RESTORING FISCAL SUSTAINABILITY IN THE EURO AREA: RAISE TAXES OR CURB SPENDING?

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With population ageing, fiscal consolidation has become of paramount importance for euro area countries. Consolidation can be pursued in various ways, with different effects on potential growth, which itself will be dragged down by ageing. A dynamic general equilibrium model with overlapping generations and a public finance block (including a pay-as-you-go pension regime, a health care system, non-ageing-related public spending and a stock of debt to be repaid) is used to compare the macroeconomic impact of four scenarios: a) increasing taxes to finance unchanged pensions and repay public debt, b) lowering future pension replacement rates and repaying public debt through a lower ratio of non-ageing-related outlays to GDP, c) raising the retirement age by 1.25 years per decade and increasing taxes only to pay off debt, and d) increasing the retirement age by 1.25 years per decade and paying off debt through a lower ratio of non-ageing-related expenditure to GDP. This last scenario is the one where growth is strongest: with gradual increases in the retirement age and spending restraint, average GDP growth in the 2010s would be 0.34 percentage point stronger than in a scenario where fiscal consolidation is achieved exclusively through tax hikes. The appropriate conclusion from the model is not that public spending is bad per se, but that cuts to lower-priority spending items can deliver surprisingly large income gains compared with the alternative of raising taxes.

Introduction and main results

1. In coming decades, large fiscal adjustments in the euro area cannot be avoided. In a period when baby boomers were in their prime working age and could have been expected to pre-fund at least part of the fiscal cost of their retirement by building a net asset position, the opposite occurred and public debt more than doubled as a share of GDP over the last 30 years (Figure 1). Unless current policy settings change, the fiscal pressures from health and pension costs mean that public debt is on an explosive path. To bring down the debt-to-GDP ratio, public accounts will have to move from today's deficits (–2.4 per cent of GDP in 2005) to temporary surpluses before settling at a balanced long-term position.

2. A wide body of literature acknowledges the magnitude of the challenge and provides estimates of the required adjustments, often referred to as "tax gaps".[1] Most applied studies of tax gaps rely on an accounting framework to estimate by how much taxes have to rise to repay or stabilise public debt, usually over several decades. While simple, this method has some drawbacks. It ignores the feedback effects of changes in taxes and public expenditure programmes on the behaviour of economic agents (notably their labour supply and saving decisions) and ultimately growth. As a result, the tax gap approach presents tax increases and expenditure cuts as

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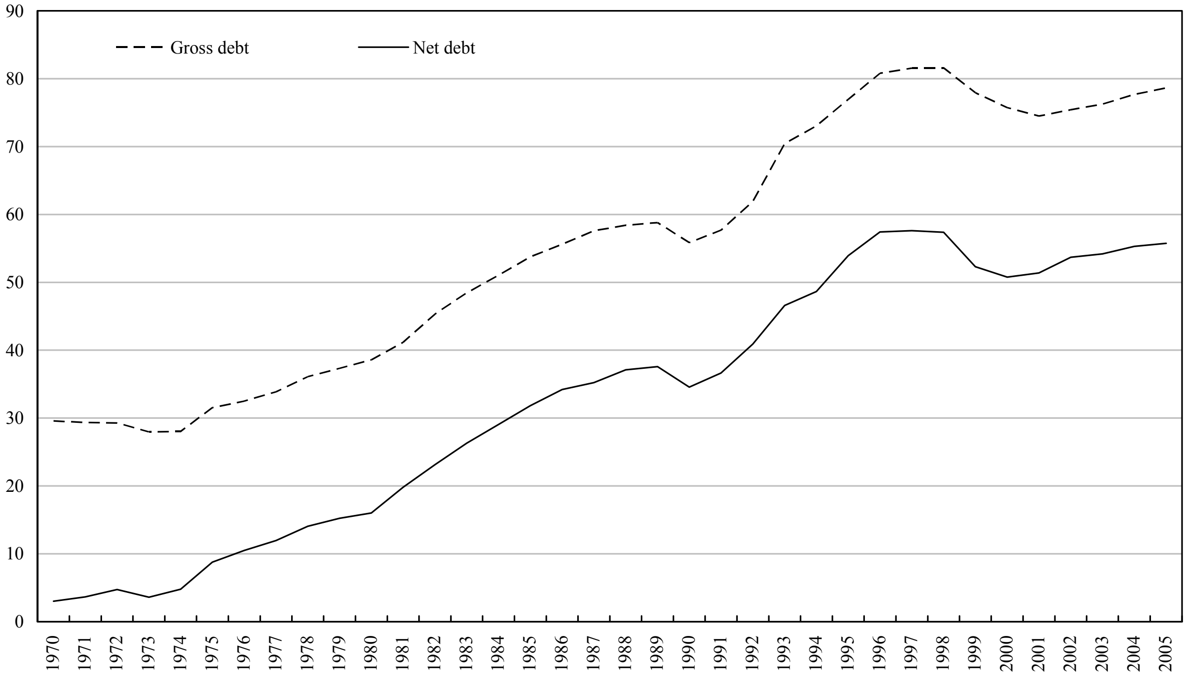
[1] See EU Commission (2006) for a recent survey of the available evidence.

Figure 1

The Irresistible Rise of the Public Debt-to-GDP Ratio in the Euro Area



Note: Gross debt refers to general government financial liabilities. Net debt is defined as gross debt minus the financial assets of the general government sector. Gross and net debt are measured on a national accounts basis, *i.e.* at market prices. These measures generally differ from the values used for the purpose of assessing compliance with the criteria derived from the Maastricht Treaty, which are estimated at face value.
Source: OECD, *Economic Outlook,* No. 79, database.

symmetrical, equivalent means of achieving fiscal consolidation. The "tax gap" terminology may even convey the impression that increasing taxes is the natural way of consolidating public accounts and paying back government debt.

In contrast with static methods, this paper models several channels through which different policy options for financing ageing-related spending pressures and repaying public debt will affect growth. A stylised dynamic general-equilibrium model has been built and calibrated on euro area data. Akin to the approach by Oliveira Martins *et al.* (2005), it is based on overlapping generations and an endogenous capital market. An important extension, however, is that here the labour market is also endogenised: changes in tax rates affect net wages, thus impacting labour supply decisions and in turn all other variables through feedback effects. The model also expands on Oliveira Martins *et al.* (2005) by including spending on health care, non-ageing-related items and debt service in the government block. In contrast with Oliveira Martins *et al.* (2005), which focuses on the effects of ageing on growth, the present model has been designed for and concentrates on comparing different policy options to restore fiscal sustainability.

3. Four scenarios of fiscal consolidation have been modelled (Table 1). The retirement age is unchanged in a first pair of scenarios where the authorities consolidate the fiscal position either by raising tax rates (scenario TU) or by lowering the pension replacement rate and reducing the ratio of non-ageing-related public spending to GDP (scenario SU). A second pair of scenarios

Table 1

The Four Scenarios

	Unchanged Retirement Age	Rising Retirement Age
Tax hikes	TU: tax hikes and unchanged retirement age	TR: tax hikes and rising retirement age
Spending restraint	SU: spending restraint and unchanged retirement age	SR: spending restraint and rising retirement age

incorporates increases in the retirement age by 1.25 years every decade coupled with tax increases (scenario TR) or reductions in the ratio of non-ageing-related spending to GDP (scenario SR). For the sake of realism, all four scenarios assume that increases in public health care spending (which the model projects endogenously) are financed by raising taxes. In all scenarios, fiscal consolidation is defined as paying off debt by 2025 so as to bring the fiscal accounts into shape just before the ageing pressures kick in in full force. There is a strong case based on intergenerational equity grounds for going further and building a net asset position so as to pre-fund spending pressures associated with the demographic transition.[2] However, given the difficulty of quantifying the desirable net asset position, aiming at zero debt is a reasonable if conservative assumption.

The model confirms that tax increases have costly economic consequences. This is not surprising given the assumptions built into the model. What is more interesting is that these costs are particularly large. Results from the model suggest that tax increases are a much more costly way to achieve fiscal sustainability when compared with spending restraint. In model simulations, annual consumption per capita is 15 per cent higher in 2050 if fiscal consolidation is achieved through expenditure restraint and increases in the retirement age (scenario SR) than through across the board tax hikes (scenario TU). Tax-based strategies depress savings, capital accumulation, the capital/labour ratio and ultimately real wages. The results are obtained with conservative assumptions most of which tend to underestimate the distortive effects of taxation (see the concluding section below).

4. Results from the model also highlight the benefit of combining expenditure restraint with appropriate structural reform (here in the form of increases in the retirement age). If expenditure restraint includes gradual increases in the retirement age in line with longevity (scenario SR), consumption per capita is 15 per cent higher than in the purely tax-based scenario TU, and 8 per cent higher than in scenario SU, where spending is curbed without adjusting the retirement age. The main forces driving strong growth in scenario SR are that a rising retirement age boosts labour supply while moderation in public spending encourages household savings and bolsters capital accumulation. The model results are consistent with intuition and empirical evidence that fiscal consolidation and structural reform are to a large extent mutually reinforcing (see also van den Noord and Cournède, 2006).

[2] This is particularly true for categories of public expenditure such as health care where providing the services is difficult to refuse and the costs can hardly be fully recovered through user charges. Working generations should pre-fund to finance their higher demand for health-care services later in their lives (see for instance OECD, 2005*a* for more details).

The model

5. The shortcomings of the tax gap analysis mentioned in the introduction can be overcome using a general equilibrium model with overlapping generations parameterised on euro area data. This analytical framework models the combined effects of public debt reimbursement and ageing-related reforms of public finances on labour and capital markets, and thus growth in the long run. Appendix 1 fully describes the model, its analytical solution and the corresponding numerical method of resolution.

6. The dynamics of the model are exclusively driven by demographics, public finance reforms, the reimbursement of public debt and the behavioural responses of economic agents in the euro area. In line with most of the literature on dynamic general equilibrium models with overlapping generations for large countries, this model does not account explicitly for effects stemming from the external side of the economy. Accounting for external linkages would smooth the dynamics of the model, but only to a limited extent. Euro area households may want to invest in younger countries to push up the rate of return on their assets. Later, in the dissaving phase, any domestic savings shortage is likely to be less binding if euro area governments can borrow on international financial markets. But such a shift in the counterpart of government debt would do nothing to solve the ultimate sustainability problem. Moreover, the rest of the world including much of the developing world is also rapidly ageing and is therefore competing for the same limited pool of capital. Home bias (the "Feldstein-Horioka puzzle"), exchange rate risks and financial systemic risk also suggest that the possible overestimation of the impact of ageing on capital markets due to the closed economy assumption is very small.

Demographics

7. The model embodies 79 cohorts each year, thus capturing in a detailed way changes in the population structure. Demographic projections for the euro area aggregate the national projections computed by Gonand (2005*a*) using official demographic assumptions. These projections are close to member countries' official demographic forecasts. Participation and unemployment rates by age groups are frozen from 2000 onwards in scenarios with unchanged retirement ages. Scenarios with rising retirement ages include corresponding changes in the participation rate of older workers. The year 2000 is used as a starting point for participation and unemployment rates because the unemployment gap was then close to nil in the euro area.

Households' maximising behaviour

8. The household sector is modelled by a standard, separable, time-additive, constant relative-risk aversion (CRRA) utility function and an inter-temporal budget constraint. The instantaneous utility function has two arguments, consumption and leisure. The average individual of a given cohort decides how much to work, consume and save so as to maximise the discounted value of their lifetime utility, corrected for risk aversion, subject to their inter-temporal budget constraint. Households endogenously choose how long they work, but their decision to participate in the labour force is exogenous. In other words, the intensive margin of labour supply is endogenous in the model while the extensive margin is exogenous.

9. Households receive wage and pension income alongside government-provided goods and services that are not related to ageing, and they also benefit from public spending on health care.[3] In the model, public health spending does not enter the revenue side of household accounts but it adds to utility by keeping them alive longer.[4] Households pay proportional taxes on labour income to finance the reimbursement of public debt, the PAYG pension regime, an always balanced health care regime, and non-ageing-related public expenditure.[5] The households' optimisation programme is fully solved in an analytic fashion (see Appendix 1 for details).

10. An important feature of this life-cycle framework is that it introduces a relationship between saving and demographics. The aggregate saving rate is positively linked to the share of older employees in the total population, and negatively to the share of retirees. When baby-boom cohorts get older but remain active, ageing increases the saving rate. When these large cohorts retire, the saving rate declines.

Production function

11. Production is modelled through a standard constant elasticity of substitution (CES) function with two inputs: capital and efficient labour. Exogenous technical progress drives the variation of multi-factor productivity (MFP) over time. As mentioned above, working time is endogenous and results from households' optimising behaviour.

12. In the long-run equilibrium, the growth rate of the gross wage per unit of efficient labour equals MFP gains because both total labour force and the capital/labour ratio (in efficiency units) are constant. There is no depreciation of capital. Including this parameter would not change the dynamics of the model since equilibrium conditions stem from saving behaviour *net* of capital depreciation. The price of the good produced by firms is normalised to 1 (*numéraire*). Inflation is abstracted from since this is a long-run model.

Four scenarios of public finance reforms achieving sustainability in the face of ageing

13. Four different scenarios of public finance reform are considered (Table 1). Appendix 2 provides a complete description of the four scenarios and the corresponding analytic formulas. As mentioned above, all scenarios achieve fiscal consolidation defined as repaying debt by 2025. Alternative scenarios where ageing-related cost pressures are financed through debt accumulation

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3 Public spending on health care includes expenditure on long-term care throughout the paper (see Appendix 2 for more details).

4 In the model, demographic change is the only driving force behind projected increases in public spending on health care. OECD (2006*a*) shows that this assumption errs on the conservative side as income- and technology-related effects are large and may even dominate the impact of demographic factors. However, as the focus of this paper is on fiscal policy and not on health-care reform, a deliberate choice has been made of retaining conservative assumptions for the health sector. The choice of this assumption has little impact on the results of the simulations for two reasons. First, the dynamics of public health spending in the model simulations reported here is consistent with the results in OECD (2006*a*) despite a small difference in the size of the increase. Second, the choice of a different assumption for increases in health expenditure would shift the results in all scenarios but would not alter their relative positions because the rise in public health expenditure is financed similarly in all scenarios (by increasing the associated tax).

5 Tax revenues are raised only on labour income and pensions in the model. A variant of the model incorporating a proportional tax on capital income has been built. The results suggest that the receipts from the capital income tax were very small compared with the revenues from taxes on labour income and pensions. This variant was not used further because adding capital taxation seriously complicates the analysis of the optimisation behaviour of households without improving the modelling of public sector accounts much.

have not been considered because they imply unsustainable dynamics while the present study focuses on comparing different ways to restore sustainability.[6]

Scenario TU: higher pension and health tax, debt reimbursed by taxes

14. In scenario TU, the PAYG pension regime is balanced each year through higher contribution rates. The replacement rate and retirement age remain unchanged. Cohorts perfectly forecast future increases in the contribution rate.

15. The stock of public debt accumulated in 2004 is equal to 71 per cent of GDP and starts being paid back (service included) from 2005 until 2025 when public debt reaches zero. The rationale for zero debt by 2025 is that government gets its fiscal house in order just before the ageing pressures really materialise. Aiming at a stock of debt of 60 per cent of GDP in 2025 would probably not be sustainable in this context and may thus not provide a helpful baseline. The interest rate on the debt is equal to the equilibrium long-term interest rate calculated endogenously by the model.

16. In this scenario, an additional proportional tax is levied on labour income and pensions to pay back government debt between 2005 and 2025. As from the time the fiscal consolidation programme is announced (2005), households are fully aware that they will have to pay this specific debt reimbursement tax supplement on their labour income or pensions between 2005 and 2025.

17. Non-ageing-related public expenditure is financed by a proportional tax on labour income. Households receive transfer income for an overall amount equal to the revenues of this tax. This non-ageing-related public expenditure regime introduces a degree of income redistribution within cohorts because the amount of taxes (in absolute terms) is not constant across individuals while the corresponding transfer payment is.

18. Assumptions for the public health care regime are the same in all scenarios. It is financed by a proportional tax on labour and pension income that balances its revenues with expenditure each year. The tax rate rises in all scenarios as public health care expenditure increases in the face of ageing. As mentioned above, health expenditure is not modelled as a transfer adding to household income. Health expenditure does however contribute to the utility of households in the model, because it is a necessary item of spending to deliver the longevity profile underlying the simulations. In other words, the utility households derive from health expenditure is not earning more but living longer.

Scenario SU: lower replacement rate of pensions, debt reimbursed by lower non-ageing-related public spending, higher health tax

19. In scenario SU, the tax rate financing pensions is frozen from 2005 on and the PAYG system is balanced thereafter by gradually decreasing replacement rates for *new* retirees. As households anticipate future cuts in the replacement rate, they rethink their labour supply, consumption and saving plans accordingly.

20. While the health regime is the same as in scenario TU, the main features of scenario SU are twofold:

- the pension replacement rate becomes endogenous after 2005,

[6] See European Commission (2006) for long-term projections of debt levels on unchanged policy settings. For a recent study of the implications of unsustainable debt dynamics for long-term economic growth, see Gonand (2005*b*).

- the reimbursement of the public debt accumulated up to 2004 is financed by lowering non-ageing-related public expenditures.

21. Both reforms are announced in 2005 and households respond immediately. For each cohort, consumption before 2005 is the same as in the increasing contribution rate scenario, where households anticipate that PAYG system reforms and public debt reimbursement rely on tax hikes. When announced in 2005, households adjust their optimal consumption and leisure path over their lifetime. Thus the reform prompts each cohort to devise new optimal inter-temporal paths for consumption and labour supply over its remaining lifetime.

Scenario TR: higher age of retirement, slightly higher pension tax, debt reimbursed by taxes, higher health tax

22. In scenario TR, the effective average age of retirement rises by one year and a quarter every ten years from 2005 until 2045 in line with forecasts of future life expectancy increases while replacement rates are unchanged. Age-specific participation rates of workers above 50 are assumed to increase in line with the changes in the retirement age. The (small) residual imbalances of the PAYG regime are covered by changes in the pension tax rate.

23. As in base scenario TU, public debt is paid back by an additional proportional tax levied on labour income and pensions between 2005 and 2025. The health regime and the non-ageing-related public spending are unchanged compared to scenario TU. As above, households respond immediately to all changes in 2005 by deriving new inter-temporal optimal consumption and labour supply paths for all cohorts.

Scenario SR: higher age of retirement, slightly lower replacement rate of pensions, debt reimbursed by lower non-ageing-related public spending, higher health tax

24. In scenario SR, the average effective retirement age increases by one year and a quarter every ten years as in scenario TR from 2005 to 2045. One difference with scenario TR is that the residual imbalances of the PAYG regime are covered by reductions in the replacement rate for new retirees. The pension tax rate is kept unchanged at its 2005 level.

25. Consistent with the focus on spending cuts, public debt is paid back by lowering non-ageing-related public spending and keeping the corresponding tax at its 2005 rate. As in all scenarios, the health regime is unchanged compared to scenario TU.

26. As above, households respond immediately to all changes in 2005 by deriving new inter-temporal optimal consumption and labour supply paths for all cohorts.

Summary of the four scenarios

27. Table 2 summarises the main characteristics of the reform scenarios simulated in the model.

Results

28. The simulation results, which are robust across variations in the parameters (see Box 1), show that the choices made to restore the sustainability of public finances can have lasting

Table 2

Main Features of the Four Modelled Scenarios of Fiscal Consolidation

	Scenario TU	Scenario SU	Scenario TR	Scenario SR
The PAYG pension regime is financed by:	higher taxes on labour income	lower replacement rates for new retirees	a rising retirement age + residual increases in pension taxes	a rising retirement age + residual cuts in replacement rates
The public debt is reimbursed between 2005 and 2025 by:	higher taxes on labour income and pensions	lower non-ageing-related expenditure	higher taxes on labour income and pensions	lower non-ageing-related expenditure
Non-ageing-related public expenditure is financed by:	a constant tax rate on labour income and pensions	a constant tax rate on labour income and pensions.	a constant tax rate on labour income and pensions	a constant tax rate on labour income and pensions
Public health care spending is financed by:	higher taxes on labour income	higher taxes on labour income	higher taxes on labour income	higher taxes on labour income

Box 1
Parameterisation, Calibration and Sensitivity Analysis

The main exogenous variables in the model are the demographic data. A set of demographic data has been constructed for the period 1910-2158. Historical values were gathered from national sources. Gonand's (2005*a*) projections have been used for the period 2000 to 2158.

The model is back to its long-run steady-state in 2080. In this situation, GDP per capita growth is exclusively determined by the exogenous growth in MFP and capital deepening grows in line with MFP, at 0.45 per cent per annum. By contrast, during the demographic transition, the dynamic equilibrium is driven by ageing and public finance reforms.

The model is calibrated on an interest rate of 3.5 per cent in the base year, corresponding to the sum of MFP gains and the discount rate, as suggested by life-cycle theory. In contrast with other studies, the model is not calibrated on technical parameters such as the relative aversion to risk to mimic observed variations in the stock of capital around the base year as procedures of this nature can bias the long-run results.

The level of the average replacement rate is computed as the ratio of pensions received per capita over gross wages received per capita in 2000. The weighted average replacement rate for compulsory pension regimes is around 62 per cent in the euro area (OECD, 2005*b*). While other values for replacement rates would modify baseline levels, sensitivity analysis indicates that differences across simulations would not be substantially affected.

The values of the tax rates financing the pension regime, the balanced health care system and the non-ageing-related public expenditure regime are set in 2004 (the year preceding the implementation of the reforms in the model) in line with the national accounts for the euro area.

In order to test the robustness of model results to alternative specifications and parameter values, extensive sensitivity analysis has been carried out (see Appendix 3). Overall, the dynamics of the results proves to be reasonably robust to changes in key parameters.

Source: Appendix 3 covers these topics in more detail.

implications for developments in output per capita and other macroeconomic variables (Figures 2, 3 and 4).

Scenarios with unchanged retirement ages

Scenario TU: strong increases in taxes and a marked fall in the saving rate

29. Balancing PAYG systems in the context of ageing requires a very sizeable increase in tax rates – on average from 10 per cent in 2000 to around 24 per cent in 2050. The proportional tax levied on labour income and pension to reimburse debt by 2025 would be around 6 per cent in 2005. Ageing would also mechanically translate into higher tax rates for financing health expenditure. Overall the tax burden increases very substantially in this scenario, from 50 per cent of the GDP in the model in 2000 to 66 per cent in 2030 (and 73 per cent in 2050). While massive, this increase is a natural reflection of the change in the dependency ratio over the period.

30. The changes in the tax-to-GDP ratio in this scenario cannot be compared with standard tax gap estimates. Tax gap estimates such as in EU Commission (2006) reflect adjustments that will have to be made over and above changes in entitlement programmes and in the tax-to-GDP ratio that are embedded in current and planned policies. Another obstacle to comparability is the dynamic nature of the model simulations which incorporate the negative feedback of higher taxes on output growth.

31. The dynamics of the capital/labour ratio reflect the relative speed of the declines in saving and labour supply both triggered by ageing over the simulation period. It is downward sloping over the projection period, mainly because of the joint impacts of the debt reimbursement tax on saving and capital accumulation up to 2025, and of increasing taxes on optimal working time over the whole period. Overall, from the 2020s on, both capital and labour are scarcer than in 2000 in this scenario while taxes are much higher.

32. The dynamics of the average working time in scenario TU, which is a component of the dynamics of the labour force, mirrors mainly the variations of the wage net of taxes. The intratemporal first-order condition in households' maximisation programme requires that net wages and working time move in tandem. Since households smooth their optimal intertemporal paths for consumption and labour supply, it is not meaningful to compute an instantaneous elasticity of working time to taxes from the outcomes of the model.

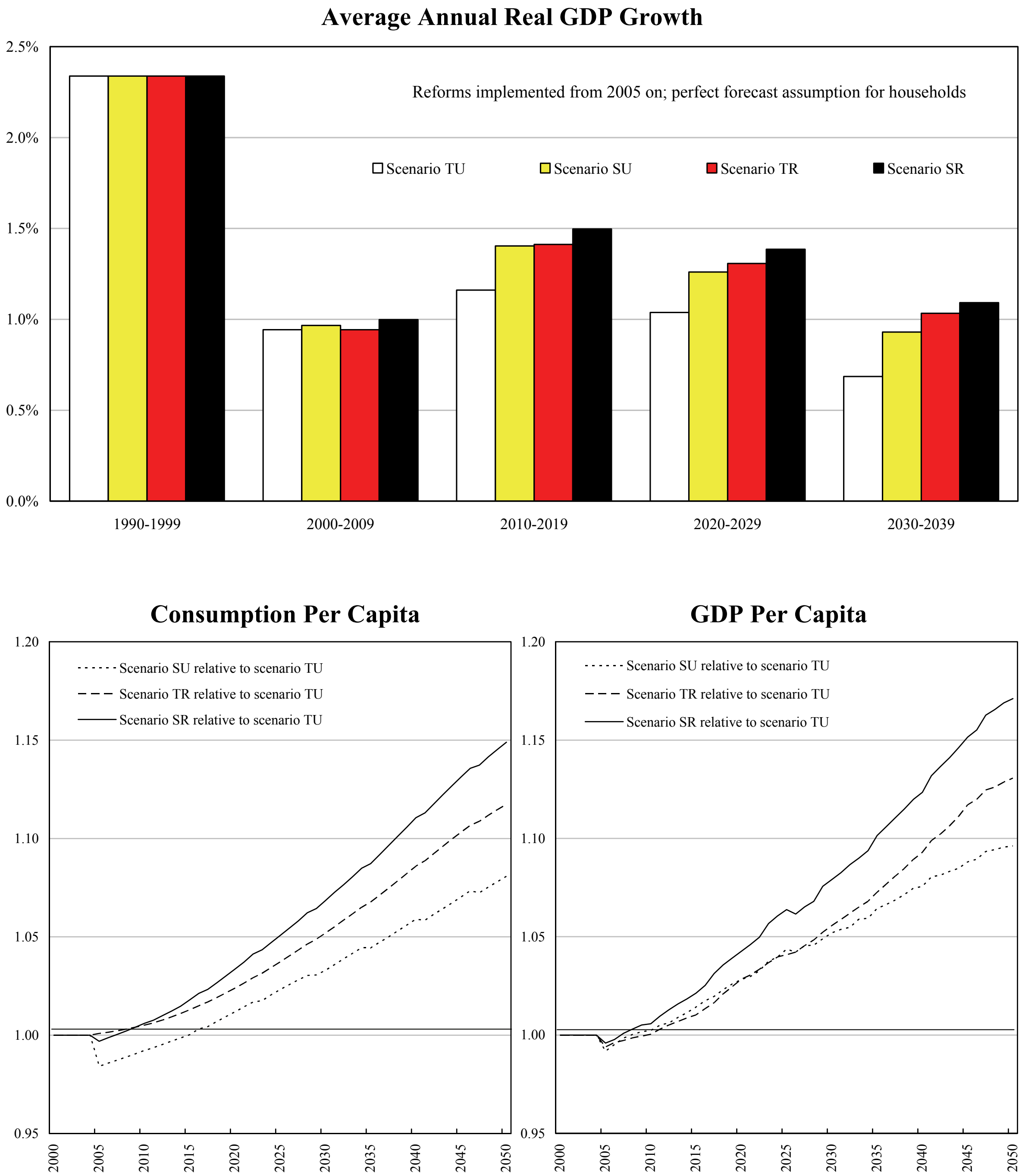
Scenario SU: public spending restraint, more savings and higher wages

33. The increase in the overall tax burden is far more limited than in scenario TU: the tax-to-GDP ratio evolves from 50 in 2000 to nearly 52 per cent in 2030. In this scenario, public health expenditure, which is increasing gradually in line with ageing, is the only item of government spending that drives taxes higher. Non-ageing-related public spending also falls between 2005 and 2025 to reimburse the debt. Overall the level of total public expenditure is 17 per cent lower in 2030 in scenario SU than in scenario TU.

34. With replacement rates of the PAYG pension regime declining to around 30 per cent from 2025 onwards, there are strong incentives for working households to increase their savings relatively to scenario TU in order to avoid a sharp reduction of their income and consumption when retired. As a result, the saving rate is around 2 percentage points higher in scenario SU than in scenario TU and capital deepening is accordingly much stronger.

Figure 2

Real GDP Growth Rate and Level



Notes:
Scenario TU: higher pension tax, debt reimbursed by taxes, higher health tax.
Scenario SU: lower replacement rate of pensions, debt reimbursed by lower non-ageing-related public spending, higher health tax.
Scenario TR: higher age of retirement, slightly higher pension tax, debt reimbursed by taxes, higher health tax.
Scenario SR: higher age of retirement, slightly lower replacement rate of pensions, debt reimbursed by lower non-ageing-related public spending, higher health tax.

Figure 3

Simulation Results for Public Finance Regimes

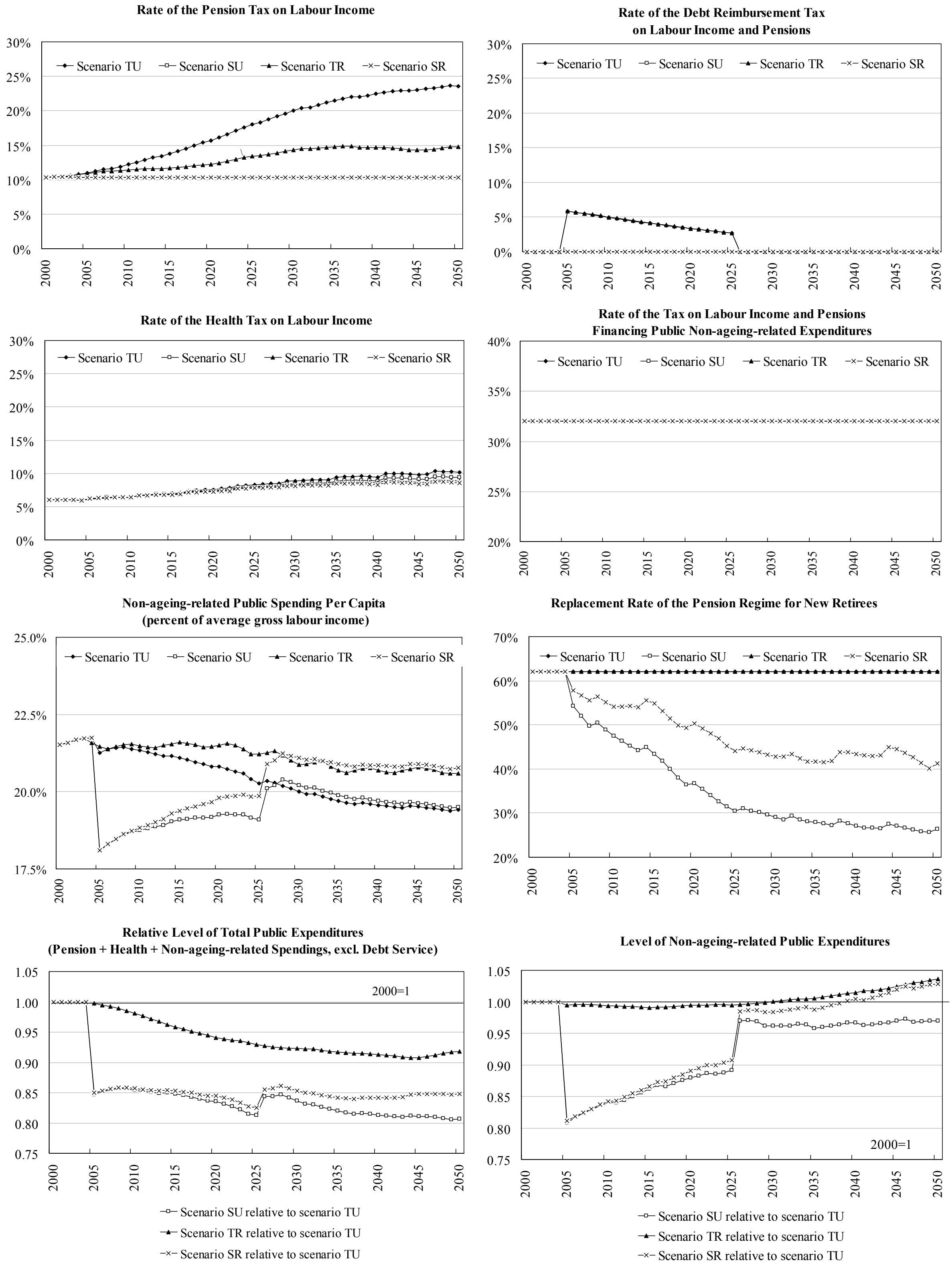
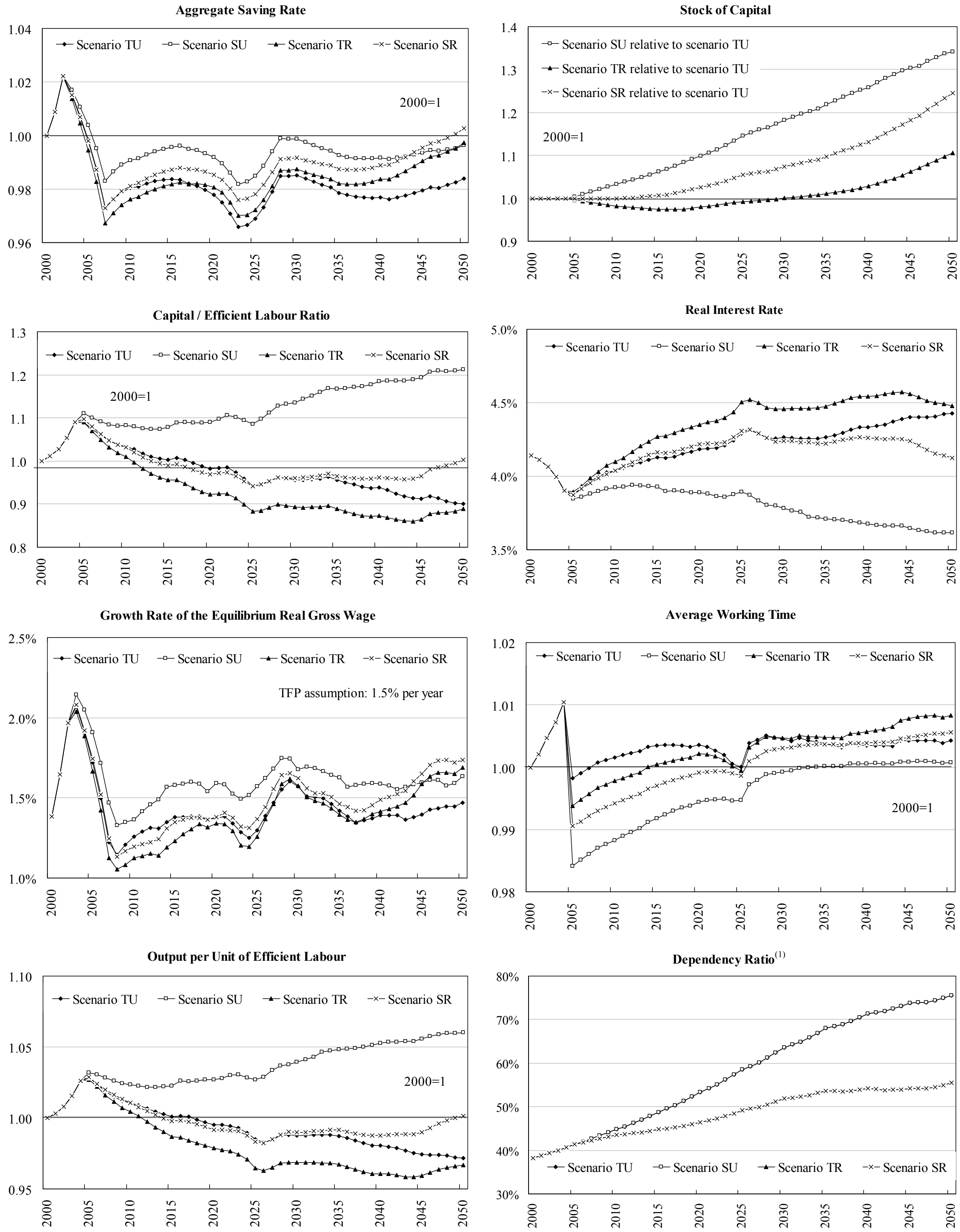


Figure 4

Simulation Results for Macroeconomic Variables



(1) Retired population/labour force.

35. In scenario SU, the gross wage is higher over the projection period than in scenario TU because the capital/labour ratio in scenario SU is broadly stable, while it declines steeply in scenario TU. As a result, the capital/labour ratio remains at far higher levels over the projection period, implying higher gross wages. Since taxes are lower, net wages are much higher than in scenario TU but there is not as much transfer income as in scenario TU.

36. In scenario SU, the optimal working time diminishes by around 2.5 per cent in 2005 when the reform is announced. This derives from the change in households' information set in 2005 and an associated strong income effect. Anticipating that future overall taxes will be lower than previously expected, and that stronger capital deepening will boost future wages, households realise that the reform in scenario SU raises their permanent income compared to scenario TU. As a result, they increase both their current consumption and the optimal level of leisure. From 2005 onwards, the optimal working time slowly rises because of the gradual rise in average productivity resulting from ageing.

Scenarios with gradually rising retirement ages

37. Scenarios TR and SR involve gradual increases in retirement ages in line with longevity. Raising the retirement age by 1.25 year per decade significantly boosts labour supply (along the extensive margin) and slows down the increase in the old-age dependency ratio.

Scenario TR: limited tax increases and much improved labour supply

38. The rise in contribution rates required to balance PAYG systems is much smaller than in scenario TU because increases in retirement age limit the fall in the dependency ratio. From 50 per cent of GDP in 2000, the share of taxes in GDP rises to 58 in 2030 against 66 per cent in scenario TU. Despite the much lower tax burden, scenario TR delivers a level of government spending that is only slightly (8 per cent in 2030) below that in scenario TU.

39. The favourable impact of a gradually rising retirement age on labour supply leads the capital/labour ratio to be slightly lower than in scenario TU. The tendency for individuals to save less because their retirement period will be shorter than in scenario TU is roughly compensated by the longer working life period during which they save. As a result, the characteristics of the equilibrium on the capital market in scenario TR are very similar to those in scenario TU.

40. As concerns the adjustment of the working time in 2005 in scenario TR, two opposite mechanisms are at work. On the one hand, future capital/labour ratios are now anticipated by households to be lower than previously thought (with past expectations in line with scenario TU). This implies that the future growth rate of wages is lower, and the cost of leisure declines. On the other hand, the rise in the tax rate financing the PAYG pension regime is now far more limited than anticipated before 2005. This pushes up the average cost of leisure ceteris paribus. Overall, the net impact on working time turns out to be negative, suggesting a stronger impact of lower labour taxes on leisure and thus utility.

Scenario SR: a tax burden in check and high levels of income

41. Scenario SR incorporates an increasing retirement age (as in scenario TR) and a fall in non-ageing-related public expenditure to reimburse the debt (as in scenario SU):

- compared with scenario SU, the gradual increase in the retirement age limits the rise in the dependency ratio and leads to a higher replacement rate. The reduction of the replacement rate needed to balance the PAYG system is 21 percentage points instead of 34 percentage points in scenario SU in 2030;
- the ratio of public spending to GDP is 15 percentage points lower in 2030 in scenario SR compared with scenario TU;
- the tax burden almost stabilises (52 per cent of GDP in 2030 instead of 66 per cent in scenario TU);
- as in scenario TR, the capital/labour ratio remains relatively close to the one simulated in scenario TU. Consequently, it is lower than in scenario SU, in line with a more favourable dynamics of the labour force over the projection period due to the increase in the retirement age.

42. The growth rate of the economy would be on average 0.2 per cent of GDP higher in the 2010s in scenario SU than in scenario TU, due to stronger capital accumulation and a far lower tax burden. This would translate into a level of real GDP per capita 5 per cent higher in 2030 in scenario SU than in scenario TU.

43. GDP growth would be even stronger in scenario SR, illustrating the favourable impact on growth of balancing the PAYG system in an ageing context by increasing the retirement age and containing public spending rather than raising taxes or strongly diminishing replacement rates. The average GDP growth rate during the 2010's would be 0.1 per cent higher in scenario SR than in scenario TR which relies more on tax hikes, and 0.34 per cent higher than in scenario TU. The cumulative impact of such differences is large: at the end of the simulation period (2050), income per head in scenario SR is 17 per cent higher than in scenario TU.

Concluding remarks

44. Model results indicate that if the large adjustments needed to restore fiscal sustainability were made by raising taxes, the induced distortions could entail large costs for economic growth, with most of the negative feedback coming through capital markets. The mechanism is that, if taxes are increased to finance an unchanged pension replacement rate, households have much less incentive to save and invest than if the replacement rate is reduced and taxes kept in check. Lower savings hold back capital deepening and ultimately depress output per worker. Even though the effect of tax increases on capital formation is large in simulation results, it may still be underestimated because capital income is not taxed in the model.

45. The negative impact of taxation on labour supply is relatively modest in simulation results but is likely to be stronger in practice because, to remain tractable, the model does not embody some potentially powerful channels:

- In the model the same tax rate applies to all labour inputs. In euro area countries, tax schedules are progressive. A consequence is that in practice the income effect will be weaker than in the model and the substitution effect will be stronger. The simulations are therefore likely to underestimate the negative feedback from higher taxes on the number of hours worked (the intensive margin of labour supply).
- While exogenous in the model, participation (the extensive margin of labour supply) is negatively affected by taxes in practice. A large body of evidence indicates that a higher labour tax wedge reduces participation, especially through its disincentive effect on second earners (OECD, 2006*b* and Jaumotte, 2003).

46. In addition to the effects captured in the model, tax-based consolidation strategies can also entail additional distortions via the impact of taxation on multi-factor productivity (MFP). Because multi-factor productivity is exogenous in the model, the simulations do not incorporate the effect of taxes on investment in human capital and research and development activities. Most studies conclude that the effect is negative and strong (Feldstein, 2006). Human capital accumulation and research and development efforts are the main drivers of multi-factor productivity growth which itself is the dominant determinant of long-term growth.

47. On the other hand, the assumption that MFP is exogenous is only valid insofar as any cuts in expenditure fall on low-priority items and those that have no or little effect on MFP. Early retirement schemes are a good example whereas high-return infrastructure projects and efficient education programmes are two examples of areas that expenditure-based fiscal consolidation strategies should largely preserve. In other words, the model implicitly assumes that €1 of public expenditure is "worth" €1 of income to households in the form of public services received, but it takes more than €1 of taxes to fund this because taxes have distortionary effects. In reality, there clearly are welfare benefits from funding a number of social programmes collectively – indeed, this is the raison d'être for public expenditure in the first place. The problem is that the costs of taxation rise sharply with the tax rate whereas the marginal benefits of public expenditure programmes fall (the best programmes are implemented first). Thus, the appropriate conclusion from the model is not that public spending is bad *per se*, but that cuts to lower-priority spending items can deliver surprisingly large income gains compared with the alternative of raising taxes.

48. The model could be extended to integrate feedbacks from the composition of public expenditure on MFP growth. Such an approach would enable quantifying the implications of different expenditure reform scenarios for long-term economic growth while taking account of feedback effects thanks to the general-equilibrium nature of the model. In addition, an extended model of this nature would shed some light on how much inefficient public spending is costing in terms of lost future growth. An important challenge before implementing this approach is to derive reliable estimates for the impact of various components of public spending on MFP.

49. The model could also be used in a normative analysis perspective to compare scenarios in terms of their implications for inter-generational fairness. The foundation of the model on the optimising behaviour of households opens the possibility of computing the lifetime utility of each cohort under the considered scenarios. The theory of social choice could then be used to examine how different options compare depending on the degree of aversion to inter-generational inequality.

APPENDIX 1
DESCRIPTION OF THE MODEL AND ITS SOLUTION

Demographics

50. The model embodies 79 cohorts each year, thus capturing in a detailed way changes in the population structure. Each cohort is characterised by its age a at year t, has $N_{t,a}$ members and is represented by one average individual. The average individual's economic life begins at 20 (a=0) and ends with certain death at $\Psi_{t,0}$ (a=$\Psi_{t,0} - 20$), where $\Psi_{t,0}$ stands for the average life expectancy at birth of a cohort born in year t.

51. In each cohort, a proportion $\upsilon_{t,a}$ of individuals are working while $\mu_{t,a}$ are unemployed and receive no income. The inactive population is divided into two components. A first component corresponds to individuals who never receive any contributory pension during their lifetime. They may get social assistance, which the model accounts for as part of government spending. A proxy for the share of the inactive population that never receives a contributory pension is found in the ratio of inactive people aged 40-44 to inactive people aged 65-69 (in 2000).[7] Distinguishing between pensioners and inactive people who never receive any pension is not only realistic but also important to get reasonable levels for the contribution rate balancing the PAYG regime. The proportion $\pi_{t,a}$ of pensioners in the population is then computed as a residual.

52. Demographic projections for the euro area aggregate the national projections computed by Gonand (2005) using official demographic hypotheses. These projections are close to member countries' official demographic forecasts. They are transformed from five-year periods (2005, 2010, …, 2050) and age groups (20-24 years, 25-29 years…) into annual data (20, 21, … , years in 2000, 2001, … 2050) using a linear interpolation. The implicit annual survival probabilities are close to UN projections (United Nations, 2002).

53. As far as labour force and working population projections are concerned, unemployment and participation rates by age groups are frozen from 2000 onwards unless otherwise stated. The year 2000 is probably a reasonable starting point because the output gap was then close to 0 in most OECD countries. More detail on assumptions about participation rates is provided when policy scenarios are analysed (see below).

Households sector's maximizing behaviour

54. The household sector is modelled by a standard, separable, time-additive, constant relative-risk aversion (CRRA) utility function and an inter-temporal budget constraint. This utility function has two arguments, consumption and leisure.

55. Introducing an endogenous labour market in general equilibrium models with OLG raises several challenges. Among others, many models compute the households' optimal behaviour using shadow wages during the retirement period (see, for instance, Auerbach and Kotlikoff, 1987; Broer *et al.*, 1994; Chauveau and Loufir, 1997; Docquier *et al.*, 2002). The use of numerically

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7 The assumption here is that the individuals not in the labour force at 40-44 will never receive a pension after 65 and remain outside of the PAYG regime. The intuition is the following: inactive individuals aged between 40 and 44 are most probably neither students nor retirees. Their number is compared to the number of inactive people between 65-69 , who in 2000 are almost all retired and still alive. In most countries, around 20 per cent of old inactive people do not receive a pension. This is the assumption in the model. This method yields realistic contribution rates.

computed shadow wages allows for meeting a temporal constraint during the retirement period, *i.e.* when the fraction of time devoted to leisure is equal to 1. These shadow wages are proxies for Kuhn-Tucker multipliers. While in principle mathematically correct, this method may not be very intuitive from an economic point of view since it assumes that agents keep optimising between work and leisure even during the retirement period. One practical issue with the shadow wage approach as implemented in this literature is that the method chosen to derive the shadow wages has an impact on the overall general equilibrium and therefore on all variables via the intratemporal first-order condition. Furthermore, this approach makes it practically impossible to derive an analytical solution to the model and seriously complicates its numerical solution.

56. These problems can be overcome by specifying the model in a way where the households' maximisation problem can be solved in two steps. The specification separates each cohort into working individuals, who decide on their optimal consumption and labour supply, and non-working individuals, whose labour supply is zero by definition.

57. The labour supply of the representative individual of a whole cohort ($\ell_{t,a} \in [0;1]$) is such that:

$$1-\ell_{t,a} = \nu_{t,a}(1-\ell^*_{t,a}) + (1-\nu_{t,a}) = 1-\nu_{t,a}\ell^*_{t,a} \leq 1$$

where $\nu_{t,a}$ is the fraction of working individuals in a cohort aged *a* in year *t* and $\ell^*_{t,a}$ is the optimal fraction of time devoted to work by the working sub-cohort.[8] The model computes the optimal $\ell^*_{t,a}$'s first, then the optimal $\ell_{t,a}$'s and the $c_{t,a}$'s (more details follow below). This two-step method is not possible in models which do not break down each cohort into sub-groups with different labour supply.

58. The objective function over the lifetime of the average *working* individual of a cohort of born in year t is:

$$U^*_{t,0} = \frac{1}{1-\sigma}\sum_{j=0}^{\Psi_{t,0}}\left[\frac{1}{(1+\rho)^j}\left[\left(\left(c^*_{t+j,j}\right)^{1-1/\xi} + \eta\left(H_j\left(1-\ell^*_{t+j,j}\right)\right)^{1-1/\xi}\right)^{\frac{1}{1-1/\xi}}\right]^{1-\sigma}\right]$$

where $c^*_{t,j}$ stands for the consumption level of the average individual of the working sub-cohort of age j in t, ρ is the subjective rate of time preference (also called psychological discount rate), σ is the relative-risk aversion coefficient,[9] $V_{t,j} = \left(\left(c^*_{t+j,j}\right)^{1-1/\xi} + \eta\left(H_j\left(1-\ell^*_{t+j,j}\right)\right)^{1-1/\xi}\right)^{\frac{1}{1-1/\xi}}$ is the CES instantaneous utility function at year t, η is the preference for leisure relative to consumption, $\frac{1}{\xi}$ the elasticity of substitution between consumption and leisure in the instantaneous utility function,

8 For instance, if $\nu_{t,a}$=70% of a cohort age a at a year t are working and devote $\ell^*_{t,a}$ of their available time to labour, then the average individual of the same cohort devotes $\ell_{t,a}$ = 35% of its available time to labour, and 65 per cent to leisure.

9 For a CRRA function, this coefficient is equal to the inverse of the intertemporal substitution coefficient.

and H_j a parameter whose value depends on the age of an individual and whose annual growth rate is equal to the annual TFP growth rate (with $H_0 = 1$).[10]

59. The intertemporal budget constraint for the working sub-cohort of age 20 (*i.e.* a=0) in year t is:

$$\ell^*_{t,0}\omega_{t,0} + \sum_{j=1}^{\Psi_{t,0}}\left[\ell^*_{t+j,j}\omega_{t+j,j}\prod_{i=1}^{j}\left(\frac{1}{1+r_{t+i}}\right)\right] = c^*_{t,0} + \sum_{j=1}^{\Psi_{t,0}}\left[c^*_{t+j,j}\prod_{i=1}^{j}\left(\frac{1}{1+r_{t+i}}\right)\right]$$

where:

- $\omega_{t+j,j}$ is the after-tax income of a working individual per hour worked such that $\omega_{t+j,j} = w_t\,\varepsilon_a(1-\tau_{t,D}-\tau_{t,P}-\tau_{t,H}-\tau_{t,NA}) + d_{t,NA}$;
- w_t stands for the gross wage per efficient unit of labour;
- the parameter ε_a links the age of a cohort to its productivity. Following Miles (1999), a quadratic function is used: $\varepsilon_a(a) = e^{0.05*(a)-0.0006*(a)^2}$, which displays an inverted U-shape pattern with a peak at 42 years;[11]
- the tax rate $\tau_{t,D}$ stands for a proportional tax on labour income and pensions financing the reimbursement of the public debt;
- $\tau_{t,P}$ stands for the proportional tax rate financing the PAYG pension regime (see *infra*), paid by households on their labour income;
- $\tau_{t,H}$ stands for the rate of a proportional tax on labour income, which finances an always balanced health care regime (see *infra*). Health expenditure has a favourable impact on the utility of individuals because it underpins longevity gains. To avoid double counting, the model therefore does not account for health expenditure as income transfers received by households (in contrast to other categories of public spending);
- $\tau_{t,NA}$ stands for the rate of a proportional tax levied on labour income and pensions to finance public non-ageing-related public expenditure $d_{t,NA}$;[12]
- $d_{t,NA}$ stands for the non-ageing-related public spending that one individual consumes irrespective of age and income. This variable is used as a monetary proxy for goods and services in kind bought by the public sector and consumed by households.

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10 Introducing this parameter stabilises the ratio of the contributions of consumption and leisure to utility when technical progress is strictly positive. The Euler equation (infra) suggests that the annual growth rate of consumption is equal, at the steady-state, to the difference between the interest rate and the discount rate, which in turn is equal to annual TFP growth. See Broer *et al.*, 1994; Chauveau and Loufir, 1995; Docquier *et al.*, 2002.

11 The Ingenue team (2001) uses the same function. Yet more recent econometric studies (Aubert and Crepon, 2003) do not confirm the decrease of individual productivity for older workers. However, sensitivity analysis shows that the impact on macroeconomic variables, especially growth, of the choice between these two assumptions is negligible.

12 Tax revenues are raised only on labour income and pensions in the model. A scenario incorporating a proportional tax on capital income has been built. The results suggested that the receipts from the capital income tax were very small compared with the revenues from taxes on labour income and pensions. This variant was not used further because adding capital taxation seriously complicates the analysis of the optimisation behaviour of households for little benefit in terms of improving the modelling of public sector accounts.

60. In such a specification, the working sub-cohort always chooses a strictly positive optimal working time throughout its life. In other terms, the representative individual associated with the working sub-cohort never retires. This property of the model does not lead to unrealistic results because each entire cohort is made of a working sub-cohort and a non-working sub-cohorts, with weights that vary with the age of the cohort. De facto, for the representative individual associated with the *whole* cohort, the retirement age is defined exogenously through the $\nu_{t,a}$'s which become equal to zero between 65 and 75 years. Since $1-\ell_{t,a} = 1-\nu_{t,a}\ell^*_{t,a}$, the representative individual associated with the whole cohort retires in the model when the exogenous parameter $\nu_{t,a}$ reaches zero.[13]

61. The first-order condition for the intratemporal optimization problem derives from equalizing the ratio between the marginal utilities of consumption and leisure with the ratio of consumption and leisure prices. In the model, the price of the goods produced is 1. The price of leisure (*e.g.* its opportunity cost) is equal to the net wage per unit of efficient labour for cohort (a,t) – *e.g.* $\omega_{t,a}$. Some algebra yields the optimal relation between $c^*_{t,a}$ and $\ell^*_{t,a} > 0$:

$$(1-\ell^*_{t,a}) = \left(\frac{\eta}{\omega_{t,a}}\right)^{\xi} \frac{c^*_{t,a}}{H_a} > 0$$

The intra-temporal optimality equation is conform to intuition: a higher after-tax work income per hour worked ($\omega_{t,a}$) prompts less leisure $(1-\ell^*_{t,a})$ and more work ($\ell^*_{t,a}$).

62. The first-order condition for the inter-temporal optimization problem derives from maximizing the inter-temporal utility function under the budget constraint. Solving with a Lagrangian and after some algebra, the following Euler equation is obtained (where $\kappa = 1/\sigma$):

$$\frac{c^*_{t,a}}{c^*_{t-1,a-1}} = \left(\frac{1+r_t}{1+\rho}\right)^{\kappa} \left(\frac{1+\eta^{\xi}\omega^{1-\xi}_{t,a}}{1+\eta^{\xi}\omega^{1-\xi}_{t-1,a-1}}\right)^{\frac{\kappa-\xi}{\xi-1}}$$

The inter-temporal optimality equation is also consistent with intuition:

- if after-tax income per hour worked ($\omega_{t,a}$) is steady and the real rate of return (r_t) is higher than the psychological discount rate (ρ), consumption will rise over time;

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13 Endogenising the retirement decision with the $\ell^*_{t,a}$ would bring about serious problems. The year when $\ell^*_{t,a}$ becomes equal to zero is closely related to the function $\varepsilon_a(a) = e^{0.05*(a)-0.0006*(a)^2}$ linking the age and individual productivity and its decline after some threshold year. Indeed, the first-order condition suggests that $\ell^*_{t,a}$=0 only if ε_a declines sufficiently so that $(1-\ell^*_{t,a}) = (\eta/\omega_{t,a})^{\xi} c^*_{t,a}$ equals 1. The associated retirement age can be very high with such a specification (more than 90). Moreover, there is a lively debate about the form of the function $\varepsilon_a(a)$, which may not decline after some threshold-year. For these reasons, endogenising the retirement decision using the $\ell^*_{t,a}$'s does not appear to be a good idea in this context. Auerbach and Kotlikoff (1987), for instance, impose an exogenous retirement age of 66 in their model.

- if after-tax work income per hour worked ($\omega_{t,a}$) rises over time and the real rate of return (r_t) is steady and not lower than the psychological discount rate (ρ), consumption ($c^*_{t,a}$) will rise over time; and
- lower risk aversion (lower σ hence higher κ) implies larger inter-temporal changes in consumption (in the natural case where the real rate of return r_t is higher than the psychological discount rate ρ).

63. Plugging this expression back into the budget constraint yields the initial level of consumption for the working cohort aged $a=0$ at year t :

$$c^*_{t,0} = \left(\omega_{t,0} + \sum_{j=1}^{\Psi_{t,0}} \left[\omega_{t+j,j} \prod_{i=1}^{j} \left(\frac{1}{1+r_{t+i}} \right) \right] \right) \Big/ \left(1 + \eta^{\xi} \omega_{t,0}^{1-\xi} + \sum_{j=1}^{\Psi_{t,0}} \left[\Xi_{t+j,j} (1 + \eta^{\xi} \omega_{t+j,j}^{1-\xi} H_j^{-1} \right] \right)$$

where $\Xi_{t+j,j} = (1+\rho)^{-j\kappa} \left(\frac{1+\eta^{\xi} \omega_{t+j,j}^{1-\xi}}{1+\eta^{\xi} \omega_{t,0}^{1-\xi}} \right)^{\frac{\kappa-\xi}{\xi-1}} \prod_{i=1}^{j} (1+r_{t+i})^{\kappa-1}$.

64. The optimal consumption path for each working sub-cohort is derived from the optimal value of $c^*_{t,0}$ and the Euler equation. The paths of the labour supplies of the working cohorts ($\ell^*_{t,a}$) are then derived from the values ($c^*_{t,j}$) using the intra-temporal first-order condition. Eventually, one can derive the optimal labour supply of the average individual of a *whole* cohort (*i.e.* $\ell_{t,a}$ such that $1-\ell_{t,a} = 1 - \nu_{t,a} \ell^*_{t,a}$).

65. Knowing the optimal paths ($\ell_{t,a}$) simplifies the computation of the optimal level of consumption of the average individual of a *whole* cohort. The values ($c_{t,a}$) are obtained by maximising the utility function of the average individual of a whole cohort, where the labour supply $1 > \ell_{t,a} = \nu_{t,a} \ell^*_{t,a} \geq 0$ is already known, *i.e.*:

$$U_{t,0} = \frac{1}{1-\sigma} \sum_{j=0}^{\Psi_{t,0}} \left[\frac{1}{(1+\rho)^j} \left[\left((c_{t+j,j})^{1-1/\xi} + \eta (H_j (1-\ell_{t+j,j}))^{1-1/\xi} \right)^{\frac{1}{1-1/\xi}} \right]^{1-\sigma} \right]$$

under the inter-temporal budget constraint:

$$y_{t,0} + \sum_{j=1}^{\Psi_{t,0}} \left[y_{t+j,j} \prod_{i=1}^{j} \left(\frac{1}{1+r_{t+i}} \right) \right] = c_{t,0} + \sum_{j=1}^{\Psi_{t,0}} \left[c_{t+j,j} \prod_{i=1}^{j} \left(\frac{1}{1+r_{t+i}} \right) \right]$$

where $y_{t+j,j}$ stands for the total income net of taxes of the average individual representative of a whole cohort, such that :

$$\begin{aligned} y_{t,a} &= \ell^*_{t,a} w_t \varepsilon_a \nu_{t,a} (1 - \tau_{t,D} - \tau_{t,P} - \tau_{t,H} - \tau_{t,NA}) + d_{t,NA} + \Phi_{t,a} \\ &= \ell_{t,a} w_t \varepsilon_a (1 - \tau_{t,D} - \tau_{t,P} - \tau_{t,H} - \tau_{t,NA}) + d_{t,NA} + \Phi_{t,a} \end{aligned}$$

66. In the above expression, $\Phi_{t,a}$ stands for the pension income received by the retirees of a cohort. It is proportional to their past labour income, depends on the age of the individual and on the age ψ_t at which an individual is entitled to obtain a full pension. Three cases may occur in the model:

1) No pension can be received before the age of 50: $If\;\;(a+20)<50\;\;\rightarrow\;\;\Phi_{t,a}=0$.
2) If an individual is above 50 but below the full-right retirement age ς_t, he or she can receive a pension reduced by a penalty. This penalty was assumed to be equal to 6 per cent per year,[14] which corresponds approximately to actuarial neutrality for current PAYG regimes. Thus:

   $$If\quad 50\leq(a+20)<\varsigma_t\quad\rightarrow\quad \Phi_{t,a}=\max\left(\ell_{t,a}p_t w_t \varepsilon_{\psi_t}\pi_{t,a}\left(1-\frac{\varsigma_t-20-a}{100/6}\right)\;;\;0\right)$$

   where p_t is the average replacement rate of the regime when retiring at age ς_t.
3) Finally, an individual will obtain a full pension if his or her age is above or equal to ς_t.

   $$If\quad (a+20)\geq\varsigma_t\quad\rightarrow\quad \Phi_{t,a}=\Phi_{t-1,a-1}\frac{\pi_{t,a}}{\pi_{t-1,a-1}}$$

   This implies that the pension of the average representative individual is flat over time (*i.e.* not wage-indexed), but is adjusted each year by the change in the number of pensioners in each cohort.

67. The optimal path for consumption stems from the Euler equation using a Lagrangian: $\frac{c_{t,a}}{c_{t-1,a-1}}=\left(\frac{1+r_t}{1+\rho}\right)^{\kappa}$ where the intertemporal substitution coefficient is equal to the inverse of the risk aversion ($\kappa=\sigma^{-1}$) parameter. The initial level of consumption $c_{t,0}$ (*i.e.* the level of consumption of a cohort of age 20 at year t) is obtained by plugging the Euler equation into the budget constraint:

$$c_{t,0}=\left(y_{t,0}+\sum_{j=1}^{\Psi_{t,0}}\left[y_{t+j,j}\prod_{i=1}^{j}\left(\frac{1}{1+r_{t+i}}\right)\right]\right)\Big/\left(1+\sum_{j=1}^{\Psi_{t,0}}\left[(1+\rho)^{-j\kappa}\prod_{i=1}^{j}(1+r_{t+i})^{\kappa-1}\right]\right)$$

68. This life-cycle framework also introduces a link between saving and demographics. In such a setting, the aggregate saving rate is positively correlated with the fraction of older employees in total population, and negatively with the fraction of retirees. When baby-boom cohorts get older but remain active, ageing increases the saving rate. When these large cohorts retire, the saving rate declines.

69. Having computed the optimal path of consumption for all the cohorts of the model, average individual saving ($s_{t,a}=y_{t,a}-c_{t,a}$) and individual wealth ($\Omega_{t,a}=(1+r_t)\Omega_{t-1,a-1}+s_{t,a}$) can be computed. The annual saving is invested in the capital market, yielding an interest rate r_t. The interest payments are capitalised into individual wealth.

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[14] This benchmark corresponds roughly to an actuarially fair penalty rate (see for instance Casey *et al.,* 2003).

Production function

70. The supply-side of the economy is modelled through a standard CES production function with two inputs, *i.e.* capital and efficient labour:

$$Y_t = \left[\alpha K_t^{1-\frac{1}{\beta}} + (1-\alpha)\left(A_t \bar{\varepsilon}_t \Delta_t L_t\right)^{1-\frac{1}{\beta}} \right]^{\frac{1}{1-\frac{1}{\beta}}}$$

where α is a technology parameter (equal to the share of capital revenue in aggregate value added for $\beta \to 1$), β is the capital/labour elasticity of substitution, K_t is the stock of productive capital in the business sector, A_t is an index associated with labour-augmenting multi-factor productivity, L_t is the total number of working individuals. $\bar{\varepsilon}_a = \sum_a \varepsilon_a \frac{\upsilon_{t,a} N_{t,a}}{L_t}$ is an average index associated with the effect of average age of employed individuals on average labour productivity. $\Delta_t = \sum_a \ell^*_{t,a} \frac{\upsilon_{t,a} N_{t,a}}{L_t}$ is the aggregate parameter corresponding to the average working time across working sub-cohorts in *t*. Thus $\Delta_t L_t$ corresponds to the total number of hours worked, and $A_t \bar{\varepsilon}_t \Delta_t L_t$ is the labour supply expressed as the sum of efficient hours worked in *t*. This labour supply is endogenous since the $\ell^*_{t,a}$'s (and thus Δ_t) are endogenous in the model. Labour market policies modifying participation rates can be taken into account through the $\upsilon_{t,a} N_{t,a}$'s which remain exogenous.

71. The production function can be written in an intensive form as $y_t = f(k_t) = \left(\alpha k_t^{1-\frac{1}{\beta}} + (1-\alpha) \right)^{\frac{1}{1-\frac{1}{\beta}}}$ where $k_t = K_t / A_t \bar{\varepsilon}_t \Delta_t L_t$ is the stock of capital per unit of efficient labour. Profit maximisation yields optimal factor prices: $r_t = \alpha k_t^{-\frac{1}{\beta}} \left(\alpha k_t^{1-\frac{1}{\beta}} + 1 - \alpha \right)^{\frac{1}{\beta - 1}}$ for capital, and $w_t = A_t (1-\alpha) \left(\alpha k_t^{1-\frac{1}{\beta}} + 1 - \alpha \right)^{\frac{1}{\beta-1}}$ where w_t is the real wage, gross of social contributions paid by households. In the long-run equilibrium, the growth rate of w_t equals TFP gains because both total labour force and the capital/labour ratio (in efficiency units) are constant. There is no depreciation of capital. Including this parameter would not change the dynamics of the model since equilibrium conditions stem from saving behaviour *net* of depreciation of capital. The price of the good produced by firms is normalized to 1 (*numéraire*). Inflation is abstracted from since this is a long-run model.

Aggregation and convergence of the model

72. In the aggregation block, capital supplied by households is $W_t = \sum_a \Omega_{t,a} N_{t,a}$. In other words, the representative stock of capital of every cohort is weighted by the size of each cohort in total population. The capital supply is normalised to 1 in the base year (*i.e.* 1989). Total efficient labour supply ($A_t \bar{\varepsilon}_t \Delta_t L_t$) is aggregated in the same way, taking account of the number of working individuals in each cohort at a given year, and is also normalised to 1 in 1989.

73. The intertemporal equilibrium of the model is dynamic: modifying the equilibrium variable (*i.e.* the endogenous interest rate or wage) in a given year changes the supply and demand of capital in that year and in any other year in the model, after as well as before the change. Numerical convergence applies to both $(\Xi_t)_d = K_t / A_t \bar{\varepsilon}_t \Delta_t L_t$ and $(\Xi_t)_s = W_t / A_t \bar{\varepsilon}_t \Delta_t L_t$, *i.e.* the demand and supply of capital per unit of efficient labour respectively. The convergence process begins with an educated guess for the demand of capital per unit of efficient labour $(\Xi_t)_d$. From this guess are derived successively r_t, w_t, $\omega_{t+j,j}$, $c^*_{t+j,j}$, $\ell^*_{t+j,j}$, $\ell_{t+j,j}$, Δ_t, $y_{t+j,j}$, $c_{t+j,j}$, $s_{t+j,j}$, W_t and eventually $(\Xi_t)_s = W_t / A_t \bar{\varepsilon}_t \Delta_t L_t$ which is the supply of capital by households per unit of efficient labour. A Gauss-Seidel convergence process is used so that $(\Xi_t)_d$ and $(\Xi_t)_s$ converge. A convergence parameter ζ is chosen so that, for $\zeta \to 0$ (typically $\zeta < 0.005$), one gets: $0 < \max\left|(\Xi_t)_d / (\Xi_t)_s - 1\right| < \zeta$. When the convergence process is completed, the equilibrium stock of capital per unit of efficient labour defines the equilibrium r_t and w_t associated with $W_t = K_t$ and L_t each year. With capital and labour markets clearing, Walras' law ensures that the market for goods is cleared too.[15]

[15] This result is ensured in the model because it requires respecting national accounts identities (*i.e.* investment equals saving and total value added equals the sum of the remunerations of production factors).

APPENDIX 2
DETAILED DESCRIPTION OF THE FOUR SCENARIOS

74. Four different scenarios of reforming public finances are considered. Scenario TU corresponds to tax financing. Scenario SU corresponds to containing public spending except health-related expenditure. The health system is balanced through higher taxes in scenario SU because this entitlement programme is presumably one where keeping spending stable as a ratio to GDP is most difficult in the face of ageing. In scenarios TR and SR, the effective retirement age rises gradually to balance the pension regime while taxes are hiked (TR) or non-ageing-related spending cut (SR) to reimburse the public debt.

Scenario TU: higher pension tax, debt reimbursed by taxes, higher health tax

75. In scenario TU, the PAYG pension regime is balanced each year through higher contribution rates ($\tau_{t,P}$). The replacement rate and retirement age remain unchanged. Cohorts perfectly forecast future increases in the contribution rate.

76. The stock of public debt accumulated in 2004 is equal to $B_{2004} = 71\%.GDP_{2004}$ and starts being paid back (service included) from 2005 until 2025 when public debt reaches zero. The rationale for zero debt by 2025 is that government gets its fiscal situation in shape just before the ageing pressures really materialise. Starting with a stock of debt of 60 per cent of GDP in 2025 would probably not be sustainable in this context and may thus not provide a helpful baseline. The rate on the debt is equal to the long-run equilibrium interest rate (r_t). In this scenario, the public debt is paid back thanks to an additional proportional tax $\tau_{t,D}$ levied on labour income and pensions between 2005 and 2025, such that:

$$\tau_{t,D} = \frac{B_{2004}/21 + r_{t-1}B_{t-1}}{\sum_a \left[\ell_{t,a} w_t \varepsilon_a v_{t,a} N_{t,a} + \Phi_{t,a}\pi_{t,a}N_{t,a}\right]} \qquad \forall t \in [2005;2025]$$

with $B_t = B_{t-1}(1+r_{t-1}) - \tau_{t,D}\sum_a \left[\ell_{t,a} w_t \varepsilon_a v_{t,a} N_{t,a} + \Phi_{t,a}\pi_{t,a}N_{t,a}\right]$ standing for the amount of public debt remaining in *t*. Households anticipate that they will have to pay $\tau_{t,D}$ on their labour income or pensions between 2005 and 2025.

77. The health regime is financed by a proportional tax ($\tau_{t,H}$) on labour income and is always balanced, such that:

$$\tau_{t,H} = \frac{\sum_a C_H h_{a,H} A_t N_{t,a}}{\sum_a \ell_{t,a} w_t \varepsilon_a v_{t,a} N_{t,a}} \qquad \forall t$$

where $h_{a,H}$ stands for the level of public expenditures for health and long-term care as a function of age *a*,[16] A_t is the total factor productivity index, and C_H is a constant of calibration such that $\tau_{2004,H} = 11\%$. As mentioned above, health expenditure is not modelled as a transfer adding to household income. Health expenditure does however contribute to the utility of households in the

16 See OECD (2006).

model, because it is a necessary item of spending to deliver the longevity profile underlying the simulations. In other words, the utility households derive from health expenditure is not higher income but living longer.

78. The non-ageing-related public expenditure are financed by a proportional tax of 18 per cent levied on (gross) labour income and pensions. Each individual in turn receives in cash a non-ageing-related public good $d_{t,NA}$, which does not depend on its age (by definition) and verifies:[17]

$$d_{t,NA} = \frac{\tau_{t,NA} \sum_a \left[\ell_{t,a} w_t \varepsilon_a v_{t,a} N_{t,a} + \Phi_{t,a} \pi_{t,a} N_{t,a}\right]}{\sum_a N_{t,a}} \qquad \forall t$$

Scenario SU: lower pension replacement rate, debt reimbursed by lower non-ageing-related public spending, higher health tax

79. In scenario SU, the tax rate financing pensions is frozen ($\bar{\tau}_{t,P}$) from 2005 on and the PAYG system is balanced thereafter by gradually decreasing replacement rates for *new* retirees. This motivates agents to increase their savings to sustain their consumption when retired.

80. The pension replacement rate after 2005 becomes endogenous and is computed, from 2005 onwards, using the recursive formula:

$$p_t = \frac{\bar{\tau}_{t,P} \sum_a^{\max(a,t)} y_{t,a} \chi_{t,a} - \sum_{a=\varsigma_t-19}^{\max(a,t)} p_{t+\varsigma_t-20-a} \varepsilon_{\varsigma_{t+\varsigma_t-20-a}} y_{t+\varsigma_t-20-a} \pi_{t,a} \chi_{t,a} \ell_{t+\varsigma_t-20-a,\varsigma_{t+\varsigma_t-20-a}}}{y_t \varepsilon_{\varsigma_t} \sum_{a=30}^{\varsigma_t-20} \left[\max\left(1 - \frac{\varsigma_t - 20 - a}{100/6}; 0\right) \pi_{t,a} \chi_{t,a} \ell_{t,a}\right]}$$

where $\chi_{t,a} = N_{t,a} / N_t$ and $\max(a,t)$ stands for the age of the oldest individuals living in year t.

81. The reimbursement of the public debt accumulated up to 2004 is financed by lowering non-ageing-related public expenditures. Thus $\tau_{t,D} = 0$ in scenario SU and the non-ageing-related public spending verifies:

$$d_{t,NA} = \frac{\tau_{t,NA} \sum_a \left[\ell_{t,a} w_t \varepsilon_a v_{t,a} N_{t,a} + \Phi_{t,a} \pi_{t,a} N_{t,a}\right] - B_{2004}/21 - r_{t-1} B_{t-1}}{\sum_a N_{t,a}} \qquad \forall t$$

82. Both reforms are announced in 2005 and households respond immediately. For each cohort, consumption before 2005 is the same as in the increasing contribution rate scenario, where households anticipate that PAYG system reforms and public debt reimbursement rely on tax hikes.

[17] With such a specification, the amount of non-ageing related public spending is indexed on TFP gains and thus remains constant as a per cent of GDP (neglecting some limited compositional effects). This non-ageing related public regime introduces some intra-cohort redistributional effects since the amount of taxes (in absolute terms) is not constant among individuals while the non-ageing related income $d_{t,NA}$ is.

When announced in 2005, households adjust their optimal consumption and leisure path over their lifetime. Thus the reform entails new optimal intertemporal paths for consumption and labour supply for each cohort over its remaining lifetime. For the working sub-cohort, the new optimal consumption path begins in 2005 at:

$$c^*_{2005,a} = \frac{(1+r_{2005})\Omega^*_{2004,a-1} + \omega_{2005,a} + \sum_{j=a+1}^{\Psi_{2005-a,0}} \left[\omega_{2005+j-a,a} \prod_{i=a+1}^{j} \left(\frac{1}{1+r_{2005+i-a}} \right) \right]}{1+\eta^{\xi}\omega^{1-\xi}_{2005,a} + \sum_{j=a+1}^{\Psi_{2005-a,0}} \left[\Xi_{2005+j-a,j} (1+\eta^{\xi}\omega^{1-\xi}_{t+j-a,j} H^{-1}_j \right]}$$

where $\Xi_{2005+j-a,j} = (1+\rho)^{-j\kappa} \left(\frac{1+\eta^{\xi}\omega^{1-\xi}_{2005+j-a,j}}{1+\eta^{\xi}\omega^{1-\xi}_{2005,a}} \right)^{\frac{\kappa-\xi}{\xi-1}} \prod_{i=a+1}^{j} (1+r_{t+i-a})^{\kappa-1}$.

83. Finally, the health regime is unchanged compared to scenario TU.

Scenario TR: higher retirement age, slightly higher pension tax, debt reimbursed by taxes, higher health tax

84. In scenario TR, a reform of the PAYG system is implemented which increases the legal age at which an individual can receive a full pension. In the model, the effective average age of retirement (ς_t) is thus raised by 1.25 years every 10 years, from 2005 onwards and until 2045. This order of magnitude is roughly in line with national forecasts of future life expectancy increases. It is assumed that age-specific participation rates of workers above 50 years of age increase in line with the changes in the age of retirement. For example, individuals work five years more in 2045 than in 2005 while benefiting from the same replacement rate. The residual imbalances of the PAYG regime are covered by changes in the tax rate ($\tau_{t,P}$). The replacement rate for new retirees (p_t) is unchanged. Households' information set is modified in 2005, entailing new intertemporal optimal consumption and labour supply paths for all living cohorts (see above).[18]

85. As in scenario TU, public debt is paid back thanks to an additional proportional tax $\tau_{t,D}$ levied on labour income and pensions between 2005 and 2025. The health regime and the non-ageing-related public expenditures system are unchanged compared to scenario TU.

[18] Incidentally, the two-steps resolution of the OLG model allows for taking account of the welfare cost associated with an increase of the retirement age. For individuals who remain in the labour force for a longer period of time due to the implementation of scenario TR, and who would have retired earlier in other scenarios, the optimal leisure time – *i.e.*, $1-\ell_{t,a} = 1-\nu_{t,a}\ell^*_{t,a}$ – diminishes significantly compared with the other scenarios. This is because the employment rates for older workers ($\nu_{t,a}$) are increased in the model in line with the increase in the retirement age ς_t. Using the distinction made by Saez (2002), the model takes account of the welfare costs associated with "extensive" variations of the labour force – through the ($\nu_{t,a}$)'s – as well as the costs deriving from "intensive" variations of the same labour force – through the optimal working time $\ell^*_{t,a}$.

Scenario SR: higher age of retirement, slightly lower replacement rate of pensions, debt reimbursed by lower non-ageing-related public spending, higher health tax

86. In scenario SR, the PAYG system is reformed and the average effective age for retirement is increased, as in scenario TR, by 1.25 years every 10 years from 2005 to 2045. Yet, in contrast with scenario TR, the residual imbalances of the PAYG regime are covered by changes in the replacement rate for new retirees (p_t) while the tax rate ($\tau_{t,P}$) remains unchanged from 2005 on. Households' information set is modified in 2005 and entails new intertemporal optimal consumption and labour supply paths for all cohorts (see above).

87. As in scenario SU, the public debt is financed by lowering non-ageing-related public expenditures. Thus $\tau_{t,D} = 0$ in scenario SR and the non-ageing-related public spending is diminished between 2005 and 2025 so as to pay back the public debt.

88. The health regime is unchanged compared to scenario TU.

89. Table 2 in the main text provides a summary view of the main features of the four scenarios.

APPENDIX 3
PARAMETERISATION, CALIBRATION AND SENSITIVITY ANALYSIS

90. The main exogenous variables in the model are the demographic data, for which the model needs a data set covering the period 1910-2158. Historical values for the period 1970-2000 are taken from national sources. For the period 1950 to 1970, annual total population growth is assumed to be 1.5 times its average annual growth for the period 1970-2000, in this way capturing the effects of the baby-boom shock. For the period 2000 to 2050 the national population projections are used. From 1910 to 1950, as well as after 2050, population level and structure by age groups are assumed to be constant.

91. The average life expectancies at birth for the cohorts born in the euro area ($\Psi_{t,0}$'s) are assumed to have increased by 2 years per decade during the 20th century, reaching close to 79 years in 2000. The growth in life expectancy decelerates in line with national projections of member countries over the projection period. After 2050, average life expectancy remains stable at 84 years.

92. The model is back to its long-run steady-state in 2080, when the economy returns to a stable population level and structure.[19] In this situation, GDP per capita growth is exclusively determined by the exogenous growth in TFP and capital deepening grows in line with TFP, at 0.45 per cent *per annum*.[20] By contrast, during the demographic transition, the dynamic equilibrium is driven by ageing and public finance reforms.

93. In the production function, K_t, L_t, ω_t and A_t are normalized to 1 in the base year of the model (1989). As in Miles (1999), there is no depreciation of capital, an assumption which has no consequence for the dynamics of the model and the equilibrium interest rate in a model with perfect competition. The annual growth rate of A_t associated with TFP gains incorporated in labour productivity in the long run (Acemoglu, 2000) is set to 1.5 per cent for all countries. This parameter should be distinguished from the age-productivity profile $\varepsilon_a(a)$ which describes the amount of efficient labour per hour worked depending on the age (a) of the worker. Lastly, the model does not attempt to trace effects of ageing on TFP and possible endogenous growth effects.

94. The capital returns/value added ratio (*i.e.* the profit share) (α) is set at 0.3 for all countries. In models incorporating a depreciation rate (Börsch-Supan *et al.*, 2003), the value for this parameter is usually higher (*e.g.* 0.4) corresponding approximately to the ratio (gross operating surplus/value added including depreciation) in the business sector. Assuming this figure of 0.4 and a standard depreciation rate as a per cent of added value of 15 per cent yields a net profit ratio of around 0.3. This is close to Miles (1999), who uses 0.25.

95. The elasticity of substitution between capital and labour is assumed to tend to 1. Thus the production function in the model is a Cobb Douglas function. A wide but still inconclusive empirical literature has attempted to estimate the elasticity of substitution between capital and labour in the CES production function. On average these studies suggest a value close to 1.[21]

[19] Sensitivity analysis shows that the results are robust to the date chosen for the long-run steady state. For instance pushing it back to 2100 does not alter the results much.

[20] Given that the capital to labour ratio (defined in efficiency units) *K/TFP.L* is constant in the long-run, the growth rate of the (*K/L*) ratio is equal to TFP growth. Therefore, in the steady state, the expression $\alpha_k(k-l)$ is equal to 0.45 per cent *per annum* (assuming a capital share of 30 per cent and TFP growth of 1.5 per cent *per annum*).

[21] Andersen *et al.* (1999) use a panel of 17 OECD countries from 1966 to 1996 to estimate a value of 1.12. This study estimates a CES production function with a Hicks-neutral technical progress, whereas in this model the function has a labour-augmenting technical progress. Yet no estimates for a wide range of countries of the elasticity of substitution of a CES function with a labour-augmenting technical progress are available (see Klump *et al*., 2004).

Sensitivity analysis suggests that choosing an elasticity of 0.8 would have changed the results only marginally.

96. The households' psychological discount rate was set at 2 per cent per annum, in line with much of the empirical literature. Different methods can be used to estimate this parameter. Analytical models, such as that by Gallon and Masse (2004), suggest using a discount rate between 2 and 3 per cent in real terms. Alternatively, econometric models like that of Gourinchas and Parker (2002) suggest a value around 3 per cent.

97. The variable ς_t is used in the model as a proxy for the length of the average working life and is approximated here by the average retirement age in each country at year t.[22] The average effective age of retirement in the euro area is currently close to 61 years.

98. The level of the average replacement rate (p_t) is computed as the ratio of pensions received per capita over gross wages received per capita in 2000. This is in line with the model's specification. This parameter is used as a proxy for the generosity of the pension system. The weighted average replacement rate for compulsory pension regimes is around 62 per cent in the euro area (OECD, 2005*b*). While other values for replacement rates would modify baseline levels (notably the saving rate and the capital/income ratio, the dynamics in simulations would not be substantially modified as suggested by sensitivity analysis (see below).

99. The risk-aversion parameter σ in the CRRA utility function is assumed to be equal to 1.33 (implying an intertemporal substitution elasticity of 0.75). This parameter assesses the intensity of the relative risk aversion or equivalently the inverse of the inter-temporal substitutability coefficient. A standard result in financial and behavioural economics is to consider this parameter as greater than 1 (see Kotlikoff and Spivak, 1981). Börsch-Supan *et al.* (2003) use a risk aversion parameter of 2.7, but this choice results from the specific calibration of their model to reproduce observed orders of magnitude around the base year. Such a high value might account for the relative insensitivity of saving behaviour to interest rate variations in their model and thus might bias the results. Kotlikoff and Spivak (1981) use 1.33. Epstein and Zin (1991) suggest values between 0.8 and 1.3 while Normandin and Saint-Amour (1998) use 1.5.

100. The model is calibrated on an interest rate of 3.5 per cent in the base year, corresponding to the sum of TFP gains and the discount rate, as suggested by life-cycle theory. Contrary to other studies, the model is not calibrated on some technical parameters (*e.g.* the relative aversion to risk) so as to reproduce broadly observed variations in the stock of capital around the base year. This procedure can indeed bias the results, as mentioned above.[23]

101. The value of the elasticity of substitution between consumption and leisure in the instantaneous utility function ($1/\xi$) tends to 1. Thus the instantaneous utility function is (almost) of Cobb-Douglas form. With this value, the model maintains a constant split of available time between work and leisure in the steady state after 2080. Setting another value would introduce a trend in the average working time, with the implication that it would converge to either 0 or 1 in the long run – an undesirable feature for the long-run equilibrium.

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22 Strictly speaking, ψ_t is defined in the model as the age at which an individual who begins to work at 20 will be able to obtain a full pension at year *t*. Yet finding an aggregate value for ψ_t thus defined would require ignoring potentially important microeconomic factors.

23 A lower value for the interest rate in the base year (*i.e.*, 1989) would slightly dampen the intensity of capital deepening.

102. The model is calibrated on the value of the preference for leisure relative to consumption (η), which is set at 0.25. This value delivers realistic labour supply profiles for cohorts taking account of weekly average working hours, weekends and unavoidable activities (including sleeping). With this value, the model generates an average working time per employee in line with standard assumptions (working 37 hours per week, 5 days per week, 48 weeks out of 52 per year, with 16 hours per day unavailable for working activities in relation with, *e.g.* sleeping, eating, commuting, family life etc…).

103. The values of $\tau_{t,P}$ (the tax rate financing the balanced pension regime), $\tau_{t,H}$ (the tax rate financing the balanced health care system) and $\tau_{t,NA}$ (the tax rate financing the non-ageing-related public expenditures system) are chosen in 2004 – the year preceding the implementation of the reforms in the model – so that total taxes amount to 49 per cent of GDP and the breaking up between the three types of public spending (financed by $\tau_{t,P}$, $\tau_{t,H}$ and $\tau_{t,NA}$) is in line with the national accounts. This method yields the following contribution rates, expressed in percentage of each relevant tax base: $\tau_{2004,P}$=10.4% ; $\tau_{2004,H}$=5.9% and $\tau_{2004,NA}$=32.0%.

Sensitivity analysis

104. In order to test the robustness of model results to alternative specifications and parameter values, extensive sensitivity analysis was carried out. Some results of this sensitivity analysis – on an earlier version of the model with an exogenous labour market (*i.e.* with $\eta = 0$), no health regime, no public debt and no ageing-related public spending – are given in Oliveira Martins *et al.* (2005). Overall, the dynamics of the results appear relatively robust to changes in some key parameters (the capital share in value-added α, the risk-aversion coefficient σ, the age-individual productivity function $\varepsilon_a(a)$, the elasticity of substitution between capital and labour β and the discount rate ρ). Joint sensitivity analysis was also carried out. Other sensitivity analysis on the parameter of preference for leisure relative to consumption (η) also suggests that the dynamics of the model is fairly robust to its parameterisation – provided, of course, that parameters remain in realistic ranges. Details are available on request.

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