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Stabilizing Pay-As-You-Go Pension Schemes in the Face of Rising Longevity and Falling Fertility: An Application to the Netherlands

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Stabilizing pay-as-you-go pension schemes in the face of rising longevity and falling fertility: an application to the Netherlands*

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Abstract

Rising longevity and falling fertility threaten the sustainability of pay-as-you-go pension schemes. This paper shows that maintaining the intergenerational balance in the Dutch pay-as-you-go pension scheme in the face of increased longevity since the introduction of the scheme in 1957 would have required a gradual increase of the retirement age to at least 68 years for the generation born in 1945. Furthermore, we show that projected increases in labour-force participation rates do not generate sufficient additional tax revenues to subsitute for the dearth of human capital caused by falling fertility rates.

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1 Introduction

Rising longevity and falling fertility threaten the sustainability of pay-as-you-go (PAYG) pension schemes. Sinn (2000) advocates a partial shift to a fully funded pension scheme in order to absorb lower fertility rates. Generations that want to consume without working when they are old, have to either save or raise children in order to provide for the resources in old age. According to Sinn (2000), generations that feature lower fertility should substitute financial capital for human capital of children as a source of pension income. In particular, lower investment in human capital as a result of falling fertility rates reduces spending on e.g. feeding, clothing and educating children. The released resources should be converted into additional savings for future pensions. In addition, raising fewer children saves time. The additional time could be used to work more and the additional labor income would be another source of savings. Concerning increased longevity, Shoven and Goda (2008) argue that living longer requires an increase in the age at which one becomes eligible for public pensions (the "retirement age") to correct for "age inflation". They argue that a failure to adjust the retirement age for mortality improvements would substantially increase the fraction of the population eligible to receive PAYG pension benefits.

We explore adjustments along the lines proposed by Sinn (2000) and Shoven and Goda (2008) for the PAYG pension scheme of the Netherlands – the so-called AOW pension scheme established in 1957. The methodological cornerstone of our approach is a benchmark scenario featuring constant lifetime fertility, mortality and labour-participation profiles since the introduction of the Dutch PAYG pension scheme in 1957. Actual fertility, mortality and labour-participation profiles observed since 1957, however, differ from the constant profiles in the benchmark scenario. Given these implied demographic and economic shocks, we compute adjustments in the public pension system that will restore the initial intergenerational balances (i.e. the present value of the difference between taxes paid and benefits received per generation) in the benchmark scenario. In particular, we consider how the initial intergenerational balances can be restored by adjusting the retirement age in response to longevity shocks, by levying non-fertility taxes in response to negative fertility shocks and by imposing non-participation taxes in case of negative labour-force participation shocks.

The rest of this paper is structured as follows. Section 2 presents a simple model of a PAYG pension scheme, while section 3 discusses the methodology of the paper. Sections 4, 5 and 6 analyze the longevity, fertility and labour-participation shocks occurred since 1957 as well as the adjustments outlined above that could have restored the initial intergenerational balances. Section 7 explores whether positive (female) labour-participation shocks have compensated for negative fertility shocks. Section 8 summarizes the main findings of the paper.

2 Model

2.1 Population and economy

Before introducing a PAYG pension scheme, we start with a simple demographic and economic model. Let us denote the remaining number of people born at time i aged $t-i$ at time t as $n_{i,t}$ with $t-i=\{0,1,2,...,D\}$ for D being the fixed maximum age an individual can reach. Accordingly, we can express the number of newborn babies at time i as $n_{i,i}$.

Let us define the fertility profile of the generation born at time i (henceforth denoted as generation i) as the age-specific fertility rates of that generation over its lifetime. More specifically, suppose that at time t, each female born at time j gives birth to $f_{j,t}^F$ female and $f_{j,t}^M$ male babies.[1] The initial size of generation i can then be defined as

$$n_{i,i}=\sum_{j=i-D}^{i-1}\left(f_{j,i}^F+f_{j,i}^M\right)n_{j,i}^F. \tag{1}$$

Let us define the longevity profile of generation i as the age-specific survival probabilities of that generation over its lifetime. The remaining female population at time t of the generation born at time i ($n_{i,t}^F$) equals

$$n_{i,t}^F=\left[\left(1-p_{i,i+1}^F\right)\left(1-p_{i,i+2}^F\right)..\left(1-p_{i,t}^F\right)\right]n_{i,i}^F, \tag{2}$$

with $p_{i,t}^F$ being the mortality rates at time t from age $(t-i)-1$ to age $t-i$ of the female generation i. Given the supposed maximum age D, $p_{i,i+D}^F=1$ by definition. For reasons of simplicity, migration is not taken into account in the model.[2] Equations (1) and (2) describe the dynamics of a population over time.

Suppose individuals can earn labour income by supplying labour. The average wage earned *per active full-time equivalent* at time t (w_t) can be expressed as

$$w_t=\frac{Y_t^F+Y_t^M}{\sum_{i=t-D}^{i=t-1}\alpha_{i,t}^F\beta_{i,t}^F n_{i,t}^F+\sum_{i=t-D}^{i=t-1}\alpha_{i,t}^M\beta_{i,t}^M n_{i,t}^M}, \tag{3}$$

with
Y_t^F: aggregate female labour income at time t
$\alpha_{i,t}^F$: labour participation of $n_{i,t}^F$ (fraction of $n_{i,t}^F$ being employed)
$\beta_{i,t}^F$: part-time factor of $n_{i,t}^F$ (number of hours worked per person employed as a fraction of the maximum number of hours).

[1] We denote the female version of each variable with the superscript F and the male version with the superscript M. In most cases below, we provide the definition of only the female version of each variable. The definition of the male version will be equivalent unless stated otherwise.

[2] Migration could be included in the model via $p_{i,t}^F$. In that case, $p_{i,t}^F$ would be negative if net inward migration would exceed deaths within a generation in a particular year.

For later use, we define the labour-participation profile of generation i as the age-specific labour-participation rates of that generation over its lifetime. Equivalently, we define the part-time profile of generation i as the age-specific part-time factor of that generation over its lifetime.

2.2 PAYG pension scheme

Now we introduce a PAYG pension scheme providing retired people with a pension benefit financed by taxes paid by non-retired people.[3] Taxes paid are proportional to average labour income. The annual revenues of the PAYG pension scheme at time t (T_t) are then equal to the sum of the taxes paid by all living generations contributing to the PAYG pension scheme

$$T_t = \sum_{i=t-D}^{t-1} \tau_t a_{i,t} \left[n_{i,t}^F y_{i,t}^F + n_{i,t}^M y_{i,t}^M \right], \tag{4}$$

with

τ_t: tax rate at time t

$a_{i,t}$: tax dummy (equal to 1 for taxable, non-retired generations and 0 for non-taxable, retired generations at time t)

$y_{i,t}^F$: average per capita labour income earned at time t by the female generation i.

The linearity of the tax system implies that we do not need to worry about intragenerational heterogeneity when computing total tax revenues. In fact, we fully abstract from intragenerational heterogeneity. We look only at averages within a generation and assume that the marginal person is equal to the average person when we consider changes in the size of a particular generation.

Suppose that the PAYG pension benefit is proportional to the average wage rate in the economy (w_t), implying that the pension benefit is not related to individual earnings. Indeed, every individual is entitled to PAYG pension benefits after reaching the retirement age, irrespective of lifetime earnings. The annual expenditures of a PAYG pension scheme at time t (B_t) are then equal to the sum of the benefits of all living generations benefiting from the PAYG pension scheme

$$B_t = \sum_{i=t-D}^{t-1} \gamma_t w_t b_{i,t} \left[n_{i,t}^F + n_{i,t}^M \right], \tag{5}$$

with

γ_t: replacement rate at time t (PAYG pension benefit as fraction of w_t)

$b_{i,t}$: benefit dummy (equal to 1 for retired generations and 0 otherwise).

[3] The distinction retired versus not-retired thus involves the eligibility for PAYG pension benefits and does not have direct consequences for labor supply. In fact, people who collect PAYG pension benefits may still work, while those who are not eligible for the PAYG benefit may not work.

Individuals either pay taxes to the PAYG pension scheme or receive benefits (implying $b_{i,t} = 1 - a_{i,t}$). The borderline is at the "retirement age", i.e. the age at which people become eligible for the PAYG pension benefit. In terms of our model, the retirement age of a generation can be shifted by changing $a_{i,t}$. The tax rate and replacement rate at time t are the same for all generations.

A PAYG pension scheme in fact implies a balanced budget at each point in time

$$T_t = B_t, \tag{6}$$

which can be maintained by adjusting either the tax rate τ_t or the replacement rate γ_t (or both). In the former case, the PAYG pension scheme is of a defined-benefit type; in the latter case it is of a defined-contribution type. As we show in appendix A, the Dutch AOW pension scheme has been a mixture of both types since its establishment in 1957. Apart from that, it deviates from the PAYG pension scheme as modelled above in three respects. First of all, the statutory tax rate is capped by law at 0.179 and applied solely to the first and second tax brackets. Hence, the tax rate in equation (4) – which defines total taxes paid to the PAYG pension scheme as a fraction of total income – is not comparable with the statutory tax rate for the AOW pension scheme. In fact, any deficits of the AOW pension scheme are supplemented by other tax receipts. Consequently, retirees also contribute to the PAYG pension scheme insofar as they pay other taxes. This implies that the tax dummy $a_{i,t}$ in equation (4) is not strictly binary in reality, but can vary between 0 and 1 for retired people depending on the supplements from the general tax system. Secondly, AOW pension benefits are related to the contemporaneous statutory minimum wage rather than the contemporaneous average (full-time) wage in the economy as assumed in our model. Finally, although we do not include immigrants in the model for reasons of simplicity, in reality they are entitled to AOW pension benefits in proportion to the period they have resided in the Netherlands.

3 Methodology

The methodological cornerstone of our paper is a benchmark scenario in which demographic and economic lifetime profiles are supposed to be constant after the introduction of the PAYG scheme (i.e. $\overline{f}_s^F$, $\overline{p}_s^F, \overline{\alpha}_s^F$, $\overline{\beta}_s^F, \overline{a}_s$ and $\overline{b}_s$, with a bar denoting the benchmark value of each variable at age s, where we have eliminated the time subscripts because these variables are assumed to be constant). Imposing the balanced budget constraint of a PAYG pension scheme (see equation 6) on the benchmark scenario, we find a consistent set of tax and replacement rates under the assumption that the replacement rate is kept constant after 2006 (see appendix A). In the absence of demographic and economic shocks, the PAYG pension scheme ultimately converges to a steady state in the benchmark scenario.

Demographic and economic shocks cause actual demographic and economic lifetime profiles to deviate from their benchmark profiles. Maintaining a balanced budget in the face of such shocks would require adjusting either the tax rate (in a defined-benefit pension scheme) or the replacement rate (in a defined-contribution pension scheme). However, these adjustments could lead to a rather arbitrary income redistribution among generations. For instance, in a defined-benefit scheme, non-retired generations would have to pay extra taxes if retired generations experience a positive longevity shock. Furthermore, in a defined-contribution scheme, retired generations would have to accept lower benefits if the labour participation of non-retired generations falls. It would seem more appropriate, however, if the generations "causing" the demographic and economic shocks would bear the external effects of their behavior on the budget of the public pension system. This principle implies that the present value of the balance of the taxes paid minus the pension benefits received by each generation over its lifetime (the so-called intergenerational balances) should remain unchanged in the face of demographic and economic shocks. In fact, maintaining intergenerational balances in the face of shocks implies that we do not necessarily impose the requirement of a public budget that is balanced at each point in time – as is the case in a pure PAYG pension scheme. Indeed, the government might save by acquiring assets or dissave by issuing public debt.

4 Longevity shocks

4.1 Analytical framework

An increase in the age-specific survival rates of a generation has two financial effects on its intergenerational balance. First of all, aggregate taxes paid by that generation rise as the average period during which people pay taxes becomes longer. Secondly, aggregate pension benefits received by that generation increase also as more people survive up to the retirement age and the average period that eligible people receive pension benefits increases.[4]

Let us now consider this more formally. The direct longevity effects on taxes paid per female generation ($\Delta\widetilde{T}_i^F$) can be calculated as the (expected) present value of the difference between on the one hand taxes paid according to the actual longevity ($\widetilde{n}_{i,j}^F$) and tax dummy ($a_{i,j}$) profile, and on the other hand taxes paid according to the benchmark longevity ($\overline{n}_{i,j}^F$) and tax dummy ($\overline{a}_{i,j}$) profile

$$\Delta\widetilde{T}_i^F = \sum_{j=i+1}^{i+D} R_{i,j}\tau_j\overline{y}_{i,j}^F\left[a_{i,j}\widetilde{n}_{i,j}^F - \overline{a}_{i,j}\overline{n}_{i,j}^F\right], \tag{7}$$

with discount factor $R_{i,j}$ defined as

$$R_{i,j} = \left[(1+r_{i+1})(1+r_{i+2})\,...\,(1+r_j)\right]^{-1}, \tag{8}$$

[4] Appendix B provides a detailed decomposition of the impact of longevity shocks on the intergenerational balance.

where r_j equals the interest rate in year j. Note that we keep discount rates constant in the face of demographic (or economic) shocks.

Equivalently, the direct longevity effects on benefits received per female generation ($\Delta\widetilde{B}_i^F$) can be calculated as the (expected) present value of the difference between on the one hand benefits received according to the actual longevity ($\widetilde{n}_{i,j}^F$) and benefit dummy profile ($b_{i,j}$), and on the other hand benefits received according to the benchmark longevity ($\overline{n}_{i,j}^F$) and benefit dummy profile ($\overline{b}_{i,j}$)

$$\Delta\widetilde{B}_i^F = \sum_{j=i+1}^{i+D} R_{i,j}\gamma_j w_j \left[b_{i,j}\widetilde{n}_{i,j}^F - \overline{b}_{i,j}\overline{n}_{i,j}^F\right]. \tag{9}$$

The implicit longevity debt of the female generation born in year i ($\widetilde{DEB}_i^F$) can be expressed as

$$\widetilde{DEB}_i^F = \Delta\widetilde{B}_i^F - \Delta\widetilde{T}_i^F, \tag{10}$$

while the total implicit longevity debt of each generation ($\widetilde{DEB}_i$) equals

$$\widetilde{DEB}_i = \widetilde{DEB}_i^F + \widetilde{DEB}_i^M. \tag{11}$$

The initial intergenerational balance of generation i can be restored by changing the retirement age (i.e. by changing $a_{i,j}$ and $b_{i,j}$) such that $\widetilde{DEB}_i = 0$. Note that this would imply that the pension scheme is no longer balanced at any point of time as in the benchmark scenario. In fact, the pension scheme is now supplemented by a funded scheme for longevity shocks.

4.2 Data

4.2.1 Benchmark

A natural candidate for the longevity benchmark would be the observed survival rates in the calender year 1957. However, the actual survival rates of generation 1892 (being the first generation receiving AOW pension benefits after its retirement in 1957 for the rest of its life) differ from these 1957 survival rates. This implies that generation 1892 would face a longevity shock after being retired. The budgetary impact of such a shock for the AOW pension scheme could be absorbed in different ways. First of all, the tax and replacement rate of all living generations could be adjusted, which would yield optimal risk sharing between generations. However, this would be at odds with our principle of unchanged intergenerational balances. Alternatively, the replacement rate of generation 1892 could be lowered in order to restore its intergenerational balance. However, this would violate the principle of consumption smoothing for that generation. A solution would be to use the age-specific survival rates of generation 1892 as the benchmark for age-specific survival rates for ages above 65. Under the assumption of perfect foresight, these expectations generate a retirement age of 65 for generation 1892. Hence, we decided to create a synthetic longevity benchmark that is the combination of the age-specific survival rates of generation 1892 above age 65 and the observed age-specific survival rates in 1957 below age 65.

Figure 1: Female longevity profiles

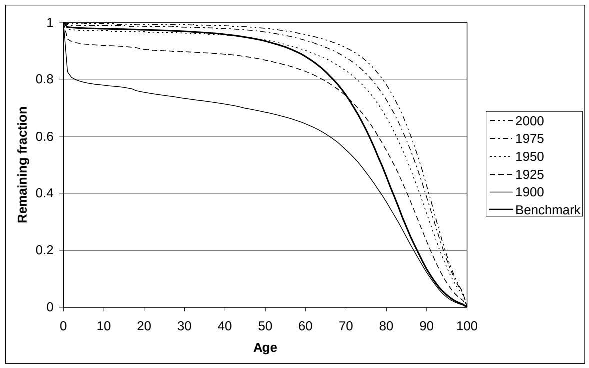
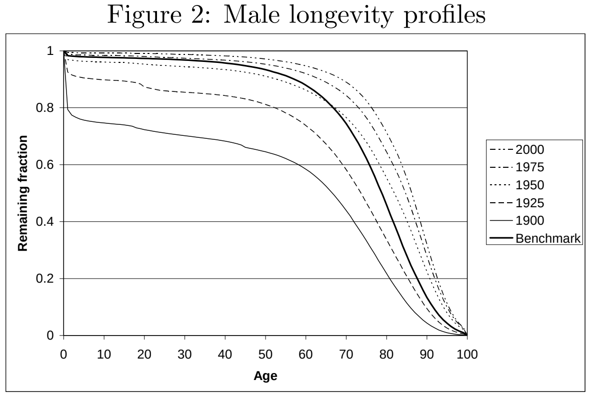


Figure 2: Male longevity profiles



4.2.2 Shocks

Figures 1 and 2 show for both genders the actual longevity profiles of the generations born in 1900, 1925, 1950, 1975 and 2000 as well as the benchmark longevity profile. For the younger generations that have not died out yet, we need to rely on projected survival rates. The official population projection of Statistics Netherlands provides survival rates up to the year 2050 (see appendix C for a complete description of the data sources used). Survival rates beyond 2050 were extrapolated using the LCFIT-version of the Lee-Carter model (http://simsoc.demog.berkeley.edu/).

An increase in age-specific survival rates leads to an outward shift of the longevity profile. Figures 1 and 2 show that the remaining longevity of the subsequent generations born in the 20th century has increased. Reduced infant mortality plays a major role. In addition, improved nutrition and health care have contributed to increased longevity (Cutler and Meara, 2001). An alternative measure for changes in longevity is the evolution of the expected (remaining) life expectancy of a generation at a certain age. Let us define the remaining life expectancy at age 65 as the expected benefit period of a generation, measuring the average period a generation receives pension benefits. Equivalently, define the life expectancy from ages 15 to 65 as the expected contribution period of a generation, measuring the average period a generation pays taxes.

Figure 3: Evolution expected contribution and benefit period per gender

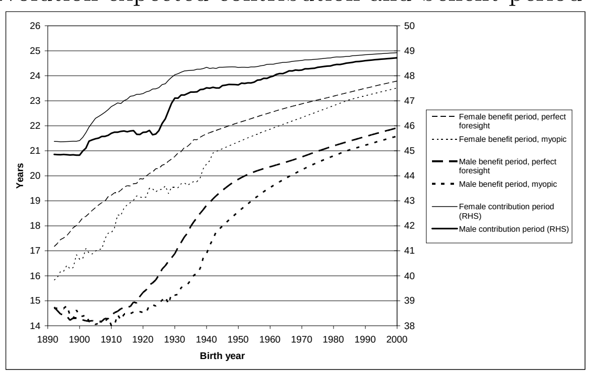


Figure 3 shows for both genders the evolution of the expected contribution and benefit period, the latter both for myopic expectations (i.e. based on the survival rates in a calender year) and perfect foresight (i.e. based on survival rates of a generation). Compared to generation 1892, the average expected contribution period for men and women will have increased by 2.9 years for generation 1945 and by 3.7 years for generation 2000. At the same time, compared to generation 1892, the average expected benefit period using perfect foresight (myopic) expectations will have increased by 4.7 (4.3) years for generation 1945 and by 6.9 (7.3) years for generation 2000. Hence, the first important conclusion that can be drawn is that the increase in the expected benefit period exceeds the increase in the expected contribution period. Moreover, an increase in the contribution period also implies that a larger fraction of a generation will have survived at the retirement age. This suggests that longevity increases have been detrimental for intergenerational balances. Secondly, there has been a convergence of both the expected contribution and benefit periods of men and women. Although initially men were lagging even more behind[5], they are gradually catching up with women over time.

[5] For male generations born between 1893 and 1907, the expected benefit period actually fell due to the so-called tobacco epidemic reducing the remaining longevity for smoking men (Janssen et al., 2007).

4.3 Adjustment

4.3.1 Equilibrium retirement age

Using the benchmark longevity profile, we start by calculating the (expected) implicit longevity debt for the generations born between 1892 and 2000.[6] In general, the longevity shocks experienced since 1957 caused an implicit longevity debt for all generations considered. Given this longevity debt, we calibrated $a_{i,j}$ in equation (7) and $b_{i,j}$ in equation (9) to compensate for the longevity debt within each generation such that intergenerational balances are unaffected by increased longevity. The new retirement age is called the *equilibrium retirement age* (ERA).

Figure 4 shows the equilibrium retirement age for all generations born between 1892 and 2000 for various combinations of the real interest rate and real wage growth after 2008. Let us first consider the ERA with a real wage growth (g) of 1% and a real interest rate (r) of 3% beyond 2008. The ERA gradually increases to 69.1 years for generation 1945 and to 70.9 years for generation 2000 in this scenario. The dashed and dotted lines show the sensitivity of the ERA for the growth rate. Higher growth raises the ERA, as it implies more generous AOW pension benefits. The fat lines show the sensitivity of the ERA for the interest rate. A higher (lower) interest rate reduces (raises) the ERA, as future pension benefits are discounted more (less).[7]

Figure 4: Equilibrium retirement age: no participation effects

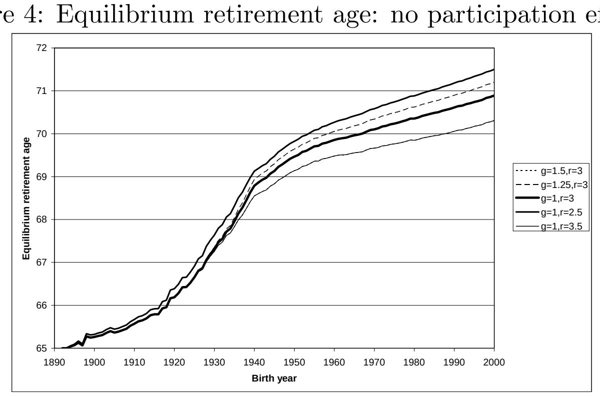


Figure 4 keeps age-specific labour-participation rates fixed at the static benchmark profile. However, increasing the retirement age might well raise age-specific labour-participation – for example, by raising the social norm at which one retires from the labour force. This would reduce the required increase in the equilibrium retirement age as higher employment rates would yield more AOW

[6] We include the actual contributions paid and benefits received since 1957. Hence, we do not include the non-paid contributions of generations born before 1942 when determining the implicit longevity debt.

[7] Note that the lines g=1.5, r=3 and g=1, r=2.5 coincide, as r-g equals 1.5 in both variants.

tax revenues.[8] Hence, the ERA as calculated in figure 4 must be considered as the upper bound for the required increase in the retirement age as it abstracts from the possible impact of higher labor-force participation on intergenerational balances. The empirical literature on the participation effects of raising the retirement age is limited. However, empirical evidence for the US (Mastrobuoni, 2006) suggests that Americans aged 62 and above have postponed their retirement by one month in response to a two-month increase of the statutory retirement age.[9] In the absence of empirical estimates for the participation effect for the Netherlands, we will assume that the participation profile (both in terms of number of people participating as well as hours worked) is stretched out from the age of 45 until the retirement age in response to changes in the retirement age. More specifically, by means of sensitivity analysis, we assume a participation effect in response to increases in the retirement age of 0%, 50% and 100% starting at the age of 45. For instance, in case of a 100% response, an increase in the retirement age by one year will increase the participation of 60-year olds to that of 59-year olds prior to the adjustment in the retirement age. This implies that the ERA required to restore the same intergenerational balances as before the longevity shock must be solved simultaneously with the participation profile, requiring an iterating numerical procedure.

Figure 5: Equilibrium retirement age: with participation effects

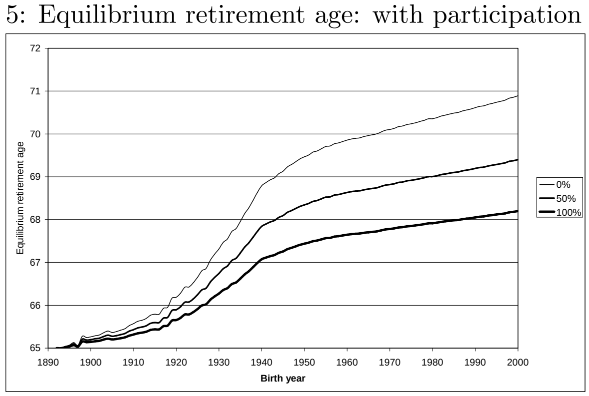


Figure 5 shows the ERA[10] for labour-participation effects ranging from 0% to 100%[11] for r=3% and g=1% after 2008. In the case of a participation effect of 50%, the ERA increases to 68.1 years for generation 1945 and 69.4 years for generation 2000. In that case, on average approximately a quarter of the required longevity adjustment is accounted for by participation changes induced

[8] Note that this effect would be even greater if we would account for other taxes than AOW taxes.

[9] In 1983, the US government announced that the statutory retirement age would be increased by two months per year starting in 2003.

[10] The calculated ERAs have been smoothed to prevent an erratic development of the ERA.

[11] Note that a labour participation effect of 0% corresponds to the line g=1, r=3 in figure 4.

by a higher retirement age. In the extreme case of a participation effect of 100%, the ERA increases to 67.3 years for the generation born in 1945 and 68.2 years for generation 2000, reflecting a lower bound for the ERA. In that case, on average almost half of the required longevity adjustment is accounted for by participation changes induced by a higher retirement age. Hence, the ERA declines with the participation effect. Accordingly, depending on the growth assumptions and the behavioral participation effects, our calculations suggest that the retirement age should gradually be raised to between approximately 68 and 70 years for generation 1945 and between 69 and 71 years for the generation born in 2000 to absorb the impact of increased longevity on intergenerational balances.

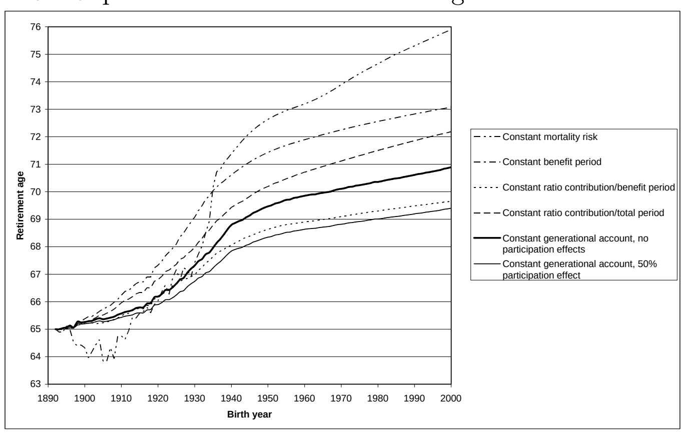
4.3.2 Alternative rules of thumb

Some authors have proposed alternative rules to determine the required increase in the retirement age in the face of higher longevity. For instance, Van Dalen *et al.* (2006) and Shoven and Goda (2008) suggested some simple rules of thumb. Unlike the ERAs, which are based on intergenerational balances, the retirement ages according to these rules of thumb are determined on the basis of demographic elements only. We will apply these and some other rules of thumb to the Dutch AOW pension scheme and finally compare the outcomes with the ERAs determined above. In order to allow for a fair comparison, we assume perfect foresight concerning future survival probabilities when applying these rules and calibrate the required retirement age for generation 1892 at 65.

Constant mortality risk at retirement The first rule of thumb keeps the mortality risk at the retirement age constant over generations (Shoven and Goda, 2008). For generation 1892, the probability of mortality at age 65 amounted to 1.9%. According to this rule, the AOW retirement age should be lowered for generations born before 1912, as their probability of mortality at age 65 actually increased due to the tobacco disease (Janssen *et al.*, 2007). However, the probability of mortality subsequently fell sharply between ages 65 and 75, a phenomenon that is known as the compression of mortality. Hence, according to this rule, the AOW retirement age should be gradually increased to 72.1 years for the generation 1945 and to almost 75.9 years for the generation 2000 (see figure 6).

Constant benefit period A drawback of the first rule is that changes in mortality at high ages are not taken into account. Hence, an alternative rule of thumb would be to keep the remaining life-expectancy (RLE) at retirement constant over generations by adjusting the retirement age (Van Dalen *et al.*, 2006). For generation 1892, the RLE at age 65 amounted to 16.0 years. According to this rule, the AOW retirement age should gradually be increased to 71.1 years for generation 1945 and 73.1 years for generation 2000. Note that the implied increase in the retirement age exceeds the increase in the RLE at age 65 as shown in section 4.2.2. This is because the marginal reduction in the RLE of a generation for every year that the retirement is increased, is less than one year. The reason behind this is that those members of that generation with a RLE of less than one year die as the retirement age is increased by one year. Put differently, those members no longer pull down the average RLE of the generation as a whole. The drawback of the former rules of thumb is that they neglect improvements of survival rates before the retirement age. Such improvements affect the intergenerational balance of a generation in two ways (see appendix B). First of all, they raise the amount of taxes contributed by a generation over its lifetime. Secondly, the fraction of a generation reaching the retirement age (and becoming eligible for retirement benefits) increases. For these reasons, we now explore two alternative rules.

Figure 6: Required increase in retirement age: some rules of thumb



Constant ratio contribution over benefit period The first rule keeps the ratio of the expected contribution period over the expected benefit period constant. This rule guarantees that a relative change in the period in which benefits are received is matched by an equally relative change in the period in which taxes are paid. For generation 1892, the expected contribution period at age 15 amounted to 45.1 years, while the expected benefit period at age 65 amounted to 16.0 years, yielding a ratio of the expected contribution period over the expected benefit period of 2.8. Keeping this ratio constant would require a gradual increase of the AOW retirement age to 68.4 years for generation 1945 and to 69.7 years for generation 2000.

Constant ratio contribution over total period Although intuitively appealing, the former rule still does not explicitly account for the fraction of a generation that reaches the retirement age – which matters for the intergenerational balance, as mentioned before. Therefore, a better rule would be to keep the ratio of the expected contribution period over the *remaining* life expectancy at age 15 (henceforth denoted as the expected *total* period) constant for each generation.[12] In fact, under this rule, both the expected contribution and expected benefit period are determined at the age of 15. Adhering to this rule would require a gradual increase of the AOW retirement age to 69.8 years for generation 1945 and to 72.2 years for generation 2000. Hence, the latter rule results in a higher AOW retirement age than the former, as it explicitly takes into account the fact that a larger fraction of a generation reaches the retirement age.

The latter rule does not account for the fact that longevity changes that occur early in the life cycle outweigh longevity changes late in the lifecycle because of time-discounting. It is mainly for this reason that the ERAs as calculated before are lower than retirement ages implied by the second alternative rule (see figure 6). Indeed, the ERA takes into account not only changes in the expected ratio of the contribution over the benefit ratio, but also the fraction of a generation that reaches the retirement age and the time discount factor. Hence, this explains why we consider the ERA superior to the considered alternative rules of thumb.

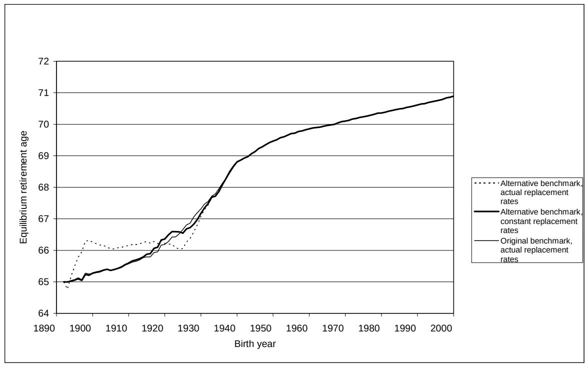
4.3.3 Equilibrium retirement age: impact of changes in replacement rates

So far, we used the actual replacement rates from the benchmark scenario to calculate the required adjustment in the AOW retirement age. However, one might argue that any decrease in the replacement rate in fact compensates for a positive longevity shock. According to this line of reasoning, the lower the average replacement rate, the smaller the increase in the ERA should be. In order to identify this effect, we now take an alternative benchmark scenario as a starting point, featuring a constant replacement rate of 0.26 over the whole period considered. The corresponding tax rates required for a balanced budget in this alternative benchmark scenario, can be derived by applying eq. (26). The bold line in figure 13 shows that the average replacement rates of the generations born between 1893 and 1920 exceed 0.26, while the average replacement rates of the generations born between 1920 and 1935 are lower than 0.26.

As a reference, the solid line in figure 7 shows the ERAs using the original benchmark scenario, while the bold line depicts the ERAs based on the alternative benchmark scenario. Both scenarios yield almost the same pattern for the ERA. The dotted line shows the ERA if we apply the actual AOW replacement rates in the alternative scenario. Hence, the difference between the dotted and the bold line provides an indication of the impact of changes in the replacement rate on the required increase of the AOW retirement age. Indeed, the ERAs of generations born before 1920 exceed the original ERAs reflecting their rather generous average replacement rates. For generations born between 1920 and 1935 it is the other way around: their ERAs are also lower than the original ERAs, reflecting their rather frugal replacement rates. For generations born after 1935, the ERAs are almost identical, as the replacement rate is kept constant

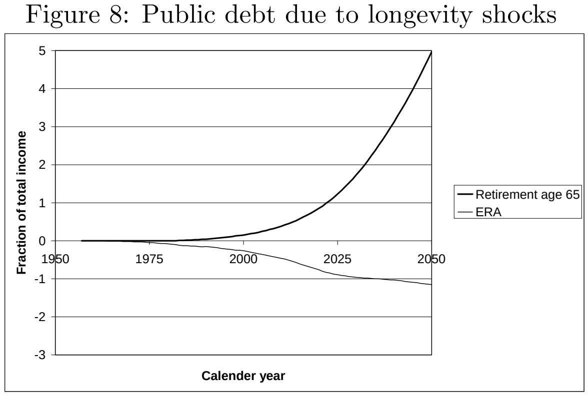
[12] This is a modified version of the rule presented in Van Dalen *et al.* (2006), who fix the contribution period at 50 years.

Figure 7: Equilibrium retirement age: impact of changes in replacement rates



at 0.26 after 2006. Summarizing, this analysis suggests that taking into account changes in average replacement rates, increases the ERAs of generations born before 1920, while it reduces the ERAs of generations born between 1920 and 1935. However, the differences remain fairly small.

Figure 8: Public debt due to longevity shocks



4.3.4 Public debt due to longevity shocks

Figure 8 shows public debt[13] of the AOW pension scheme before and after the change in the retirement age[14]. With a constant retirement age, debt is exploding, due to the longevity shocks that have occurred since 1957. With retirement ages equal to the ERAs calculated before, the government acquires

[13] Apart from the direct longevity effects on intergenerational balances, there are also (small) cross-effects of coinciding longevity, fertility and labour-force participation shocks. These effects are spread evenly over public debt due to longevity, fertility and participation shocks.

[14] A minus sign implies that the PAYG pension scheme has build up assets.

assets to cover future longevity increases. Hence, figure 8 shows that increasing the retirement age to ERA levels will restore the sustainability of the AOW pension scheme in the face of longevity shocks.

5 Fertility shocks

5.1 Analytical framework

5.1.1 Shocks

The first-order demographic effect of a decrease in age-specific fertility rates is an immediate fall in the number of babies born. However, it is important to note that there are also higher-order effects. As future generations will be smaller, fewer babies today implies also fewer babies in the future, even if the fall in age-specific fertility rates would be temporary. Hence, the full implications of a fertility shock can only be determined in a recursive fashion by comparing complete demographic projections after and before (temporary) fertility shocks.

Let us now analyze this formally. Suppose that the number of female babies generated by female generation i at time t changes from age-specific benchmark value $\overline{f}^F_{t-i}$ to $\widehat{f}^F_{i,t}$ in year t, but remains at the age-specific benchmark values $\overline{f}^F_{t-i}$ after year t. Suppose also that the fertility profiles of all other female generations stay at the benchmark from year t on. Denote the projected size of the arbitrary female generation l at time j before the fertility shock as $\overline{n}^F_{l,j|i,t}$ and after the fertility shock as $\widehat{n}^F_{l,j|i,t}$. The marginal change in the size of $n^F_{l,j}$ due to this temporary fertility shock at time t caused by the female generation i ($\Delta n^F_{l,j|i,t}$) then equals

$$\Delta n^F_{l,j|i,t} = \widehat{n}^F_{l,j|i,t} - \overline{n}^F_{l,j|i,t}, \tag{12}$$

for $l = [t, \infty]$ and $j = [l, l + D]$.

In terms of intergenerational balances, a negative fertility shock implies both a loss in taxes paid and a fall in future pension benefits received by future generations. The present value at time t of the change in future taxes contributed by all generations born after time t caused by the fertility shock at time t attributable to the generation born at time i ($\Delta\widehat{T}^F_{i,t}$) equals

$$\Delta\widehat{T}^F_{i,t} = \sum_{l=t}^{\infty}\sum_{j=l}^{l+D} R_{t,j}\tau_j\overline{a}_{l,j}\overline{y}^F_{l,j}\Delta n^F_{l,j|i,t}. \tag{13}$$

Equivalently, the present value at time t of the change in future pension benefits received by all generations born after time t caused by the fertility shock at time t attributable to the generation born at time i ($\Delta\widehat{B}^F_{i,t}$) equals

$$\Delta\widehat{B}^F_{i,t} = \sum_{l=t}^{\infty}\sum_{j=l}^{l+D} R_{t,j}\gamma_j\overline{b}_{l,j}\overline{w}_j\Delta n^F_{l,j|i,t}. \tag{14}$$

Hence, the implicit non-fertility debt arising due to the fertility shock at time t attributable to generation i ($\widehat{DEB}_{i,t}^{F}$) can be expressed as

$$\widehat{DEB}_{i,t}^{F} = \Delta\widehat{B}_{i,t}^{F} - \Delta\widehat{T}_{i,t}^{F}, \tag{15}$$

where it can be shown that $\widehat{DEB}_{i,t}^{F}$ will converge to a finite value in a dynamically efficient economy.[15]

The total implicit non-fertility debt of generation i ($\widehat{DEB}_{i,t}$) caused by the fertility shock at time t can now be expressed as

$$\widehat{DEB}_{i,t} = \widehat{DEB}_{i,t}^{F} + \widehat{DEB}_{i,t}^{M}. \tag{16}$$

5.1.2 Adjustment

The initial intergenerational balance can be restored in two alternative ways. A first possibility would be to levy an additional "non-fertility" tax on generation i when this generation is raising children. As generation i saves time and resources that would otherwise be spent on raising children in the period following the negative fertility shock, it would be logical to levy such a non-fertility tax in this period. In that case, the government in fact saves on behalf of generation i, which would not have to save privately to absorb the negative consequences of the fertility shock for its consumption at old ages. We will denote this variant as the "non-fertility tax young" (NFTY) variant, as additional taxes are paid at young ages. Suppose the child-rearing period equals S years analogous to the time it takes to raise children until they enter the labour market at age S, and define the income growth rate of generation i at time $t+m$ as $g_{i,t+m}$. Then we can spread the implicit non-fertility debt over S years by converting it into an annuity defined as

$$\widehat{DEB}_{i,t} = \sum_{m=1}^{S} \frac{(1+g_{i,t})(1+g_{i,t+1})\dots(1+g_{i,t+m})}{(1+r_t)(1+r_{t+1})\dots(1+r_{t+m})} x_{i,t}, \tag{17}$$

with non-fertility taxes $x_{i,t+m} = (1+g_{i,t})(1+g_{i,t+1})\dots(1+g_{i,t+m})\, x_{i,t}$ being a constant fraction of the income of generation i at time $t+m$.

A second possibility to restore the intergenerational imbalance caused by a negative fertility shock, would be to lower the replacement rates of the pension benefits generation i will receive. In fact, this would be equivalent to taxing (gross) pension benefits. Therefore, we denote this variant as the "non-fertility tax old" (NFTO) variant. Let us now consider the NFTO-variant more formally. Suppose the present value of all non-fertility debts incurred by generation i during its life can be expressed as

$$\widehat{DEB}_{i} = \sum_{t=i}^{i+D} R_{i,t}\widehat{DEB}_{i,t}. \tag{18}$$

[15] This is the case if the real interest rate exceeds the sum of the productivity growth and the population growth.

The average non-fertility tax rate on pension benefits required to service this non-fertility debt (κ_i) in the NFTO-variant can now be expressed as

$$\kappa_i = \frac{\widehat{DEB}_i}{BEN_i}, \tag{19}$$

with BEN_i being the present value at birth of the *gross* pension benefits received by generation i. The *net* replacement rate of the pension benefit received by generation i at time t ($\widehat{\gamma}_{i,t}$) then equals

$$\widehat{\gamma}_{i,t} = (1 - \kappa_i)\,\gamma_t. \tag{20}$$

Accordingly, the net replacement rates at time t ($\widehat{\gamma}_{i,t}$) now differ among generations depending on the fertility shocks that can be attributed to them.

In fact, by levying a non-fertility tax, in both variants the PAYG pension scheme is supplemented with a funded scheme for fertility shocks. Compared with the NFTY-variant, in the NFTO-variant non-fertility taxes will be levied in a later stage of the life cycle, implying that there will be less public savings over time. However, in the NFTO-variant, forward-looking individuals aiming at consumption smoothing will compensate the future fall in pension benefits following a negative fertility shock by additional savings when they are young. Hence, in terms of national saving, the increase in private savings in the NFTO-variant will compensate for the lower level of additional public savings. This is in fact the scenario that Sinn (2000) had in mind; he advocated a private funded system to supplement a smaller public PAYG system.

5.2 Data

5.2.1 Benchmark

A natural candidate for the fertility benchmark would be the fertility rates registered in the calender year 1957. These rather high fertility rates, however, would generate an exploding population in the benchmark scenario. Moreover, we would register quite large negative fertility shocks in the period after 1957. Therefore, as an alternative, we adopted a benchmark fertility profile that ultimately generates a constant population. A necessary condition for such a fertility profile is that so-called completed fertility (reflecting the number of babies a woman gives birth to over her lifetime) amounts to 2.1. Accordingly, to arrive at a benchmark fertility profile, we proportionally decreased the age-specific fertility rates registered in the calender year 1957 in such a way that completed fertility equals 2.1.

5.2.2 Shocks

Figures 9 and 10 show the fertility profiles of generations born between 1935 and 1970 as well as the benchmark fertility profile. For the youngest generations, we had to resort to fertility projections of Statistics Netherlands. Note that perfect foresight is not a necessary condition for fertility shocks (unlike

Figure 9: Fertility profiles: generations 1935-1950

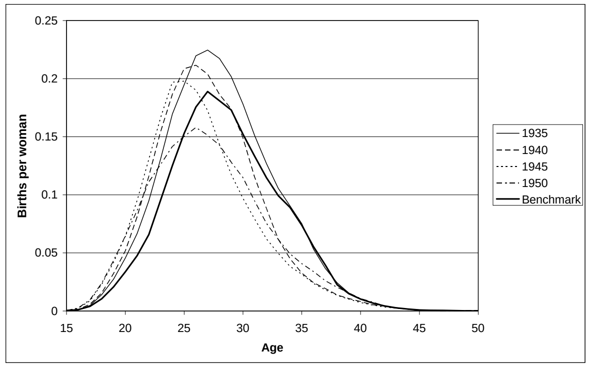
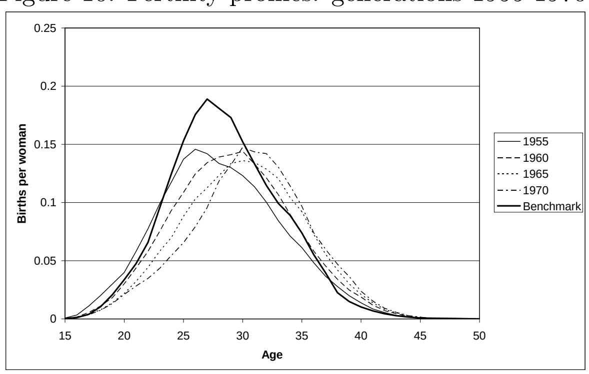


Figure 10: Fertility profiles: generations 1955-1970



longevity shocks): unexpected fertility shocks can be attributed to the generation responsible for the fertility shock. The area below each line represents the completed fertility. As argued above, the benchmark fertility is characterized by completed fertility of 2.1, which is consistent with a constant population in the long run. The completed fertility of the generations born before 1943 exceeded 2.1, implying that these generations caused positive fertility shocks. However, the completed fertility of the generations born since 1943 has fallen rapidly, implying that these generations have caused negative fertility shocks. Finally, note that age-specific fertility at older ages fell for the oldest generations considered, while it increased again for younger generations. The former can be explained mainly by the increased use of contraception, which has facilitated a more smooth birth pattern over the lifecycle of women. The latter can be explained by the wish to postpone the motherhood-stage in the lifecycle, which in turn is related to increased female labour participation at younger ages.

5.3 Adjustment

This sub-section calculates the non-fertility taxes required to restore intergenerational balances in response to fertility shocks. Using the benchmark fertility profile, we start by calculating the implicit non-fertility debt as defined in section 5.1.1. In general, the present value of female benefits that are saved due to a negative fertility shock exceeds the present value of the male benefits saved, as women tend to live longer. At the same time, the loss in male taxes due to a fertility shock exceeds the loss in female taxes, as men tend to earn more than women. Both effects make boys more valuable to the government budget than girls. Overall, the loss in taxes due to negative fertility shocks exceeds the benefits saved, implying that lower fertility generates positive non-fertility debt. As discussed in section 5.1.2, this implicit non-fertility debt could be serviced by levying non-fertility taxes at young (NFTY) or old ages (NFTO).

Figure 11: Non-fertility taxes at young ages: generations 1930-1960

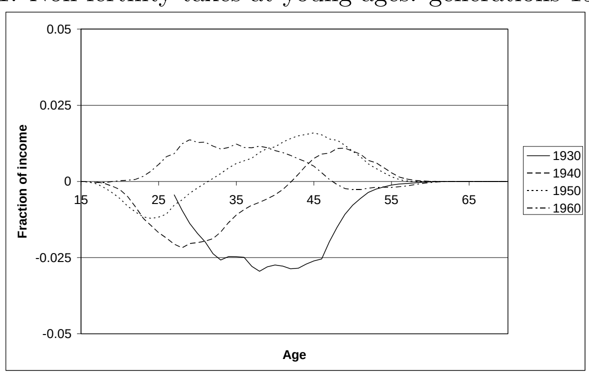
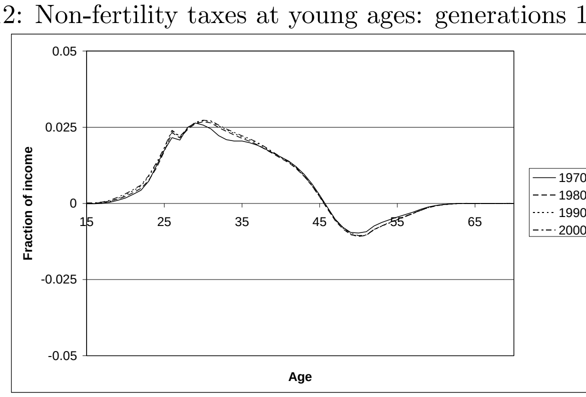


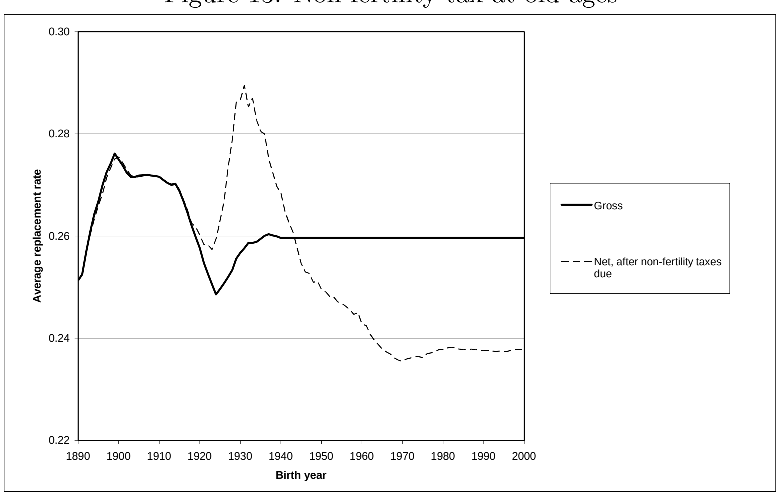
Figure 12: Non-fertility taxes at young ages: generations 1970-2000



5.3.1 Non-fertility tax young

Recall that in the "non-fertility tax young" (NFTY) variant, the generations causing the negative fertility shock pay a non-fertility tax shortly after the shock has occurred. More precisely, the implicit non-fertility debt due at a certain age is smoothed over 20 years when calculating non-fertility taxes due. Figures 11 and 12 show the implied non-fertility taxes due in this variant for generations born between 1930 and 2000 as fraction of their contemporaneous income. The non-fertility taxes due for generation 1930 are actually *negative* over the whole life cycle, as its completed fertility (3.0) exceeds the completed fertility of the benchmark (2.1). Put differently, generation 1930 would be entitled to a fertility bonus in this variant. Generations born between 1930 and 1960 initially also receive fertility bonuses as age-specific fertility remains relatively high at young ages (see figure 9). However, as mentioned before, at older ages their fertility drops significantly due to increased use of contraception. Consequently, at older ages they have to pay non-fertility taxes. For the youngest generations it is the other way around. In fact, non-fertility taxes due for generations born after 1970 show a typical hump-shaped pattern peaking around age 30. However, as mentioned before, at older ages their fertility is relatively high due to postponed motherhood, making these generations entitled to fertility bonuses. For generation 2000, the non-fertility taxes due peak at age 30 at 2.5% of contemporaneous income.

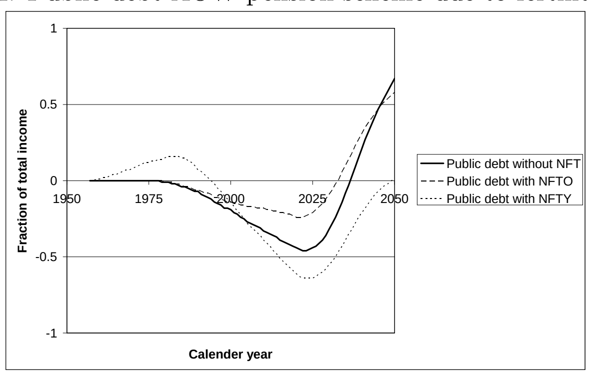
Figure 13: Non-fertility tax at old ages



5.3.2 Non-fertility tax old

Non-fertility debts in the "non-fertility tax old" (NFTO) variant are serviced by taxing AOW pension benefits (see section 5.1.2). Figure 13 shows the average gross and net replacement rates over lifetime in the NFTO-variant for generations born since 1892.[16] After-non-fertility-tax net average replacement rates (represented by the dashed line in figure 13) for generations born before 1943 actually exceed gross replacement rates, as their completed fertility exceeded the benchmark. Hence, these generations would receive a bonus on their AOW pension benefits in this variant, just as they would receive a tax bonus when they are young in the NFTY-variant. However, the AOW pension benefits of generations born after 1943 would be taxed to compensate for their non-fertility debt. As a consequence, generation 2000's average net replacement rates would be approximately 2 percentage points below its gross replacement rates.

Figure 14: Public debt AOW pension scheme due to fertility shocks



5.3.3 Public debt due to fertility shocks

Figure 14 shows the impact of fertility shocks on public debt as well as the impact of non-fertility taxes on public debt. As a reference, the solid line shows the public debt of the AOW pension scheme due to fertility shocks in the absence of any non-fertility tax. The exploding debt pattern clearly illustrates that the AOW pension scheme becomes unsustainable in the absence of compensating non-fertility taxes. The dotted (dashed) line shows the evolution of public debt when a non-fertility tax would be levied at young (old) ages. In both variants non-fertility savings are initially negative, as generations with a high completed fertility receive a fertility bonus. However, this is reversed when fertility rates start to fall. Under both variants, the AOW pension scheme will start to accumulate assets. However, in the NFTY-variant, more assets are generated than in the NFTO-variant, due to the difference in the timing of the non-fertility tax in the life cycle. Summarizing, generations born since 1943 have generated

[16] Average gross replacement rates for generations 1892 until 1943 are (partly) based on the actual replacement rates until calender year 2006 (see appendix A). Replacement rates beyond 2006 are supposed to be constant.

an implicit non-fertility debt, which might have been serviced either by levying non-fertility taxes at young ages or taxing their AOW pension benefits (i.e. effectively cutting net replacement rates) at old ages.

6 Labour-force participation shocks

6.1 Analytical framework

The higher its labour participation, the more taxes a generation pays to the AOW pension scheme. However, a labour-participation shock does not affect the benefits a generation receives, as these benefits are not related to a generation's earnings (see equation 5). Hence, a positive labour-participation shock improves the intergenerational balance. Let us consider this now more formally. The direct impact of taxes paid by generation i due to a labour-force participation shock ($\underline{\Delta T_i^F}$) is equal to the present value of the difference between on the one hand the taxes paid according to the actual participation profile ($\alpha_{i,j}\beta_{i,j}z_{i,j}$) and on the other hand the taxes paid according to the benchmark participation profile ($\overline{\alpha}_s\overline{\beta}_s\overline{z}_s$ for $s = j - i$)

$$\underline{\Delta T_i^F} = \sum_{j=i+1}^{i+D} R_{i,j}\tau_j \left[\alpha_{i,j}\beta_{i,j}z_{i,j} - \overline{\alpha}_s\overline{\beta}_s\overline{z}_s\right] w_j\overline{a}_{i,j}\overline{n}_{i,j}^F, \tag{21}$$

with $z_{i,j}$ being the age-specific wage-factor of $n_{i,t}^F$ scaling $w_{i,t}^F$ to w_t (see appendix A). This implies that the implicit non-participation debt of generation i equals

$$\underline{DEB_i} = -\underline{\Delta T_i^F} - \underline{\Delta T_i^M}. \tag{22}$$

Tax savings due to positive labour-participation shocks can be returned to the generations causing these shocks at the time these shocks occur. In fact, such generations could receive this as a participation bonus. However, tax losses due to negative labour-participation shocks should be compensated for by additional "non-participation" taxes at the moment these shocks occur. These taxes should be levied on the generations causing the negative labour-participation shocks in order to restore the initial intergenerational balance.

6.2 Data

Labour-participation profiles ($\alpha_{i,j}\beta_{i,j}z_{i,j}$) consist of three components, for which data about the participating fraction ($\alpha_{i,j}$) and hours worked ($\beta_{i,j}$) of a generation are available; these will be analyzed more closely below. Unfortunately, long series of the age-specific wage factor ($z_{i,j}$) are not available. In fact, we only have data for the age-wage factor in the period 1995-2005. For our calculations, we calibrated $z_{i,j}$ in such a way that the implied development of aggregate labour income is consistent with the actual development of aggregate labour income.

6.2.1 Labour participation

We start by analyzing shocks in labour participation. As benchmark participation profile, we take the age-specific labour-participation rates in the calender year 1957. Figures 15 and 16 show the (expected) labour-participation profiles of the generations 1935, 1950, 1965, 1980 and 2000. For the younger generations, we relied on projections generated by CPB Netherlands Bureau for Economic Policy Analysis ranging to 2050. Beyond 2050, we assumed constant age-specific labour participation. Note that perfect foresight is not a necessary condition for labour-participation shocks (unlike longevity shocks): unexpected participation shocks can be attributed to the generation responsible for the participation shock.

Figure 15: Female labour-participation profiles

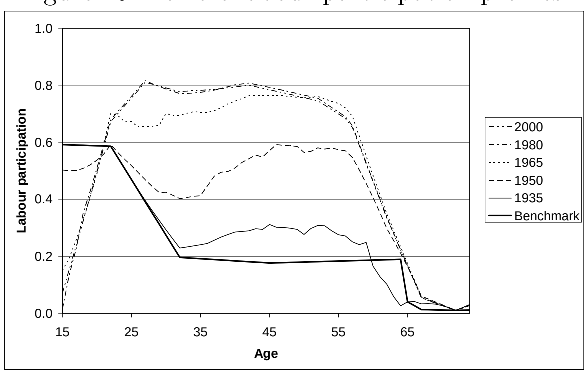
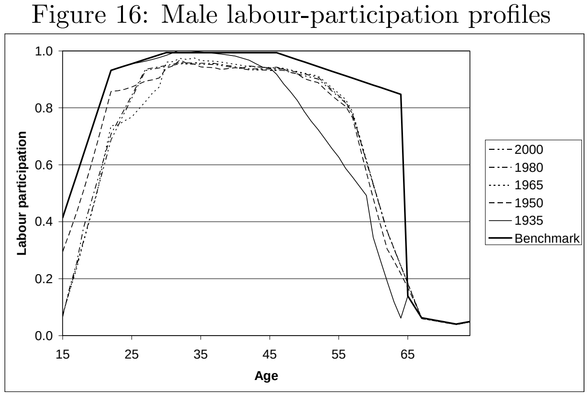
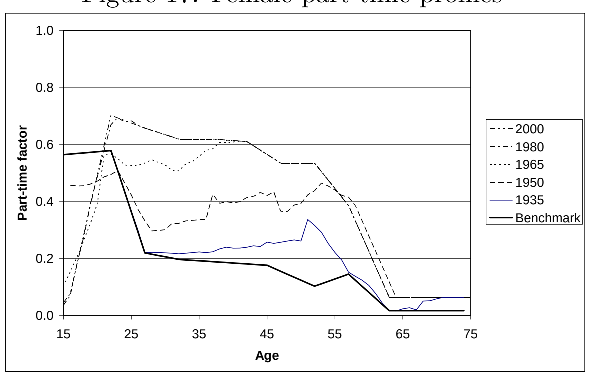


Figure 16: Male labour-participation profiles



Three observations stand out. First of all, female labour participation has increased substantially in comparison with the benchmark. Although the causality is difficult to determine, it is clear that this is related to the negative fertility shocks shown above. Secondly, labour participation at young ages has fallen for both genders, which can be attributed to the fact that more years are spent on education. Although this reduces the tax base in the short term, it broadens the tax base in the long run if real wages and participation rates at higher ages are higher due to better education. Finally, male labour participation at higher ages has fallen substantially in comparison with the benchmark. This is especially the case for the oldest generations under consideration. Note the non-monotonic development of male old-age labour participation across cohorts. For generations born before 1915 (reflected in the benchmark), older males featured high participation rates. However, participation rates fell substantially for generation 1935, which reflects the policy in the 1980s to withdraw older workers from the labour market and provide them with disability or early retirement benefits in order to reduce youth unemployment. For the generations born since 1950, labour participation at higher ages is projected to increase again in view of more actuarially fair supplementary pension benefits, which no longer discourage people from working longer.

Figure 17: Female part-time profiles



6.2.2 Part-time factor

Now we will analyze shocks in the part-time factor since 1957. As benchmark part-time profile, we take again the age-specific hours worked in the calender year 1957. Figures 17 and 18 show the (expected) part-time factor[17] of the generations 1950, 1965, 1980 and 2000, where age- and gender-specific part-time profiles for the period 2007-2100 have been assumed to be constant starting from 2007. Note that perfect foresight is not a necessary condition for shocks in the part-time factor (unlike longevity shocks): unexpected shocks can be attributed directly to the generation responsible for the shock. Most striking is the (expected) convergence between women and men: women have increased the number of working hours, while men have reduced them.

[17] The maximum number of hours per week is set at 48.

Figure 18: Male part-time profiles

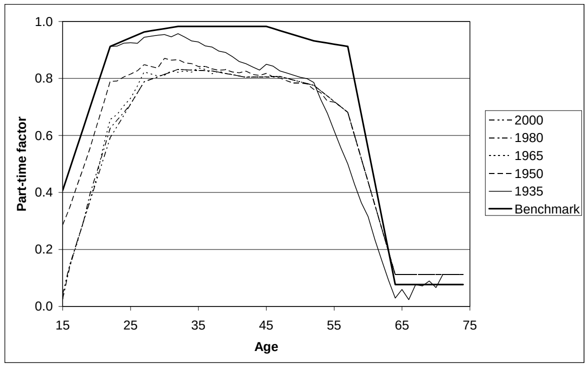
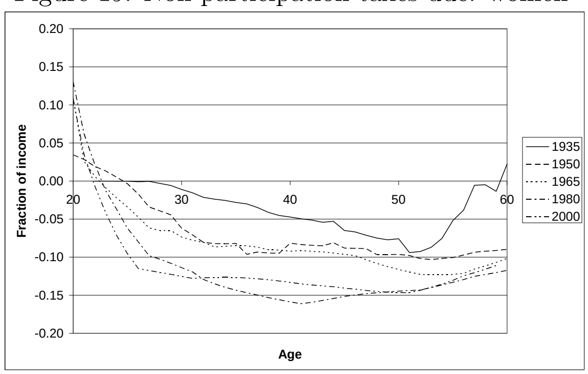


Figure 19: Non-participation taxes due: women



6.3 Adjustment

6.3.1 Non-participation taxes due

Figure 19 shows the female non-participation taxes due as a fraction of contemporaneous income. Actually, almost all female generations are entitled to a participation bonus caused by the increase in female participation. Expected participation bonuses peak for the female generation 2000 at 15 percent of its income. Figure 20 shows the male non-participation taxes due as a fraction of contemporaneous income. All male generations considered should pay a non-participation tax as a consequence of decreased male labour participation. Figure 21 shows the overall non-participation taxes due as a fraction of contemporaneous income. Most generations should pay non-participation taxes, especially at young and old ages, while some generations receive some participation bonuses at middle-ages. Hence, the female participation bonuses do not

Figure 20: Non-participation taxes due: men

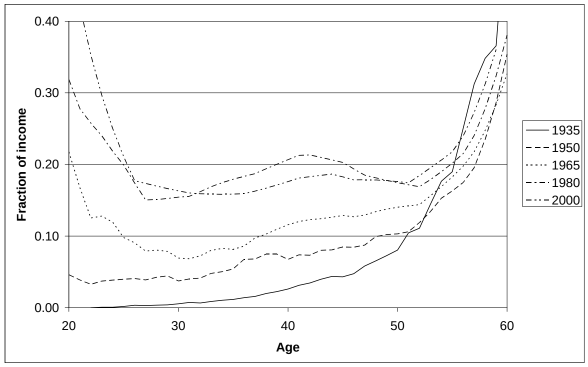
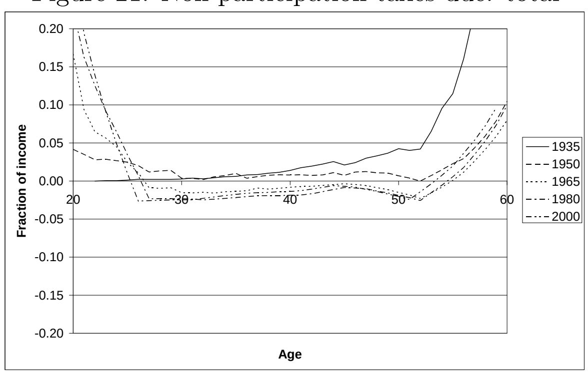


Figure 21: Non-participation taxes due: total

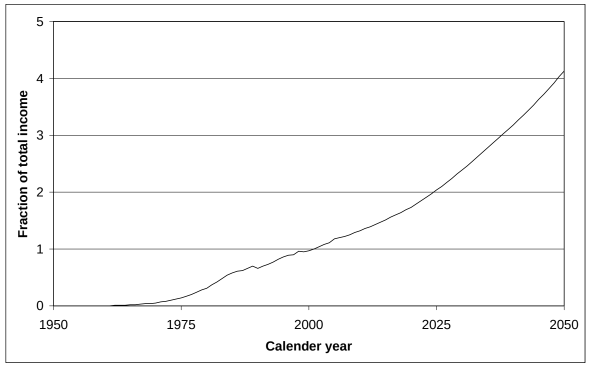


fully compensate for the male non-participation taxes.

6.3.2 Public debt due to labour-participation shocks

Figure 22 shows the public debt of the AOW pension scheme due to labour-participation shocks. Public debt due to participation shocks is exploding, reflecting the fact that increases in female participation do not fully compensate for the decreases in male labour participation. By definition, public debt due to participation shocks will be zero when male generations pay their non-participation taxes due and female generations receive their participation bonuses.

Figure 22: Public debt AOW pension scheme due to participation shocks



7 Participation bonuses vs. non-fertility taxes due

So far, we have assumed that negative fertility shocks are compensated for by non-fertility taxes, while positive participation shocks are compensated for by participation bonuses. As noted before however, one could argue that negative fertility shocks are directly related to positive (female) participation shocks. Hence, it is interesting to analyze whether participation bonuses have compensated for non-fertility taxes due. More specifically, we will determine the balance of participation bonuses versus non-fertility taxes due per gender and generation. We start by splitting the non-fertility taxes due per generation between the corresponding male and female generation. One could argue that non-fertility debt should be especially assigned to women, as they gave birth to fewer children and worked more. However, any specific division of non-fertility taxes between genders would be arbitrary. Therefore, we decided to split the non-fertility taxes on a fifty-fifty base. Then we calculate for each generation and gender the balance of the participation bonuses and the fertility taxes due. Finally, for every generation we calculate the present value of this balance and express it as a percentage of the present value of future AOW pension benefits in order to allow for a fair comparison between generations and genders. Figures 23 and 24 show the resulting balance for female and male generations born since 1892 as a fraction of the present value of future pension benefits.

The balance is positive for all female generations, as participation bonuses more than offset the non-fertility taxes due. This would also be the case if we would have assigned all non-fertility taxes to women. Put differently, female labour participation has, in general, increased more than sufficiently to compensate for (half of) the negative fertility shocks. However, for men the *negative* participation bonuses have even added to the non-fertility taxes due. Hence, the decrease in male labour participation has added to the existing implicit

Figure 23: Participation bonus versus fertility taxes due: women

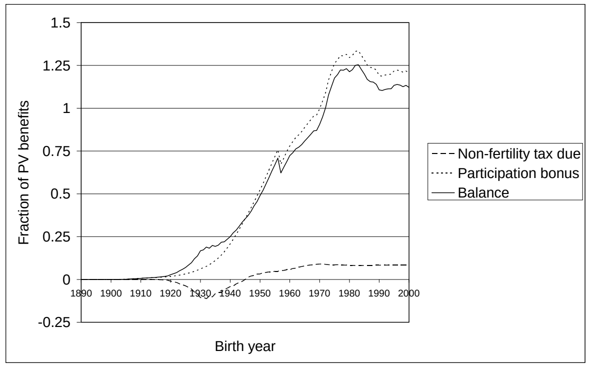
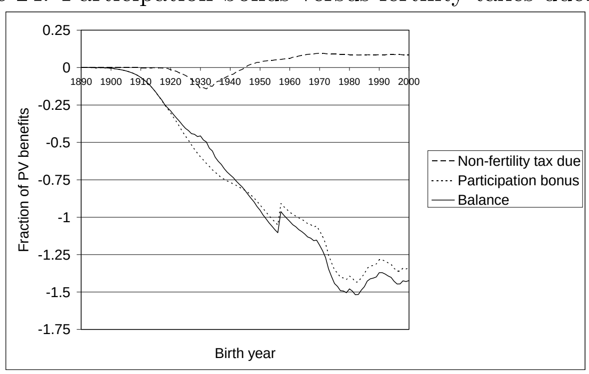


Figure 24: Participation bonus versus fertility taxes due: men



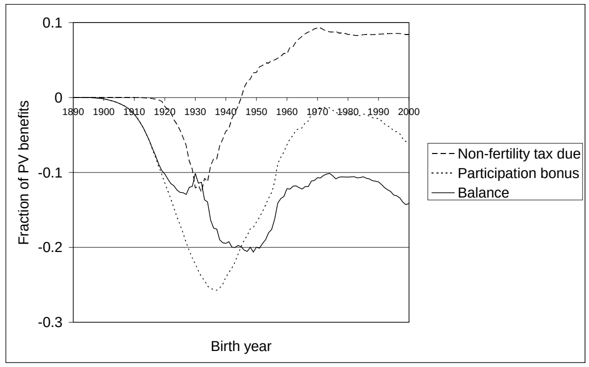
non-fertility debt.

Figure 25 shows that the balance for men and women has overall been negative for almost all considered generations. Hence, these calculation suggest overall that changes in labour participation have not fully compensated for the fall in fertility. Thus, the coincidence of dropped fertility, increased female labour participation and decreased male labour participation has ultimately been detrimental for the sustainability of the AOW pension scheme.

8 Summary and conclusions

This paper explores adjustments that maintain intergenerational balances in a PAYG pension scheme in the face of fertility and longevity shocks. Generations with fewer children save time and resources, allowing them to work and save more. Imposing non-fertility taxes on such generations generates the resources

Figure 25: Participation bonus versus fertility taxes due: total



required to restore intergenerational balances in the face of fertility shocks. Moreover, raising retirement ages in response to longevity shocks ensures that the agents who live longer pay for the additional retirement benefits they receive over their longer expected lifetime.

The methodological cornerstone of our paper is a demographic and economic benchmark scenario where longevity-, fertility- and labour-participation-profiles as well as retirement ages remain constant and in which the PAYG pension scheme features a balanced budget at each point in time. The benchmark scenario allows us to determine the longevity-, fertility- and labour-force participation shocks that have occurred in reality and the way in which these shocks have affected intergenerational balances. Concerning longevity shocks, we have assumed that there is perfect foresight.

We applied the approach outlined above to the Dutch AOW pension scheme as established in 1957, the so-called AOW pension scheme. We started by identifying the demographic and economic shocks per gender and generation since 1957 before calculating their impact on the intergenerational balances of all generations born between 1892 and 2000. In general, age-specific survival probabilities have increased substantially for both genders. Although women still tend to live longer than men, the survival probabilities of men and women are converging. At the same time, completed fertility for generations born after 1943 has fallen below the benchmark which is consistent with a constant population in the long run. Finally, gender-specific labour-participation profiles have converged since 1957 as men have reduced their labour participation, while women have increased their labour participation.

Our calculations suggest that the retirement age should be increased to at least 68 years for the generation born in 1945 in order to compensate for increased longevity. Furthermore, we show that projected increases in labour-force participation rates do not generate sufficient additional tax revenues to offset the dearth of human capital as a result of declining fertility rates.

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A Benchmark scenario

Here we consider how we can derive a set of tax and replacement rates consistent with the balanced-budget constraint in the benchmark scenario. Define average per capita labour income earned at time t by the female generation i ($y^F_{i,t}$) as

$$y^F_{i,t} = \alpha^F_{i,t}\beta^F_{i,t}z^F_{i,t}w_t, \tag{23}$$

with $z^F_{i,t}$ being the age-specific wage-factor of $n^F_{i,t}$ scaling $w^F_{i,t}$ to w_t. The age-specific wage-factors of generation i over its lifetime will be denoted as its relative wage profile. Combining equations (3), (4), (5) and (23) with equation (6) gives the following equilibrium condition required for balanced budgets in the benchmark scenario

$$\frac{\tau_t}{\gamma_t} = \frac{\sum_{i=t-D}^{t-1} \bar{b}_{i,t}\left[\bar{n}^F_{i,t} + \bar{n}^M_{i,t}\right]}{\sum_{i=t-D}^{t-1} \bar{a}_{i,t}\left[\bar{n}^F_{i,t}\bar{\alpha}^F_{i,t}\bar{\beta}^F_{i,t}\bar{z}^F_{i,t} + \bar{n}^M_{i,t}\bar{\alpha}^M_{i,t}\bar{\beta}^M_{i,t}\bar{z}^M_{i,t}\right]} = \bar{k}_t, \tag{24}$$

with $\bar{k}_t$ being the *effective* old-age dependency ratio at time t: the ratio of the number of PAYG pension beneficiaries at time t over the *effective* number of PAYG tax payers at time t in the benchmark scenario. Note that the definition of the effective old-age dependency ratio deviates somewhat from the conventional definition of the old-age dependency ratio where $\alpha_{i,t} = \beta_{i,t} = z_{i,t} = 1$ for both genders. Note also that the average wage (w_t) is irrelevant for the parameters τ_t and γ_t. This is because we suppose that benefits received from and taxes paid to the PAYG pension scheme at time t are both indexed to average wages. Using equation (24), the tax rate at time t required for a balanced defined-benefit PAYG pension scheme in the benchmark scenario can now be expressed as

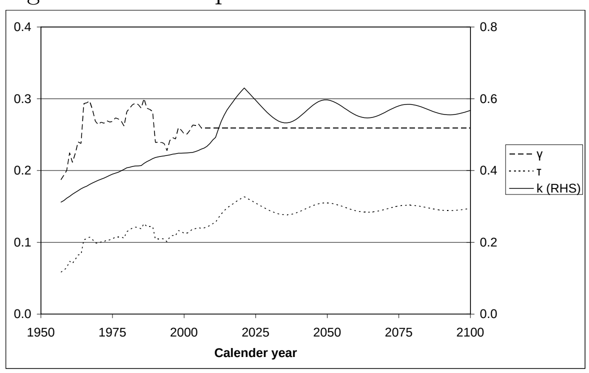
$$\tau_t = \overline{k_t}\gamma_t, \tag{25}$$

for given replacement rates γ_t. Alternatively, the replacement rate required at time t for a balanced defined-contribution PAYG pension scheme in the benchmark scenario can be expressed as

$$\gamma_t = \frac{\tau_t}{\overline{k_t}}, \tag{26}$$

for given tax rates τ_t. Figure 26 shows the development of the tax (τ_t) and replacement rates (γ_t) and the *effective* old-age dependency ratio ($\bar{k}_t$), when all demographic and economic variables are kept at their benchmark profiles. Note that the effective old-age dependency ratio reaches its steady-state value (0.57) in an oscillating movement. Using equation (5) we can derive the implied replacement rates since 1957 from the actual total AOW benefits paid. Figure 26 shows that the replacement rate initially rose in the period following the introduction of the AOW pension scheme in 1957. However, since 1986 it fell somewhat. In order to find a consistent path for the tax rate, we combined the implied replacement rate with the evolution of the effective old-age dependency ratio in the benchmark scenario (see equation 24). We find that the tax rate should have been increased from 0.06 in 1957 to 0.12 in 2006 in the benchmark scenario. Hence, the AOW pension scheme has been a mixture of DB and DC in the past. However, beyond 2006, we will treat the AOW pension scheme as a DB PAYG pension scheme in the benchmark scenario. Hence, the replacement rate is kept constant at 0.26. Changes in the effective old-age dependency ratio after 2006 are now absorbed by parallel changes in the tax rate in order to keep the budget balanced.

Figure 26: PAYG parameters benchmark scenario



B Balancing longevity changes by adjusting the retirement age: a stylized model

In section 4.3.1 we derived the equilibrium retirement age by means of numerical simulations. This appendix provides a theoretical decomposition of the required change of the equilibrium retirement age. To this end, we use a simplified and stylized version of the model applied in section 4.3.1. First of all, we refrain from gender differences in the demographic and economic variables considered. Secondly, we suppose that the economy is in the steady-state, implying a constant and stable tax rate. Thirdly, all variables are defined in continuous time.

B.1 Population and economy

The remaining population at time t of the generation born at time i can be expressed as

$$n_{i,t} = s_{i,t} n_{i,i}, \tag{27}$$

with
$n_{i,i}$: initial size generation born at time i

$s_{i,t}$: function representing the cumulated survival probabilities at time t of the generation born at time i.

Suppose that all working individuals of generation i earn wage $w_{i,t}$ at time t with

$$w_{i,t} = w_{i,i} \exp\left[(t-i)\, g\right], \tag{28}$$

for g being the constant wage growth rate and

$$w_{i,i} = w_0 \exp\left[ig\right]. \tag{29}$$

B.2 PAYG pension scheme

Suppose the generation born at time i pays a proportional tax rate τ on wage income. Total taxes paid by individuals of generation i at time t at ages $t-i = \{S, R_i\}$ $(tax_{i,t})$ then yield

$$tax_{i,t} = \tau part_{i,t} w_{i,t}, \tag{30}$$

with $part_{i,t}$ being a function representing the average labour participation (hours worked as a fraction of the maximum number of hours) at time t of generation i.

Suppose that $part_{i,t}$ is a positive function of the retirement age R_i

$$part_{i,t} = part_{i,t}\left(R_i\right). \tag{31}$$

Hence, we assume that the higher the retirement age, the longer people will participate.

Suppose that the government determines the retirement age of generation i (R_i) as a function of its cumulative survival function $(s_{i,t})$

$$R_i = R\left(s_{i,t}\right).$$

Put differently, we suppose that the longer people live, the higher will be their statutory retirement age to compensate for "age inflation" (Shoven and Goda, 2008).

Finally, every individual of the generation born at time i receives benefits $b_{i,t}$ at time t at ages $t-i = \{R_i, D\}$

$$b_{i,t} = \gamma w_{i,t}, \tag{32}$$

with γ being the fixed replacement rate.

B.3 Intergenerational balance

The total amount of taxes a generation contributes to the PAYG pension scheme over its lifetime depends on several factors. First among them is the fraction of the generation i still alive at age S ($s_{i,i+S}$): the larger $s_{i,i+S}$, the more taxes it pays. The second factor is the average life expectancy of that generation from age S to age R_i: the longer it lives on average in this period, the more taxes it pays. Third is the labour participation of that generation: the higher the labour participation, the more taxes it pays. Fourth is the wage growth rate of that generation: the higher the growth rate, the more taxes it pays. Finally, the present value of tax payments at young ages is higher than tax payments at higher ages. In order to summarize the latter three factors in one number, we introduce the concept of the economically expected effective contribution period ($E_i\left[R_i - S\right]$) of the generation born at time i. Formally, we define $E_i\left[R_i - S\right]$ as

$$E_i\left[R_i - S\right] = \frac{\int_{t=i+S}^{t=i+R_i} n_{i,t} part_{i,t} \frac{\exp[(t-i)g]}{\exp[(t-i)r]} dt}{n_{i,i+S}}, \tag{33}$$

implying

$$E_i\left[R_i - S\right] = f\left(s_{i,t}, part_{i,t}, R_i\right). \tag{34}$$

Note that in the special case of $r = g$ and $part_{i,t} = 1$ for all $S < t - i < R_i$

$$E_i\left[R_i - S\right] = \int_{t=i+S}^{t=i+R_i} \frac{s_{i,t}}{s_{i,i+S}} dt, \tag{35}$$

which is exactly the demographic definition of the life expectancy from age S to age R_i.

The present value of total taxes paid by the generation born at time i (T_i) can now be expressed as

$$T_i = \int_{t-i=S}^{t-i=R_i} \frac{n_{i,t} tax_{i,t}}{\exp\left[(t-i)\,r\right]} dt. \tag{36}$$

The total amount of benefits that a generation receives from the PAYG pension scheme over its lifetime depends on several factors. First among them is the fraction of the generation i still alive at age R_i ($s_{i,i+R_i}$): the larger $s_{i,i+R_i}$, the more benefits a generation will receive. The second factor is the remaining life expectancy of that generation after retirement: the longer it lives on average, the more benefits it receives. Third is the wage growth rate during its retirement period: the higher the wage growth rate, the more benefits it receives. Finally, the present value of benefits paid just after retirement is higher than the present value of benefits paid at higher ages. In order to summarize the latter three factors in one number, we introduce the concept of the economically expected effective benefit period ($E_i\left[D - R_i\right]$) of the generation born at time i. Formally, we define $E_i\left[D - R_i\right]$ as

$$E_i\left[D-R_i\right]=\frac{\int_{t=i+R_i}^{t=i+D} n_{i,t}\frac{\exp[(t-i)g]}{\exp[(t-i)r]}dt}{n_{i,i+R}}, \tag{37}$$

implying

$$E_i\left[D-R_i\right]=f\left(s_{i,t},R_i\right). \tag{38}$$

Note that in the special case of $r=g$

$$E_i\left[D-R_i\right]=\int_{t=i+R_i}^{t=i+D}\frac{s_{i,t}}{s_{i,i+R_i}}dt, \tag{39}$$

which is exactly the demographic definition of the (remaining) life expectancy from age R_i to age D.

The present value of total benefits received by the generation born at time i (B_i) can now be expressed as

$$B_i=\int_{t-i=R_i}^{t-i=D}\frac{n_{i,t}b_{i,t}}{\exp\left[(t-i)\,r\right]}dt. \tag{40}$$

Using equations (36) and (40), the intergenerational balance at time t of the generation born at time i ($net_{i,t}$) can be expressed as

$$net_{i,t}=n_{i,i}w_0\exp\left[ig\right]\left(\tau s_{i,i+S}\left[E_i\left(R_i-S\right)\right]-\gamma s_{i,i+R_i}\left[E_i\left(D-R_i\right)\right]\right). \tag{41}$$

B.4 Longevity changes

Now consider a change in the age-specific mortality probabilities of generation i (i.e. a change in $s_{i,t}$) and call this a longevity change. The total differential of the intergenerational balance of the generation born at time i (net_i) alive at time t equals:

$$\frac{dnet_{i,t}}{ds_{i,t}}=n_{i,i}w_0\exp\left[ig\right]\left\{\begin{array}{c}\tau\left[\frac{\partial s_{i,i+S}}{\partial s_{i,t}}\left[E_i\left(R_i-S\right)\right]+s_{i,i+S}\frac{\partial\left[E_i(R_i-S)\right]}{\partial s_{i,t}}\right]\\ -\gamma\left[\frac{\partial s_{i,i+R_i}}{\partial s_{i,t}}\left[E_i\left(D-R_i\right)\right]+s_{i,i+R_i}\frac{\partial\left[E_i(D-R_i)\right]}{\partial s_{i,t}}\right]\\ +\tau s_{i,i+S}\frac{\partial R_i}{\partial s_{i,t}}\frac{\partial\left[E_i(R_i-S)\right]}{\partial R_i}-\gamma\frac{\partial R_i}{\partial s_{i,t}}\left[\frac{\partial s_{i,i+R_i}}{\partial R_i}\left[E_i\left(D-R_i\right)\right]+s_{i,i+R_i}\frac{\partial\left[E_i(D-R_i)\right]}{\partial R_i}\right]\\ +\tau s_{i,i+S}\frac{\partial R_i}{\partial s_{i,t}}\frac{\partial part_{i,t}}{\partial R_i}\frac{\partial\left[E_i(R_i-S)\right]}{\partial part_{i,t}}\end{array}\right\}. \tag{42}$$

The intergenerational balance of generation i remains unchanged at time t if

$$\frac{\partial R_i}{\partial s_{i,t}} = \frac{\gamma\left[\frac{\partial s_{i,i+R_i}}{\partial s_{i,t}}\left[E_i\left(D-R_i\right)\right]+s_{i,i+R_i}\frac{\partial[E_i(D-R_i)]}{\partial s_{i,t}}\right]-\tau\left[\frac{\partial s_{i,i+S}}{\partial s_{i,t}}\left[E_i\left(R_i-S\right)\right]+s_{i,i+S}\frac{\partial[E_i(R_i-S)]}{\partial s_{i,t}}\right]}{\tau s_{i,i+S}\left[\frac{\partial[E_i(R_i-S)]}{\partial R_i}+\frac{\partial part_{i,t}}{\partial R_i}\frac{\partial[E_i(R_i-S)]}{\partial part_{i,t}}\right]-\gamma\left[\frac{\partial s_{i,i+R_i}}{\partial R_i}\left[E_i\left(D-R_i\right)\right]+s_{i,i+R_i}\frac{\partial[E_i(D-R_i)]}{\partial R_i}\right]}. \tag{43}$$

Using equation (43), the required change of the retirement age in response to the longevity shock can be disentangled in eight partial effects. We start with the numerator of equation (43), which measures the effect of longevity changes on taxes paid and benefits received by a generation. The first term between square brackets determines the partial effect of longevity changes on the benefits paid to generation i. We denote this as the longevity effect on benefits. More specifically, this effect depends on the partial effect of longevity changes on the cumulated survival function of generation i at age R_i ($\frac{\partial s_{i,i+R_i}}{\partial s_{i,t}}$) and the partial effect of longevity changes on the expected benefit period of generation i ($\frac{\partial[E_i(D-R_i)]}{\partial s_{i,t}}$). The second term between square brackets in the numerator determines the partial effect of longevity changes on the taxes contributed by generation i. More specifically, this effect depends on the partial effect of longevity changes on the cumulated survival rate of generation i at age S ($\frac{\partial s_{i,i+S}}{\partial s_{i,t}}$) and the partial effect of longevity changes on the expected effective contribution period of generation i ($\frac{\partial[E_i(R_i-S)]}{\partial s_{i,t}}$).

We now turn to the denominator of equation (43), which measures the counterbalancing effect of changes in the retirement age in response to longevity changes on taxes paid and benefits received by a generation. The first term reflects the partial effect of changes in the retirement age on the taxes contributed by generation i. We call this the retirement-age effect on taxes. More specifically, this effect depends on both the (partial) direct and indirect effect of changes in the retirement age on the expected effective contribution period ($\frac{\partial[E_i(R_i-S)]}{\partial R_i}$ and $\frac{\partial part_{i,t}}{\partial R_i}\frac{\partial[E_i(R_i-S)]}{\partial part_{i,t}}$). The second term in the denominator determines the partial effect of changes in the retirement age on the benefits received by generation i. We call this the retirement-age effect on benefits. More specifically, this effect depends on the partial effect of changes in the retirement age on the cumulated survival rate of generation i at age R_i ($\frac{\partial s_{i,i+R_i}}{\partial s_{i,t}}$) and the partial effect of changes in the retirement age on the expected benefit period $\frac{\partial[E_i(D-R_i)]}{\partial R_i}$.

Table 1: decomposition partial effects changes in longevity for generation i

		via size generation	*via effective period*	*via labour participation*
Taxes	*Longevity*	$-\tau\frac{\partial s_{i,i+S}}{\partial s_{i,t}}\left[E_i\left(R_i-S\right)\right]$	$-\tau s_{i,i+S}\frac{\partial[E_i(R_i-S)]}{\partial s_{i,t}}$	
	Retirement age		$\tau s_{i,i+S}\frac{\partial[E_i(R_i-S)]}{\partial R_i}$	$\tau s_{i,i+S}\frac{\partial part_{i,t}}{\partial R_i}\frac{\partial[E_i(R_i-S)]}{\partial part_{i,t}}$
Benefits	*Longevity*	$\gamma\frac{\partial s_{i,i+R_i}}{\partial s_{i,t}}\left[E_i\left(D-R_i\right)\right]$	$\gamma s_{i,i+R_i}\frac{\partial[E_i(D-R_i)]}{\partial s_{i,t}}$	
	Retirement age	$-\gamma\frac{\partial s_{i,i+R_i}}{\partial R_i}\left[E_i\left(D-R_i\right)\right]$	$-\gamma s_{i,i+R_i}\frac{\partial[E_i(D-R_i)]}{\partial R_i}$	

Table 1 summarizes the partial effects identified above. Note that participation effects require a behavioral response of the members of the generation involved: they have to decide whether they will increase labour participation in response to changes in the retirement age.

C Data sources

C.1 Mortality data

Age- and gender-specific mortality data as from 1935 can be found on the website of Statistics Netherlands (http://statline.cbs.nl/statweb). For the period before 1935, we relied on age- and gender-specific mortality data from NIDI. For the period 2008-2050, we have relied on mortality figures used in Statistics Netherlands' 2008 population projections. Mortality figures for the period 2050-2100 were generated using the LCFIT-version of the Lee-Carter model (http://simsoc.demog.berkeley.edu/).

C.2 Fertility data

For the female generations born between 1935 and 2000, (projections of) age-specific fertility data (with fertility age classes ranging from 15 until 50 years) can be found on the website of Statistics Netherlands (http://statline.cbs.nl/statweb, "Vruchtbaarheidscijfers per geboortegeneratie"). For generations born between 1900 and 1935, only total fertility is available. Fertility profiles for these generations were constructed by proportionally increasing the fertility profile of generation 1935 in such a way that the implied total fertility is consistent with actual total fertility.

C.3 Wages

The overall nominal wage sum since 1957 is (with some data breaches that have been interpolated) available on the website of Statistics Netherlands (http://statline.cbs.nl/statweb). Gender-specific total wage series were allotted in proportion to the labour participation of each gender (see below). Long series for the age-factor $z_{i,t}$ are not available. As a proxy for the age profile in wages we used the relative average age-wage factor in the period 1995-2005. For our calculations, we calibrated $z_{i,t}$ in such a way that the implied development of aggregate labour income is consistent with the actual development of aggregate labour income.

C.4 Interest rates and inflation

Nominal interest rates were constructed by means of an inflation mark-up on the real interest rate. The GDP-deflator was used as a proxy for inflation in the period 1957-2008. Inflation is supposed to be 2% beyond 2008.

C.5 Labour participation

Overall labour participation per gender since 1957 (with some data breaches that have been interpolated) is available on the website of Statistics Netherlands (http://statline.cbs.nl/statweb) as well as a age-specific labour participation per five-year period. For the period 2007-2050, we applied the projected age- and gender-specific labour-participation profiles as projected by CPB Netherlands Bureau for Economic Policy Analysis. Beyond 2050 we assumed that age-specific labour participation profiles remain constant.

C.6 Part-time factor

Data on total hours worked since 1957 can be found in the database of Groningen Growth and Development Centre (http://www.ggdc.nl/), while Statistics Netherlands provided age profiles on hours worked for men and women between 1995 and 2007. In order to create long series for age and gender specific hours worked, total hours worked since 1957 were allotted to men and women in proportion to the hours worked between 1995 and 2007. Moreover, the age profile in hours worked between 1995 and 2006 was used as a proxy to allot total hours worked per gender to individual ages. Finally, in order to calculate a part-time factor, we assumed a maximum of 48 hours per week to be worked. Moreover, age- and gender-specific part-time profiles for the period 2007-2100 were assumed to be constant starting from 2007.