Should tax rates fall over time if future demographic development is uncertain? A simulation approach

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Very preliminary, not to be quoted

Abstract

This paper analyses the impact of demographic uncertainty on intertemporal tax policy on the basis of an applied general equilibrium model for the Netherlands. In contrast to the familiar concept of tax smoothing the analysis shows that demographic uncertainty gives rise to a precautionary motive in intertemporal government policy, featuring higher tax rates in the short run and lower tax rates in the more distant future. In the absence of uncertainty the opposite result is found with low tax rates now and high tax rates in the future. On balance the precautionary motive in intertemporal taxation if found to dominate indicating that optimal tax policy for the Netherlands implies falling tax rates over time.

Key words: Ageing, Sustainability, Tax smoothing, , Demographic uncertainty
JEL code: H60, J11

1 Introduction

That most economies face an ageing problem is certain. Less certain, however, is the size of the problem and the appropriate response of budgetary policies. A few additional years of life expectancy may have a serious impact on the size of the ageing problem. Demographic uncertainty is large, and makes the urgency of policy reform uncertain as well. Some argue that uncertainty is a reason for extra precaution in budgetary policy (Auerbach and Hassett, 2001, Van der Ploeg, 2007), implying high tax rates in the short run to reduce the cost of risky taxation in the more distant future. This seems in contrast with Barro's (1979) conventional result on tax smoothing which implies that tax rates such that they can be expected to be held at their current levels. The underlying idea is that taxes are distortionary and tax smoothing minimizes the distortions. If new information arrives, tax rates will generally need to be revised, but again such that no further revisions are necessary if the future evolves as expected.

A major question is whether this theory holds true if we recognize that the world is uncertain. There are good reasons to think not. In particular, it can be argued that precautionary saving strategies dominate tax smoothing strategies. Efficiency point of view (possibly also distributional argument for precaution in case of disjunctive generations.)

From the microeconomic literature, we know that income uncertainty is an argument for precautionary saving. Theoretically, this is so if the adverse utility consequences of bad times are considerably severe (relative to the positive utility effects of good times). Formally, this relates to the sign of the third derivative of the utility function (Leland (1968)). Precautionary saving is also found in the data (see Engen on unemployment risk, Blundell?). Should governments react to macroeconomic uncertainty, just like households react to microeconomic uncertainty? This would be bad news in an ageing society. Tax smoothing already calls for government wealth accumulation; precautionary saving means that governments should be even more ambitious.

Precautionary saving in the government budget would not necessary in a complete market environment, where the government can insure against bad and good times and thereby smooth tax rates not only across time periods but also across states of nature (Lucas and Stokey (1983)). Unfortunately, this ideal world is far beyond reality for government finance. Barro's world in which public debt is held in fixed interest bonds seems closer to reality. But also in Barro's world uncertainty does not inevitably lead to precaution in tax policy. On the contrary, the conventional representation of Barro's model takes the costs of taxation to be quadratic, in which case the result of strict tax smoothing may still prevail (see e.g. Romer 2006). This result is, however, restrictive in at least two respects. First, there are good reasons why the cost of taxation are not quadratic but involve convex marginal costs, especially as the costs are intended to stand for the welfare cost of the tax distortion. Second, Barro's analysis is restricted to the efficiency of raising taxes, and ignores the broader context of uncertainty in a welfare theoretic context. As the costs of taxation tend to be higher in bad states of the economy when income is low and the tax rates are high, one should also take account of the risk features of future tax revenues. Van der Ploeg (2007) expands on the first point, and analyses the political economy of precautionary taxation in the presence of convex marginal political costs of taxation. This paper takes a broader perspective and considers the role of precautionary budgetary policy in a consistent welfare theoretic framework. It does so in two steps: First it analyses the optimal timing of taxation in a simple analytical model. It will show that

Barro's theory was meant not only to be normative, but also positive. One could argue that the same holds true for the theory of optimal debt policies under uncertainty. However, the prescription of tax rates falling over time and a reduction of public debt is not easily found in the data.

2 Tax smoothing under uncertainty: an analytical model

Following Barro (1979) we neglect the consequences of the taxation for the intergenerational distribution of income. This is done by assuming a Ricardian framework where generations are linked through bequests and gifts, and the present generation takes account of utility of generations in the entire future. Here this is captured in a simple three period model of one generation which decides on the optimal consumption and taxation plan over the entire future. (The problem can also be written as a dynamic programming problem, but that would not change the basic findings of this analysis). The future is uncertain on two accounts: both future income and as well as the life expectancy are uncertain at a aggregate level. In this manner the model takes account of non-diversifiable economic and demographic risk.

Utility of the representative agent is given by the discounted sum of utility in the three periods of life:

$$U = U(C_1) + \frac{E[V]}{1+\rho} \tag{1}$$

with

$$V = U(C_2) + \frac{nU(C_3)}{1+\rho}$$

where C_i represents consumption in period i, ρ time preference, and n the - uncertain - remaining duration of life in period 3. We assume that living some extra time (n) in period 3 yields positive welfare. The agent works and pays taxes in the first two periods of life, and receives a given pension in period three as long as he or she lives. Then the budget constraint reads:

$$C_1 + \frac{C_2}{1+r} + \frac{nC_3}{(1+r)^2} = Y_1 - T_1 + \frac{Y_2 - T_2}{1+r} + \frac{nG}{(1+r)^2} \qquad (2)$$

where Y, T, G, and r features income, taxation, public pension and the interest rate. Finally, the government raises taxes on income in the first two period to finance pensions in the third period as well as collection cost of taxation

$$T_1 + \frac{T_2}{1+r} = \frac{nG}{(1+r)^2} + f(t_1)Y_1 + \frac{f(t_2)Y_2}{1+r} \qquad (3)$$

where $f(t_i)Y_i$ represents the collection cost for the tax rate $t_i = T_i / Y_i$, with $f', f'' > 0$. Households optimise the time path of consumption, and the government decides on the time path of taxation maximising total welfare U. In a certain world this model features perfect tax smoothing as efficiency in taxation requires the time path of taxation $\{t_1, t_2\}$ to be such that it minimizes the present value of collection cost, thus $f'(t_1) = f'(t_2)$, and therefore $t_1 = t_2$.

Under some specific assumptions this result of perfect tax smoothing carries over to an uncertain world. In case of linear marginal collection costs ($f''=0$) the conventional Barro result of perfect smoothing can be found under uncertainty as well (Romer (2006)). This analysis is typically restricted to efficiency of taxation only and neglects the welfare costs of covariance between consumption and costs of taxation. In this paper we broaden the scope in this respect. In this respect our analysis differs from Van der Ploeg (2007), who also focuses on efficiency only.

Uncertainty is introduced as follows. Economic uncertainty is incorporated in the form of uncertain income Y_2 in the second period. The interest rate r on private savings and public debt is assumed to be certain and given on international capital markets. Demographic risk is related to (average) life expectancy n in this model. Information on n is revealed in period 2 at the same time as Y_2 becomes known. This structure implies that no new information is revealed after period 2. This helps to confine the problem while capturing the essentials about economic and demographic uncertainty.

The households problem is to maximise U (1) subject to the budget constraint (2). Solving the model recursively for the second and third period we can write second period welfare V in an indirect fashion as

$$V = V\left(X \ , n\right) \qquad (4)$$

where

$$X = (1+r)(Y_1 - T_1 - C_1) + Y_2 - T_2 + \frac{nG}{1+r}$$

is the second period's budget and n the remaining life time in the third period. Using the government budget constraint (3) this can also be written as a resource constraint

$$X = (1+r)Y_1 + Y_2 - (1+r)C_1 - [(1+r)f(t_1) + f(t_2)] \qquad (5)$$

where the last term between square brackets is the sum of the collection cost of taxation. Using definition (1) and invoking the envelope theorem the impacts of X and n on second period welfare V are found to be

$$V_x = U'(C_2) \ , \ V_n = U(C_3)/(1+\rho) \qquad (6)$$

respectively.

Using these results for the second period solution and taking account of the households budget constraint (2) the optimisation problem in period 1 leads to the familiar first order condition for consumption

$$1 = E\left[\left(\frac{1+r}{1+\rho}\right)\frac{U'(C_2)}{U'(C_1)}\right] \qquad (7a)$$

Similarly using the budget constraint for the government (3) maximisation of welfare (10) gives the following condition for the tax policy

$$1 = E\left[\left(\frac{1+r}{1+\rho}\right)\frac{U'(C_2)}{U'(C_1)}\left(\frac{1-f'(t_1)}{1-f'(t_2)}\right)\right] \quad (7b)$$

Finally, writing $C_2 / C_1 = 1 + g$ and denoting $\tau_2 / \tau_1 = 1 + h$, assuming a coefficient of risk aversion equal to θ, these first order conditions can be approximated using a second order Taylor expansion as:

$$0 = r - \rho + \theta E[g] - 1/2\theta(1+\theta)\operatorname{var}(g) \quad (8a)$$

$$0 = r - \rho + \theta E[g] + \chi E[h] + \theta\chi \operatorname{cov}(gh) - 1/2\theta(1+\theta)\operatorname{var}(g) - 1/2\chi(\varphi+\chi)\operatorname{var}(h) \quad (8b)$$

where $\chi = \left(\frac{f'(t_1)}{1-f'(t_1)}\right)\frac{f''(t_1)\,t_1}{f'(t_1)}$ and $\varphi = \frac{f'''(t_1)\,t_1}{f''(t_1)}$ represent the – transformed - elasticity of the first derivative and second derivative of the *f(t)* function respectively. Upon substitution of the result for consumption growth (8a) the condition for tax policy (8b) reduces to

$$E(h) = \theta \operatorname{cov}(g,h) - \frac{1}{2}(\varphi+\chi)\operatorname{var}(h) \quad (9)$$

Clearly, the tax rate is not constant in general if one allows for uncertainty. The first term concerns the non-diversifiable part of shocks in tax rates. This term arises as we have assumed that the government is unable to hedge shocks in its portfolio in a Lucas & Stokey fashion. If revisions in tax rates (h) are negatively related to shocks in consumption growth (g), which is plausible at first sight, this will lead to tax policies featuring falling tax rates over time, $E(h)<0$. This deviation from strict tax smoothing may be considered as a second best reaction to the inability to hedge to these shocks through the portfolio choice of the government (Bohn, ##). Precaution in tax policy is further motivated by the second component in (9). This term is related to the variance in the tax rate is similar to the well-known precautionary savings term in the consumption equation. In this model this term consists of two parts. The factor φ relates to the third derivative of the $f(t)$ function. In case of a quadratic cost function this term is zero (φ=0). Convexity of the cost function provides makes it less attractive to postpone taxes to the – uncertain – future. As a result tax rates should decline over time. But even in case of quadratic costs tax policy in our model is sensitive to the variance of the tax rate. This implies that also in the case of quadratic cost strict tax smoothing no longer holds. This is due to the fact that the additional collection costs have to be finance by raising the tax rate even further creating a concavity in the relation between tax revenues and tax rate. This is often not taken into account in other representations of Barro's tax smoothing model (e.g. Romer, 2006).

Covariance between consumption and tax rates

Shocks in demography affect the tax rate as well as private consumption leading to a non-zero covariance between *g* and *h*. Focusing on the second period when the shocks are revealed, the adjustments in tax rate t_2 and consumption C_2 to shocks in life expectancy and output growth can be determined from the budget constraints 3 and 5, respectively. Defining output growth by $1+m = Y_2 / Y_1$ and taking differentials of consumption and tax rates with regard to the shocks in *n* en *m* we obtain for shocks in consumption growth *g* and the growth in the tax rate *h*

$$g = E(g) - \psi \Delta n + \mu \Delta m \qquad (10a)$$

$$h = E(h) + \eta \Delta n - \lambda \Delta m \qquad (10b)$$

where Δ denotes the shocks, and the coefficients are given by (writing *f* and f' for $f(t_2)$ and $f'(t_2)$)

$$\psi = \frac{\kappa}{1+r}\left(\frac{C_3}{C_1} + \frac{f'}{1-f'}\frac{G}{C_1}\right) > 0$$

$$\mu = \kappa\left((1-f) + \frac{f'}{1-f'}\frac{T_2}{C_1}\right) > 0$$

$$\eta = \frac{G}{T_1}\frac{1}{(1+r)(1+m)(1-f')} > 0$$

$$\lambda = \frac{t_2 - f}{t_1(1+m)(1-f')} > 0$$

where $\kappa = \frac{dC_2}{dX} = \left(1 + \frac{n}{1+r}\frac{1+\eta}{1+r}\left(\frac{\theta}{\theta - \zeta(r-\eta)}\right)\right)^{-1}$ where $\zeta = -\frac{U'''(C_2)C_2}{U''(C_2)}$ represents the coefficient of relative prudence and the growth rate g is approximated by $(r-\eta)/\theta$. Assuming that shocks in life expectancy and economic growth are independent, thus cov (n,m)=0, we obtain the following results for the variance in h and the covariance between h and g,

$$\begin{aligned} \text{var}(h) &= \eta^2 \text{ var}(n) + \lambda^2 \text{ var}(m) \\ \text{cov}(g,h) &= -\psi\eta \text{ var}(n) - \lambda\mu \text{ var}(m) \end{aligned} \quad (11)$$

Reminding that the tilt of the tax path depends negatively on the covariance between consumption and the tax rate and positively on the variance of the tax rate, this result that uncertainty leads to precaution in tax policy, both on account of economic uncertainty and demographic uncertainty.

Qualifications

This analytical model reveals the basic ideas underlying the impact of uncertainty on optimal tax smoothing. A number of qualifications are in order, however. First, it ignores the distributional impact of taxation. Frontloading of taxation to reduce the costs of uncertainty leads to an extra burden for current generations, which may or may not be or may desirable from an intergenerational perspective. These distributional effects may provide a convincing reason why we do not observe this type of precautionary budgetary policies in reality. A second qualification concerns the modelling of the welfare costs of taxation. In this model we followed Barro's concept of collection cost, and extended it into a welfare theoretic framework. In this analytical model we deliberately ignore distortionary impact of taxation on labour markets and other markets. This is helpful in order to keep the model tractable at an analytical level. In the next section these results will be reproduced on the basis of a full scale simulation model. This model features endogenous labour and distortionary taxation, and incorporates tax policy over a long time horizon. This simulation approach will provide insight in the magnitude of demographic uncertainty and its impact on optimal tax smoothing. The increased realism come at a price, however. Rather than solving the full optimal path for taxation, it focuses on the welfare implications of different tax rates in two periods, those before 2025 and those after 2025.

3 The GAMMA model[1]

The simulations in the remainder of the paper use a dynamic general equilibrium overlapping generations model for the Netherlands, GAMMA. The model is a Auerbach-Kotlikoff (1987) type of model with overlapping generations of households who maximize some intertemporal utility function according to lifecycle theory, firms that maximize profits under the constraint of a CRS technology and a government that behaves according to some rules of thumb that are inspired by economic reality. Different from the original Auerbach-Kotlikoff model is that GAMMA describes a small open economy and distinguishes between first-pillar basic pensions and second-pillar supplementary pensions.

The lifecycle model in GAMMA is fairly standard, except on two aspects. First, utility is such that the demand for leisure depends on its price, but not on the amount of household wealth.[2] Second, the model adds taste shift parameters such as match the model's outcomes with lifetime consumption and labour profiles.

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.

Like the Auerbach-Kotlikoff model, GAMMA is essentially a deterministic model. 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.[3] 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 below.

[1] For a detailed description of the GAMMA model see CPB (2007).

[2] 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.

[3] 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.

4 Maximizing social welfare under demographic certainty[4]

Foreseeable trends, among which population ageing is the most important one, make current fiscal policies unsustainable (Van Ewijk *et al.* (2006)). Hence, at some point in time the government must implement fiscal changes that decrease expenditures and/or increase revenues. As a reference point for our welfare analysis, 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. 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 but the permanent tax rate increase that enforces it is unique. As such, the tax rate increase can be interpreted as a measure of the fiscal sustainability gap.[5]

Obviously, tax smoothing is not the only policy that will close the sustainability gap. For instance, balancing the budget year to year would also be sufficient. However, theory suggests that such a policy would come at the cost of a higher excess burden due to the distortionary effects of variable tax rates over time. Conversely, in the context of a dynamic economy with multiple agents and a long time horizon, the tax smoothing policy does not necessarily optimize efficiency either as we demonstrate below.

In order to find out whether precautionary fiscal policies would be able to achieve higher levels of social welfare, we split the simulation period 2006-2205 up into two periods, 2006 to 2025 and 2026 to 2205.[6] As a money measure of household utility, the per-individual equivalent variations *ev* for a variety of tax policies are calculated as follows:

$$U_0(W_0 + ev) = U_1(W_1)$$

where U_0 and U_1 are ordinal utility levels as functions of lifetime wealth W_0 and W_1 in the baseline and alternate scenarios 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:

[4] This and the following section rely heavily on Armstrong *et al.* (2007).

[5] This measure was developed by Blanchard *et al.* (1990).

[6] The dividing line between the sub-periods is arbitrary but experiments have revealed that the choice does not have a significant effect on the results. Although the solve 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 as infinite sums. As a result, the utility of cohorts entering the economy after 2205 is accounted for.

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

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[7] above or below the tax smoothing rate in the first period and readjusting the rate in the second period to make government finances sustainable.

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

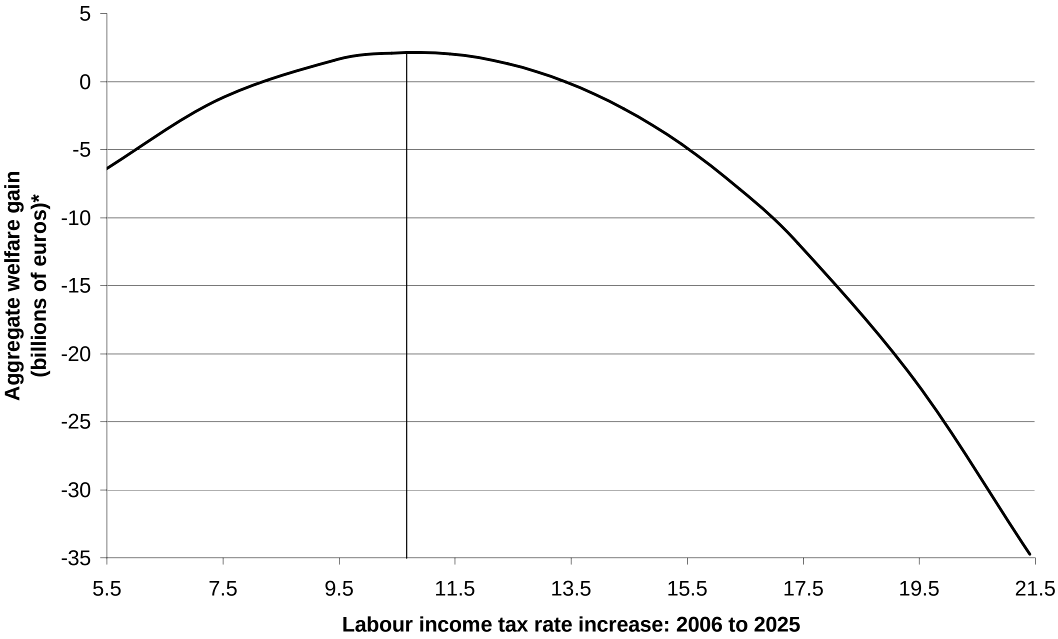
2006-2025	5.4	7.4	9.4	10.4	11.4	12.4	13.4	14.4	15.4	16.4	17.4	19.4	21.4
2026-2205	15.7	15.1	14.5	14.2	14.0	13.7	13.4	13.1	12.9	12.6	12.3	11.8	11.3

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.

[7] -8,-6,-4,-3,-2,-1,1,2,3,4,6,8.

Figure Erreur ! Style non défini..**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).

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 on optimal tax policy from productivity growth, inflation, the depreciation allowance for firms, revenues from natural gas exploitation and population growth. Only when all these factors are eliminated from the model do the simulation results show that tax smoothing maximizes social welfare with this methodology. 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.

5 Stochastic demographics

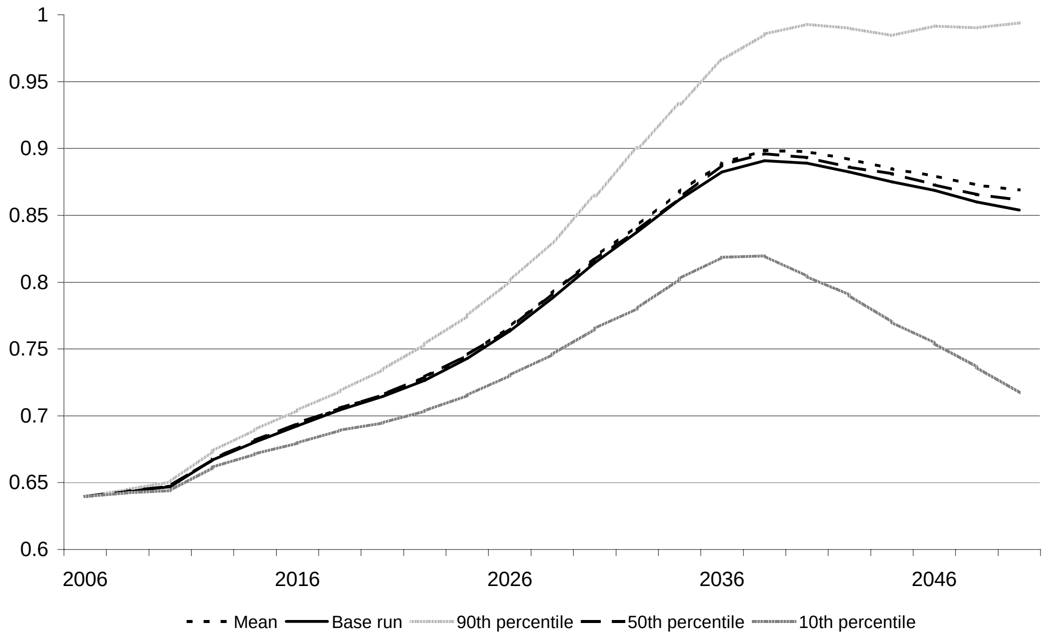
In this section we formalize the effects that uncertainty in demographic developments can have on economic and fiscal variables by simulating projections based on population forecasts of the Netherlands produced by PEP (Program for Error Propagation).[8] The program applies stochastic processes to the 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.[9]

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

[9] 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.

Figure 5.1 Stochastic distribution of the total dependency ratio

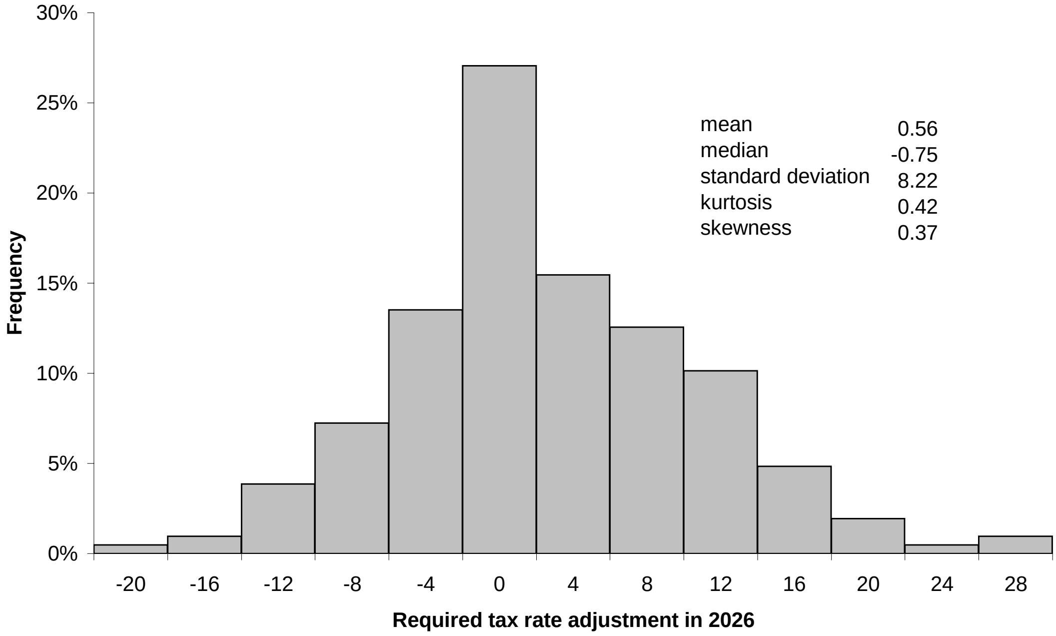


The base run line corresponds to the population point forecast that was used in the deterministic scenario in the previous section. The percentile lines are not single paths of the PEP simulations. Rather, they are trend lines connecting cumulative distributions in each forecast year. So at each point 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% increase in 2006**



It is evident that the required tax rate change distribution is not symmetric.[10] 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. 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.

[10] 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.

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

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

[a]*Expected tax rate increase.*

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:

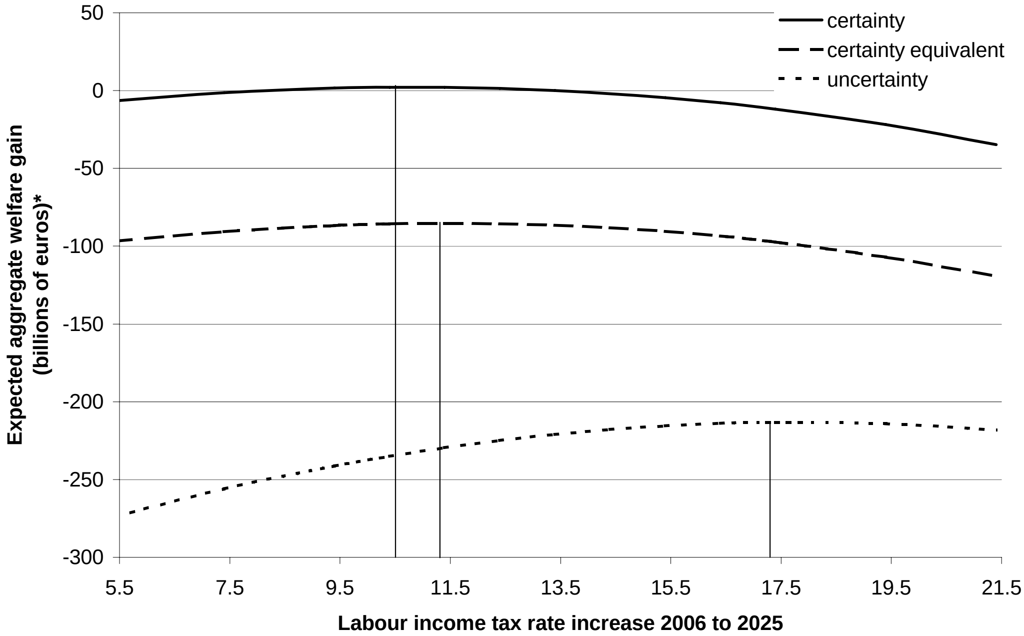
$$U_0(W_0 + ev_u) = E[U_1(W_1)]$$

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. Since the reference scenario is the (certain) tax smoothing path, 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 the uncertainty. For example, at the tax smoothing rate, the total cost of uncertainty to all cohorts is approximately €221 billion (1.45% 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. At the tax smoothing rate, 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 €134 billion in welfare equivalents (.88% 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). 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[11] 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[12] from the same policy change is approximately €249 billion (5% of lifetime wealth). On balance, this policy minimizes the aggregate consequences of uncertainty.

Figure 6.3 Welfare-maximizing tax policies and the long run budget constraint under certainty and uncertainty

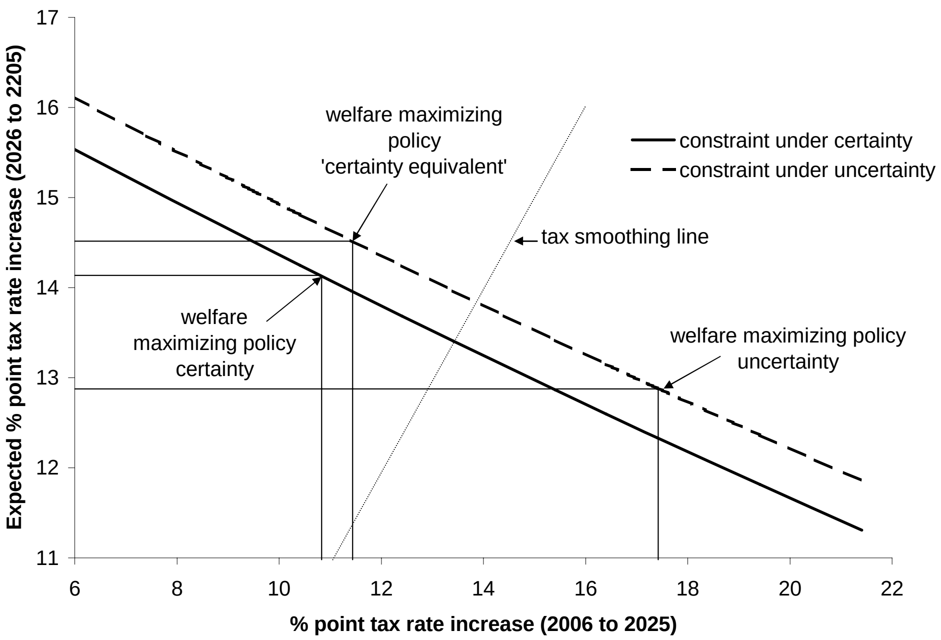


Figure 6.3 shows more explicitly the relationship between the welfare maximizing tax policies and the sustainability constraint. The solid diagonal line represents the combination of labour income tax rate increases in the periods 2006 to 2025 and 2026 to 2205 that will sustain the government budget 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

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

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

uncertain, as in Table 5.1. It is easy to see that the introduction of uncertainty can be interpreted as a shift in the 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

Demographic uncertainty may be a reason for extra precaution in budgetary policy. Stochastic simulations indicate that uncertainty gives rise to a precautionary motive in intertemporal tax policy. The optimal labour tax rate is found to increase by 7 percentage points in the short run due to demographic uncertainty. This effect dominates the decrease in the short-term tax rate by 2.5 percentage points relative to the ‘tax smoothing’ rate that is found in the absence of uncertainty.

The improvement in terms of welfare of such alternative tax policies is modest, however. The welfare gain of going from strict tax smoothing to a more optimal 7 point higher short-term tax rate is quite small, amounting to 0.0004% of GDP in annuity terms. This may vindicate why distributional concerns tend to be given more weight when analysing intertemporal aspects of taxation rather than efficiency arguments.

Of course this story depends on a few significant abstractions from reality. First, demographic uncertainty is not the only one source of risk influencing optimal fiscal policy. Other sources include a variety of economic uncertainties such as variability in productivity, interest rates, labour participation rates and inflation among others. Focusing on only one type of risk may underestimate the extent to which the government should exercise precaution when setting fiscal policy.

Secondly, the simulation experiment presented here assumes that the government is somewhat naive about future developments. The government’s uncertainty about the true demographic structure of the population is resolved in 2026 and in the preceding twenty years it is completely ignorant about how the population is developing. Of course, governments typically have better information than this. The impact of fertility shocks is not likely to be fully felt until at least twenty years after they occur and, as such, are unlikely to catch the government by surprise. Likewise, mortality shocks that increase life-spans, and by extension budgetary requirements, usually can be anticipated by the development of new medical technologies.

These qualifications concern the quantitative conclusions of this analysis. However, the focus here is on the qualitative result that fiscal precaution may be welfare improving in an ex-ante sense.

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