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DEMOGRAPHIC UNCERTAINTY AND FISCAL POLICY

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Demographic Uncertainty and Fiscal Policy

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Alex Armstrong, Nick Draper, Andre Nibbelink and Ed Westerhout*

Abstract

It is well known by now that population ageing threatens the sustainability of fiscal policies in many countries. Although a number of policy options are available to address the problem, the uncertainty surrounding the future development of the population complicates matters.

This paper analyses the economic, intergenerational and welfare effects of several alternative taxation policies that can be used to close the fiscal sustainability gap: immediate tax smoothing, delayed tax smoothing and balanced budget policies. A distinction is made between a consumption tax and a labour income tax. In addition, the influence of demographic uncertainty on the results of these policies is analysed from a number of perspectives. Simulated population shocks show the effect of demographic volatility on macroeconomic and fiscal variables. Stochastic simulations are presented to produce probabilistic bounds for the future development of the economic outcomes and to analyse the issue of optimal fiscal policy under uncertainty.

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1. Introduction

A number of studies have pointed out that ageing populations render current fiscal policies unsustainable in many industrialised countries. With unchanged policies, the sizeable changes in the ratio of retirees to workers that is expected in the future will eventually make public deficit and debt ratios explode. Policy adjustments can take a variety of forms: examples are increasing one or more tax rates, cutting one or more types of public expenditure or implementing reforms that increase the rate of labour market participation. In addition, given the choice of a particular policy instrument, different timing options are available. In particular, one may decide to act immediately or to change policies at some specified date in the future. There are infinite combinations of these options.

A complicating factor for policy-makers is that the future development of the population is uncertain. At the household level, mortality risk affects the consumption and labour supply decisions of individuals, which in turn have policy implications. More directly, demographic uncertainty gives rise to the possibility of a government role in intergenerational risk-sharing. In considering the fiscal adjustments required to restore sustainability, policy-makers must evaluate not just the efficiency and welfare consequences of various policy instruments but also the influence of demographic uncertainty on the results of the policies.

The first part of this paper considers the situation in which future demographic developments are known with certainty to policy-makers. Three policy options to restore fiscal solvency are explored along with their economic, intergenerational and welfare effects: immediate tax smoothing, delayed tax smoothing and balanced budget policies. This approach allows us to assess how much the three differ in terms of economic efficiency and how they compare in terms of redistribution between generations. It also helps us to explain why not a single country has adopted immediate tax-smoothing policies that would restore the sustainability of fiscal solvency: policies for delayed tax smoothing and a balanced budget are much more favourable to current generations than those aimed at immediate tax smoothing, whereas the efficiency losses from these two sets of policies are relatively small.

The second part of the paper addresses the impact of demographic uncertainty on public debt policies from a number of perspectives. First the interaction between demographic and economic variables is demonstrated by showing the effect of a variety of demographic shocks on a sustainable tax smoothing policy. Then stochastic population forecasts for the Netherlands are used to produce probabilistic bounds for the development of Dutch public finances. In this way, a distribution of possible economic outcomes is presented spanning the period up to 2050. Finally, the influence of demographic uncertainty on optimal policy is explored by extending our model to allow for the possibility of precautionary public saving when the government acts as a welfare-maximising agent.

There is some earlier literature on the efficiency implications of different types of public debt policies. Cutler et al. (1990) compared the efficiency losses of immediate tax smoothing and balanced budget policies and found them to differ only slightly in the US. Van Ewijk et al. (2000) performed a similar exercise with similar outcomes for the Netherlands. Flodén's (2002) study for European countries found substantial welfare differences, however. He gives two reasons for the difference in results. First, the population in European countries is expected to age more dramatically than that of the US. Second, the average European economy features a much larger public sector and higher tax rates. According to welfare economics, welfare is convex in tax rates, which means one would expect deviations from optimal debt policies to have more serious welfare consequences in the case of Europe. The analysis of tax distortions in Sweden and the US by Jonsson & Klein (2003) underscores the role of the size of the public sector.

Our analysis differs from these earlier papers in at least two aspects. First, it compares different policies also in terms of intergenerational redistribution. Second, it distinguishes different types of tax smoothing. In a world with more than one type of taxation, different instruments are available in which the efficiency (and redistribution) effects may be quite different.

The paper adopts a computable general equilibrium (CGE) model of the Dutch economy. The model contains overlapping generations of households. Thus it allows us to calculate the effects that different types of policies and demographic uncertainty have on the redistribution between generations. In particular, the redistribution between current and future generations is interesting, if the interests of current generations determine policy choices.

The structure of the paper is as follows. Section 2 briefly discusses the dynamic CGE model that we used for our calculations, named GAMMA. Section 3 describes the future development of the economy under the condition of unchanged fiscal policies. This motivates the quest for policy reforms that restore fiscal sustainability. Section 4 analyses two forms of immediate tax smoothing: the first uses a labour income tax as an instrument, the second a consumption tax. Sections 5 and 6 analyse forms of delayed tax smoothing and balanced budget policies. Section 7 shows how demographic shocks impact public policy and considers variables in the model. Section 8 presents the results of stochastic simulations that produce distributions of the effects of policies, providing a richer analysis than that using a deterministic demographic scenario. Finally, section 9 analyses the effects of demographic uncertainty on optimal government policy. Section 10 concludes.

2. Efficiency and equity evaluation using the GAMMA model

This study uses the dynamic general equilibrium model GAMMA, which gives a stylised picture of the long-term economic development using an overlapping generational framework. The model's strength is its thorough descriptions of both the government sector using generational accounting and the pension sector. The model incorporates life-cycle behaviour of households and endogenous labour supply. As these decisions depend on expectations over a long period the model assumes forward-looking behaviour on the part of individuals. In this aspect the model deviates from more traditional CPB models that have a shorter time horizon. The approach used here is necessary for a consistent analysis of the consequences of budgetary policies over a long time horizon. The focus on long-term consistency comes at the price of some abstractions in other aspects. For example, full forward-looking behaviour is obviously too strong an assumption. Also firm behaviour is modelled in a very rudimentary fashion. So the model's results have to be understood as a benchmark for the research questions at hand and not in all respects as the most realistic description of the world. To understand the results some knowledge of GAMMA model seems necessary.

The GAMMA model attaches the following features to the Dutch economy. First, it considers the Dutch economy to be small relative to the outside world. In particular, domestic policies do not affect the interest rate, which is determined on world capital markets. Second, the goods produced at home are perfectly substitutable with those produced abroad. Third, the model is deterministic. Lifetime uncertainty is recognised, but perfect capital markets enable households to insure against this type of risk. The GAMMA model features perfect foresight: expectations coincide with realisations. Furthermore, agents are rational (i.e. they maximise their utility functions given the constraints they face) and have free access to perfect and complete capital markets.

The GAMMA model is used throughout this study. The baseline projection of section 3 is produced by GAMMA, but in a special way: labour participation and the consumption profile over the life cycle are determined outside the model and are used to calibrate the model. Using GAMMA for the baseline also ensures that the income, consumption and wealth of households are consistent. The behavioural underpinnings in GAMMA are especially relevant to the policy analyses presented in sections 4, 5 and 6 and the sensitivity analyses of sections 7, 8 and 9.

The GAMMA model distinguishes three important channels through which the government budget influences household behaviour: taxes on labour, the consumption tax and the capital tax on household savings. As labour supply depends on net wages, labour income taxation and consumption taxation reduce labour supply. Pensions in their current form increase labour supply. This effect, which is not frequently recognised, results from the implicit government subsidies in pensions: pensions are taxed at a lower rate than labour income and pension savings are exempted from the capital tax. As participation in pension funds is obligatory, this pension subsidy acts as a subsidy of labour supply. In addition, the capital tax affects savings. The real rate of return declines if this tax rate increases, which makes saving less attractive. Labour income tax and consumption tax also have an influence on savings. To understand this mechanism we have to go into the life-cycle model, which provides the basic theoretical framework for modelling household behaviour.

2.1 Household savings

According to the life-cycle theory, households rationally choose levels of current and future consumption and labour supply (leisure). Every household is represented by a finitely-lived adult. 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).

Labour supply and its complement, leisure, only depend on the marginal reward of labour; the wealth effect is assumed to be zero.[1] According to this life-cycle model households smooth the utility of consumption and leisure over their life cycle, which implies that in principle every year they consume goods and leisure in fixed proportions. This in turn suggests a positive correlation between consumption and labour supply. The time profile of consumption depends on the difference between the interest rate and the rate of time preference. Total (broad) expenditure is constrained by total wealth, which equals the sum of their financial wealth and the discounted value of their potential[2] future labour and pension income.

The GAMMA model accounts for the fact that over the life cycle, consumption profiles are hump-shaped. This can be explained by, among other factors, household composition. For instance, households with children consume more. Taking account of these kinds of age effects, the life-cycle model appears consistent with the data (Ree & Alessie, 2006).

2.2 Firm behaviour

Firms are assumed to operate in competitive markets where prices are given by world market prices. The cost of capital is given. As a corollary, the incidence of taxes is fully shifted to

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[1] Lumsdaine & Mitchell (1999) conclude in their survey article that the wealth effect on labour supply is small relative to the price effect.

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

labour. In a small open economy the wage rate has to accommodate changes in both the cost of capital and the tax rate. The model assumes that wage accommodation takes place without any delay. Production takes place with labour and capital according to a constant elasticity of substitution (CES) production technology. Capital deteriorates at a constant rate. The productivity of labour is assumed to depend on age. In particular, different age cohorts have different productivity levels. Apart from their productivity, the labour supplied by households of different ages is homogeneous. Labour productivity grows at a given rate in time (see Table 1). Capital adjusts without any delay.

Table 1. Parameters in the GAMMA model

Rate of labour-augmenting technological progress (%)	1.7
Substitution elasticity of labour and capital	0.5
Rate of time preference (%)	1.3
Intertemporal substitution elasticity	0.5
Rate of inflation (%)	2
Nominal rate of return on bonds (%)	3.5
Risk premium on shares (%)	3
Real discount factor	3
Substitution elasticity leisure and consumption	0.3

Source: Authors.

The fast adjustment of wages and capital is not realistic from a short-term point of view. The simple firm model is acceptable; however, for long-term analyses of this study, which focus on the consequences of budgetary policies over a long time horizon.

2.3 Pension funds

The private pension sector (second pillar pensions) has a large influence on the government budget, if only through its size. We have already discussed the fact that 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 a subsidy, which stimulates labour market participation. 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.

We assume 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.

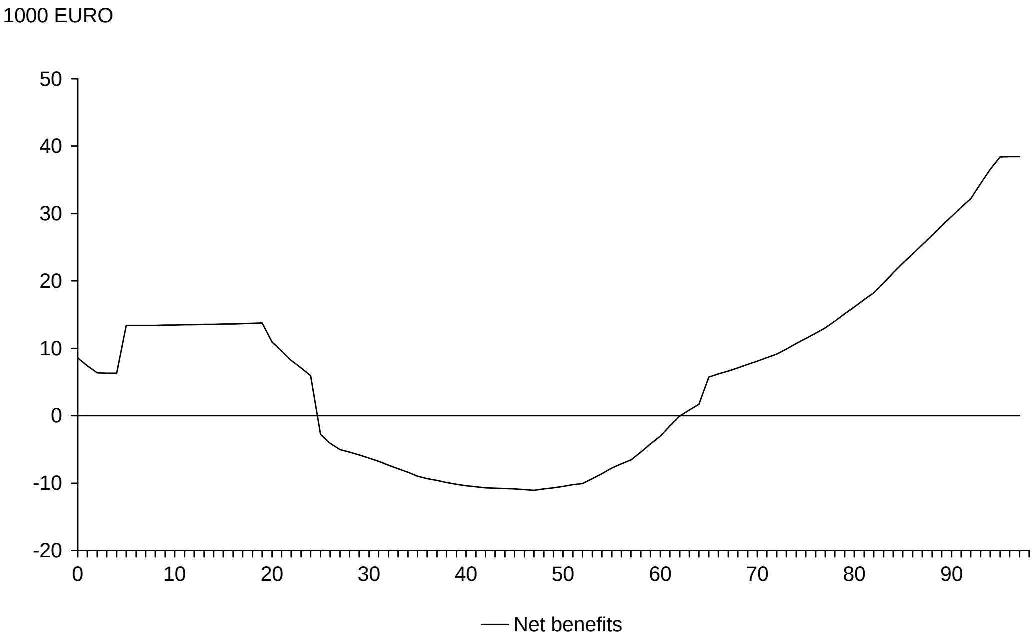
2.4 The public sector

This study emphasises the effects of policies for the intergenerational distribution of welfare. For this purpose we use the traditional framework of Generational Accounting (GA) for modelling the government budget.

Generational accounts calculate the net benefit that generations would receive from the government if current fiscal rules were continued. Therefore one extrapolates the age profile of net benefits, i.e. public expenditures (imputed to age groups) minus taxes, into the future. Figure

1 shows the age profile of the net benefit to the government budget for our base year 2006. Overall, the young and the elderly benefit from public finances, while the middle-aged are net contributors. In the original form of GA, as developed by Auerbach, Gokhale & Koflikoff (1991), this age profile is assumed to remain constant over time, apart from an indexation to productivity. The method of GA has been extended for the Netherlands (Ter Rele, 1998), Bovenberg & Ter Rele, 2000) by taking account of projected changes in these age profiles that result from a number of trends that are expected to have an impact on tax revenues and expenditure.

Figure 1. Age profile of net benefits from the government (2006)



The age profiles are combined with projections for the aggregates of each spending and tax component to determine the fiscal benefits and burdens for each age category.

The GA approach in this study assumes that all government expenditures are assigned to generations, even though a significant portion of expenditures are general and not age related. Those expenditures that are not age related (e.g. military expenditures or infrastructure) are distributed evenly over all individuals.

2.5 Concluding remarks

The dynamic, overlapping generation model GAMMA extends the generational accounting model GA by ensuring consistent underpinnings and by including important economic behavioural effects. These extensions make the model more convenient for fiscal policy and sensitivity analysis, because GAMMA takes into account feedback mechanisms. Moreover, the GAMMA model is more convenient for the analysis of intergenerational distribution effects. The GAMMA model gives separate distribution effects for the government and pension sectors in the form of net benefits and makes compensating variations available as an overall distribution indicator. Both the sensitivity and policy analyses with GAMMA become more realistic through modelling household and firm behaviour.

3. Government finances are unsustainable because of population ageing

How will public finances develop if social security grows in step with welfare and there are no corrective budgetary measures? A baseline projection has been calculated on that premise for the period 2006-2100 to answer this question.[3]

3.1 Assumptions for the baseline projection

Drafting a projection of the future development of public finances requires assumptions to be made about movements in various exogenous variables. These variables include the discount rate the government has to use to determine the present value of future primary budget surpluses and labour-augmenting technical progress. In the baseline projection the discount rate is equal to 3%.

Labour-augmenting technical progress in the baseline projection amounts to 1.7% per year. The actual increase of labour productivity in the market sector could differ slightly from this owing to changes in the age profile of the workforce. The underlying assumption is that employees' productivity increases during their years of service until they reach the age of 53. Any changes in the capital intensity of the production process can lead to temporary differences between movements in productivity in the market sector and labour-augmenting technical progress. Moreover, growth in labour productivity is affected by other factors as well. For example, the partial elimination of natural gas revenues will in the coming decades slightly depress growth in labour productivity at the macro level.

3.2 Development of public finances without budgetary measures

Table 2 shows the development of public finances in the baseline projection. The deficit of the economic and monetary union (EMU) is projected to reach 1.9% of GDP in 2006. In subsequent years, the budget deficit will initially decrease without budgetary measures. This decrease is in part owing to the fact that the EMU deficit in 2006 is distorted by cyclical factors. The cyclical element in the budget deficit in 2006 is estimated at 1.4% of GDP. This element gradually dwindles to zero in the baseline projection after 2006, as the economy recovers to a situation in 2010 that is neutral in cyclical terms. The EMU deficit also improves in the coming years in the baseline projection because interest payments – as a percentage of GDP – decline at the assumed nominal interest rate of 3.5%. The government will realise a reduction in interest payments upon refinancing the repaid government debt.

The improvement of the EMU deficit puts an end, in the baseline projection, to the increase in the government debt ratio seen in the past few years. The initial accelerated growth of nominal GDP also contributes to this, as the denominator of the government debt ratio increases more swiftly as a result. These favourable developments in terms of government debt and the debt ratio will not last very long in the absence of budgetary measures. Because of the influence of population ageing, the primary EMU balance slowly but surely deteriorates in the baseline projection after 2010. The reason is that the increase in public pensions (AOW) and health care expenditure in the next few decades will outstrip GDP growth; moreover, natural gas revenues will gradually decline. While revenues from tax and social security premiums also increase more strongly than GDP as a result of population ageing, this favourable development is not

[3] The baseline projection presented here deviates from the projection in Van Ewijk et al. (2006), for two reasons. First, the latter study uses the population forecast of the Statistics Netherlands, which deviates from the population forecast used here. Second, the initial situation is different because it is not calibrated. This leads to deviations in the outcomes for the base year.

sufficient to offset the comparatively strong increase of demographically-sensitive public expenditure and the gradual decline in natural gas revenues.

Table 2. Public finances without budgetary measures in the baseline projection

	2006	2020	2040	2060	2100
Expenditures					
Social security	12	13.3	15.8	15.7	15.9
– public pensions	4.7	6.4	9.1	9	9.2
– disability benefits	2	1.9	1.6	1.6	1.6
– unemployment benefits	1.2	1	1	1	1
– other benefits	4.1	4	4.1	4.1	4.1
Health care	8.8	10.1	13.3	14	14
Education	5	5	5.3	5.3	5.4
Other expenditure excluding interest payments	19.2	18.5	18.2	18.2	18.2
Interest payments	2.5	2.3	5.1	11.3	28.9
Total	47.9	49.7	58.3	65	82.9
Revenues					
Income tax and social security contribution	21.8	23.6	25.2	25.2	25.6
– of which on pension income	1.8	2.4	3.7	3.8	4
Indirect and other taxation	14.7	15.8	17.2	17.1	17.1
– of which on consumer expenditure by population aged 65 and older	1.9	2.8	4.3	4.2	4.2
Corporate income tax	2.6	2.5	2.4	2.3	2.3
Natural gas revenues	1.6	0.8	0.1	0	0
Other income	5.2	5.3	5.3	5.3	5.3
Total	46	48	50.1	49.9	50.2
EMU balance	-1.9	-1.7	-8.2	-15.1	-32.7
Primary EMU balance	0.6	0.6	-3	-3.8	-3.7
EMU debt [a]	54.7	49.1	110.7	239	605
Government net wealth [a]	60.2	51.7	-20.1	-150.7	-517.6

[a] Value at the end of the year
Source: Authors' simulation results.

3.3 Economic development in the baseline projection

Table 3 shows the development of a number of macroeconomic variables in the period 2006-2100. Notably, the share of national consumption in GDP increases strongly in this period. This share peaks around 2040 after which it decreases somewhat. The increase in the share of national consumption is produced by comparatively strong growth of three consumption categories. The first among these is private consumption. The rapid increase in pensions that accompanies population ageing results in an increase in the share of private consumption in GDP. That share peaks around 2040, when the private consumption rate will have risen by 8.1

percentage points compared with 2006. Second, the share of government consumption in GDP likewise increases in the projection. The increase occurs largely after 2020 as a result of the comparatively strong growth in demand for care. In 2040 the share of government consumption in GDP, especially as a result of rising expenditure on health care, is higher by 4.3 percentage points in the baseline projection than in 2006.[4] Third, corporate investment also outpaces GDP in the projection in the period 2006-40.

Table 3. Economic development without budgetary measures in the baseline projection

	2006	2020	2040	2060	2100
	% GDP				
GDP components					
Wage income	50.2	52.9	52.6	52.8	52.8
Net other income	23.3	19.1	18.3	18.2	18.2
Depreciation	14.8	15.3	15.2	15.1	15.1
Indirect taxes less subsidies	11.5	12.5	13.8	13.7	13.7
GDP	100	100	100	100	100
Components of national consumption					
Private consumption	46.2	50	54.3	54	54
Government consumption	26.3	27.2	30.6	31.2	31.3
Corporate investment	17.8	18	20.3	19.7	19.9
Government investment	2.6	2.6	2.6	2.6	2.6
National consumption	92.9	97.8	107.7	107.5	107.7
Balance of trade surplus	7.1	2.2	-7.7	-7.5	-7.7
Balance of primary revenues from abroad	0.4	5.9	4	-2.2	-19.7
Balance of secondary revenues from abroad	-1.6	-1.5	-1.5	-1.5	-1.5
Balance of current foreign transactions	5.9	6.6	-5.2	-11.2	-28.9
Net foreign assets [a, b]	0.0	43.6	14.7	-115	-477
GNP [c]	100.4	105.9	104	97.8	80.3

[a] Increase compared with 2006
[b] Value at the end of the year
[c] GDP plus balance of primary revenues from abroad
Source: Authors' simulation results.

The increase in corporate investments occurs mainly in the years 2020-40. That is because the growth rate of the labour supply available to businesses gradually becomes less negative after 2020, enabling businesses to realise a higher growth of production, which in turn requires increased rates of investment.

Overall, national consumption increases much more strongly than GDP. As a result the surplus on the balance of trade deteriorates. Nonetheless, the Netherlands will realise a very considerable surplus in international trade in the coming decade. On the basis of this unsustainable policy, the trade balance surplus is expected to be 7.1% of GDP in 2006.

[4] The share of employment in care in total employment will rise sharply in the coming decades. According to the CBP study by Huizinga & Smid (2004), that share is estimated to rise from almost 11% in 2001 to some 18% in 2040.

The international trade balance surplus gradually decreases in the projection and shifts into a deficit as from around 2025. This eventually results in an international trade balance deficit of 7.7% of GDP in 2040.

The question arises as to whether these trade deficits can be financed without problems. The answer to that question is that it will be very difficult without additional budgetary measures. The Netherlands will realise insufficient current account surpluses, leading to a very fast decline of the foreign assets position. The accompanying deterioration of the balance of primary revenues from abroad makes financing the trade deficit unlikely. The next section analyses possible budgetary policies to meet this deficit.

4. Which one-time tax increase restores sustainability?

This section presents two tax smoothing simulations: one that uses the consumption tax and one that uses the tax on labour income to make government finances sustainable. A comparison of the results shows that the two instruments differ in terms of economic efficiency and intergenerational distribution. A consumption tax is a more efficient instrument than a labour income tax, as it taxes not only workers, but also retirees and individuals of working age who live on social security. In both instances, however, current generations lose because of the increase in taxes required to restore fiscal sustainability.

The choice of a tax base has important implications for savings and output, the distribution of welfare across generations as well as the level of economic efficiency in the economy. It is outside the scope of this paper to elaborate on all these aspects. Here we only present the macroeconomic effects.

The immediate tax change needed to obtain fiscal sustainability results in tax rate increases of 7.7 and 11.8 percentage points respectively, for the consumption tax and the labour income tax. The reason the consumption tax can be lower is because it has a wider base – a consequence of two factors. First, the labour income tax excludes persons who live on social security. Second, only the consumption tax affects the consumption possibilities of retirees. Thus a consumption tax is a levy on existing financial wealth. Since the deadweight loss from taxation increases with tax rates, consumption tax smoothing is more efficient than that for labour income tax smoothing.

Overall, the two taxes have similar macroeconomic effects. Yet the change in GDP is negative in the labour income tax scenario and positive in the consumption tax scenario because here we measure GDP in market prices that include indirect taxes. In both cases there is a decline in the share of national consumption in GDP and in the absolute level of its main component, private consumption. In the short run, the private consumption decline is larger in the consumption tax scenario. In the long run, however, the decline is greater in the labour income tax scenario. These findings can be explained as follows. In the consumption tax scenario, labour supply is permanently higher, allowing for a higher level of consumption compared with the labour income tax scenario. All generations are affected by the consumption tax increase for the rest of their lives as shown by the decreases in private consumption in the range of 14.7 to 11.4%. In the labour income tax scenario however, the tax increase leaves presently retired generations unaffected. This explains the smaller decline of private consumption in the short and medium term. When the generations of people who are retired at the time the tax increase sets in gradually leave the economy, the consumption effect increases over time. Ultimately, the consumption decline is larger in the labour income tax scenario, not only because of lower labour supply, but also because of smaller savings in the short and medium run.

A change of the income or consumption tax rates have per point nearly the same influence on labour supply (same semi-elasticity): work becomes less attractive, because the spending possibilities decline. The larger income tax increase together with the same semi-elasticity brings about a proportionately larger fall in labour supply (see Table 4). The labour costs of firms will not change, because taxes cannot be shifted on to capital in a small open economy.

Table 4. Macroeconomic development in the cases of consumption or labour income tax smoothing

		2006	2020	2040	2060	2100
Consumption tax increase						
National consumption (% GDP)	(D)	-10.0	-3.6	-3.6	-3.3	-3.3
Balance of trade surplus (% GDP)	(D)	10.2	4.0	4.0	3.8	3.7
Balance of current foreign transactions (% GDP)	(D)	10.1	6.8	12.0	18.1	35.7
Net foreign assets [a] (% GDP)	(D)	10.6	71.5	182.5	314.2	681.6
Gross national product [b] (% GDP)	(D)	0.1	-2.8	-7.9	-14.2	-31.9
Labour supply (labour years)	(%)	-1.6	-1.4	-1.3	-1.4	-1.4
Production (GDP)	(%)	0.8	1.7	2.3	2.2	2.3
Private consumption	(%)	-14.7	-13.3	-11.8	-11.5	-11.4
Consumption tax rate	(D)	7.7	7.7	7.7	7.7	7.7
Labour income tax increase						
National consumption (% GDP)	(D)	-10.4	-3.8	-4.1	-4.2	-4.2
Balance of trade surplus (% GDP)	(D)	10.1	3.6	3.9	4.0	4.0
Balance of current foreign transactions (% GDP)	(D)	9.7	6.3	11.8	18.1	35.8
Net foreign assets [a] (% GDP)	(D)	7.8	57.3	160.0	289.2	656.5
Gross national product [b] (% GDP)	(D)	0.4	-2.7	-7.9	-14.2	-31.9
Labour supply (labour years)	(%)	-2.2	-1.9	-1.8	-1.9	-1.9
Production (GDP)	(%)	-3.3	-3.2	-3.3	-3.4	-3.4
Private consumption	(%)	-11.1	-12.1	-12.6	-13.1	-13.1
Labour income tax rate	(D)	11.8	11.8	11.8	11.8	11.8

[a] Value at the end of the year
[b] GDP plus balance of primary revenues from abroad

Note: D refers to an absolute difference from the baseline projection, while % points to a relative difference from the baseline projection.
Source: Authors' simulation results.

Table 5 presents information on the development of the government budget under the two tax smoothing scenarios. Primary public expenditure is partly linked to net production and partly linked to wages. Since there is very little change in the wage rate, non-interest expenditures under both scenarios decrease in absolute terms owing to the decrease in net production. Nevertheless, since GDP measured in market prices rises under the consumption tax, public expenditure relative to GDP falls. Under the labour income tax scenario, GDP initially declines faster than net production and so the change in primary public expenditure relative to GDP is positive. This explains the different signs of non-interest expenditures in the two simulations.

Table 5. Development of public sector variables in the cases of consumption or labour income tax smoothing

	2006	2020	2040	2060	2100
Consumption tax increase			% GDP		
EMU balance	1.3	5.4	11.0	17.3	35.0
Primary EMU balance	1.3	3.2	4.0	4.1	4.1
EMU debt [a]	-2.1	-48.0	-148.6	-277.7	-645.3
Government net wealth [a]	0.7	45.4	145.5	274.5	642.1
Expenditures	-0.6	-3.2	-8.4	-14.6	-32.3
– interest payments	0.0	-2.1	-6.9	-13.2	-30.9
– primary expenditures	-0.6	-1.1	-1.5	-1.4	-1.4
Revenues	0.7	2.2	2.6	2.7	2.7
Labour income tax increase					
EMU balance	3.3	7.3	12.4	18.5	36.3
Primary EMU balance	3.4	4.2	3.8	3.7	3.8
EMU debt [a]	-2.0	-69.2	-181.3	-310.7	-678.5
Government net wealth [a]	5.3	71.1	182.8	312.1	679.8
Expenditures	1.4	-1.9	-7.1	-13.2	-31.0
– interest payments	0.1	-3.1	-8.5	-14.8	-32.5
– primary expenditures	1.3	1.2	1.4	1.6	1.5
Revenues	4.7	5.4	5.3	5.3	5.3

[a] Value at the end of the year

Source: Authors' simulation results.

The development of government income in either case can be explained in a similar way to the change in primary expenditure. In the long run, government revenues consume a larger share of GDP under the labour income tax than under the consumption tax. Again, this says as much about the impact of the tax change on GDP as it does about the government's accounts. The implication is that the labour income tax has a more adverse effect on the economy's output. As a result, we witness a relative increase in the public sector's share of the economy. The overall suggestion is that the large tax base makes the consumption tax a more efficient instrument than a labour income tax.

5. Consequences of a policy postponement

This section explores whether present generations can be protected by postponing the policies of tax smoothing for some time. Here, we account for possible anticipation effects. Given that our model features perfect foresight, it would be strange to assume that policy-makers can fool households by letting them believe that policies will remain unchanged and then after some time renege on these promises. More in line with the idea of perfect foresight is that it is public knowledge how long policy-makers will wait before taking policy actions. Rational behaviour then makes households act on this information.

Without economic behaviour, postponement would increase the change in the tax rate that is needed to close the sustainability gap. Because of economic behaviour, however, this direct effect may be mitigated somewhat. The adverse instantaneous reaction of the tax base to tax rate increases strengthens the direct effect, but the anticipation of future tax rates causes a rise in private savings, thereby increasing the future tax base.

A later starting year of tax smoothing results in a larger debt in percentages of GDP at that date. Larger debt brings about more debt service, which can only be raised through a decline of the primary deficit. Since the primary deficit has to decline through tax increases, this implies the later the sustainability policy starts, the larger the necessary tax rate. Table 6 illustrates this for each type of tax.

Table 6. Tax smoothing according to the starting year

		2006	**2026**	**2046**
Consumption tax rate	D	7.7	9.4	11.7
Labour income tax rate	D	11.8	14.9	18.9

Note: D refers to an absolute difference from the baseline projection expressed in percentage points
Source: Authors' simulation results.

As noted earlier, our calculations presume that households know when the tax smoothing policy reform will set in. Table 7 reveals that this anticipating behaviour is favourable for the government budget. In order to smooth consumption over their life cycles, households diminish their consumption in the period before the consumption tax increases (see Figure 2), but do not change their labour supply in this period. The boost in private saving increases financial wealth in the year that the policy reform takes place. Thus the consumption tax base increases because households anticipate the future rise in tax rates. This explains why the tax rate increase can be slightly smaller if the policy adjustments are anticipated.

Table 7. Consumption tax increase with and without anticipation

		2006	**2026**	**2046**
With anticipation	D	7.7	9.4	11.7
Without anticipation	D	7.7	9.7	12.3

Note: D refers to an absolute difference from the baseline projection expressed in percentage points
Source: Authors' simulation results.

Figure 2 presents the development of private consumption according to the starting year of the tax increase. For comparison, the effect of tax increases starting in 2006, 2026 and 2046 are shown for scenarios in which the policy changes are either pre-announced by the government in 2006 or are unexpected up until the year of implementation.

In the two unexpected scenarios, there are sudden and extreme reductions in consumption in the years when the policy changes takes place. Since the required tax increase in 2046 is higher than that in 2026, the decrease in consumption also greater. When the future policy changes are known to individuals, the change in consumption behaviour is more gradual, as households accumulate more savings in anticipation of higher taxes in the future. The figure reveals that, despite the fact that pre-announcing is favourable relative to an unexpected policy measure, it does not fully compensate for the damage of postponing the policy measure.

Figure 2. Percentage change of consumption according to the starting year of the tax increase, consumption taxation

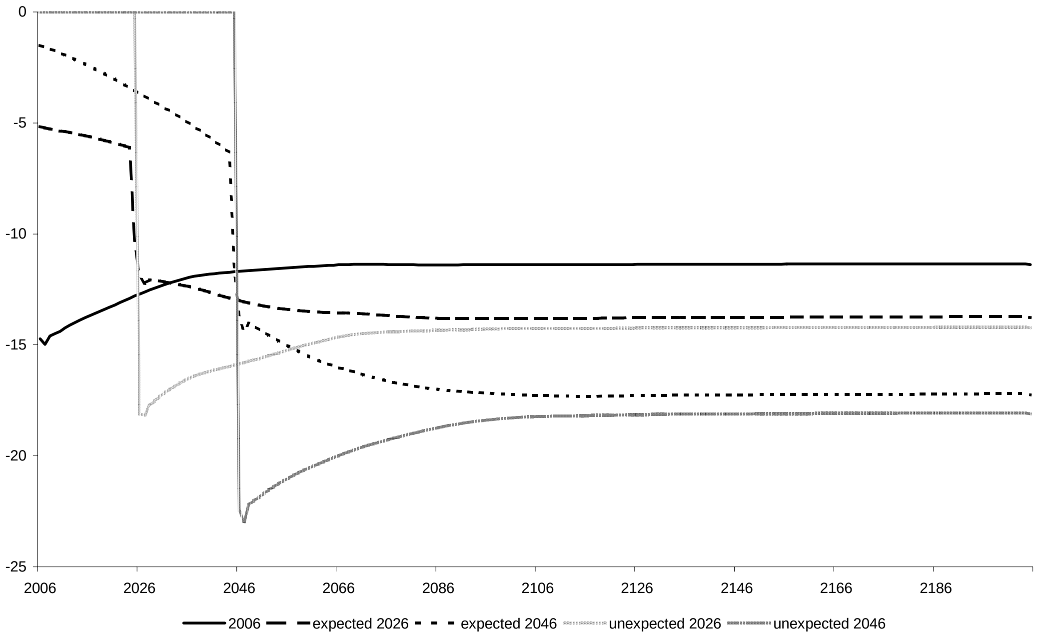


Figure 3 presents the labour supply development under various tax change scenarios and conveys a similar message as Figure 2. Moreover, it illustrates a characteristic of our model. Total wealth has no influence on labour supply since people do not start working harder when their wealth declines.[5] Thus there is very little difference in labour supply effects between the expected and unexpected policy changes. In the case of an immediate tax increase (in 2006), the effect on labour supply is small and remains at a relatively constant level compared with the base case scenario.

Figure 4 presents the absolute change of the primary deficit as a percentage of GDP according to the starting year of the consumption tax increase. The figure illustrates an upwards spike in the primary deficit in the expected tax-increase scenarios immediately before the policy measure becomes effective. This increase is linked to the decrease in labour supply. The year before the policy measure, investments decline sharply to make the capital stock consistent with the lower labour supply. This leads to a one-time decline in the indirect tax receipts on investments. As a consequence, the required decrease in the primary deficit in the first year after the tax change is greater in the anticipated scenario than in the unanticipated scenario. In this case, then, an unexpected policy change leads to a less volatile economic effect. The decline of the primary deficit will be larger as the policy measure is larger.

[5] The marginal utility of consumption is constant in the instantaneous utility function.

Figure 3. Percentage change of labour supply according to the starting year of the tax increase, consumption taxation

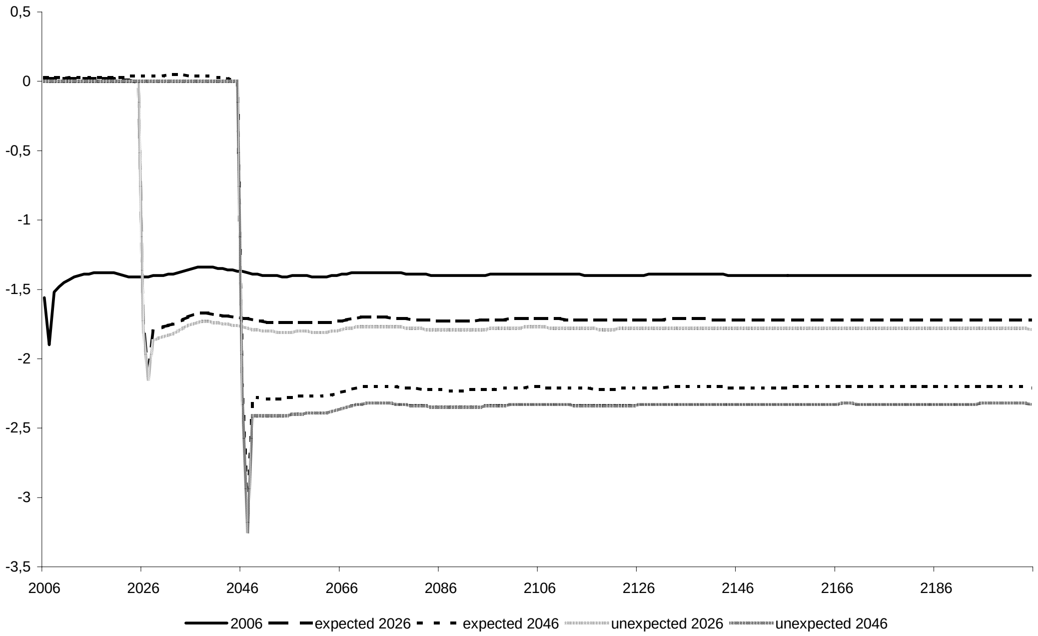


Figure 4. Absolute change in the primary deficit (% GDP), according to the starting year of the tax increase, consumption taxation

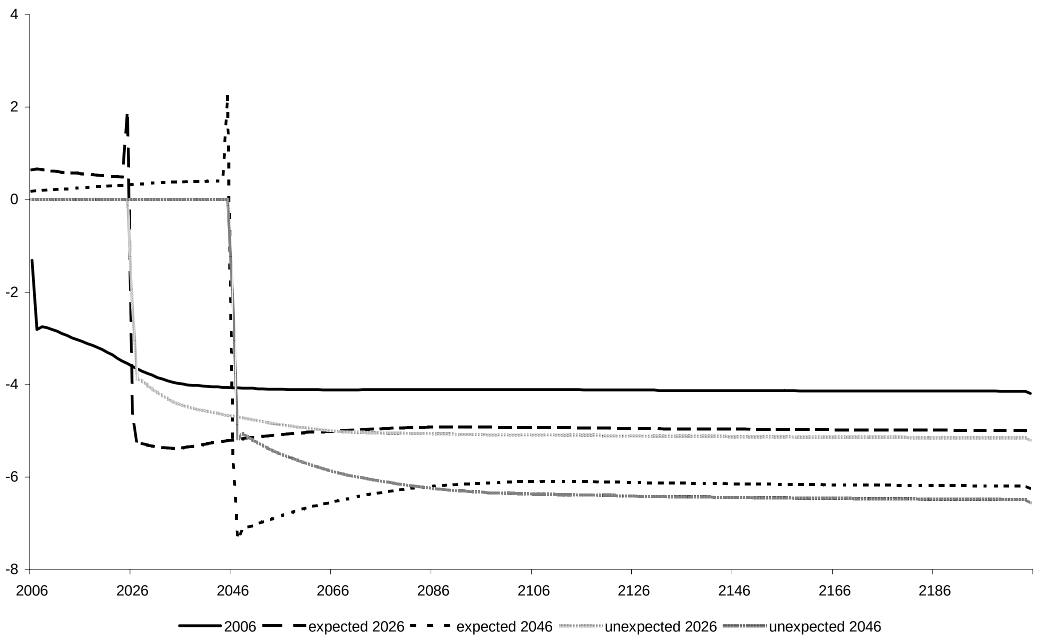
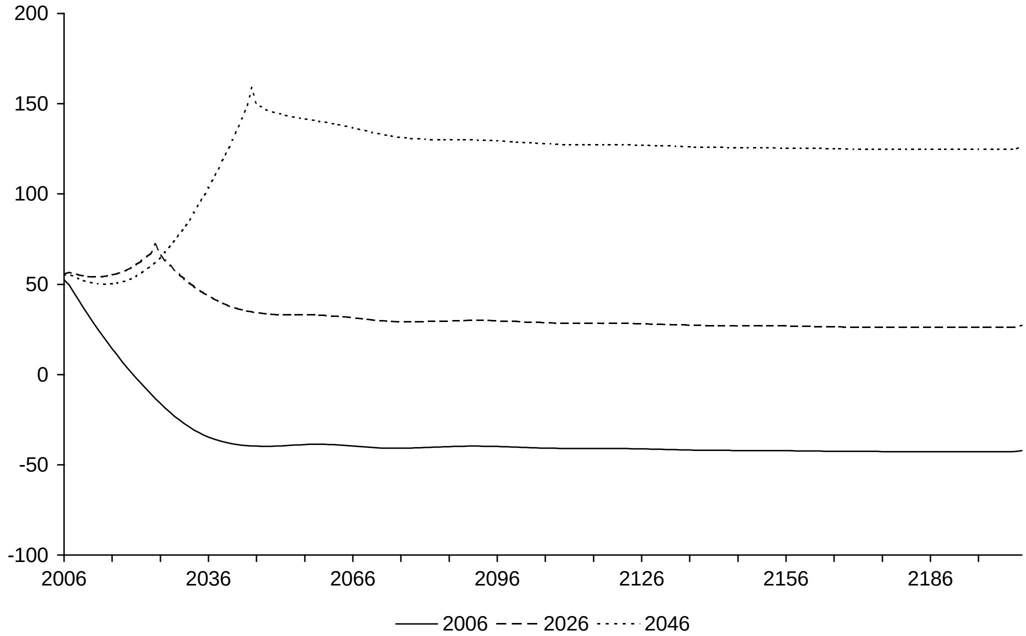


Figure 5 illustrates the development of the absolute level of the government debt. It can be seen that postponing the necessary measure increases the long-run public debt-to-GDP ratio.

Figure 5. Absolute level of government debt (% GDP), according to the starting year of the tax increase, consumption taxation

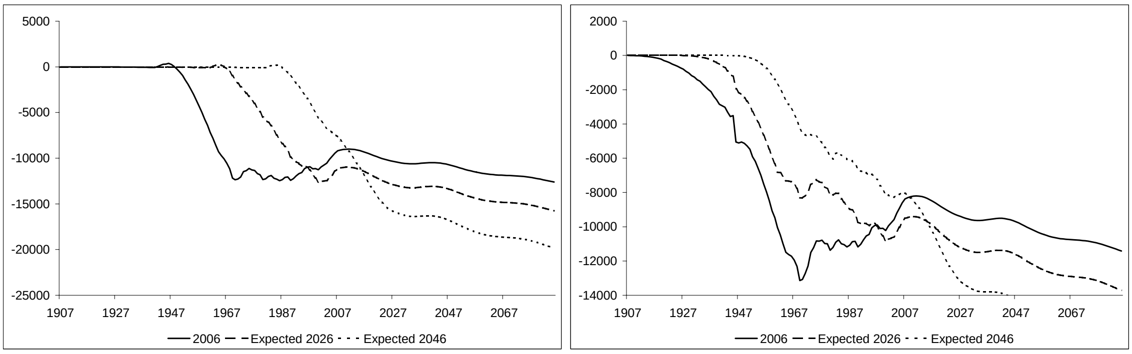


In all cases the debt-to-GDP ratio is stabilised in the long run. Yet only the immediate consumption tax increase reduces the debt to around zero. Fiscal sustainability requires that at any given date, the government's liabilities must be less than or equal to the present value of its future revenues. In each of the delayed tax-increase scenarios, taxes are higher than in the immediate tax-increase scenario and therefore so are the discounted future revenues summed indefinitely into the future. Thus the level of the government's debt relative to GDP can be higher. The longer the delay in implementation, the higher is the required tax-rate increase, the level of government debt and the associated debt service requirements.

Figure 6 presents the net benefits from the government per cohort, which we interpret as a measure of intergenerational redistribution between the private and the public sector. The figure shows that the implementation of tax smoothing policies reduces the net benefits that households reap from the public sector. The reason is that they face a tax increase that is not matched with an increase of government transfers. For older generations, the change in net benefits decreases with age. This reflects the fact that older generations are hurt less by higher taxes because their remaining working (living) periods are smaller.

The figure also shows the effect of postponing the implementation of tax smoothing policies until 2026 and 2046. Most of the present generations experience smaller net benefit losses. Likewise, future generations witness an increase of their net contributions to the public sector. Globally speaking, the effects of postponement on the net benefit changes are greatest for the generations of working age.

Figure 6. Net benefits from the government sector per cohort by year of birth; left panel for consumption tax, right panel for labour income tax.



6. Pros and cons of a gradual policy

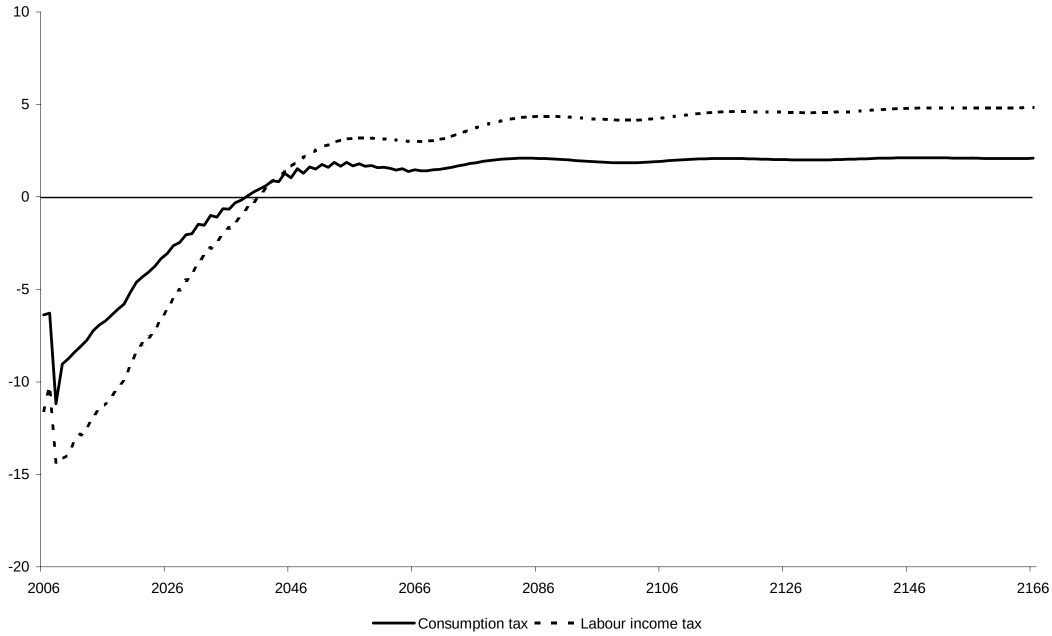
Postponement of policy reforms obviously benefits present generations. Unlike our base case scenario of an immediate increase of tax rates, the postponement scenarios feature discontinuous tax rate profiles. One way to avoid these discontinuities is to pursue a more gradual policy of balancing the budget in each year, i.e. keeping the public debt-to-GDP ratio at its initial level. Note that these balanced budget policies, like tax smoothing policies, meet the requirement of fiscal sustainability.[6] Indeed, policies are fiscally sustainable if they stabilise the long-run public debt-to-GDP ratio.

Here we present balanced budget simulations relative to tax smoothing simulations. We assume the government wants to stabilise the public debt-to-GDP ratio at its initial level; that is, the level in 2006. It is then possible to postpone the necessary tax increase, which means a sharp decline relative to the tax smoothing scenario (Figure 7). The tax rate development will then follow the dependency ratio, which is the main determinant of the primary deficit development. After about 40 years, tax rates become slightly higher than those based on tax smoothing. The fast increase of the tax rate in the first few decades slows down in line with the development of the dependency ratio. Following 60 years, both balanced-budget tax rates remain at roughly constant (higher) levels relative to the tax smoothing rates. The difference is greatest in the case of the balanced budget with the labour income tax, again owing to its smaller tax base.

Since taxes are initially relatively lower, consumption and labour supply are greater than in the tax smoothing scenario in the beginning of the simulation period. In the case of labour income tax, consumption becomes permanently lower after 50 years, while in the consumption tax case, consumption becomes lower after about 35 years. The long-term effects on labour supply of the balanced budget policies are less severe, although there is still a decrease relative to the tax smoothing case after about 35 years. In the long run, the relative differences stabilise and the balanced budget policy using the labour income tax has the most adverse effect on consumption and labour supply because of the higher tax burden.

[6] For a formal proof, see Appendix A.

Figure 7. Absolute change of the tax rate to obtain a balanced budget, relative to a tax smoothing path



Figures 8 and 9 show how this tax pattern is reflected in the private consumption and labour supply patterns.

Figure 8. Percentage change of private consumption, balanced budgets relative to tax smoothing

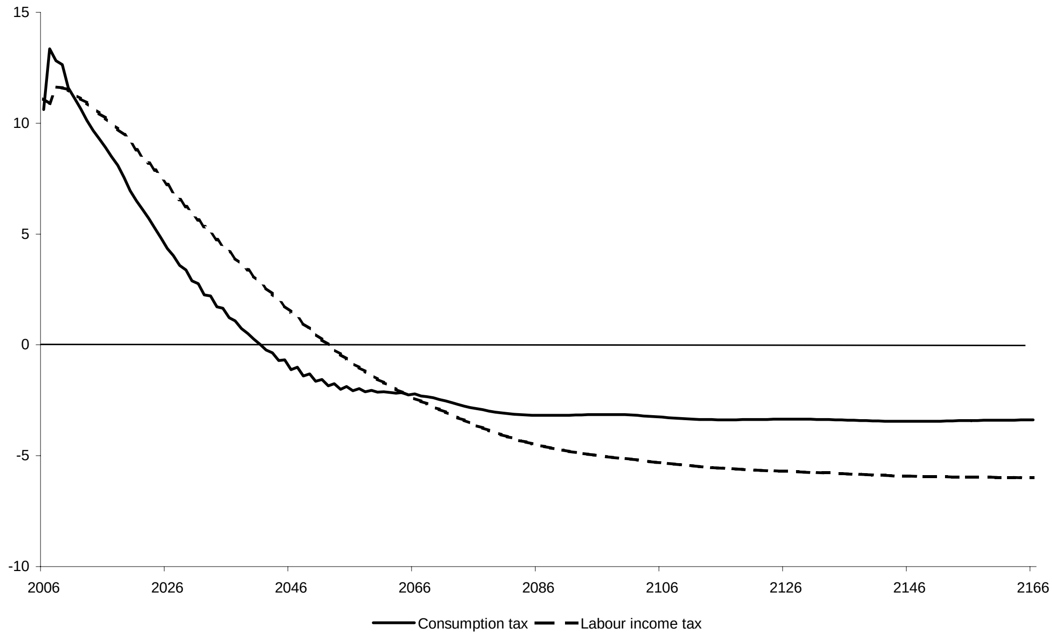


Figure 9. Percentage change of labour supply, balanced budgets relative to tax smoothing

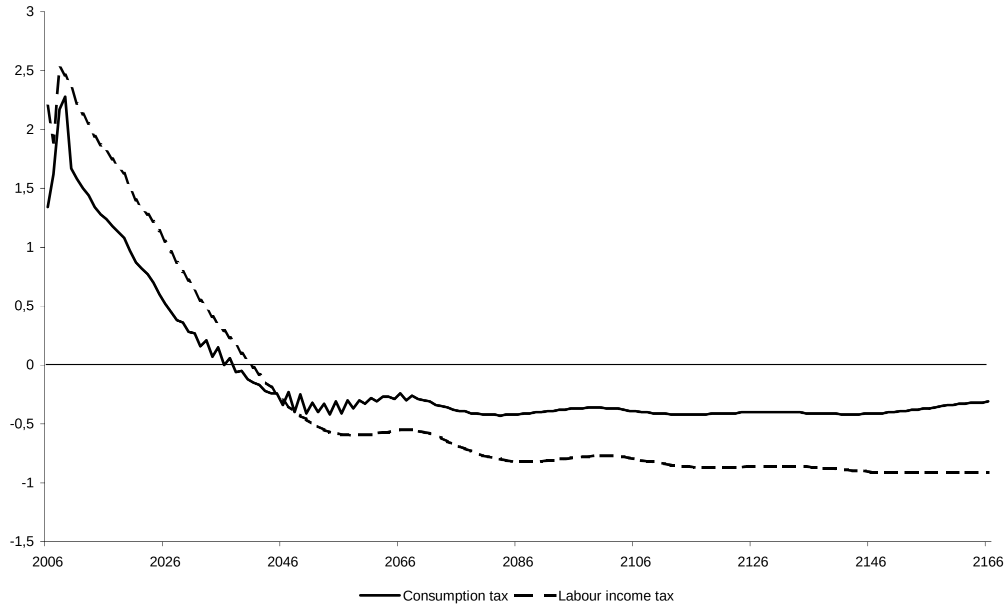
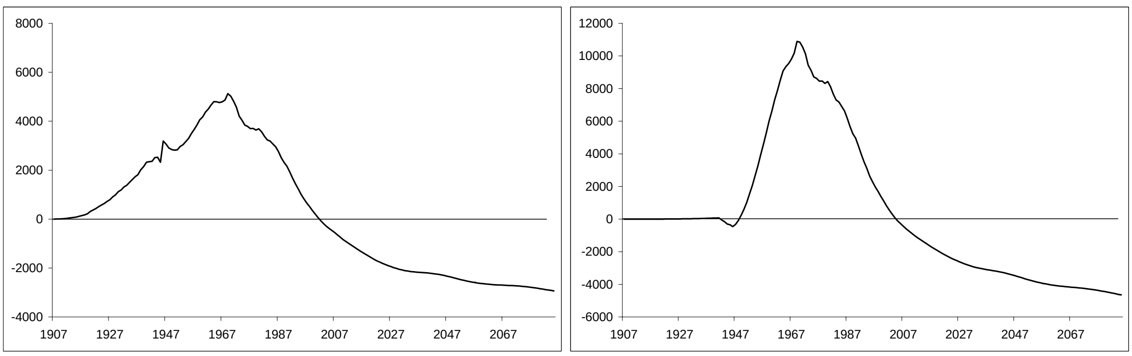


Figure 10 illustrates the net public benefits by cohort from a balanced budget policy relative to the tax smoothing case. It can be seen that net benefits develop more positively for living generations, particularly those of working age, whereas future generations suffer a deterioration of their net benefits. The explanation is that under balanced budget policies, today's generations are not required to share the burden of future fiscal imbalances. Balanced budget policies using the labour income tax are the most favourable to present generations (except retirees who are indifferent to tax smoothing or balanced budgets) and the most damaging to future generations.

Figure 10. Net benefits from the government sector per cohort by date of birth, balanced budgets relative to tax smoothing; left panel consumption tax, right panel income tax



It is clear from this analysis why balanced budget policies are attractive from a political point of view. By taking a gradual approach, present generations are exempted from sharing the burden of future fiscal imbalances. Additionally, since today's working-age cohorts are net contributors to government finances (Figure 1), it can be argued that considerations of intergenerational equity make a gradual approach the preferred policy option. On the other hand, there are strong arguments that tax smoothing policies are optimal from the point of view of economic efficiency (see Barro, 1979, Kingston, 1991 and Scott, 1999).

7. The influence of demographic shocks on the sustainability problem

In order to illustrate the effects of demographic variability on the macroeconomic and fiscal outcomes of the model, here we simulate three demographic shocks. This will demonstrate both the workings of the model and highlight the way in which demographic changes influence debt policy decisions. Respectively, we apply permanent shocks in 2006 to the fertility rate, the net immigration rate and the mortality rate. All three of the shocks increase the projected population in 2026 by 3.45%[7] relative to the baseline but have differing effects on dependency ratios. As a result, economic outcomes are influenced in varying ways. In both the baseline and shock scenarios, the long run debt-to-GDP ratio is stabilised by a one-time rise in the labour income tax rate.

7.1 Effects of a positive fertility shock

Table 8 shows the results of a permanent 16% increase in the number of births per each woman of childbearing age relative to the baseline population scenario. It can be seen that the shock has a significant effect on the size of the total population in the long run, setting it on a course that makes it over 27% higher than in the base path by 2100.

Table 8. Effects of a 16% increase in fertility relative to the baseline scenario with tax smoothing

	2006	2020	2040	2060	2100
Demography					
Total population (% change)	0.18	2.49	6.49	12.72	27.20
Old-age dependency ratio (D)	0.00	0.00	-4.20	-10.24	-11.07
Total dependency ratio (D)	0.00	4.25	3.70	2.01	0.95
Government finance					
Government expenditure (D as a % of GDP)	0.08	0.61	0.40	-0.91	-0.99
Government revenue (D as a % of GDP)	0.27	0.33	0.15	-0.47	-0.49
Primary deficit (D as a % of GDP)	-0.19	0.28	0.25	-0.44	-0.51
Government debt (D as a % of GDP)	-0.10	-0.62	13.19	21.40	12.92
Economic development					
GDP (% change)	-0.22	-0.18	3.31	11.28	25.41
Labour supply (% change)	-0.17	-0.14	4.61	12.59	27.07
Capital stock (% change)	-0.17	-0.15	3.74	12.17	26.20
Private consumption (D as a % of GDP)	-0.15	-0.17	-0.71	-1.76	-1.59
Balance of trade surplus (D as a % of GDP)	0.66	-0.37	-1.14	0.10	0.69
Labour income tax rate (D)			0.67		

Note: D refers to an absolute difference from the baseline projection, while % points to a relative difference from the baseline projection.

Source: Authors' simulation results.

[7] The figure of 3.45% is approximately one standard deviation at 2026 in the stochastic population distributions produced by the Programme for Error Propagation (PEP).

The dependency ratios are also influenced but in opposite ways. The old-age dependency ratio is unaffected until 2040, when the new larger cohorts begin to reach working age. From that point on, the number of elderly persons to workers is more than 10 percentage points lower. This beneficial result of the shock is balanced by a temporary increase in the total dependency ratio, owing to permanently larger school-age cohorts. As a result, the sustainability of government finances requires a small increase in the labour income tax rate of 0.67%.

Macroeconomic variables in the simulation are influenced by both the demographic developments and the required tax increase. Initially, the increase in fertility has no direct effect on labour supply or GDP: only the tax increase slows output slightly. Over time, though, as the workforce grows, GDP grows in step with the population change relative to the base.

7.2 Effects of a positive immigration shock

Table 9 shows the effects of a 17.5% increase in number of new immigrants entering the Netherlands each year. In this scenario, by 2100 the population is projected to be over 15% larger than in the base run. Nonetheless, the effects on the dependency ratios are rather modest, lowering them slightly over the long term. The sustainable labour income tax rate can only be lowered a mere 0.72 percentage points.

Table 9. Effects of a 17.5% increase in immigration relative to the baseline scenario with tax smoothing

	2006	**2020**	**2040**	**2060**	**2100**
Demography					
Total population (% change)	0.12	2.38	6.02	9.90	15.56
Old-age dependency ratio (D)	0.00	-2.21	-5.24	-3.70	-2.22
Total dependency ratio (D)	0.00	-0.57	-2.50	-1.52	-1.07
Government finance					
Government expenditure (D as a % of GDP)	-0.10	-0.44	-1.12	-1.03	-0.64
Government revenue (D as a % of GDP)	-0.26	-0.40	-0.80	-0.66	-0.53
Primary deficit (D as a % of GDP)	0.15	-0.05	-0.32	-0.38	-0.11
Government debt (D as a % of GDP)	0.04	1.63	2.50	-2.02	-7.88
Economic development					
GDP (% change)	0.27	2.99	7.47	11.08	16.46
Labour supply (% change)	0.16	3.10	7.62	11.09	16.41
Capital stock (% change)	0.31	3.24	7.80	11.32	16.56
Private consumption (D as a % of GDP)	0.13	-0.09	-0.47	-0.20	0.04
Balance of trade surplus (D as a % of GDP)	-1.11	-0.55	0.38	0.20	0.00
Labour income tax rate (D)			-0.72		

Note: D refers to an absolute difference from the baseline projection, while % points to a relative difference from the baseline projection.

Source: Authors' simulation results.

The slight tax decrease combined with the increase in the labour force from immigration results in a positive development of GDP, increasing it to a level over 16% higher than the base run by 2100.

7.3 Effects of a negative mortality shock

Table 10 shows the results of a permanent 32.5% decrease in the mortality rate per age cohort in 2006. Unlike in the previous two shock simulations, there is no exponential growth in the total population, but there is a large increase in the old-age dependency ratio. There is a relative increase in the number of elderly persons in the population, while the number of potential workers is almost unchanged. As a result, there is a significant impact on government finances. The required sustainable labour income tax rate must be 8.3 percentage points higher than in the base run as a result of increased age-dependent public expenditure.

Table 10. Effects of a 32.5% decrease in the mortality rate relative to the baseline scenario with tax smoothing

	2006	2020	2040	2060	2100
Demography					
Total population (% change)	0.28	3.04	4.57	4.29	4.15
Old-age dependency ratio (D)	0.00	11.08	14.26	13.98	12.54
Total dependency ratio (D)	0.00	3.54	6.56	6.18	5.70
Government finance					
Government expenditure (D as a % of GDP)	0.56	2.50	4.85	5.30	4.88
Government revenue (D as a % of GDP)	3.27	4.24	4.10	4.22	4.31
Primary deficit (D as a % of GDP)	-2.71	-1.75	0.75	1.08	0.58
Government debt (D as a % of GDP)	-1.90	-41.10	-61.93	-54.43	-52.76
Economic development					
GDP (% change)	-2.32	-1.58	-2.02	-2.21	-2.12
Labour supply (% change)	-2.15	-1.25	-1.27	-1.31	-1.21
Capital stock (% change)	-2.22	-1.22	-1.25	-1.32	-1.21
Private consumption (D as a % of GDP)	0.05	-1.45	-2.93	-3.42	-3.48
Balance of trade surplus (D as a % of GDP)	7.38	-0.06	-0.22	-0.21	0.12
Labour income tax rate (D)			8.30		

Note: D refers to an absolute difference from the baseline projection, while % points to a relative difference from the baseline projection.

Source: Authors' simulation results.

Likewise, there is very little beneficial effect on output resulting from the increase in the population. The potential labour force is relatively unaffected, while the higher labour income tax rate discourages workers and lowers labour supply. The tax distortion produces a decrease in GDP of over 2% by 2100 relative to the baseline.

It can therefore be concluded that the consequences of demographic variability on factors and public finances depend not just on the scale of the variability but also the source of the variability. Unexpected increases (or decreases) in the population may have either positive or negative budgetary effects depending on how they influence the makeup of the population as represented by the dependency ratio.

8. Stochastic demographics

In this section we formalise 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 the Programme for Error Propagation (PEP) developed by Alho & Spencer.[8] The programme applies stochastic processes to the forecasted development of fertility, immigration and mortality rates. By generating 250 separate stochastic population paths and using them to simulate 250 GAMMA simulations, we arrive at a distribution of possible macroeconomic and fiscal outcomes that can be given a probabilistic interpretation. It should be noted that each of these stochastic GAMMA simulations is itself deterministic: economic agents are farsighted and face no uncertainty. Approaching the question of demographic uncertainty in this manner offers a great advantage over using deterministic forecasts that simulate the results of, for example, worst-case and best-case scenarios in addition to point estimates. That approach provides no information on the likelihood of each outcome.[9]

8.1 Probabilistic distribution of demographic developments in the Netherlands

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 11 shows the stochastic distribution of the total dependency ratio as forecast until 2050.

The base run line corresponds to the population point forecast that was used in the baseline scenario in previous sections. 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 in the base run, the 50th percentile and mean lines are all very close to one another in the figure.

It can be seen that the dependency ratio is almost certain to rise in the coming decades, but it is uncertain by how much. By around 2040 the ratio will level off and possibly decline thereafter. It will remain at a relatively consistent level, however, somewhere between 0.85 and 0.95 with a 60% level of probability.

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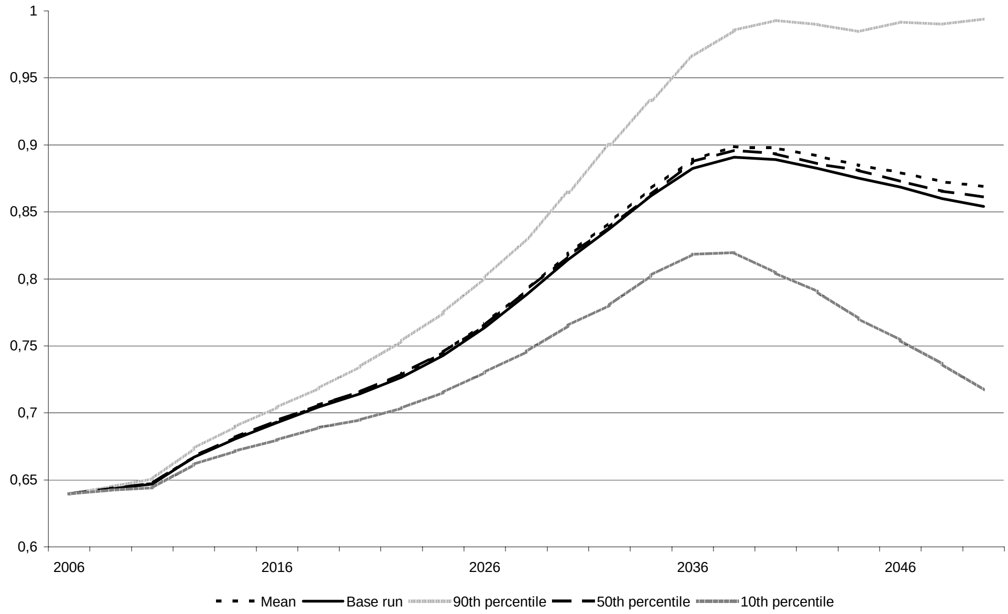
[8] For a technical description of the PEP programme see Alho & Spencer (1997) or the PEP user manual (retrieved from http://joyx.joensuu.fi/~ek/pep/userpep.htm).

[9] For a more detailed discussion of the pros and cons of using stochastic simulations, see Bonenkamp et al. (2006).

Figure 11. Stochastic distribution of the total dependency ratio

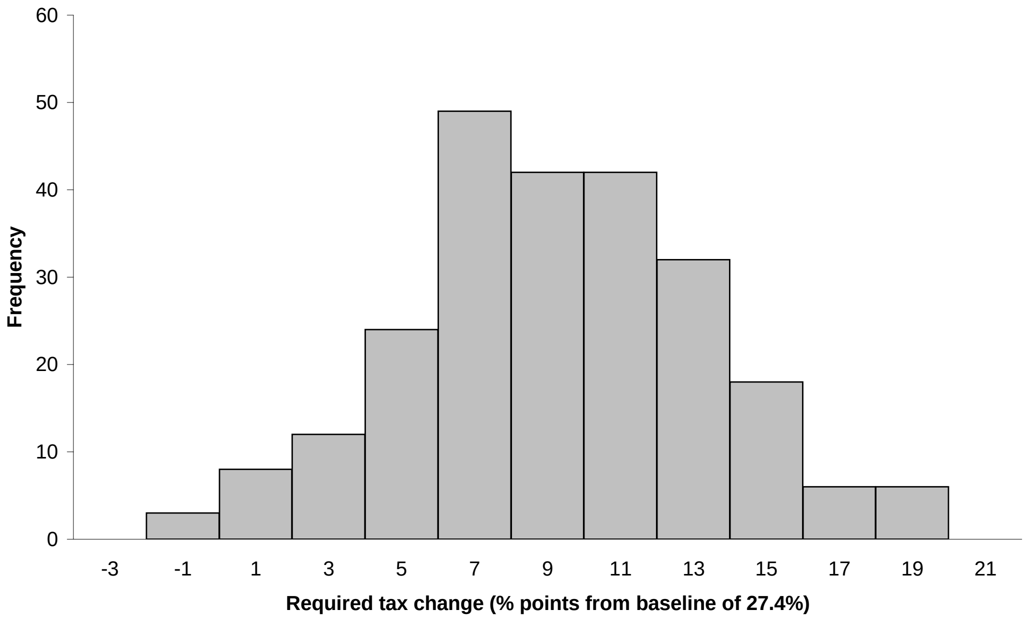


8.2 Probabilistic distribution of the required consumption tax increase

This interpretation of forecasted demographic developments naturally leads to a probabilistic interpretation of the sustainability gap as characterised by the consumption tax increases that are required to sustain the budget in each scenario.

Figure 12 presents the required increases as a frequency distribution. It should be noted that the figure omits a number of outlying simulated tax rates that radically diverge from the central projection. The average necessary consumption tax increase is 8.5 percentage points from the baseline level of 27.4%.

Figure 12. Stochastic distribution of the consumption tax increases required to make the government budget sustainable

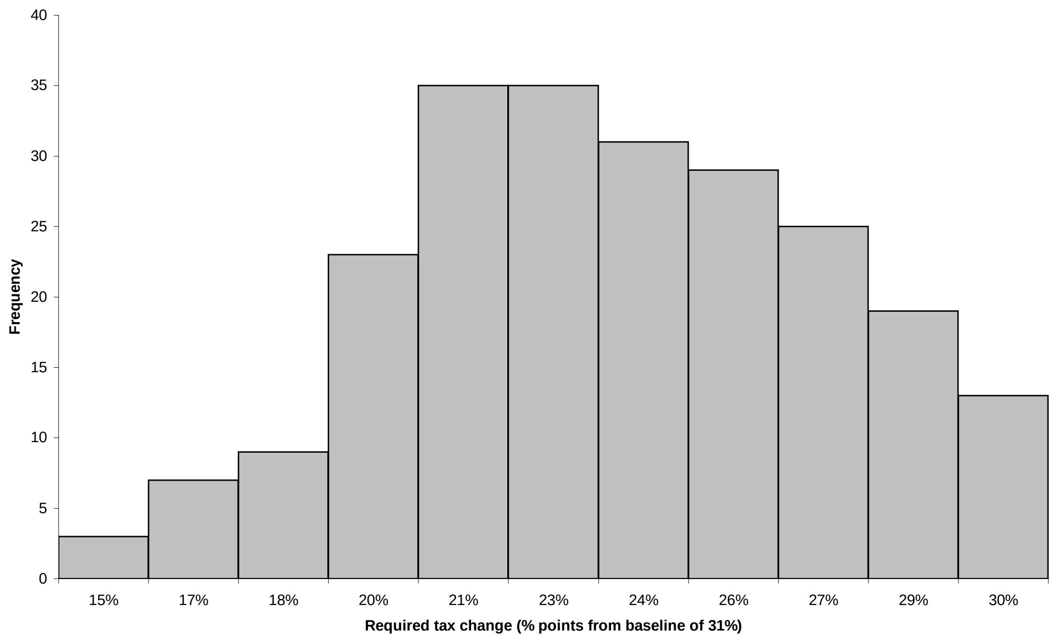


Even if the mean required tax rate increase of 8.5% is immediately adopted, the government budget will only be sustained with 50% probability.[10] It is obviously questionable whether this is adequate. In the next section we apply welfare analysis to demonstrate that a policy of budgetary pre-funding can be optimal when there is demographic uncertainty.

9. Demographic uncertainty and optimal debt policy

In this section, to keep the simulation analysis tractable, a number of simplifications have been made to the GAMMA model. Among these are: setting rates of inflation and productivity growth to zero, eliminating the private pension system, eliminating taxes on profits and assets and setting all interest/discount rates equal in addition to a number of technical simplifications. We also return to using the labour income tax as the instrument used to sustain government finances. Figure 13 shows the frequency distribution of the stochastic required labour income tax increases using this simplified version of the model. The mean of the required changes is 22.7% from the baseline of 31.1%. It should be noted that these estimates are not considered to be realistic and are presented only to establish a baseline.

Figure 13. Stochastic distribution of the labour income tax changes required to make the government budget sustainable with the simplified version of the model



9.1 Optimal policy under demographic certainty

It was remarked in an earlier section that the literature on optimal taxation has the result that tax smoothing policies minimise the distortionary effects of taxation and maximise social welfare. Here we use the GAMMA model to show that this result does not necessarily hold when the effects of an ageing population are taken into account. To measure the impact on overall utility of a policy change we construct a social welfare function that aggregates the discounted equivalent variations of all living and future cohorts. The equivalent variation is the necessary

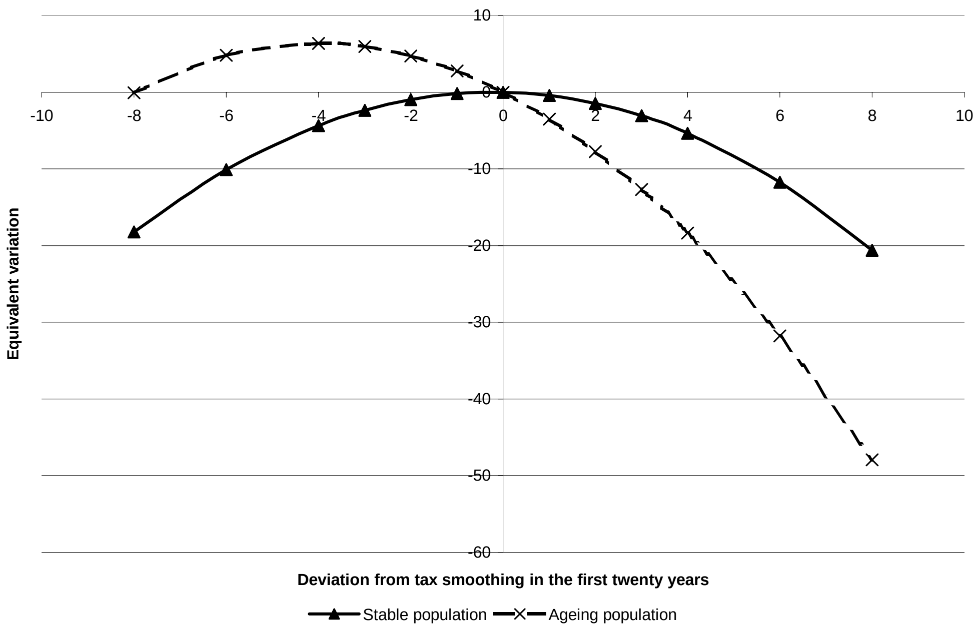
[10] Compare with the increase of 7.7 percentage points required in the central path.

lump sum monetary transfer that would achieve the same impact on utility as the policy change. So a positive aggregated equivalent variation implies a welfare improvement from the benchmark case and vice versa.

Here we use as a benchmark case a tax smoothing policy where the government budget is made sustainable by a one-time increase in 2006 of the labour income tax rate. We compare this to alternative scenarios where we either increase or decrease the tax rate by a specified number of percentage points over the simulation period 2006 to 2026. Then over the remainder of the simulation period (until 2206), the tax rate is adjusted to make the government budget sustainable. If the initial tax rate is lower (higher) relative to the tax smoothing rate, the future tax rate will be higher (lower). Aggregating the equivalent variations will cancel out any redistributional effects of the policies and leave us with a pure measure of the distortionary effect of the tax rate differences.

Figure 14 shows the aggregated equivalent variations over a grid of thirteen policy points from two different population runs. The first run keeps the 2006 total population and demographic composition constant over the duration of the simulation. It can be seen that the curve connecting the aggregated equivalent variations reaches a maximum through the central axis, implying that tax smoothing is optimal, in accordance with theory. The second population run is based on the central projection of the population of the Netherlands produced by the PEP programme, which features an ageing population profile. The peak of the curve is situated in the neighbourhood of -4 percentage points, indicating that the optimal policy sets the tax rate 4 percentage points below the tax smoothing rate until 2026 and then increases it thereafter to a tax smoothing rate that sustains the budget.

Figure 14. Aggregate equivalent variations of alternative tax policies under the condition of population certainty [a]



[a] Relative to tax smoothing at a 22.3% increase

The explanation for this result is as follows. Labour supply varies by age. According to the data with which the GAMMA model is calibrated, as people approach retirement age their labour supply becomes more elastic. Table 11 presents the percentage change in labour supply resulting from a 1 percentage point increase in the labour income tax rate for three age cohorts.

Table 11. Labour supply elasticities with respect to the tax rate by age cohort

20 year-olds	-0.39
40 year-olds	-0.06
60 year-olds	-0.95

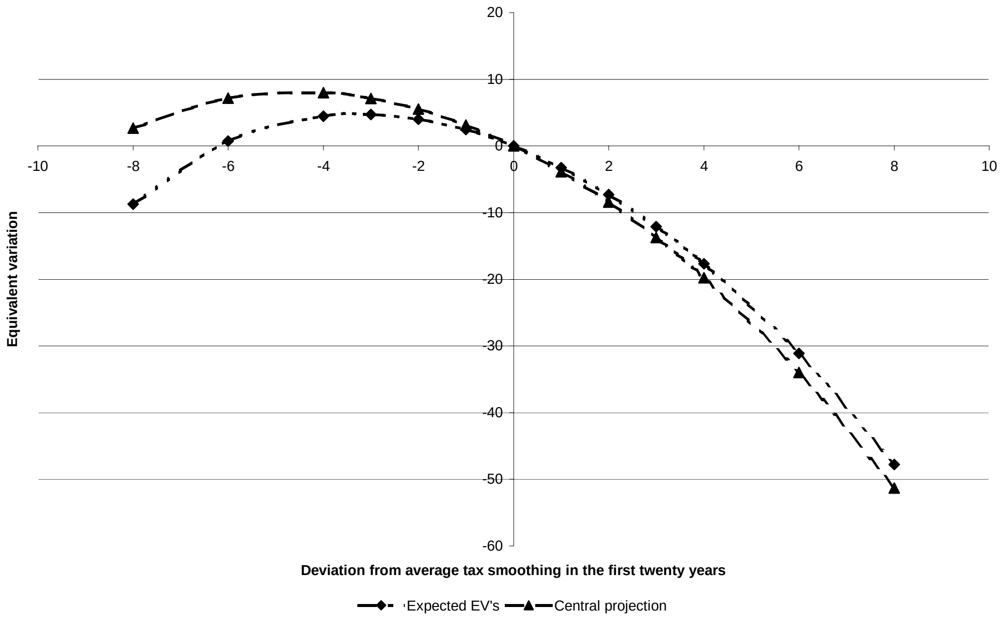
Source: Authors' simulation results.

Under the current population forecast, the post-war baby boom generation will be reaching the ages where labour supply is most elastic, meaning that the aggregate labour supply will be more elastic than in the future. Since higher labour supply elasticity implies higher distortions from labour income taxation, it is intuitively clear that efficiency would be served by taxing current cohorts at a lower rate. Conversely, in the case of a stable population profile, the aggregate labour supply elasticity is constant and so the argument for front-loading taxes does not hold.

9.2 Optimal policy under demographic uncertainty

Having established the welfare-maximising taxation policy where the future population development is known, we now calculate the optimal policy under uncertainty. In this case, the best the government can do is to choose the policy that maximises the *expected* aggregate equivalent variations. The procedure for calculation is as follows. A distribution of stochastic population projections is produced by the PEP programme.[11] For each projection, the aggregate equivalent variation is calculated over the grid of policy points as above. Then the expected aggregate equivalent variation for each policy point is calculated by averaging over the population projections. The result is the curve denoted 'expected EVs' illustrated in Figure 15.

Figure 15. Aggregate equivalent variations of alternative tax policies under the condition of population uncertainty [a]



[a] Relative to average tax smoothing at 22.7%

[11] Based on 138 PEP projections.

For comparison, the aggregate equivalent variations curve (denoted 'central projection') associated with the central population forecast is shown. This can be interpreted as either the curve corresponding to the case of certainty or the curve that is faced by a government that ignores uncertainty by assuming that the most likely demographic scenario will occur.[12] In either case, it can be seen from the figure that taking uncertainty into account implies that the optimal tax rate (in the neighbourhood of -3 percentage points from average tax smoothing) in the period until 2026 is higher than it would be otherwise (-4% from average tax smoothing). In other words, a welfare-maximising government will pursue a precautionary fiscal policy. Since individuals are assumed to be risk-averse (from the form of their utility functions), their risk aversion is reflected in the social welfare function.

10. Conclusions

The paper tackles several questions. In the first part of the paper we compare a variety of taxation and debt policy options when the future development of the population is known with certainty. The choice of the tax base is investigated and it is confirmed that consumption tax smoothing is a more efficient policy than labour income tax smoothing owing to its larger tax base. The consequences of postponing a sustainability policy are investigated and it is demonstrated that the later the sustainability policy starts the larger the necessary tax rate. In addition, the intergenerational distributional effects may be quite large for working-age generations. We also compare tax smoothing policies with balanced budget policies. Here, similar conclusions apply.

In the second part of the paper we address the interaction between demographic uncertainty and fiscal policy. Simulated demographic shocks show that the required policy responses to maintain sustainable debt levels depend not just on the direction and magnitude of the total population changes but also on the way in which the shocks affect dependency ratios. Stochastic simulations produce a probability distribution of the sustainability gap as characterised by the tax rate increase required to keep government finances solvent indefinitely. We also use stochastic simulations to demonstrate how a welfare-maximising policy under demographic uncertainty implies the optimality of precautionary saving at the public level.

[12] Note that this is the same projection as the 'ageing population' projection in Figure 14. The aggregate equivalent variation curve is slightly different, however, because in Figure 15, we use the expected tax smoothing rate (averaged from stochastic simulations) as a baseline policy as opposed to the (deterministic) tax smoothing rate for the central projection.

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Appendix A. A Balanced Budget Policy is Sustainable

Let B denote the level of public debt, r the real interest rate, G the level of public expenditure, C the level of private consumption, L labour income and τ_t^c and τ_t^l the tax rates on consumption and labour income respectively. We have the following version of the accumulation equation for public debt (for simplicity, we assume here that the government levies consumption taxes and labour income taxes only):

$$B_t = (1+r_t)B_{t-1} + G_t - \tau_t^c C_t - \tau_t^l L_t \tag{A1}$$

Forward iteration yields an expression that includes the level of debt at infinity:

$$B_o + \sum_{t=0}^{\infty}\left[G_t - \tau_t^c C_t - \tau_t^l L_t\right]\prod_{\tau=0}^{t}(1+r_\tau)^{-1} = \lim_{t\to\infty} B_t \prod_{\tau=0}^{t}(1+r_\tau)^{-1} \tag{A2}$$

Fiscal policies are now said to be sustainable if the RHS of equation (A2) equals zero. If not, the RHS of equation (A2) is a measure of the size of the sustainability problem.

The policy simulations all impose the sustainability of fiscal policies, i.e. they manage to bring down the RHS of equation (A2) to zero, albeit in different manners. The policies of immediate tax smoothing raise some tax rate, either on consumption or labour income, once and for all in the first year of the simulation period. The change in the tax rates for the case of consumption taxation can be expressed as follows:

$$\tau_t^c = \tau_t^{cN} - \tau_t^{cO}$$

$$\tau_t^{cN} = \left[\lim_{t\to\infty} B_t \prod_{\tau=0}^{t}(1+r_\tau)^{-1} - B_o - \sum_{t=0}^{\infty}\left[G_t - \tau_t^l L_t\right]\prod_{\tau=0}^{t}(1+r_\tau)^{-1}\right] / \sum_{t=0}^{\infty} C_t \prod_{\tau=0}^{t}(1+r_\tau)^{-1} \tag{A3}$$

The expression for the tax rate change in case of labour income taxation is similar. Note that the levels of consumption and labour income in general depend on the contemporaneous and future levels of all tax rates, reflecting the general equilibrium nature of the model.

The policies of delayed tax smoothing can be expressed similarly, except for two changes. Time zero does not refer to the first year of the simulation period, but to some later future year (10 or 20 years for example). As a consequence, B_o refers to the level of public debt at that later future year. In general, this is not the level of public debt that applies in the base case scenario at that time. Indeed, knowledge of the smoothing policies that will be set at some future date may lead economic actors to anticipate this, thereby changing the development of the economy and thus the level of the public debt at the time of policy implementation.

Balanced budget policies imply tax rates that stem from the dynamic accumulation equation (for the case of consumption taxation, the case of labour income taxation is similar):

$$\tau_t^{cBB} = \left[r_t B_0 + G_t - \tau_t^l L_t\right] / C_t \tag{A4}$$

Again, consumption and labour income result from calculations that reflect the balanced budget policies and will in general thus depend on the whole time path of these tax rates.

The tax smoothing policy simulations imply solvency of the public sector by definition. This applies to immediate and delayed tax smoothing policies. It can easily be shown that the simulations of balanced budget policies impose solvency as well. The reason is that, in case of balanced budget policies, the RHS of equation (A2) reduces to the initial level of public debt, discounted back an infinitely long period of time. It will be obvious that this equals zero.

Appendix B. Robustness of the PEP Results

This note assesses the robustness of the population model results when combined with PEP by comparing the statistics from the output of 250, 500, 1000 and 5000 simulations. The central limit theorem states that given a distribution with a mean μ and variance σ^2, the sampling *distribution of the mean* approaches a *normal distribution* with a mean (μ) and a variance σ^2/N as N, and the *sample size*, increases. Since the true population values of μ and σ^2 are not known, it is not possible to assess the true extent of the bias in the moments of the sampling distribution. Nevertheless, we would expect that the sample mean converges to the true population mean as N increases and the same with sample standard deviation, which is expected to converge to the true population standard deviation. In the Gaussian normal distribution the values for the higher moments are zero for both for skewness and kurtosis.

The following details the properties of the sample distributions under a different number of draws for a selection of variables:

Total population

- Mean: 18.9 m for N=5000; 18.8 m for others
- Median: 18.8 m for N=250; 18.9 m for others
- St. dev.: increases with N
- Kurtosis and skewness: both approach Gaussian normal with N=5000

Dependency ratio

- Mean: 0.45 for all N
- Median: 0.45 for N=5000; 0.46 for others
- St. dev.: 0.06 for all N
- Kurtosis and skewness: both approach Gaussian normal with N=5000

Total number of immigrants

- Mean and median: 0.007 for all N
- Kurtosis and skewness: both increase as N increases

Total number of emigrants

- Mean: 0.004 for N=5000; 0.003 for others
- Median: 0.004 for all N
- St. dev. : 0.002 for N=5000; 0.006 for others
- Kurtosis and skewness: no clear pattern

Total deaths

- Mean and median: 0.01 for all N
- St. dev. : 0.001 for N=5000; 0.005 for others
- Kurtosis and skewness: approaches Gaussian normal with N=5000; prior to 5000, no clear pattern

Total number of children

- Mean and median: 0.21 for all N
- St. dev. : 0.008 for all N
- Kurtosis and skewness: no clear pattern for kurtosis; distribution becomes less skewed as N increases

The most commonly used number of simulations currently is 250 owing to the time-consuming nature of the estimation process. The above summary of the properties of the sample distributions indicates that moments of the distribution only change for N=5000 in most cases. While ideally the analysis should be performed on as many simulations as possible, in practice 5000 projections on the GAMMA model would currently not be reasonable as a result of the high time costs. The graphs clearly indicate that the variables that are highly sensitive to the number of simulations are the total number of emigrants and total deaths. The relative importance of these variables in the overall model has to be taken into account when deciding the optimal number of simulations.

In conclusion, both the graphs and the summary statistics indicate that although the mean and median projections are not sensitive to the number of simulations, the differences are considerable in the third and the fourth moments and N increases. It would be advisable to commence a similar robustness exercise using the overall GAMMA model to assess whether 250 projections are enough for robust estimation.

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