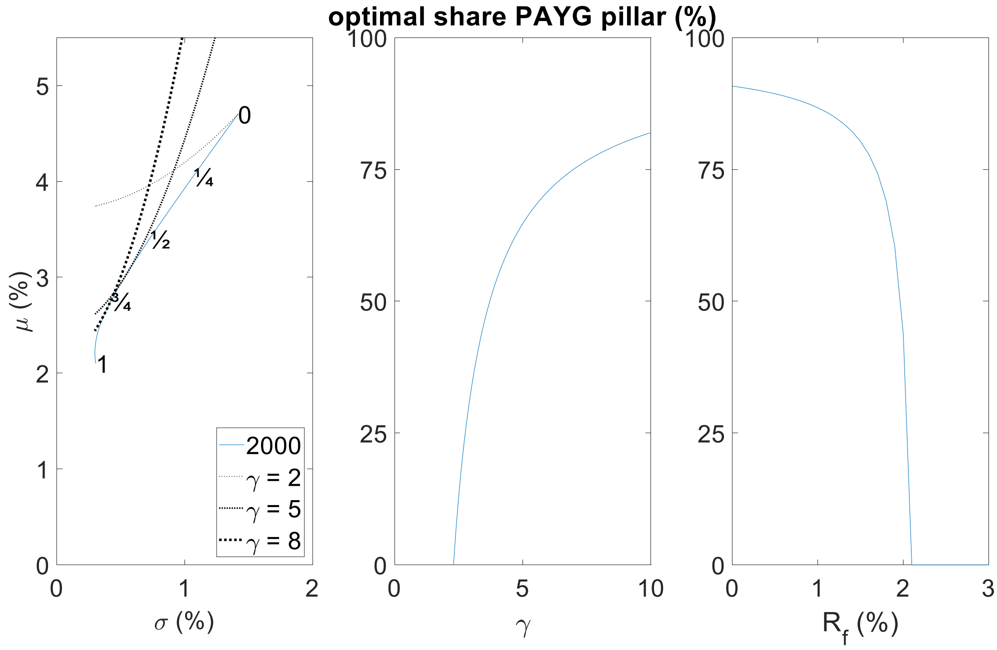
mix is a funded pillar-only mix, irrespective of the risk aversion, if the risk-free nominal interest rate exceeds 2%.[6] The average duration of new accruals is about thirty years, which has a risk-free rate of about 3% in our scenario set (Table A.1). Again, a transition towards a very large funded pillar and thus a very small PAYG pillar may have very negative effects on public finances when current retirees are compensated for the loss on their PAYG benefits.

The utility functions $U(r_t; \gamma)$ and $V(IRR; \gamma)$ give somewhat mixed results. Our preferred utility function U favors the funded pillar more strongly, while V particularly favors the funded pillar in case a risk-free asset is available. This could reflect the fact that U is in real terms, thereby rewarding indexation policies in the funded pillar. Another explanation involves the time horizon of the different concepts. The IRR is an annual return that is averaged over the lifecycle, while the replacement rate varies

6 We assume that shorting the risk-free asset is allowed.

Figure 9: Preferred share of PAYG pillar for cohort 2000.

Left: Feasible set by combining PAYG and funded pillars (solid blue line). Indifference curves correspond to three different levels of risk aversion γ in the absence of a risk-free asset (dashed lines). Middle: Preferred PAYG share for different levels of risk aversion in the absence of a risk-free asset. Right: Preferred PAYG share for different risk-free interest rates.



over the lifecycle. As such, the replacement rate may benefit nonlinearly from compounding returns in the funded pillar. This may explain a stronger preference for the funded pillar with the utility function *U*.

5. Discussion and conclusions

Our results suggest that even if low interest rates put pressure on funded pensions, a switch from a 50-50 mix to a larger pay-as-you-go (PAYG) pillar is not an attractive long-term solution. In the short run, current working cohorts and pensioners are biased towards the PAYG pillar since their PAYG contributions are a sunk cost. However, our simulation results indicate a higher expected return on funded pillar contributions than on PAYG contributions. This leads on average to higher pensions in a scheme that is oriented to the funded pillar. The main intuition is the Aaron rule which indicates a higher return on contributions to the funded pillar compared to contributions to the PAYG pillar. Nonetheless, young cohorts prefer a mix of PAYG and funded pension schemes so as to benefit from diversification effects between the two pillars. This result remains robust when we permanently lower interest rates.

Our analysis does not take considerations into account that would otherwise strengthen our result. First, the pillar returns can be more strongly correlated if in practice the long-term correlation between wages and stock returns is positive and the long-term correlation between interest rates and the dependency ratio is negative. Second, control rights on the assets of a funded pension scheme may give room for housing market interventions, sustainable investments, and shareholder activism. On the other hand, social preferences might be better aligned with a larger PAYG pillar than our model suggests. First, we do not consider within-cohort effects on income distribution. In several countries, an adequate non-earnings-related PAYG pillar (zero pillar) plays an important role in the relief of poverty. Second, our analysis ignores the negative balance on an imaginary public PAYG account during a transition towards a larger funded pillar.

The future return on pension contributions is probably lower than in the past. The return in the PAYG pillar has a downward trend due to the increasing dependency ratio. The return on funded pensions remains probably lower than in the past due to low interest rates. Instead of enlarging the PAYG pillar, there are alternative responses to the increasing cost of retirement that do not lead to further deterioration of the effective return on pension contributions: increasing the retirement age, increasing the contribution rate to funded pillar pensions or accepting a lower replacement rate for a given level of contributions. A mix of these responses is being implemented in several European countries. Denmark, Germany, Belgium, France, Greece, and the Netherlands have raised, or are in the process of raising the retirement age. The guarantees on funded pillar returns have been lowered in Denmark, Sweden, and Belgium. Germany is expanding its funded pillar (Riester-Rente) in light of population aging.

Appendix

A. Descriptive statistics

Demographics

The top plot in Figure A.1 shows that, in our scenario set, life expectancy continues to increase, possibly at a slightly lower rate. This is in line with predictions by the United Nations (UN (2015) *link*), Statistics Netherlands (Statline, *link*), and the Dutch Actuarial Association (*link*). The bottom plot in Figure A.1 indicates that the old-age dependency ratio increases sharply until 2040. This steep increase, which is in line with the forecast by Statistics Netherlands (*link*), is due to a relatively large cohort born in the 1960s (*link link*). Note that the bottom plot in Figure A.1 is the reciprocal of Figure 6.

Figure A.1 Period life expectancy and old-age dependency ratio.
Old-age dependency ratio is the number of people aged 70 and over, divided by the number of people aged between 25 and 69. Solid lines are means over 2,000 simulations, medians are qualitatively the same. Dotted lines are 5% and 95% quantiles of the simulations.

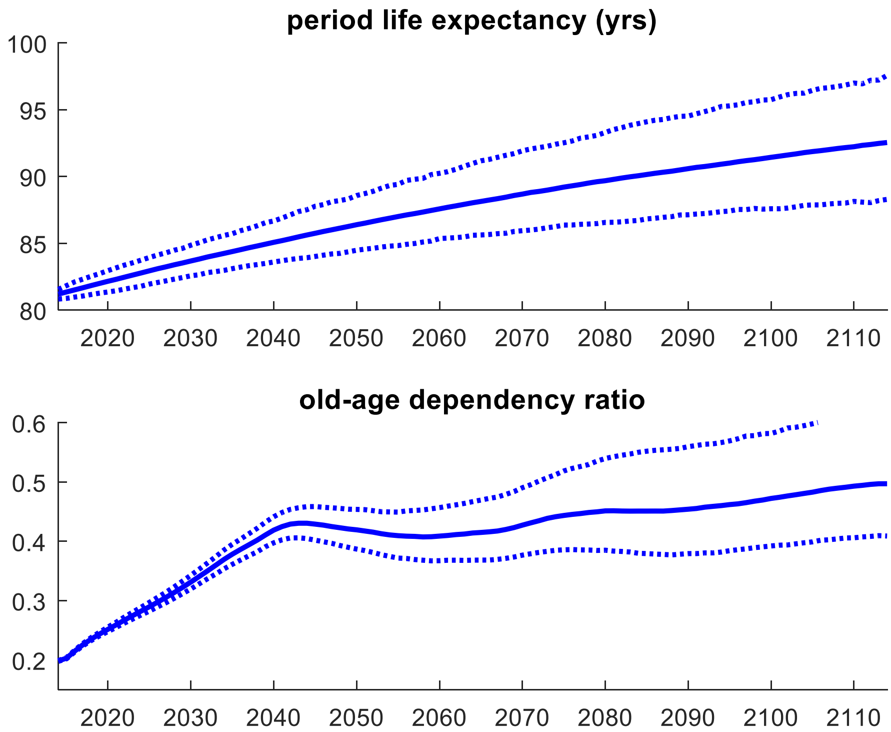


Figure A.2: Median term structure up to 75 years at the 100-year horizon.

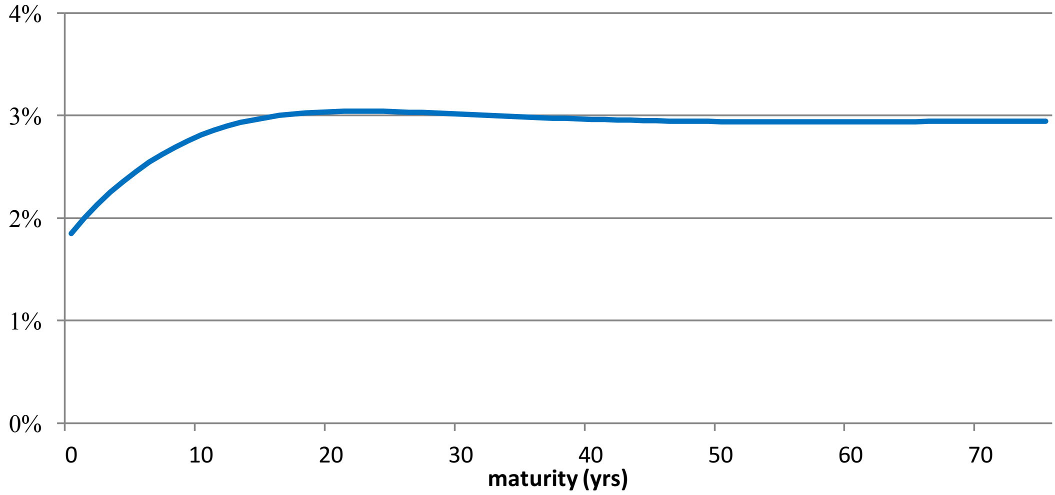


Table A.1: Descriptive statistics of the 1-year interest rate R[1 yr], the 10-year interest rate R[10 yr], the 30-year interest rate R[30 yr], the stock return S, and the inflation rate π.

	R[1 yr]	R[10 yr]	R[30 yr]	S	π
Average μ (%)	1.91	2.77	3.00	6.73	1.70
Standard deviation σ (%)	1.45	1.36	1.08	18.2	0.71
Minimum (%)	-0.25	-0.17	0.25	-78.2	-0.48
Maximum (%)	7.50	8.45	7.07	132.3	4.06
Correlation matrix					
R[1 yr]	1	0.73	0.61	-0.04	0.72
R[10 yr]	0.73	1	0.98	-0.03	0.53
R[30 yr]	0.61	0.98	1	-0.02	0.44
S	-0.04	-0.03	-0.02	1	-0.04
π	0.72	0.53	0.44	-0.04	1

Financial scenarios

The financial scenario set is based on the model in Wu and Xia (2016). This Zero Lower Bound (ZLB) scenario set implements a lower bound on forward rates at -0.25%. Muns (2017) contains more details on the estimation of this model using euroswap data. The portfolio return is the return of stocks and bonds less portfolio costs of 0.5% per year. Portfolio costs include asset management, transaction and execution costs.[7]

7 This is a rough estimate as costs are sometimes subtracted from otherwise higher returns. It is based on 232 pension funds covering 99% of the Dutch pension market. *http://www.lcpnl.com/nl/nieuws-en-publicaties/nieuws/2016/20161027_uitvoeringskosten_pensioenfondsen_2016/*. An overview is presented in DNB *Table 8.19*.

Figure A.2 depicts the median term structure at the 100-year horizon. Table A.1 reports descriptive statistics of the interest rate *R* for 1, 10, and 30-year durations, the stock return *S*, and the inflation rate π. All statistics are annually compounded and evaluated at the 100-year horizon of 2,000 simulations. The top lines are the geometric average μ, the standard deviation σ, the minimum, and the maximum. It is assumed that annual wage inflation rate is 0.5%-point above annual price inflation. The bottom lines represent the correlation matrix.

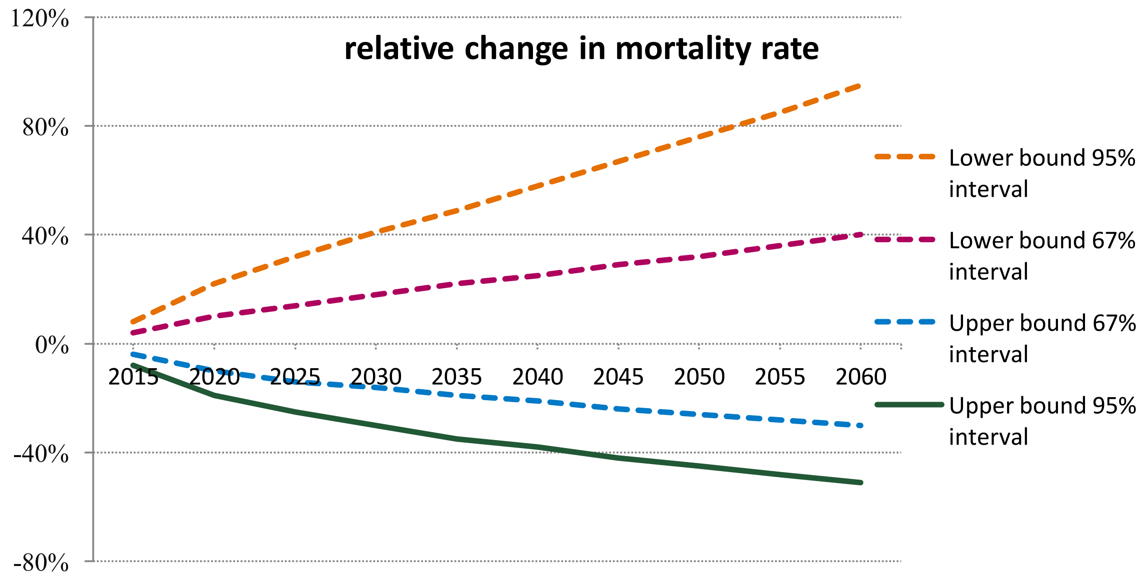
B. Mortality shock

To recover the required change in mortality rate *m(x)*, we find for each simulation period t the adjustment a_t in the survival function that gives the corresponding lower bound $LE_t^{95\%}$ of the life expectancy,

$$\mathbb{E}[\tilde{X}] = \sum_{y=0}^{\infty} \mathbb{P}(X > y)^{(1+a_t)} = LE_t^{95\%} \quad \mathbb{P}(X > y)^{(1+a_t)} = \exp\left(-\int_{x=0}^{y} (1+a_t)m(x)\,\mathrm{d}x\right).$$

The solid line in Figure A.3 indicates the required adjustment a_t which we apply to the mortality rate scenarios. The adjustment is more pronounced for more distant years since the confidence bands of the life expectancy forecast are wider at a longer horizon.

Figure A.3: 67% and 95% confidence intervals of relative changes in Dutch mortality rates per year.
Source: Statistics Netherlands, forecast 2014.



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