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# Fiscal Prefunding in Response to Demographic Uncertainty

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## Abstract in English

Uncertainty in demographic developments lowers expected future welfare levels. Increasing current tax rates and decreasing expected future tax rates may compensate part of the welfare loss that is due to demographic uncertainty. In doing so, the government effectively pursues a precautionary fiscal policy analogous to the precautionary life-cycle saving behaviour that households may exhibit in the presence of income uncertainty.



*Key words: Fiscal policy, Demographic Uncertainty*

*JEL code: H2, D50*



## Abstract in Dutch

Onzekerheid over de toekomstige demografische ontwikkeling vermindert het verwachte toekomstige welvaartsniveau. Deze verwachte toekomstige welvaartsdaling kan worden tegengegaan door een relatieve verhoging van de huidige belastingvoet en een relatieve verlaging van de verwachte toekomstige belastingvoet. Hiermee introduceert de overheid een voorzorgsmotief bij haar fiscale politiek analoog aan het voorzorgsmotief bij het spaargedrag van huishoudens ingeval van toekomstige onzekerheid.



*Steekwoorden: fiscale politiek, demografische onzekerheid*

# Contents

## Summary

Uncertainty in demographic developments lowers expected future welfare levels. Increasing current tax rates and decreasing expected future tax rates may compensate part of this welfare loss. In doing so, the government effectively pursues a precautionary fiscal policy analogous to the precautionary life-cycle saving behaviour that households may exhibit in the presence of income uncertainty. In this paper, we apply the CGE model GAMMA in combination with stochastic population forecasts to compare alternative fiscal policy rules under assumptions of both demographic certainty and uncertainty. A comparison of the policy rules shows that setting short-term tax rates higher than expected long-term tax rates is a welfare improving strategy in response to demographic risk. This result arises not just because of the risk aversion of households but also because of the concavity of the government's revenue function. Although the precautionary policy is welfare improving, it does relatively little to mitigate the expected aggregate utility loss from demographic uncertainty.

# 1 Introduction

As with many other industrialized countries, the ageing population of the Netherlands is expected to render current fiscal policies unsustainable in the coming decades (Van Ewijk *et al.* (2006)). The sizeable changes in the ratio of retirees to workers will increase demographically sensitive public expenditures beyond the ability of current revenue arrangements to cope. Adequate remedies may take a variety of forms like tax rate or premium increases, spending reductions or institutional reforms.

Uncertainty in the scale and direction of future demographic developments presents an added problem to policy makers because the magnitude of the required adjustments is not fully known. Possible strategies for dealing with this uncertainty include delaying policy reforms until the uncertainty is resolved or making adjustments based on the assumption that demography will develop according to the most likely scenario. In this paper, however, we show that a government faced with demographic uncertainty whose interest is in maximizing the expected welfare of society should pursue a precautionary fiscal policy. A precautionary policy in this case involves front-loading taxes: that is, setting tax rates such that they are expected to decrease over time.

It is a well known result in the public finance literature that a policy that smoothes tax rates over time minimizes the excess burden from distortionary taxation (Barro (1979)). This result holds if marginal distortions are directly linked to tax rates and the government has perfect foresight about future revenue requirements. In an uncertain world, a policy that minimizes expected tax distortions will not in general meet the necessary condition for a socially optimal policy: expected marginal utility smoothing over time.

Consumer theory suggests that future uncertainty may be a reason for households to engage in precautionary saving (Leland (1968), Sandmo (1970)). In the simplest form of the theory, consumption levels while young are negatively correlated with the variance of future economic outcomes. However, this type of precautionary behaviour is typically assumed to occur over the life-cycle and does not account for the intergenerational implications of uncertainty. As a result there may be a role for the government to act as an agent on behalf of future generations. In doing so, the government pursues a policy of fiscal precaution (Steigum (2001), Auerbach and Hassett (2001)). If capital markets are complete, portfolio strategies can be constructed that completely eliminate future uncertainty by, in essence, insuring the government against unexpected shocks (Lucas and Stokey (1983)). In reality markets are far from complete and it is an empirical question what gains can be achieved from portfolio strategies (Bohn (1990)).

Using a dynamic applied general equilibrium model of the Dutch economy in combination with stochastic population forecasts, we assess the utility loss to society arising from demographic uncertainty as it pertains to the fiscal system. It is demonstrated that this loss can be mitigated by increasing tax rates on presently living generations above the level required to sustain government finances in expectation. This analysis not only confirms the current theory on optimal dynamic taxation but also quantifies the magnitude of the problem as well as the extent to which government policy can help to solve it. Gomes *et al.* (2006) use a simulation model to assess the welfare loss resulting from government procrastination in announcing policy decisions. However, as far as we are aware, ours is the first study to use simulation techniques combined with stochastic population forecasts to address the question of optimal fiscal responses to social risk resulting from demographic uncertainty.

The paper is organised as follows. Part 2 briefly discusses the dynamic applied general equilibrium model that we use for our simulations. Part 3 describes the projected development of the Dutch economy and fiscal position if policies were to remain as they are in 2006. This motivates the need for policy reforms that restore sustainability. Part 4 reports the simulation results of a sustainable policy in a deterministic setting and derives a social welfare maximizing tax policy under condition of demographic certainty. This tax policy will serve as a baseline reference to determine the welfare implications of demographic uncertainty. Part 5 presents the results of simulations based on stochastic projections of the population development in the Netherlands that mimic demographic forecast errors. Part 6 then uses these simulations to determine the welfare consequences of demographic uncertainty and to show how accounting for this source of risk affects the welfare maximizing policy derived in Part 4.

# 2 The GAMMA model[1]

This paper uses the dynamic general equilibrium overlapping generations model, GAMMA, to produce projections of long-term economic and fiscal developments in the Netherlands. The model features thorough descriptions of the public sector and the private pension system as well as of household and firm behaviour.

Each household in GAMMA is represented by a finitely-lived adult whose economic behaviour is guided according to life-cycle theory. Households maximize their expected lifetime utility subject to a budget constraint by choosing a time path of total consumption. Lifetime expenditure is constrained by total wealth, which equals the sum of financial wealth and the discounted value of potential future labour and pension income.[2] Bequests are abstracted from. The necessary condition for intertemporal utility maximization implies total consumption smoothing, where the slope of the time profile of total consumption depends on the difference between the interest rate and the rate of time preference.

Total consumption consists of both goods and leisure. The instantaneous utility function is such that labour supply depends only on the marginal reward of labour; that is, there is no wealth effect.[3] Because households smooth total consumption, increases in labour supply must be compensated by more consumption of commodities, implying a positive correlation between goods consumption and labour supply.

Taste shift parameters that determine the demand for leisure and goods consumption for each age cohort are calibrated with estimated lifetime consumption and labour profiles of the Netherlands. A result of the calibration procedure is that, given that the wage elasticity of leisure demand is constant, the wage elasticity of labour supply is age-specific.

GAMMA considers the Dutch economy to be small relative to the outside world. In particular, goods produced at home are perfectly substitutable with those produced abroad, so commodity prices are determined by the global market. Domestic policies do not affect the interest rate, which is determined on world capital markets. Households have no market power in the labour market so wages are determined by the user cost of capital through the factor price frontier. This implies that the incidence of profit taxation is fully shifted to labour.

Production takes place with labour and capital according to a CES production technology. The model assumes a perfect labour market: wage accommodation takes place without any delay. The productivity of labour is assumed to depend on age. Otherwise labour supplied by households of different ages is homogeneous. Capital also adjusts without any delay. The fast adjustment of wages and capital may not be realistic from a short-term point of view, but is acceptable for the long-term analysis of this study.

[1] For a detailed description of the GAMMA model see chapter 2 of Draper and Armstrong (2007).

[2] Potential labour income is defined as income with labour time equal to the total available time.

[3] The wealth effect is assumed to be zero. Lumsdaine and Mitchell (1999) conclude in their survey article that the wealth effect on labour supply is small relative to the price effect.

| Table 2.1 | Parameters in the GAMMA model |
|---|---|
| Rate of labour-augmenting technological progress (%) | 1.7 |
| Substitution elasticity labour and capital | 0.5 |
| Rate of time preference (%) | 1.3 |
| Intertemporal substitution elasticity | 0.5 |
| Rate of inflation (%) | 2.0 |
| Nominal rate of return on bonds (%) | 3.5 |
| Risk premium on shares (%) | 3.0 |
| Real discount factor (%) | 3.0 |
| Price elasticity of leisure | 0.25 |

Revenues for the public sector consist of contributions to the public pension scheme and receipts from profit and income taxation as well as indirect taxation, which is levied on consumption and investment. Base path tax rates are calculated as the ratio between tax revenues and the tax base in the base year, so there is no progressivity in the income tax system. The sale of publicly-owned land and ownership of other public assets are also sources of income for the government. The government is assumed to keep the holdings of government assets constant relative to the net output of the private sector.

Public sector expenditures are modelled according to a generational accounting framework. Expenditures on age sensitive items such as health care, education and public pensions have their own age profiles so aggregate expenditures on these items develop from year to year accordingly along with demographic changes. In addition they grow over time proportionally with the wage rate. All individuals are assumed to receive the same benefit from defence and public administration spending. These expenditures rise with GDP.

The private pension sector has a large influence on the government budget, if only through its size. Pension premiums can be deducted from income before taxes are determined, while pension benefits are taxed. The difference between the tax rate on labour income and pensions implies an implicit subsidy. This is a subsidy on labour market participation since private pensions are mandatory for workers. The large direct influence of the pension system is thus twofold: it implies a delay of the tax receipts and it gives a subsidy on pension savings. The total pension premium rate consists of two components, the contribution rate and the catching-up premium rate. The actuarial fair contribution rate finances the accrual of pension rights while the catching-up premium finances (possible) wealth deficits of a pension fund. It is assumed that old-age benefits, including government pensions, are a certain percentage of average wages earned over the working period. Furthermore, old-age benefits are indexed to prices and partly to wages, reflecting the situation for the average Dutch pension fund.

Essentially the model is deterministic. Agents have perfect foresight; that is, their expectations coincide with realisations. Lifetime uncertainty is recognised, but perfect capital markets enable households to insure against this type of risk.[4] In this study, however, the deterministic model is integrated with stochastic population projections in order to produce uncertainty at the macroeconomic level. In addition, tax rate changes caused by demographic shocks are unanticipated by households. So while there is no influence of this uncertainty on individual behaviour, the expected utility of cohorts who experience demographic risk is affected. This effect will be further explained later on in the paper.

Values of exogenous variables are taken such as to reflect the current state of the Dutch economy. Values of parameters that describe the behaviour of households and firms are partly taken from the literature and partly calibrated on data for the Dutch economy. Table 2.1 summarizes.

[4] Longevity risk is assumed to be diversified; each household receives an annuity from a life insurance company in return for bequeathing it its remaining assets upon death (Yaari (1965)). This type of idiosyncratic risk is fundamentally different from the aggregate risk facing the government arising from demographic uncertainty. The government has no insurance market available to it.

# 3 Ageing and unsustainable government finances

As a first step in the analysis, it must be determined what effect population changes will have on the government's budget balance in the coming years if fiscal arrangements stay unchanged from their state in 2006 and the population develops along a deterministic path. Since fiscal pressures will almost inevitably force the government to introduce reforms eventually, this scenario is not considered to be realistic. However it will serve as a baseline against which the policy measures presented later in the paper will be compared. A simulation has been calculated using a point forecast of demographic developments in the Netherlands. The baseline population projection presented here deviates from the projection used in Van Ewijk *et al.* (2006) and Armstrong *et al.* (forthcoming) which was based on a projection by Statistics Netherlands (CBS).[5]

Table 3.1 shows the projected total demographic development for selected years in the baseline scenario.[6] It can be seen that the total population of the Netherlands is expected to increase by a significant degree over the next century. Moreover, there likely will be large changes in the composition of the population. A large increase in the projected number of elderly people due to longer life expectancies will cause the old-age dependency ratio, the number of pensioners divided by the number of workers, to almost double by 2040. In the following decades, the ratio stabilizes at this high level. In addition, the total dependency ratio, the number of children plus pensioners divided by the number of workers, is also expected to increase, though to a lesser degree. The current net outflow of migrants is projected to be reversed, but this will be insufficient to compensate for the overall greying of the population.

[5] The two population forecasts deviate mainly due to differences in the assumptions made about longevity. The projection used in this discussion paper was produced by the EU Commission-funded UPE ('Uncertain Population for Europe') project (see Alho and Nikander (2005)). This UPE projection assumes much larger future reductions in mortality rates than the CBS projection. Which of the two should be judged more realistic is not relevant here. The analysis in this discussion paper reports work done in an international consortium, in which it was agreed for reason of comparability to use the UPE projection. Noteworthy is that CBS recently updated its demographic projection in the direction of the UPE projection that is used here (see http://www.cpb.nl/nl/pub/cpbreeksen/notitie/05mrt2007_2/notitie.pdf).

[6] Obviously, we cannot simulate the model up to infinity. We cut off the simulations in 2205, in which year the economy has achieved a steady-state equilibrium. Although the solution period for the simulations is only 2006 to 2205, all lead variables including utility and wealth levels are solved forward from the steady-state year 2205 as infinite sums. As a result, the utility of cohorts entering the economy after 2205 is accounted for. The reason for choosing 2205 as the end of the simulation period is thus purely technical. In order to show that current fiscal policies are unsustainable in the long run in the light of population ageing, a period up to 2050 suffices. Therefore, we report only figures for this period.

| **Table 3.1** | **Key indicators under the baseline scenario with unchanged policies** | | | | |
|---|---|---|---|---|---|
| | 2006 | 2020 | 2030 | 2040 | 2050 |
| | thousands of persons | | | | |
| **Demography** | | | | | |
| Total population | 16,354.55 | 17,257.10 | 17,875.00 | 18,317.38 | 18,615.01 |
| Number of newborns | 181.78 | 188.40 | 198.10 | 192.10 | 198.41 |
| Life expectancy - females (years) | 81.15 | 81.95 | 83.27 | 84.78 | 86.19 |
| Life expectancy - males (years) | 76.89 | 78.36 | 79.83 | 81.18 | 82.44 |
| Number of net immigrants | – 10.19 | 45.57 | 46.63 | 47.73 | 48.78 |
| Number of children | 3975.64 | 3836.79 | 3907.34 | 4073.05 | 4074.09 |
| Number of potential workers | 10,071.53 | 10,137.87 | 9930.21 | 9781.02 | 10,129.35 |
| Number of retirees | 2465.61 | 3405.07 | 4178.51 | 4622.33 | 4576.72 |
| Old-age dependency ratio (%) | 25 | 34 | 42 | 47 | 45 |
| Total dependency ratio (%) | 64 | 71 | 81 | 89 | 85 |
| **Government finance** | % GDP | | | | |
| Primary expenditures | 45.6 | 47.4 | 50.9 | 53.1 | 53.7 |
| Revenue | 45.1 | 47.2 | 48.9 | 49.6 | 49.3 |
| Primary deficit | 0.6 | 0.2 | 1.9 | 3.5 | 4.4 |
| Debt | 56.1 | 65.1 | 94.6 | 144.0 | 211.0 |
| **Economic development** | | | | | |
| GDP (billions of euros) | 509.8 | 642.5 | 736.8 | 878.0 | 1057.2 |
| Labour supply (thousands of fte's) | 6462.1 | 6841.0 | 6620.4 | 6606.0 | 6756.5 |
| Capital stock (billions of euros) | 1761.1 | 2305.1 | 2632.3 | 3145.1 | 3798.2 |
| Private consumption | 45.8 | 50.9 | 54.8 | 55.7 | 55.1 |
| Current account balance | 9.7 | 2.8 | – 3.4 | – 7.4 | – 7.2 |

These changes will have significant effects on government finances if fiscal arrangements remain as they are. The debt to GDP ratio is projected to explode to an unmanageable level, a development that is directly connected to the ageing population. Table 3.1 shows a gradual increase of public revenue as a percentage of GDP due to increased tax receipts from the consumption tax levied on retired cohorts and the taxation of supplementary pension incomes. However, this favourable development is not enough to offset the comparatively strong growth of demographically sensitive public expenditure, specifically public pension outlays and health care expenditure. Sustained primary budget deficits combined with the accumulated interest burden results in a debt to GDP ratio of more than 200% by 2050 in this baseline scenario. This figure exceeds the estimate presented in Van Ewijk *et al*. (2006) which projects a debt to GDP ratio of around 100% in 2050 with unchanged policies. The difference is partly due to the omission in the simulations in this study of government income from taxes on asset wealth[7] as well as the differing assumptions about the population development. However, we do not

[7] This simplification was made to facilitate consistency between the discount rates of households and the government, a requirement of the welfare analysis in this study.

expect the nature of the baseline scenario to have any effect on the qualitative results of our stochastic simulation analysis.

The ageing of the population is also reflected in macroeconomic developments. Although GDP shows growth over the long run due to productivity improvements and the increase in the size of the workforce associated with a higher population, increased national consumption due to ageing results in a current account deficit of more than 7% of GDP by 2040.

# 4 Maximizing social welfare under demographic certainty

It is clear that at some point current policies will require adjustment and that the government must implement fiscal changes that decrease expenditures and/or increase revenues. In order to set a reference point for our welfare analysis, here we run a tax smoothing simulation in a deterministic setting. The tax smoothing policy is a one-time increase in 2006 of the labour income tax rate that sustains government finances indefinitely into the future. Note that this tax smoothing policy is not the same as a policy that balances the budget from year to year. The algorithm in the GAMMA model that adjusts tax rates to make government finances sustainable takes a long-run view of the fiscal situation. It requires only that the debt to GDP ratio stabilizes at a steady-state level which is sufficient to ensure that the present value of all future revenues will cover the present value of all future expenditures. This level may be either positive or negative, depending on the values of the variables entering the intertemporal government budget constraint. However, the level of the debt to GDP ratio in steady state is unique and the same holds true with respect to the permanent tax rate increase that enforces it. As such, the tax rate increase can be interpreted as a measure of the fiscal sustainability gap (Blanchard *et al.* (1990). The fact that we present a tax smoothing scenario does not mean that this is the only way to achieve fiscal sustainability (many other solutions will do the same; some of them can be found in this paper) or the best way (indeed, it is not, as will be shown below). Indeed, the tax smoothing scenario represents nothing more than a benchmark against which other scenarios can be judged.

Table 4.1 shows the fiscal and macroeconomic effects of the required 13.4% point increase in the labour income tax rate.[8]

**Table 4.1 Fiscal and Macroeconomic effects tax smoothing policy**

| | 2006 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| | % GDP | | | | |
| **Government finance** | | | | | |
| Primary expenditures | 47.0 | 48.7 | 52.5 | 54.8 | 55.5 |
| Revenue | 50.5 | 53.6 | 55.2 | 55.8 | 55.4 |
| Primary deficit | – 3.4 | – 4.9 | – 2.7 | – 0.9 | 0.1 |
| Debt | 53.6 | – 18.5 | – 55.2 | – 72.6 | – 76.0 |
| **Economic development** | | | | | |
| GDP (billions of euros) | 490.5 | 619.3 | 707.7 | 842.6 | 1012.7 |
| Labour supply (thousands of fte's) | 6280.3 | 6678.3 | 6458.8 | 6449.8 | 6591.3 |
| Capital stock (billions of euros) | 1711.2 | 2247.5 | 2565.2 | 3068.4 | 3701.9 |
| Private consumption | 42.7 | 46.4 | 49.4 | 49.6 | 48.7 |
| Current account balance | 21.2 | 6.3 | 0.6 | – 2.9 | – 2.5 |

[8] From an average labour income tax rate of 29% in 2006.

The tax increase has obvious beneficial effects on government finances, allowing for sustained primary surpluses and reducing the debt ratio to a stable and sustainable level. However, higher taxes have the effect of reducing net marginal wages and, as a result, labour supply is permanently lowered by two to three percent. The erosion of the tax base means that tax rate increases must be proportionally higher than the shortfall in revenues. In addition, the capital stock adjusts quickly to accommodate the lower labour supply and so domestic production suffers. The impact of the tax on households can be seen in the decline of private consumption relative to the baseline scenario. Not only is consumption lower relative to GDP, but since GDP is lower in the tax smoothing scenario, the absolute level of private consumption is only about 90% of its level in the baseline scenario each year.

In order to determine the effects on social welfare of discontinuous tax policies using the GAMMA model, the simulation is split up into two periods, 2006 to 2025 and 2026 to 2205.[9] As a money measure of household utility, the per-individual equivalent variations *ev* for a variety of tax policies are calculated as follows:

$$U(W_0 + ev, t_0) = U(W_1, t_1)$$

where $U$ is ordinal utility as function of lifetime wealth $W_0$ and $W_1$ in the baseline and alternate scenarios respectively and $t_0$ and $t_1$ denotes tax policy in the baseline and alternate scenario respectively. In this instance, the baseline scenario is the simulation with a tax smoothing policy, so the equivalent variation is the lump sum money transfer that would have the same influence on lifetime utility as a policy change away from tax smoothing. Thus a positive equivalent variation implies a welfare improvement over tax smoothing and vice versa. In order to construct a social welfare function, the equivalent variations for all cohorts, present and future, are aggregated[10]:

$$SWF = \sum_{a=20}^{99} ev_a^{2006} p_a^{2006} + \sum_{y=2007}^{\infty} ev_{20}^{y} p_{20}^{y}$$

where the subscript *a* indicates the age of the cohort, *y* indicates the year and $p_a^y$ is a weight indicating the population size of cohort aged *a* in the year *y*.

Twelve alternate policy simulations are run relative to the tax smoothing policy by setting the tax rate some number of percentage points[11] above or below the tax smoothing rate in the first period and readjusting the rate in the second period to make government finances sustainable.

[9] The dividing line between the sub-periods is a little arbitrary. We have taken the first sub-period to cover 20 years. As projections usually find population ageing to peak in about 40 years time, the first sub-period is just half the period that is most relevant for projections. Experiments have revealed that this choice does not have a significant effect on the results.

[10] Equivalent variations of future generations are made comparable with those of current generations by appropriate discounting.

[11] -8,-6,-4,-3,-2,-1,1,2,3,4,6,8.

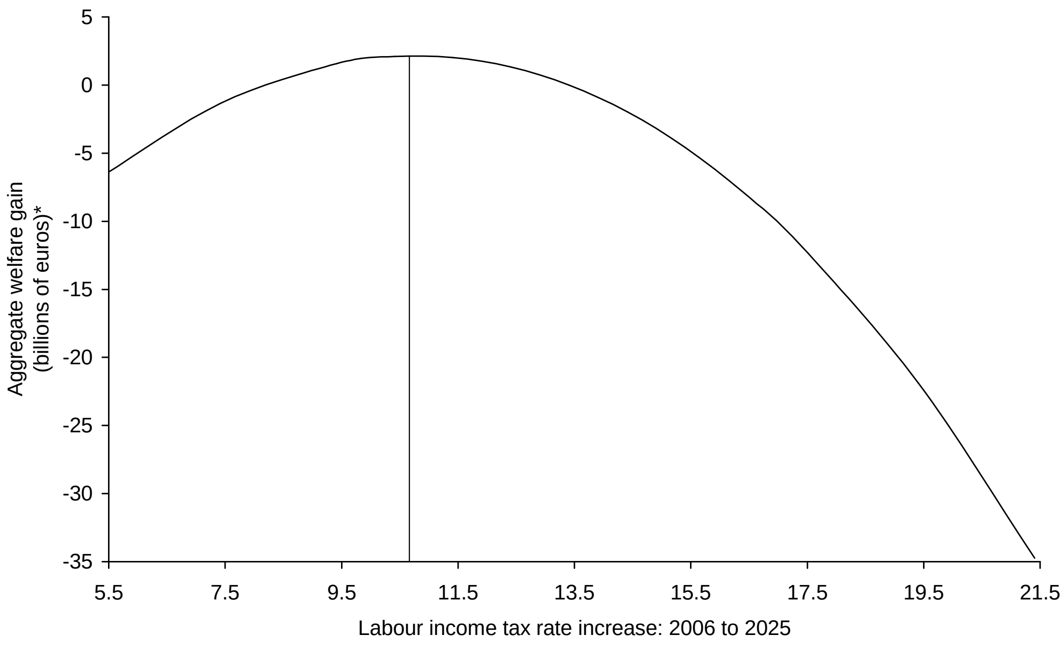
**Table 4.2 Labour income tax rate increases in the deterministic policy scenarios**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | %-points | | | | | | | | | | | | |
| 2006-2025 | 5.4 | 7.4 | 9.4 | 10.4 | 11.4 | 12.4 | 13.4 | 14.4 | 15.4 | 16.4 | 17.4 | 19.4 | 21.4 |
| 2026-2205 | 15.7 | 15.1 | 14.5 | 14.2 | 14.0 | 13.7 | 13.4 | 13.1 | 12.9 | 12.6 | 12.3 | 11.8 | 11.3 |

The government's sustainability constraint implies that a tax rate below (above) the tax smoothing rate over the first period will require a tax rate above (below) the tax smoothing rate in the second period as is illustrated in Table 4.2. It can be seen that the deviations from the tax smoothing rate in the second period are substantially less than the corresponding deviations in the first period. This is because the second period is much longer than the first. As a result, the required budgetary response to deficits or surpluses carried over from the first period can be drawn out over a longer time frame, so the tax rate response will be proportionally smaller.

It is clear that each simulation will involve some intergenerational redistribution relative to the baseline. Aggregating the equivalent variations over all cohorts gives a measure of the net welfare consequences of each policy. Figure 4.1 plots the aggregated equivalent variation levels for each policy point against the percentage point tax rate increase in the period 2006 to 2025. The points are joined by a curve, the peak of which indicates the welfare maximizing policy.

**Figure 4.1 Social welfare curve in the deterministic scenario**




*Relative to a scenario with a 13.4% point tax rate increase in 2006.

It can be seen from the figure that the social welfare maximizing policy under demographic certainty sets the tax rate increase in the neighbourhood of 10.8% points in the first period (2006 to 2025). Referring to Table 4.2, one can verify that this implies that the welfare maximizing tax rate should be approximately 14.1% points above the present rate in the second period (2026 to 2205).[12]

Why is tax smoothing not optimal in these simulations? The dynamic taxation literature typically presents the problem in the context of a representative agent setting with a finite time horizon. In contrast to the real world as well as to a complex simulation model such as GAMMA, this constitutes a significant simplification. Kingston (1991) derived the necessary and sufficient conditions for the optimality of equalizing wage tax rates over time in a dynamic general equilibrium framework. These conditions include constant labour supply elasticity and constant relative risk aversion. Since constant aggregate labour supply elasticity is not necessarily present in the GAMMA model, there is no reason to expect that a constant tax rate policy would maximize social welfare.

There is another reason why the tax smoothing policy does not maximize welfare in the GAMMA model. Indeed, the labour income tax rate is not the only government policy variable that has an influence on the marginal reward of labour. The baseline scenario features the decline of premiums for the VUT, the Dutch PAYG-financed early retirement scheme, and decreasing catching-up premiums. Wedge smoothing then calls for increasing rather than constant tax rates. Also, there appear to be influences from other factors. When premiums for the VUT and catching-up premiums, inflation, the depreciation allowance for firms, revenues from natural gas exploitation and population growth are eliminated from the model do the simulation results show that tax smoothing maximizes social welfare. This result is not of prime importance, however. We only establish the welfare maximizing tax policy in the deterministic setting as a reference in order to assess how it is affected when demographic uncertainty is introduced.

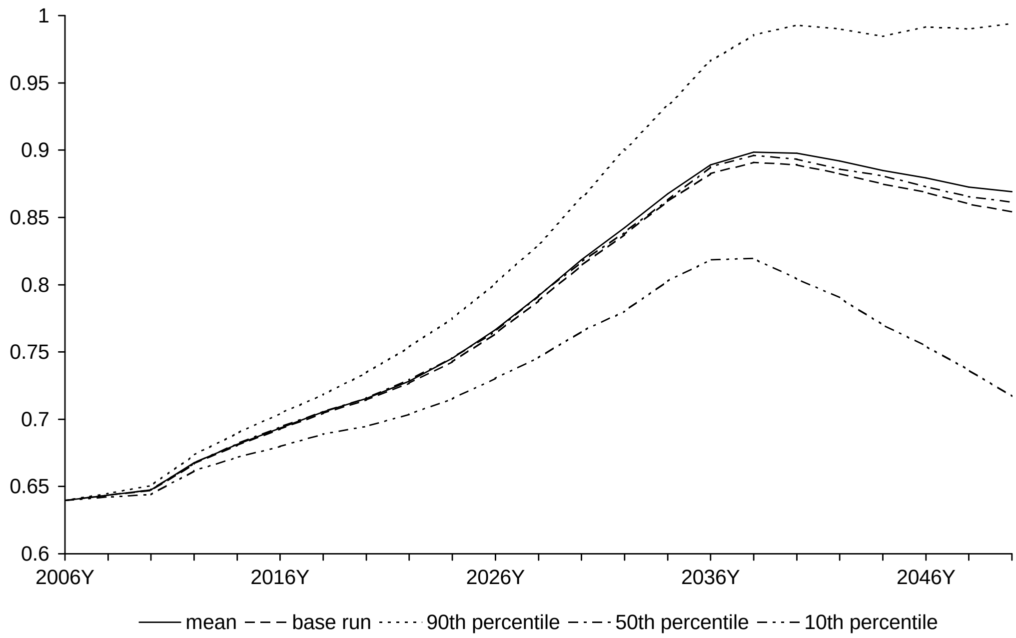
[12] Under this policy, the debt to GDP ratio stabilizes at a level of approximately -56.7% by 2050. Compared with the policy of tax smoothing, the policy that maximizes social welfare under demographic certainty builds up a smaller amount of wealth. This conforms to higher tax rates from 2026 onwards.

# 5 Stochastic demographics

In this section, we formalize the effects that uncertainty in demographic developments can have on economic and fiscal variables by simulating projections based on population forecasts of the Netherlands produced by PEP (Program for Error Propagation).[13] The program applies stochastic processes to the forecasted development of fertility, immigration and mortality rates. By generating a large number of stochastic population paths and using them as bases for GAMMA simulations, we arrive at a distribution of possible macroeconomic and fiscal outcomes that can be given a probabilistic interpretation.

The most important demographic statistic concerning fiscal policy is the total dependency ratio. Since the funding of health care, public pensions and education makes up a substantial proportion of government outlays and labour income tax comprises a large share of government income, an increase in this ratio is bound to put pressure on fiscal balances. Figure 5.1 shows the stochastic distribution of the total dependency ratio as forecast until 2050 based on 207 PEP forecasts.[14]

**Figure 5.1 Stochastic distribution of the total dependency ratio**




[13] See Alho and Spencer (1997) and the PEP user manual at http://joyx.joensuu.fi/~ek/pep/userpep.htm.

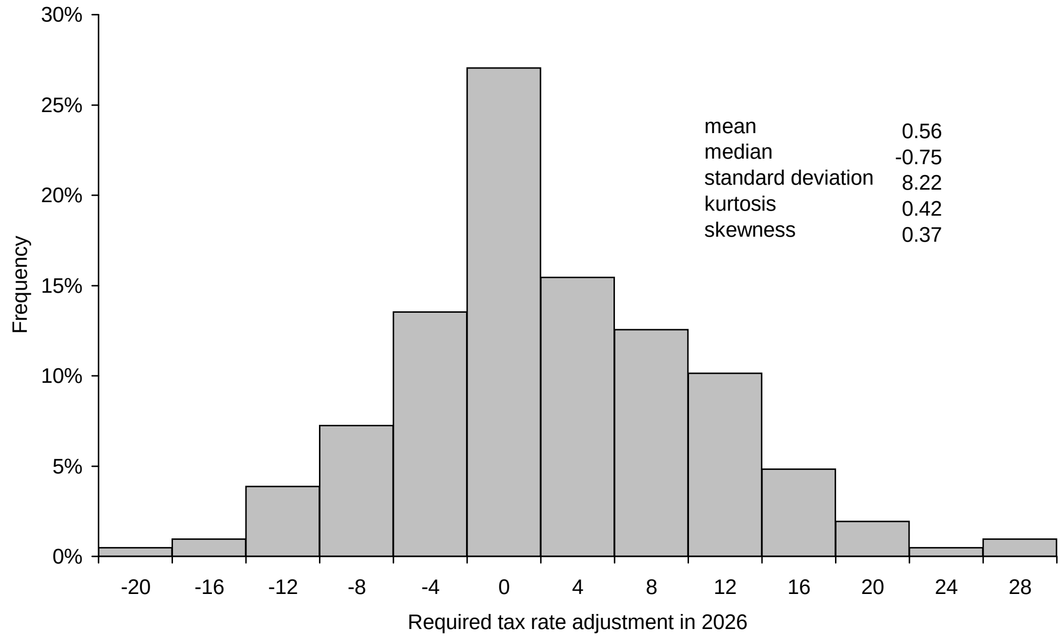
[14] Originally 250 simulations were run. Those simulations that failed to solve or that produced total population levels above 50 million in the final simulation year (2205) were omitted from the sample. Note that, in the baseline simulation, the total population in 2205 is 20.2 million. We have found that increasing the number of stochastic simulations above 250 does not significantly increase the robustness of the demographic estimates. This number was chosen in view of the large demand on computing time from running numerous policy variants for each of the stochastic projections.

The base run line corresponds to the population point forecast that was used in the deterministic scenario in the previous section. The percentile lines are not single paths of the PEP simulations. Rather, they are trend lines connecting cumulative distributions in each forecast year. So at each point on the 10th percentile line, 90% of the dependency ratio forecasts for that year lie above the line. The symmetry of the forecasts is evident in that the base run, 50th percentile and mean lines all lie very close to one another on the figure.

It can be seen that the dependency ratio is almost certain to increase in the coming decades, but it is uncertain by how much. By around 2040 the ratio will level off and possibly decline thereafter. However it will remain at a relatively consistent level somewhere between .75 and .95 with a 60% level of probability.

Figure 5.2 shows how this demographic uncertainty is translated into uncertainty regarding future fiscal requirements. Suppose in the first instance, the tax rate is set in 2006 at the (deterministic) tax smoothing rate for all stochastic paths. Then in 2026, the true demographic development for each path is 'revealed' and the tax rate is readjusted to sustain the budget indefinitely. Figure 5.2 presents the required increases as a frequency distribution. The average necessary labour income tax rate increase in 2026 is .56% points above the tax rate in the period 2006 to 2025.

**Figure 5.2** **Distribution of labour income tax increases in 2026 required to sustain the budget following a 13.4% point increase in 2006**



It is evident that the required tax rate change distribution is not symmetric.[15] This contrasts with the highly symmetric dependency ratio forecasts produced by the PEP program. The explanation for this lies in the non-linearity between tax revenues and tax rates. Tax distortions have the effect that a given increase in the tax rate is not matched by a proportional increase in revenues because of erosion of the tax base due to the substitution by households towards leisure consumption. Furthermore this disparity is exacerbated as tax rates are higher. As a result, while the stochastic distribution of revenue requirements may be quite symmetric, the mean of the required tax rate increases is driven towards the upper end of the distribution. So due to the influence of this excess burden, it is not sufficient to impose the sustainable tax rate associated with the most likely demographic scenario. Sustaining government finances in expectation requires imposing the *expected* sustainable tax rate, which in general will be higher than the sustainable tax rate in the expected path.

As Table 5.1 illustrates, this effect from stochastic revenue requirements will have an influence on the second period tax rates in the welfare experiments that were presented above. For each of the thirteen policy strategies, the first period tax rate is set to the same level as in the deterministic scenarios. However, it can be seen that the expected second period tax rate is proportionally higher in each case. This effect can be interpreted as a shift in the government's sustainability constraint due to the excess burden of distortionary taxation.

**Table 5.1 Labour income tax rate increases in the stochastic policy scenarios**

| | %-points | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006-2025 | 5.4 | 7.4 | 9.4 | 10.4 | 11.4 | 12.4 | 13.4 | 14.4 | 15.4 | 16.4 | 17.4 | 19.4 | 21.4 |
| 2026-2205[a] | 16.3 | 15.7 | 15.1 | 14.8 | 14.5 | 14.2 | 14.0 | 13.7 | 13.4 | 13.1 | 12.9 | 12.4 | 11.9 |

[15] Skewness = .374505. A rule of thumb test for the significance of skewness is: if the ratio of the sample skewness divided by its standard error is greater than two or less than negative two, skewness is different from zero. The standard error of skewness can be approximated by $(6/N)^{1/2}$, with N the sample size. The calculated test statistic is 2.1997, so the null hypothesis that skewness is zero is rejected.

# 6 Maximizing social welfare under demographic uncertainty

In this section, the welfare maximizing fiscal policy under demographic uncertainty is determined in a similar way as it was for demographic certainty in the deterministic scenario. In addition, the consequences for social welfare of this uncertainty are also assessed. As before, a grid of first period tax rates is chosen around the central policy of a 13.4% point increase. For each of these scenarios, 207 stochastic simulations are run and for each simulation the tax rate is adjusted in the second period to sustain the budget. Because the second period tax rate depends on the demographic development, it is determined by the stochastic process. Therefore the lifetime utility of those cohorts who are economically active in those years is also stochastic. The expected equivalent variation for each household relative to the baseline scenario (tax smoothing as in the deterministic scenario) is calculated:

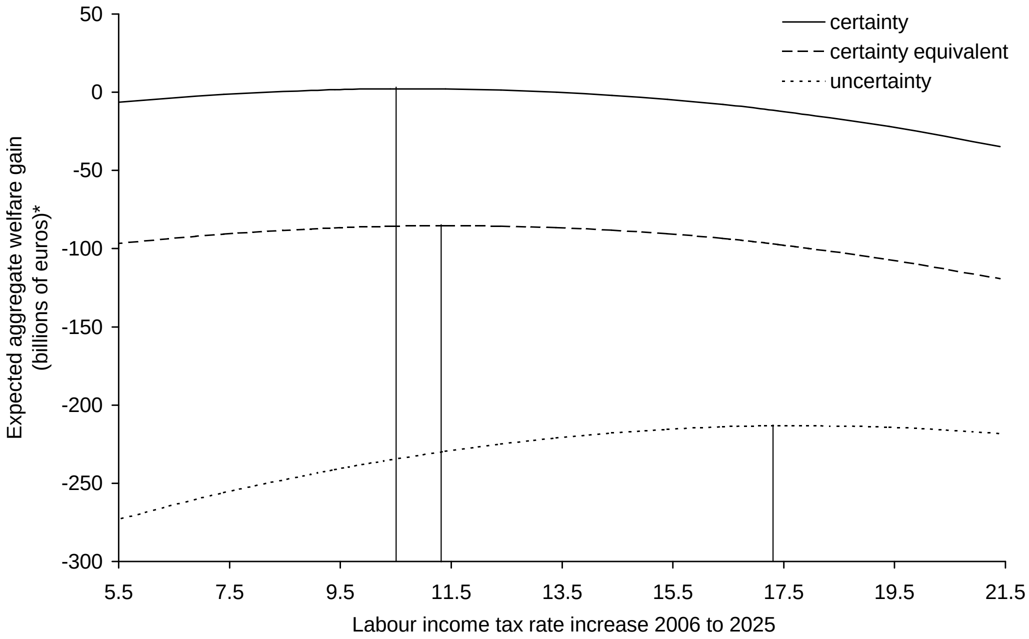
$$U(W_0 + ev_u, t_0) = E\left[U(W_1, t_1)\right]$$

Note that the lifetime utility level in the baseline scenario is non-stochastic, so only the right-hand-side of the equation has the expectation operator. As in the deterministic scenarios, the expected equivalent variations are aggregated to construct a social welfare function:

$$SWF_u = \sum_{a=20}^{99} ev_{u\,a}^{\,2006} E[p_a^{2006}] + \sum_{y=2007}^{\infty} ev_{u\,20}^{\,y} E[p_{20}^{y}]$$

The expected welfare consequences of each policy are plotted in Figure 6.1 and joined by the welfare curve denoted *uncertainty*. For reference, the welfare curve from the deterministic scenario is also included in the figure and denoted *certainty*. This is just the same curve as that depicted in Figure 4.1. The welfare curve denoted *certainty equivalent* is constructed by running a series of deterministic policy simulations, setting the tax rates exogenously to be the same as the expected tax rates in the stochastic scenarios (as in Table 5.1). These simulations reflect the influence of the shift in the sustainability constraint on welfare while omitting the influence of net income risk on household utility.

**Figure 6.1 Social welfare curves in the deterministic and stochastic scenarios**




*Relative to a deterministic scenario with a 13.4% point tax rate increase in 2006.

It can be seen that the peak of the expected welfare curve for the stochastic scenarios is located below and to the right of the peak of the welfare curve associated with the deterministic scenarios. The shift downwards represents the welfare loss to society arising from the presence of risk stemming from demographic uncertainty in the future. Moving from a state of certainty to a state of uncertainty is equivalent in utility terms to reducing the aggregated lifetime wealth of all cohorts affected by demographic risk. For example, evaluated at the welfare-maximizing tax rate under certainty, the total cost of uncertainty to all cohorts is approximately €235 billion (1.54% of the lifetime wealth for all cohorts aggregated through time) - the vertical distance between those two curves. The vertical distance between the uncertainty curve and the certainty equivalent curve represents the social welfare loss solely attributable to the implied shift in the government's expected sustainability constraint. It comprises approximately €87 billion (.57% of lifetime wealth) of the total welfare loss from demographic uncertainty.

In Figure 6.1, the vertical distance between the expected welfare curve for the uncertainty case and the certainty equivalent curve represents the welfare loss resulting from uncertainty not attributable to the implied shift in the government's expected sustainability constraint. This loss, valued at approximately €148 billion in welfare equivalents (.97% of lifetime wealth), arises solely because of the income risk suffered by households. The rightward shift in the expected welfare curve shows the effect of uncertainty on the welfare-maximizing policy in the simulations. Because the consequences of demographic uncertainty are borne almost entirely by future generations, the government can reduce the net welfare loss to society by decreasing their expected tax burden and setting the tax rate in the period 2006 to 2025 at approximately 17.4% points above the present level (about 6.6% points higher than the welfare maximizing policy in the absence of demographic uncertainty). The resulting expected tax rate in the year 2026 onward is then only 12.9% points above the present level.[16] By doing so, the government distributes the costs of uncertainty more evenly over all generations, present and future. For example, the expected gain in welfare of future generations[17] from shifting from the preferred policy under certainty to the preferred policy under uncertainty is approximately €271 billion (2.6% of lifetime wealth) in money equivalents. The expected welfare loss to current generations[18] from the same policy change is approximately €249 billion (5% of lifetime wealth). On balance, this policy minimizes the aggregate consequences of uncertainty.

**Figure 6.2 Welfare-maximizing tax policies and the long run budget constraint under certainty and uncertainty**

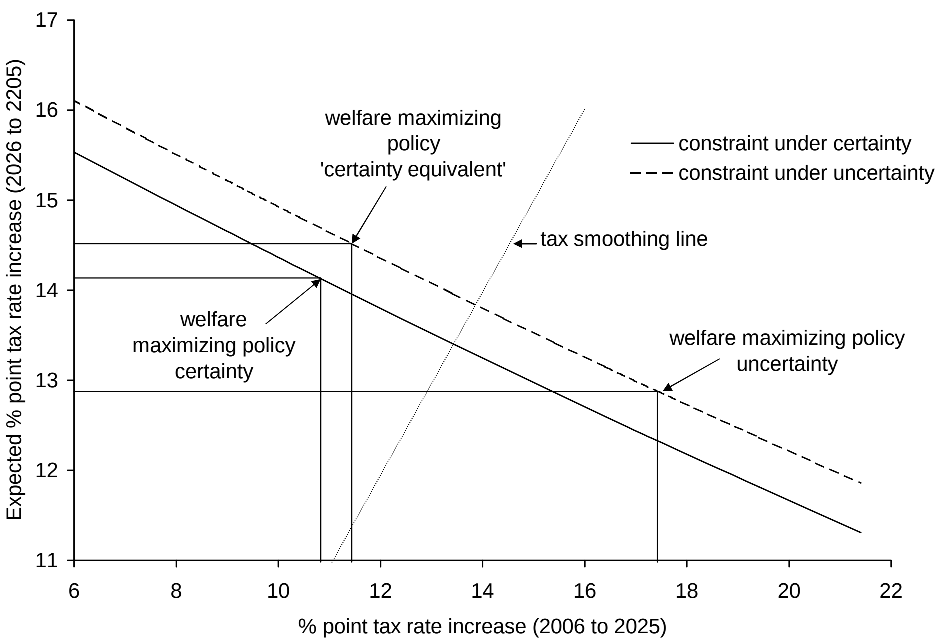



Figure 6.2 shows more explicitly the relationship between the welfare maximizing tax policies and the sustainability constraint. The solid diagonal line represents the combination of labour income tax rate increases in the periods 2006 to 2025 and 2026 to 2205 that will sustain the government budget if the demographic development follows the deterministic path, as in Table 4.2. The dashed line represents the combination of first and second period tax rate increases that will sustain the budget in expectation if the demographic development is uncertain, as in Table 5.1. It is easy to see that the introduction of uncertainty can be interpreted as a shift in the

[16] The expected debt to GDP ratio in 2050 is approximately −106.1%. Compared with the policy of tax smoothing, the policy that maximizes social welfare under demographic certainty accumulates more financial wealth. This conforms to lower tax rates from 2026 onwards.

[17] Those who will turn 20 years old in 2007 and all cohorts afterwards.

[18] Those 20 years old and older in 2006.

constraint. In addition, the three welfare maximizing policy points are indicated along with a ray depicting the (expected) tax smoothing policies along each of the sustainability constraints.

# 7 Concluding remarks

Judging from this analysis, it is clear that the welfare implications of demographic uncertainty are quite large. It is equally clear that, given the assumptions made here, the extent to which the government can mitigate its effects is relatively small. If evaluated at the welfare maximizing rate under certainty, the total expected welfare loss from demographic uncertainty is valued at over €235 billion for all cohorts into the indefinite future. Increasing the tax rate by a further 6.6% points for the next twenty years will only reduce this loss by about €22 billion.

Of course this story relies on a few abstractions from reality. First, the model abstracts from any impact of demographic risk on the behaviour of households. In case a policy reform changes the degree of future uncertainty, this may affect household saving. Prefunding policies are a good example as they provide some insurance to future tax rate changes. This household saving effect is not taken into account. However, we do not consider this to be problematic since quantitatively this effect seems fairly small. Even if the savings effect were non-negligible, the corresponding welfare effect would probably be close to zero.

Second, demographic risk is only one source of risk influencing fiscal policy. Other sources include a variety of economic uncertainties such as variability in productivity, interest and inflation rates, and labour participation rates among others. Naturally these types of risks are bound to interact with each other, as they are bound to interact with demographic risk. Focusing on only one type of risk may underestimate the extent to which the government should exercise precaution when setting fiscal policy.[19]

Finally, the simulation experiment presented here is a stylized representation of the problem facing policy makers. It is assumed that the government is somewhat naive about future developments and also that it is quite restricted as to when it can implement policy reforms. The government makes an immediate reform decision in 2006 and then has to delay any policy adjustment until 2026 when the uncertainty about the true demographic structure of the population is resolved. In the mean time, it is completely ignorant about how the population is developing. Of course, governments are typically better informed than this and would be able to make gradual policy readjustments as new information became available. This flexibility should help to mitigate the adverse effects of demographic uncertainty to some extent.

These qualifications may have effects, one way or the other, on the quantitative conclusions of this analysis. Therefore, we want to stress that our calculations should not to be taken literally. Rather, they should help to get an idea of the order of magnitude of the effects of demographic uncertainty.

[19] For a discussion of the relative impact of demographic risk versus economic risk see Bonenkamp *et al.* (2006).

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