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This paper examines the impact of public debt and population ageing on medium-term growth. In many EU countries, public debt rose significantly following the financial crisis and the persistent weakness of economic growth will probably stretch fiscal consolidation efforts into the medium term. This will overlap with the economic and financial challenges raised by rapidly ageing populations, which will lower potential growth and increase pressure to reform public pension systems based on the pay-as-you-go principle. Applying a variety of macro-economic models, this paper produces the following main findings (i) a sustained fiscal consolidation could boost annual real growth by 0.5% on average over the period to 2020, (ii) raising labour force participation rates to meet EU2020 targets could increase annual growth by 0.1% on average over the period to 2030, (iii) reforms to pension benefits can mitigate the tax increase required to finance pay-as-you-go systems in ageing economies, raising annual growth in GDP per capita by 0.2%–0 .5% on average over the period to 2040.

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Section 2 evaluates the impact of fiscal consolidation on medium-term growth in EU countries. The ECB's new Multi-Country Model (NMCM) is used to construct plausible medium-term scenarios extending to 2020. Separate simulations for the main country blocks of the NMCM analyse the impact of a harmonised fiscal consolidation effort. Results indicate heterogeneous effects of fiscal consolidation across the main euro area countries, reflecting different estimates of consumption and investment sensitivity as well as speed of adjustment in labour and product markets, but also different initial debt levels and differences in size/openness (and therefore competitiveness effects). The sovereign risk channel suggests that reductions in risk premia may help to attenuate the contractionary effect of fiscal consolidation. If policy is credible and sovereign bond yields fall in response to declines in the public debt-to-GDP ratio, this channel can be strengthened by forward-looking financial markets, as these will anticipate announced reductions in debt. The effect remains significant even if there is only imperfect pass-through from sovereign yields to the financing conditions faced by households and firms.

Section 3 adopts a longer-term perspective, focussing on the impact of population ageing. The standard growth accounting framework is extended to disaggregate the labour input into different categories (by age, sex, citizenship and education). This disaggregated approach emphasises that population ageing will generate a composition effect on the average labour participation rate, lowering the contribution of labour to potential growth. An illustration with Italian data indicates that migration assumptions can be crucial to determine medium-term potential growth. The proposed approach can also assess the impact on potential growth of structural reforms aimed at raising participation rates in specific segments of the population (e.g. women or older workers).

Section 4 extends the analysis of ageing from the partial equilibrium perspective of growth accounting to a general equilibrium framework. Three National Central Banks (NCBs) of the euro area have adapted OLG macro-models to study demographic change. Although calibrated to different countries (Portugal, Luxembourg and Finland), these models are simulated using a harmonised demographic shock designed to compare the impact on medium-term growth of different policy responses. Responding solely through higher social contributions/labour taxes will require unrealistic adjustments and lower medium-term growth. A 2-year increase in the retirement age reduces pension costs and increases social contributions, but the increase in taxation required to stabilise public debt remains unrealistic and continues to lower medium-term growth substantially. When these measures are combined with a reduction in pension replacement rates, labour supply rises and the impact on growth is mitigated. It is also possible to raise consumption taxes to limit

the required increase in social contributions/labour taxes, further boosting medium-term growth.

To summarize the conclusions of this paper, despite considerable heterogeneity across EU countries, medium-term growth prospects are weak given the challenges posed by high public debt and ageing populations. The NMCM simulations suggest that credible fiscal consolidation can improve growth prospects, especially since countries with high initial debt levels can potentially benefit from sharp reductions in the sovereign risk premium. The growth accounting analysis quantifies the effect of ageing populations on medium-term growth, with a focus on how structural reforms to raise labour participation rates can boost labour input. The DSGE simulations suggest that current public pension systems based on the pay-as-you-go principle will become unsustainable as the population ages, requiring appropriate reforms to address this challenge. Structural reforms to improve the functioning of labour and product markets can contribute to improving medium-term growth prospects.

The paper carries three main implications for economic modelling. First, the international perspective is important (there can be international spillovers through labour and capital markets as well as through trade). Second, agent heterogeneity should not be neglected (composition effects on labour participation can affect aggregate outcomes). Third, models need to analyse the interaction between different policies.

The paper also contains several policy implications. There is substantial evidence that higher public debt impairs long-term economic growth. Empirical estimates suggest a critical debt threshold around 90% of GDP, but it is important to keep debt well below this level to provide sufficient "fiscal space" to counter adverse shocks. Since several Member States have seen debt increase rapidly since the crisis, action is required to return to debt levels that do not hinder medium-term growth. In the medium-term, the sovereign risk channel may foster growth by lowering risk premia in response to current efforts at fiscal consolidation. However, this requires financial markets to perceive fiscal commitments as credible and pass through lower sovereign yields to the financing conditions faced by firms and households. Population ageing will also pose a substantial challenge to controlling debt and maintaining medium-term growth. The projected drop in revenue and explosion in expenditures from public pension systems will require substantial reform. At the European level, fiscal policy coordination and greater labour migration may help the transition. However, pension reforms must combine several different policy measures. Although increases in social contributions/labour taxes may be politically attractive, they cannot bear all the adjustment without creating perverse incentive effects, lowering labour supply and medium-

term growth. A combination of measures with offsetting effects is required since agents will adjust their behaviour in general equilibrium.

Contents

1. Introduction

In many EU countries, the return to sustainable public finances will require fiscal consolidation over an extended period and might affect prospects for medium-term growth. This may overlap with the new challenges associated with demographic ageing in the medium-term. This paper presents three applied chapters covering (a) medium-term fiscal consolidation scenarios up to 2020 using the ECB New Multi-Country Model, (b) long-term growth accounting exercises up to 2032 disaggregating labour input to analyse the impact of ageing and structural reforms, (c) analysis of reforms to pay-as-you-go public pensions using dynamic general equilibrium models that incorporate demographic features within the New Open Economy framework.

Box 1 below provides a survey of the theoretical literature on general equilibrium effects of debt on economic growth and welfare. Section 2 on medium-term fiscal consolidation includes Box 2, which surveys empirical research on debt thresholds and Box 3, which reviews the empirical literature on risk premia and sovereign bond yields. Section 3 on growth accounting exercises with disaggregated labour input includes Box 4, which reviews the literature on structural reforms and their impact on economic growth. Finally, Section 4 on ageing in dynamic general equilibrium models includes Box 5, which surveys the broader literature on ageing, welfare and pensions in general equilibrium.

Box 1: Research on general equilibrium effects of public debt on output and welfare[1]

In a closed economy general equilibrium, forward-looking agents may anticipate that an increase in government debt will be accompanied by future tax increases. Therefore, if the conditions for Ricardian equivalence hold, increases in government debt will not affect agent decisions. In the real world, a variety of factors can account for the failure of Ricardian equivalence: agents plan on finite horizons (Poterba and Summers (1987)), market imperfections (i.e. liquidity constraints) prevent them optimising on an infinite horizon and taxes distortions imply that postponing the tax burden will have economic effects[2]. Empirical studies (see Bernheim (1987), Seater (1993), or Heathcote (2005)) provide evidence that these mechanisms are important, explaining why government debt does affect economic decisions, generating feedback effects between debt and growth.

[1] Prepared by Edgar Vogel.

[2] Elmendorf and Mankiw (1999) summarize the literature on the theoretical effects of government debt.

General equilibrium effects of debt on output are usually modelled by combining heterogeneous agents and incomplete markets to produce uninsurable idiosyncratic risk as in Aiyagari (1994) or Huggett (1993). Agents are initially identical but are subject to different labour market shocks over time, so that heterogeneity is not imposed ex ante but reflects endogenous household decisions. Capital market imperfections impose a borrowing constraint on agents, who find they cannot buy insurance against idiosyncratic risk. Therefore they accumulate assets to insure themselves against the possibility of a long series of negative labour market shocks. Most models assume no aggregate uncertainty so that the rate of return is constant.

In this context, government debt affects output via (i) changes in the government's budget constraint (affecting public spending or taxation) or (ii) changes in capital intensity (affecting wages and interest rates). Within the latter channel, Flodén (2001) distinguishes three channels by which government debt can affect factor prices.

1. **Level effect**: increasing government debt crowds out capital, lowering output and wages and raising interest rates. Other things equal, this has a negative welfare effect. Higher interest rates increase private incentives to save, but not enough to maintain the same level of private capital while also covering additional government financing requirements. Therefore aggregate capital stock (and output) will be lower in the new equilibrium even though private agents save more.
2. **Insurance effect**: higher government debt raises interest rates but lowers wages, reducing the share of private income subject to idiosyncratic shocks. In principle, this makes total lifetime income safer, reducing risk and therefore private savings (positive welfare effect).
3. **Redistribution effect**: changing factor prices also affect the income composition of the economy. Higher interest rates raise the return on saving (positive welfare effect), but the lower capital stock reduces wages (negative welfare effect). A priori, it is unclear which effect dominates.

To sum up, incomplete market models with heterogeneous agents give rise to complex effects of debt on welfare, so it is not surprising that the quantitative literature is inconclusive. Two effects are clear at the aggregate level: more government debt crowds out capital and lowers aggregate output.

In an early contribution, Aiyagari and McGrattan (1998) calibrate a model to US data and find that welfare effects of increasing government debt are in general very low. They estimate that welfare is maximized when government debt is around 66% of GDP and that deviations in either direction have only negligible welfare effects, so there is little incentive to change policy. Flodén (2001) confirms this finding but also shows that government debt can in-

crease welfare if transfers are relatively low (around 10% of GDP). He suggests that increasing debt can have positive welfare effects because it offsets inefficiently high precautionary savings, since credit constraints are relaxed by higher interest rates. However, the government could improve risk sharing (with less need for self-insurance) by increasing transfers to provide insurance directly. Higher transfers reduce the positive welfare effect from higher interest rates, but the increase in tax distortions then means that instead of accumulating debt governments should accumulate assets, which would increase the capital stock, output, and wages. Flodén (2001) finds that a government that jointly chooses its level of debt and transfers to maximise welfare should accumulate an asset stock (negative debt) of about 100% of GDP and set transfers around 23% of GDP. In another paper, Flodén and Lindé (2001) show that income uncertainty also plays a role. Comparing the US with Sweden, they find that in the US, where the labour market is risky, the benefits of government insurance dominate the costs of tax distortions. The opposite is true in Sweden, where labour markets are less risky.

Dávila, Hong, Krusell, and Ríos-Rull (2012) stress that aggregate welfare effects also depend on the distribution of income and wealth across the population. If asset ownership is concentrated on few households, then only a minority will benefit from higher debt while most households will suffer. The few households who hold assets will benefit both from the insurance effect (since public debt provides a liquid and high-return asset for self-insurance) and from the redistribution effect (since their interest income will rise with interest rates). However, the majority of households will enjoy neither of these benefits since they do not hold assets, and they will actually suffer from the redistribution effect as wages fall. In addition, all households will suffer from the level effect since higher debt lowers the capital stock and therefore output. Dávila et al. (2012) conclude that reliable quantitative estimates require matching the observed distribution of income and wealth.

Röhrs and Winter (2012) attempted to explicitly match the wealth and earnings distribution of the US economy, where a very small share of the population accounts for most of the wealth. After accounting for the empirically observed skew in the distribution of income and wealth, the result in Aiyagari and McGrattan (1998) is reversed. This is because Aiyagari and McGrattan used a stochastic income process that generates very little dispersion, so their economy is populated by many "average" agents holding some asset and earning "average" wage income. In these conditions, the effect of higher interest rates and lower wages roughly cancel, attenuating the welfare effect of changing debt. When income and wealth are concentrated on a minority of households, Röhrs and Winter find that public debt has large negative welfare effects, implying that the government should save to accumu-

late assets (they estimate the optimal level of public sector assets at 50% of GDP if debt is financed by changes in capital taxation and 110% of GDP if financed by changes in labour taxation). However, Röhrs and Winter (2012) recognise that this may not be politically feasible since the welfare change is negative along the transition to that optimum. Given that wealth is concentrated in the hands of a few, they observe that the most practical way to reduce debt is to raise capital taxes and lower labour taxes.

On the other hand, Desbonnet and Weitzenblum (2012) find that if the optimal level of debt is positive then the transition to higher debt levels generates additional welfare gains. First, freed resources can raise consumption. Second, distortions can be reduced by cutting tax rates along the transition path. Third, a temporary drop in labour taxes will stimulate labour supply and households enjoy temporarily higher wages. Because of the higher labour supply, interest rates "overshoot" their long-term level, temporarily raising the return on savings. As short-run benefits from higher debt materialize immediately but welfare losses from overshooting the long-run steady state are discounted, the welfare-maximizing debt level is much higher than if we only compare initial and final steady states. This explains why even benevolent governments could have an incentive to raise debt above the long-run optimum.

Desbonnet and Kankanamge (2011) added aggregate risk to the incomplete markets framework with idiosyncratic risk. With this modification, they find an optimal level of debt around 5% of GDP. In their model, the government smoothes consumption over the business cycle by adjusting public expenditure (which does not provide utility) instead of debt. This removes the insurance effect of debt, which therefore only crowds out capital and affects factor prices. Eliminating aggregate shocks, the optimal debt level drops to about 2% of GDP. This reflects the fall in risk once interest rates become deterministic, which reduces the need for savings as insurance. This also means that the higher rate of return on assets is less important. The main shortcoming of this paper is that labour supply is exogenous, which deprives agents of an additional margin of adjustment when they approach their credit constraint or when wages are temporarily high. This restriction artificially boosts the role of interest rates as the "price of self-insurance".

Shin (2006) introduces idiosyncratic risk and incomplete markets in the framework of Lucas and Stokey (1983) or Aiyagari, Marcet, Sargent, and Seppälä (2002). In this setup, the government uses debt to minimize tax distortions over time while agents hold assets to self-insure against bad labour market outcomes. Thus both agents and the government have a precautionary savings motive. There is only one risk-free bond with a maturity of one year. In this setting, a trade-off appears between tax distortions and self-insurance:

the government wants to hold assets and keep distortions constant (i.e. adjust debt instead of taxes to offset shocks) but this lowers the equilibrium interest rate, reducing private self-insurance. The question is who should provide insurance against income risk: agents via savings or government via smoothing distortions? In a representative agent context, Shin finds that the government should accumulate assets (consistent with Lucas and Stokey (1983)). However, in a heterogeneous agent framework, Shin concludes that the government should issue debt. This is because if individual uncertainty is combined with aggregate shocks then agents are best placed to insure themselves and the rate of return should be higher (debt should crowd out capital). Instead, when risks are identical across agents (no heterogeneity) it is more efficient to keep distortions constant (government should have negative debt). However, this result is derived in a highly stylized model designed to focus on the most important channels, so the quantitative findings need to be interpreted with caution.

In summary, the main result from this literature is that public debt crowds out capital, raises interest rates and lowers wages and output. Public debt can also have positive welfare effects, as it provides a safe asset for self-insurance against idiosyncratic risk and because higher interest payments will favour households who hold assets. Therefore, on balance the effect of debt on growth is theoretically ambiguous. However, since asset-holding is usually concentrated on a minority of the population, the positive welfare effects are probably limited. Models calibrated to match the observed skew in the distribution of income and wealth suggest that the optimal level of debt is negative (governments should accumulate assets) or at least close to zero. Given the unequal distribution of assets, government should consider providing other insurance mechanisms, for example through transfers. The optimal level of debt is also negative if governments seek to smooth tax distortions over time, since they will require an asset buffer to offset adverse shocks.

Although current debt levels may be above the optimum, decreasing debt involves short-term welfare losses that create a political obstacle. Even in models where the optimal long-run level of public debt is negative, short-run losses of debt consolidation may exceed discounted long-run gains, inducing myopic governments to accumulate debt.

2. Medium-term scenarios: fiscal consolidation and sovereign risk channel[3]

This section presents medium-term scenarios constructed with the ECB New Multi-Country Model (NMCM). It then compares this baseline to scenarios including fiscal consolidation, focussing on the impact on real GDP growth and the government debt-to-GDP ratio. Additional simulations explore the impact of the sovereign risk premium channel, by which fiscal consolidation may lower borrowing costs, and examine the sensitivity of results to alternative assumptions on the pass-through of lower interest rates to private sector financing conditions. Box 2 reviews empirical research estimating debt thresholds and Box 3 reviews research on risk premia and sovereign bond yields.

2.1. Model-based medium-term scenarios

Given the high levels of government debt in some countries, an extended period of fiscal consolidation may be required before the debt-to-GDP ratio is lowered significantly. This has triggered a growing debate on the effects of fiscal austerity on growth. To some degree, disagreement may reflect different outcomes across countries that could be attributed to different structural factors or differing states of the economy. However, some of the differences may be explained by the complex interaction between debt ratios, interest rates and growth. The larger the size of public sector debt (relative to GDP) the more financial markets will be concerned about its sustainability, raising the risk premium and the costs of debt financing and therefore depressing GDP growth. Worsening growth perceptions may also feed back onto interest rates, driving up the risk premium. However, once agents anticipate improvements in the debt-to-GDP ratio, this relationship can also run in reverse, with risk premia falling and interest rate reductions supporting output growth.

In this section we assess the macroeconomic impact of fiscal consolidation in euro area countries, and how these effects can vary depending on the response of the sovereign risk premium and its transmission to private financing conditions. Such an exercise requires a plausible medium-run baseline beyond the standard 3-year projection horizon, which is provided by the ECB's New Multi-country Model. Some medium-term fiscal consolidation scenarios illustrate the macroeconomic impact in euro area countries. In this context, a full macroeconomic model offers a number of advantages:

[3] Prepared by Alistair Dieppe and Alberto González Pandiella with input from T. Warmedinger.

- the analysis can be benchmarked against the long-run properties of the model,
- general equilibrium effects (inter-relations across variables) are accounted for,
- alternative assumptions can be compared,
- treatment can be harmonised across countries.

The ECB's New Multi-country Model is documented in Dieppe et al. (2013). It is a large-scale estimated model which covers Germany, France, Italy, Spain, and the Netherlands along with an additional block, referred to as "small countries block" which aggregates the remaining euro area countries. The underlying framework assumes optimising agents form expectations according to a learning rule that is consistent with the model and has stable properties.

Medium-run analysis in macro-models typically starts from the so-called Balanced Growth Path (BGP), a steady-state equilibrium in which major aggregates grow at the same rate over time and the real interest rate is constant. The BGP requires very strong assumptions (e.g. only labour-augmenting technical progress, stationary capital-output ratio and constant factor shares) which unfortunately are not consistent with the data. Nevertheless, the BGP remains a useful theoretical concept to ensure stability and consistency of the long-run baseline.

The NMCM treatment of the supply side allows realistic medium-run fluctuations in income shares while ensuring long-run convergence to the BGP. This is because the estimated elasticity of substitution in the CES production function is below unity, but cross-equation restrictions ensure asymptotic stability. The explicit modelling of the medium run makes the NMCM particularly suitable to study scenarios extended over longer periods.

In the long-run BGP, real growth in GDP and components matches the sum of growth in labour force and in productivity. Foreign and domestic inflation are both 2%, and wages grow at the inflation rate plus productivity growth. The NMCM is inverted on this path to derive an extension that is consistent with the long-run BGP.

The NMCM can then produce a medium-term projection which eventually converges to the BGP. In order to reach such a convergence path, total factor productivity (TFP) developments onwards are assumed to be such that the output gap closes by 2023. This was implemented via higher TFP growth

rates than those in the pre-crisis period, particularly for Spain and Italy[4]. The key (exogenous) assumptions are extended until 2020. In particular, world demand, competitor import and export prices, oil prices and short and long-term interest rates are taken from the IMF World Economy Outlook projections. The euro exchange rate is kept fixed. All simulations are run in single-country mode (neglecting trade spill-overs)[5]. National labour force assumptions are taken from the European Commission's medium-term outlook. A national fiscal rule (described in the annex I) is activated to keep the debt-to-GDP ratio stable[6].

These assumptions imply convergence to a country-specific BGP over the long-run, but allow deviations over the next 10 years (the period of interest). For each of the big-5 countries and the "small countries" bloc, Figures 1 to 3 report the average projected debt-to-GDP ratio and average real and nominal GDP growth over the five year period, 2016–2020, and compares with the 5 year period prior to 2008. The debt-to-GDP ratio is higher in all countries except Germany reflecting that the fiscal rule in this scenario is activated to keep debt-to GDP ratio stable. Conditional on the underlying assumptions, average real GDP growth in this scenario is below pre-crisis levels for all countries. However, Euro area nominal GDP is broadly in line with the pre-crisis average, implying that average euro area inflation is above 2%. It is important to stress that this conditional projection is only meant to represent one possibility from the set of plausible paths. Of course, changes in key underlying assumptions (trends in TFP or labour force, external growth, and external inflation) will modify the medium-term baseline[7]. Therefore, the baseline is only intended to serve as a benchmark to compare alternative scenarios in terms of the impact of different assumptions.

Below we focus on a fiscal consolidation scenario and illustrate the sensitivity of medium-term growth to the sovereign risk premium, its effects on private financing conditions, and forward-looking behaviour in financial markets.

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[4] A more conservative scenario could be to extend historical TFP trends over the medium-term horizon, which could be interpreted as a scenario of no change and of limited effects of structural reforms on TFP. Another alternative could be the convergence of technological progress across countries based on the premise of technology transfer and a catch-up to the technological frontier

[5] Convergence among euro area countries to a common BGP is left for later work.

[6] In the baseline, direct taxes paid by households adjust to stabilise the debt-to-GDP ratio. Other fiscal variables are linked to nominal GDP. Interest payments depend on the level of the debt and the effective interest rate paid on government debt.

[7] The two following sections focus on issues surrounding the medium-term labour input assumptions. TFP assumptions are linked to the literature survey on structural reforms in Box 4.

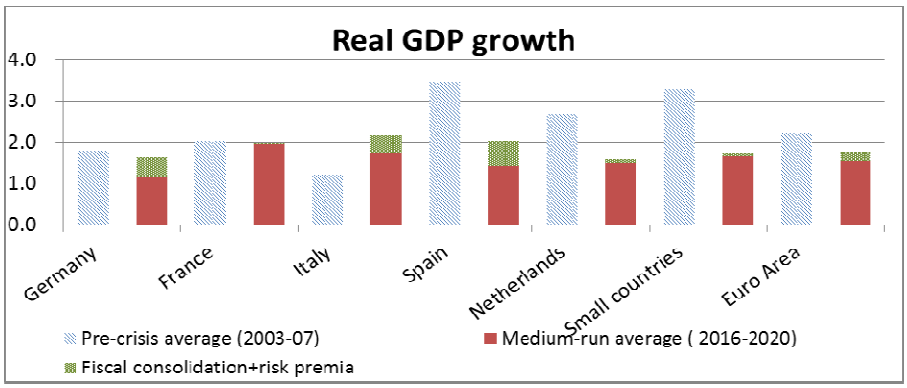


Figure 1: NMCM scenarios – average real GDP growth

Note: Scenarios are based on mechanical simulations of the NMCM without any additional judgement.

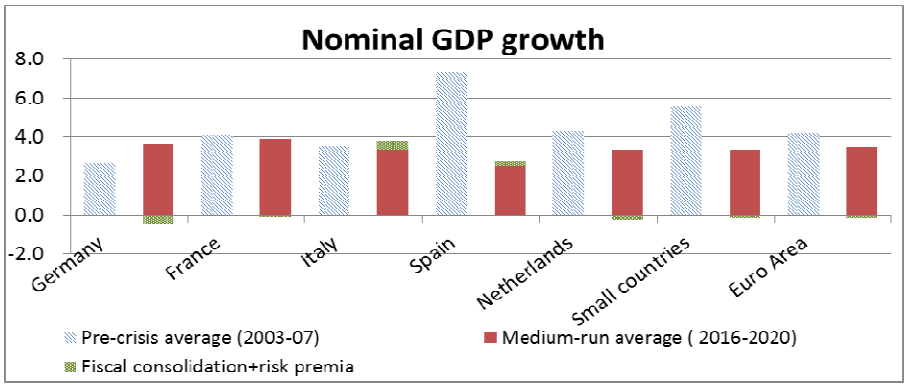


Figure 2: NMCM scenarios – average nominal GDP growth

Note: Scenarios are based on mechanical simulations of the NMCM without any additional judgement.

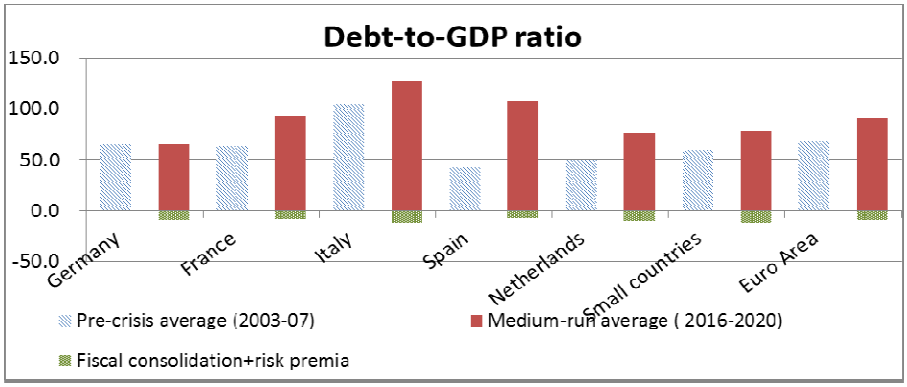


Figure 3: NMCM scenarios – average government debt-to-GDP ratios

Note: Scenarios are based on mechanical simulations of the NMCM without any additional judgement.

2.2. Fiscal consolidation scenarios

To assess the medium-run implications of further fiscal consolidation across countries, we consider a standardised consolidation measure which represents a 2% of GDP adjustment every year. The same fiscal consolidation effort is considered in all country blocks to make results more comparable. In order to put this into context, the EU fiscal compact envisages a target annual reduction of 1/20th of the debt in excess of 60% of GDP. Therefore, a fiscal consolidation representing 2% of GDP would be required for a country with a 100% debt-to-GDP ratio. However, the fiscal compact would require larger fiscal consolidation effort for Italy because of its higher initial debt-to-GDP ratio and a lower effort for Germany or France.

The additional fiscal consolidation is assumed to start in 2012 and continue to the end of the simulation[8]. In order to make the results comparable across countries, the previous fiscal rule (targeting a constant debt-to-GDP ratio) is replaced by one that imposes an ex ante 2% of GDP adjustment each year, even if the debt-to-GDP ratio drops below 60%. Since fiscal contraction via reduced expenditure or increased taxation has different macro-economic effects, the consolidation scenario is implemented by reducing government consumption by (ex-ante) 1% of GDP and increasing direct labour taxes by (ex-ante) 1% of GDP. An increase in consumption taxes would have a similar effect since the NMCM does not capture labour supply effects, but higher taxes affect output via a reduction of personal disposable income.

Table 1 shows the cumulated effects on nominal and real GDP as well as the debt-to-GDP ratio over a 1, 3 and 6 year horizon. The first year effects on real and nominal GDP are negative, mostly reflecting the direct effect of the expenditure cuts. This causes an initial increase in the debt-to-GDP ratio given the fall in nominal GDP. Work by the European Commission[9] demonstrates that this counter-intuitive short-term increase in debt-to-GDP ratio depends on the level of debt as well as the short-run fiscal multipliers[10].

[8] Agents in the NMCM do not know the duration of the consolidation effort in advance but learn it over time. Learning is faster in some countries, mainly affecting the dynamics but also explaining some cross-country differences in the medium-run.

[9] Special topics II.1 and II.2 in Quarterly Report on the Euro Area, Vol. 11, No. 3 (2012).

[10] Learning effects in the NMCM mean that short-run multipliers depend on the state of the economy as well as the policy instrument used for fiscal consolidation.

Table 1: Medium-run effects of fiscal consolidation – cross-country

	Germany			France			Italy			Spain			Netherlands			Small countries			Euro Area		
	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs	1 Yr	3 Yrs	6 Yrs
Real GDP																					
Fiscal consolidation	-1.5	-1.0	-0.2	-1.0	-1.1	-1.1	-1.0	-1.1	-0.7	-1.4	-1.7	-0.9	-1.2	-1.0	-1.2	-0.9	-0.8	-0.6	-1.2	-1.1	-0.7
+ and risk premia	-1.5	-1.0	-0.2	-1.0	-1.0	-1.0	-1.1	-1.0	0.3	-1.4	-1.6	-0.5	-1.2	-1.0	-1.2	-0.9	-0.7	-0.5	-1.2	-1.0	-0.4
+ and forward risk premia	-1.5	-0.9	-0.2	-1.0	-1.0	-1.0	-0.2	0.6	1.0	-1.1	-0.8	1.0	-1.2	-1.0	-1.2	-0.9	-0.7	-0.5	-1.0	-0.6	-0.1
Nominal GDP																					
Fiscal consolidation	-1.6	-2.7	-4.1	-1.3	-2.0	-2.2	-1.2	-2.3	-3.0	-1.9	-3.7	-5.2	-1.6	-1.8	-2.3	-1.1	-1.4	-1.6	-1.4	-2.3	-3.1
+ and risk premia	-1.6	-2.7	-4.0	-1.3	-2.0	-2.1	-1.3	-2.2	-1.5	-1.9	-3.7	-4.5	-1.6	-1.8	-2.2	-1.1	-1.4	-1.5	-1.4	-2.3	-2.7
+ and forward risk premia	-1.6	-2.7	-4.0	-1.3	-1.9	-2.0	-0.3	0.4	1.4	-1.6	-2.4	-1.0	-1.6	-1.8	-2.2	-1.0	-1.3	-1.4	-1.2	-1.6	-1.8
Change in Debt-to-GDP																					
Fiscal consolidation	-0.9	-3.4	-7.6	-1.0	-3.0	-6.7	-1.2	-2.6	-5.8	-0.4	-1.4	-4.3	-0.8	-3.7	-8.1	-1.4	-4.8	-10.2	-1.0	-3.2	-7.2
+ and risk premia	-0.9	-3.5	-7.8	-1.0	-3.1	-7.2	-1.1	-2.7	-9.7	-0.4	-1.4	-5.3	-0.8	-3.8	-8.3	-1.4	-4.9	-10.6	-1.0	-3.3	-8.2
+ and forward risk premia	-0.9	-3.4	-7.0	-1.0	-3.5	-8.3	-2.3	-7.4	-16.3	-0.6	-3.0	-10.1	-0.8	-3.8	-8.2	-1.4	-5.1	-11.1	-1.2	-4.4	-10.0

Note: Cumulative growth effects for real and nominal GDP and change in debt-to-GDP based on NMCM simulations.

The effects of a fiscal consolidation strategy based on tax increases are more protracted in all countries, as they entail a reduction in real disposable incomes, which gradually decreases private consumption and output. One aspect driving cross-country differences is that the revenue effects are more persistent in France and in the smaller country block where the propensity to consume out of current income is relatively low.

Nonetheless, the negative impact on GDP is almost entirely concentrated in the first year although fiscal adjustment continues in the following years. In the NMCM, the competitiveness channel plays a key role in the adjustment process, so the initial negative effects from fiscal consolidation are offset after the first year by competitiveness gains due to lower prices and wages which boost exports and growth. One key aspect is how quickly prices and wages adjust to the negative demand shock. Estimates suggest the downward adjustment of wages and prices is quicker in Germany compared to other countries where prices are more persistent or the degree of indexation is higher. The extent of openness to international trade is also crucial when comparing results for more open economies like Spain or Germany to those of less open economies like France. Furthermore, the price elasticity of exports also plays a major role as product differentiation allows countries to act as price-setters in international markets.

In the case of Spain, the GDP effects are dynamic (strong initial negative effects, but also with a relatively quick rebound), reflecting the fact that, according to NMCM estimates, labour demand in Spain is strongly affected by

contemporaneous developments. This reflects the short-term nature of the Spanish labour market which includes low dismissal costs so that a fall in activity is associated with a rapid increase in unemployment, similarly, once the economy starts to grow firms also start to hire again. Overall, given that estimated price competitiveness gains are higher in Germany and Spain, fiscal consolidation in these countries leads to stronger growth after 6 years compared to the other country blocks of the NMCM.

After 10 years fiscal consolidation actually raises real GDP growth and cuts the debt-to-GDP ratio by around 10 percentage points in all countries.

This analysis is subject to two key caveats. First, the NMCM estimates the speed of nominal adjustment, but it does not explicitly consider downward price and wage rigidities that may be present in some countries. These could limit competitiveness gains and reduce the export response. Second, simulations are carried out in single-country mode, which might overestimate competitiveness gains in a context of simultaneous fiscal consolidation across countries.

2.2.1. The sovereign risk premium channel

So far, the analysis does not consider possible improvements in financial market sentiment due to the reduction in the debt-to-GDP ratio. To assess this effect we introduce a so-called sovereign risk premium channel by which interest rates respond to changes in the debt-to-GDP ratio. This is implemented using the estimated non-linear relationship in Corsetti et al. (2013) which is based on a cross-section of countries (see Figure 4). Similar non-linear effects are found by other studies in the literature (see Box 1), however, given the uncertainties surrounding the estimates due to limited data, this relationship could be considered an upper bound for those countries with high debt levels.

The sovereign risk premium increases (decreases) disproportionately with increases (decreases) in the debt-to-GDP ratio. We initially assume that changes in the sovereign risk premium are fully reflected in the financing conditions faced by firms and households[11]. Incorporating this channel improves real GDP growth in the fiscal consolidation scenario by encouraging investment by firms and consumption by households. This increases domestic demand and further dampens the initially contractionary effect of fiscal consolidation. However it should be noted that spillover effects are excluded (as in European Commission, 2012, Quarterly Report on the Euro Area, 11, p. 3).

[11] In the NMCM the short-term interest rate enters directly in the household consumption equation and a weighted average of long and short-term interest rates enters the firm investment equation (weights reflect the economy's financing structure, i.e. housing market).

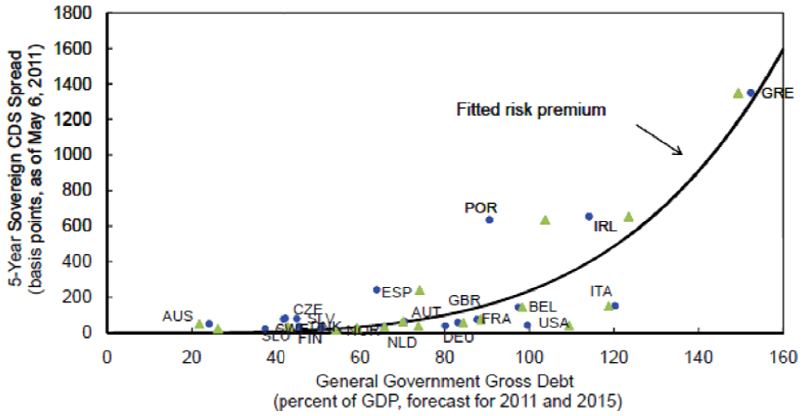


Figure 4: Sovereign risk premia versus debt-to-GDP ratio
Source: Corsetti et al. (2013).

Box 2: Empirical research estimating debt thresholds [12]

According to the conventional view (Elmendorf and Mankiw (1999)), government debt may stimulate aggregate demand and economic growth in the short term, but will raise interest rates and depress investment, leading to lower output in the long run[13].

In some circumstances, a negative effect on growth may appear even in the short run. First, high levels of public debt may trigger market concerns about fiscal sustainability or reduced scope for counter-cyclical fiscal policy. Such concerns can raise the sovereign risk premium, increasing debt servicing costs and possibly tightening credit conditions for households and firms. As highlighted in de Grauwe (2011), these effects could be greater for countries inside a monetary union, since they issue debt in a currency over which they have no control. Corsetti et al. (2013) stress that sovereign risk can affect borrowing conditions in the broader economy (the "sovereign-risk channel of transmission") emphasizing the potential negative effects from a crisis of confidence.

Second, a country with a high level of debt may be tempted to use inflation to erode the real value of the debt held by creditors (debt monetization), which in turn could increase inflation expectations (see Cochrane (2011), for a survey on the relationship between debt and inflation). Finally, a govern-

[12] Prepared by Esther Gordo, Owen Grech and Dmitry Kulikov.
[13] The total impact on interest rates may depend on structural or institutional characteristics of the economy (degree of openness, liquidity constraints, price and wage stickiness), the fiscal and the macroeconomic situation (fiscal space, size of the output gaps), or market perceptions of fiscal sustainability. The complex nature of the problem might explain the range of estimates reported in the empirical literature (see Laubach (2009)).

ment with higher debt is more likely to resort to distortionary taxation to raise the necessary revenue to cover interest costs. Barro (1979) pointed out that the deadweight loss associated with tax distortions rises more than proportionally with tax rates. If the private sector anticipates these effects on output, then debt increases will affect consumption and investment decisions already in the short term.

In their seminal contribution, Reinhart and Rogoff (2010) examine economic growth at different levels of debt using a sample of 44 countries over a period around 200 years. They find no correlation between debt and growth at low or moderate levels of debt, but when the debt ratio is above 90%, median growth rates tend to fall by about one percent. However, Reinhart and Rogoff's findings have been subject to several criticisms. Herndon, Ash and Pollin (2013) find that coding errors, selective use of data, and unconventional weighting of summary statistics lead to distorted estimates, which are substantially weaker after corrections.

Several other papers raise the endogeneity problem associated with possible reverse causality or simultaneity between public debt and GDP growth. While debt may have a negative effect on growth through the channels mentioned above, the link between debt and growth could also run in the opposite direction. Low economic growth can raise public debt by reducing tax revenues and raising public expenditures linked to automatic stabilizers and discretionary policy. Debt and growth may also be jointly determined by a third variable. For example, Padoan et al. (2012) suggest that banking or confidence crises may switch the economy to a "bad equilibrium" or debt trap.

Despite criticism of the work by Reinhart and Rogoff, many recent empirical studies (see below) corroborate the negative relationship between debt and growth, often finding evidence of a debt threshold. In order to address the endogeneity issue, these more recent papers often use instrumental variables or include lagged or initial values of the debt-to-GDP ratio, identifying effects on growth both in the short run and in the long run.

Focusing on the short-term impact, Baum, Checherita and Rother (2013) examine 12 euro area countries over 1990–2010, applying dynamic panel methods to the threshold panel approach proposed by Hansen (1999). Their results confirm that the short-term impact of debt on GDP growth is positive and highly significant, but only when debt is below 67% of GDP. For debt ratios above 95%, any additional debt has a negative short-term impact on economic activity. In particular, they find that increasing the debt ratio by one percentage point can lower GDP growth next year by 0.06 percentage points in the following year. Using the same approach, Padoan et al. (2012)

obtain a short-term impact of 0.014 percentage points, for debt levels close to 90% of GDP.

Turning to the long-term impact of debt on growth, studies using five-year averages of GDP growth also find a non-linear relationship with a threshold around 90% of GDP. Kumar and Woo (2010) studied a panel of 38 advanced and emerging economies from 1970 to 2007 and estimated that a 10 percentage point increase in the debt-to-GDP ratio is associated with a 0.2 percentage point drop in real per capita GDP growth. This negative effect is amplified when the 90% debt-to-GDP threshold is exceeded. They interpreted this adverse effect in terms of slower growth in labour productivity associated with reduced investment. Checherita and Rother (2012) use data for 12 euro area countries over a period of about 40 years and arrive at a broadly similar conclusion: government debt impairs long-term growth (including potential/ trend growth) when it reaches 90%–100% of GDP. Cecchetti, Mohanty and Zampolli (2011) use a panel of 18 OECD countries from 1980 to 2010 to identify similar level and threshold effects of public debt. Their results suggest that a 10 percentage point increase in the public debt-to-GDP ratio leads to a reduction in real per capita GDP growth by more than one tenth of a percentage point. The negative effect on economic growth appears when debt approaches a threshold around 85–95% of GDP[14].

Are these thresholds different for other types of debt? Reinhart, Reinhart and Rogoff (2012) distinguish between three varieties of debt overhang: public debt overhang, external (public and private) debt overhang and private non-financial sector debt overhang. Using the large historical dataset in Reinhart and Rogoff (2009), they find an adverse impact on the long-run economic growth from each of the three kinds of debt overhang. Focusing on public debt, Reinhart et al. (2012) identify 26 episodes where it exceeds 90% of GDP and find that they lowered average annual growth by 1.2 percentage points in both advanced and emerging economies (confirming results in previous research). The average duration of these public debt overhang episodes is around 23 years.

Turning to external debt, both public and private, Reinhart et al. (2012) suggest that the threshold may be lower, given the narrower range of instruments to reduce it (for example, financial repression is not feasible). However, for advanced economies their results suggest a 90% threshold similar to the one for public debt. For emerging economies, instead, the threshold appears to be significantly lower. In part, this may reflect the "debt intolerance"

[14] Panizza and Presbitero (2012) challenge these conclusions, arguing that lags are poor instruments because debt-to-GDP ratios are persistent. They reverse the results in Cecchetti et al. (2011) using different instruments with the same data.

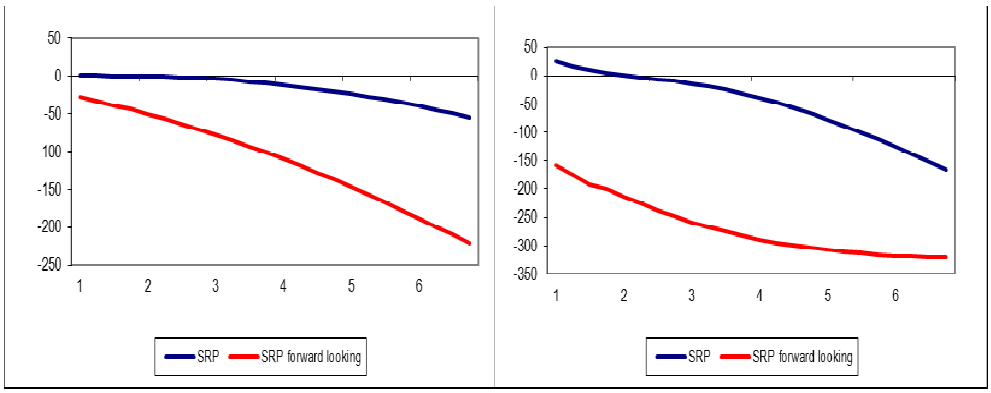
phenomenon affecting emerging economies with a particularly poor credit history. For this subset, Reinhart, Rogoff and Savastano (2003) find a "safe" threshold of external debt as low as 15–20% of GDP. The lower threshold for emerging countries is confirmed by Pattillo, Poirson and Ricci (2011), who find that external debt in excess of 35–40% of GDP is detrimental for economic growth in a panel of 93 emerging market economies from 1969 to 1998. They estimate that doubling the external debt-to-GDP ratio reduces average growth by 0.55 to 1.51 percentage points.

Finally, focussing on private non-financial sector debt, Cecchetti, Mohanty and Zampolli (2011) estimate a threshold around 70–80% of GDP. In a panel of 18 OECD countries covering 1980 to 2010, they find that the impact of private debt is roughly half that of public debt (about 0.09 percentage points). Arcand, Berkes and Panizza (2012) analyse a panel of 133 countries from 1960 to 2010 and find that additional "financial deepening" begins to have a negative impact on growth once private credit exceeds 100% of GDP.

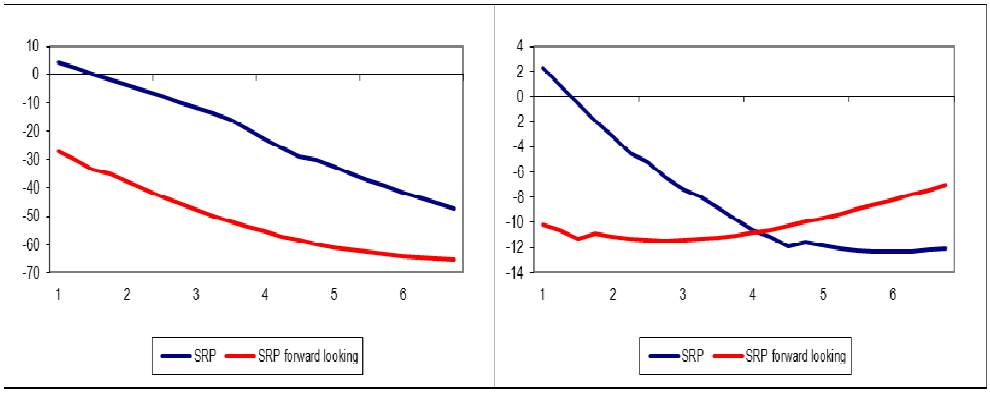
In addition, Reinhart, Reinhart and Rogoff (2012) briefly touch upon the potential interaction between different types of debt overhang, noting that several countries in the recent crisis saw much of their private debt transformed into public debt. Evidence on this issue is still rather limited.

The effect on the sovereign risk premium are presented in Figure 5 and the resulting change in the debt-to-GDP ratios and real and nominal GDP growth are reported in the second row of Table 1. Differences across countries are partially due to the starting level of government debt, as the impact on the risk premium is magnified by the assumed non-linearity. For countries with relatively low debt-to-GDP ratios, such as Germany, the Netherlands and France, incorporating the sovereign risk premium channel has a rather limited effect. The impact is more significant for Spain, Italy, where the starting debt-to-GDP ratio is higher. In addition, NMCM estimates suggest that investment in Spain and Italy is more responsive to changes in financing conditions, which also helps to further reduce the debt-to-GDP ratio in those countries.

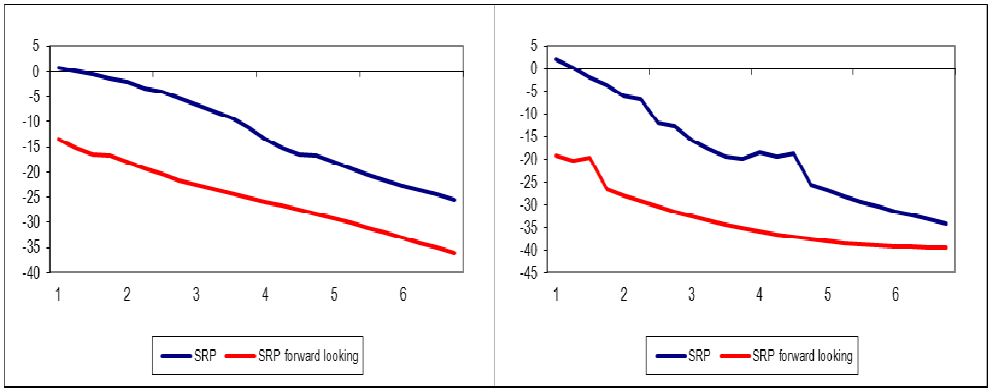
Figures 1 to 3 illustrate the additional growth effects from fiscal consolidation. There is a marked boost to growth in Germany and Spain, (primarily due to the competitiveness effects), but also in Italy and the smaller countries block (due to the fall in the risk premium).



Spain Italy



France Germany



Netherlands Small countries

Figure 5: Changes in sovereign risk premia with respect to baseline (basis points)

2.2.2. Forward-looking financial markets

Financial markets are generally modelled as having forward-looking behaviour. If the fiscal consolidation path announced by governments is fully credible and financial markets have perfect foresight then they will fully anticipate the fall in debt and adjust the risk premium accordingly[15]. We consider the case where the sovereign risk premium reflects the debt-to-GDP ratio three years ahead (instead of the contemporaneous level of this ratio). As shown in Figure 5, assuming forward-looking financial markets implies a faster fall in interest rates and therefore positive effects on output. For Italy, the positive effect of improved financing conditions more than offsets the contractionary effect of fiscal consolidation at a 3-year horizon, i.e there is a quicker rebound in growth. For Spain, given that government debt is smaller relative to GDP, the contractionary effect is fully offset only at the 6-year horizon.

2.2.3. Sensitivity analysis: pass through to private financing conditions

The analysis above assumes that improvements in the sovereign risk premium are fully passed through to private sector financing conditions. Corsetti, Kuester, Meier and Müller (2013) present empirical evidence suggesting pass-through is only 55%. Although their evidence is limited to large companies, pass-through could be higher for small and medium enterprises and for households, especially in times of generalised financial market stress.

Given the uncertainty surrounding these assumptions, Table 2 also considers the effects on GDP growth assuming only 50% pass-through for Italy and Spain. As could be expected, the implications for growth are less favourable.

2.2.4. Summary

There is an on-going debate concerning the impact on growth of fiscal consolidation programmes aimed at correcting imbalances. On the one hand, fiscal consolidation could have an adverse impact on growth via direct effects from lower government consumption or higher taxes. On the other hand, lower debt levels could reduce the sovereign risk premium, potentially providing a positive boost to growth.

[15] This part of the model is solved iteratively to ensure full consistency.

Table 2: Effects on real GDP growth of fiscal consolidation – sensitivity analysis concerning pass-though from changes in sovereign risk premia into private sector financing conditions

	Real GDP						Nominal GDP					
	Italy			Spain			Italy			Spain		
	1 Yrs	3 Yrs	6 Yrs	1 Yrs	3 Yrs	6 Yrs	1 Yrs	3 Yrs	6 Yrs	1 Yrs	3 Yrs	6 Yrs
Fiscal consolidation	-1.0	-1.1	-0.7	-1.4	-1.7	-0.9	-1.2	-2.3	-3.0	-1.9	-3.7	-5.2
	Full pass-through						*Full pass-through*					
+ and risk premia	-1.1	-1.0	0.3	-1.4	-1.6	-0.5	-1.3	-2.2	-1.5	-1.9	-3.7	-4.5
+ and forward risk premia	-0.2	0.6	1.0	-1.1	-0.8	1.0	-0.3	0.4	1.4	-1.6	-2.4	-1.0
	50% pass-through						*50% pass-through*					
+ and risk premia	-1.1	-1.1	-0.3	-1.4	-1.7	-0.7	-1.3	-2.3	-2.3	-1.9	-3.7	-4.8
+ and forward risk premia	-0.8	-0.6	-0.0	-1.3	-1.4	-0.3	-1.0	-1.4	-1.3	-1.8	-3.3	-3.8

Note: Cumulative growth effects for real and nominal GDP and change in debt-to-GDP based on NMCM simulations.

The NMCM can address this question via medium-run simulations for countries within the euro area. The first point to emphasise is that medium-run growth prospects reflect a range of assumptions concerning TFP and labour input, but also estimated speeds of adjustment in the labour or product markets and output responsiveness to changes in competitiveness. All in all, the extended baseline suggests real growth will be lower in the medium term compared to 2003–2007 and finds significant differences across euro area economies.

Considering the effects of debt on growth, the NMCM results suggest that sustained fiscal consolidation raises real growth over the medium-term horizon, even with no risk-premium effects. Linking the sovereign risk premium to contemporaneous movements in government debt, fiscal consolidation improves growth prospects, especially for euro area countries where debt levels are highest and the risk premium can therefore fall further. Once risk-premium effects are modelled as forward-looking (assuming credible government commitments to reduce debt), then fiscal consolidation can have positive growth effects even at short horizons in countries with higher initial levels of debt. However, the strength of the link between risk premia and sovereign debt has been questioned in the academic literature and more work is needed on the extent of pass-through to private financing conditions.

Overall, the general conclusion is that the debt-to-GDP ratio may have a non-linear impact on the sovereign risk premium, in which case a reduction from high debt levels could help to support growth over the medium term. The strength of this sovereign risk premia channel and therefore the impact on growth depends on (a) the initial level of debt (b) the extent to which financial markets respond to announced reductions in debt (c) the degree of pass-through from sovereign risk premium to firm and household financing conditions (d) the speed of adjustment in investment and employment and the sensitivity of output to changes in price competitiveness. Estimates suggest these vary significantly across euro area countries.

Box 3: Research on risk premia and sovereign bond yields[16]

The empirical literature[17] on the determination of sovereign bond yields initially concentrated on emerging markets (Edwards (1986), Uribe and Yeu (2006)), but more recent studies have focussed on euro area countries. Favero et al. (1997) studied these issues at the beginning of the economic and monetary union. The early years of EMU saw a convergence of long-term government bond rates that has been studied extensively (for example, Ehrmann et al. (2011)).

Codogno et al. (2003) and Manganelli and Wolswijk (2009) studied the impact of international risk factors on bond spreads. Balli (2008) focussed on time-variation in the integration of European government bond markets using multivariate GARCH models. Results suggest that the default risk factor and other macroeconomic and fiscal indicators had little impact on sovereign bond yields after the beginning of monetary union. For new EU countries, Alexopoulou et al. (2009) assess the role of fundamentals in driving long-term sovereign bond spreads starting in 2001. A related set of papers addresses the determinants of yield spreads in monetary unions other than EMU, e.g. Ang and Longstaff (2013) and Schuknecht et al. (2009).

In general, the increased role of macroeconomic fundamentals reduced the contribution from global factors, as investors obviously discriminated more across countries (Barrios et al. (2009)). Beber, Brandt and Kavajecz (2008) showed that the bond market in euro area countries increased the weight on credit quality and liquidity, although this varied over time.

A very recent literature focuses on possible contagion during the sovereign debt crisis. Amisano and Tristani (2012) find evidence of contagion based on

[16] Prepared by Niki Papadopoulou.

[17] Stähler (2013) surveys a separate literature on sovereign default in dynamic stochastic general equilibrium.

a Markov-switching model of sovereign yield spreads. Other papers on this issue are Favero (2012) and Favero and Missale (2012). Several studies, including Claeys and Vasicek (2012), De Santis (2012) and Missio and Watzka (2011), report that rating announcements generated contagion effects in the euro area. Calice et al. (2013) show that sovereign CDS market liquidity affected sovereign bond spreads spilling over to several countries, including Greece, Ireland and Portugal. Finally, Zhang et al. (2014) develop a measure of the probability of default on the debt of a given country conditional on default in another country.

Contributions from Martell (2008), Aizenman et al. (2013), Beirne and Fratzscher (2013), De Grauwe (2012) and Dungey et al. (2000) focus on international determinants of sovereign bond yields, both for emerging market economies or for the euro area. In particular, D'Agostino and Ehrmann (2013) examine determinants of sovereign bond spreads among G7 countries, considering global risk aversion as well as macroeconomic fundamentals. These authors stress the role of expectations about future fundamentals, and do not define sovereign bond spreads relative to some benchmark country. One key finding is that domestic macroeconomic fundamentals are more important than fundamentals in the benchmark country. However, the relative contributions of different determinants vary considerable over time.

Recent empirical evidence suggests a non-linear relationship between long-term government bonds yields and expected (rather than current) levels of public debt. For example, Corsetti, Kuester, Meier and Muller (2013) estimate a non-linear relationship between sovereign risk premia and expected debt using cross country evidence. Such non linear effects are also found by Bayoumi et al. (1995) for the US states, by Ardagna et al. (2007) for OECD countries, and by Haugh et al. (2009) for euro area countries.

Finally, a number of other studies test for the existence of spill-over effects from sovereign risk premia to private borrowing costs. As highlighted in Corsetti et al. (2013) rising sovereign risks can drive up private sector borrowing costs, unless higher risk premia are offset by looser monetary policy. Although estimates are rather imprecise, there is no doubt these spillovers constitute an additional "sovereign risk" channel through which fiscal policy affects output, as lower public deficits improve private-sector financing conditions. This relationship was also studied by Haugh et al. (2009), Bayoumi et al. (1995) and Ardanga et al. (2007).

3. Long-term growth accounting: Impact of ageing on potential growth[18]

This section proposes an extension of standard growth accounting that can be used to analyse how changes in the composition of the working population can affect the aggregate participation rate and therefore long-term growth. The framework is applied to quantify the impact of demographic changes, of immigration and of an increase in participation rates that could be related to structural reforms. Box 4 reviews the research literature studying the impact of structural reforms on economic growth.

As part of the Broad Macro-economic Projection Exercise (BMPE), National Central Banks provide projections of potential output for individual euro area countries. These are based on a standard growth accounting framework, with potential output obtained by using an aggregate Cobb-Douglas production function to combine projected labour input, capital input and total factor productivity. Euro area potential output is then obtained by aggregating NCB projections. However, the approaches and assumptions used by National Central Banks are not fully harmonised and rely on considerable expert judgment.

This section proposes to extend the standard growth accounting exercise by disaggregating labour input along several dimensions (sex, age, citizenship) to assess the impact on potential growth of a shifting population structure. As is common practice, labour input projections are based on official long-term population forecasts developed by national statistical institutes within the Ageing Working Group of the EU Economic Policy Committee. These are published in the European Commission Ageing Report (European Economy (2011), No 4). However, estimates are usually based on the aggregate population projections and average participation rates. The proposal here is to exploit the detailed projections at a more disaggregate level to study how changes in population structure will affect average participation rates, aggregate labour input and potential growth in the medium term.

Aggregate population statistics disguise heterogeneity across population groups, especially in terms of labour force participation. For instance participation rates are higher for men and for immigrants. Participation rates also increase with the level of education attainment, although more educated individuals enter the labour force later in life. Past data on participation rates by subgroups of the population is collected through the harmonised Labour Force Survey and is available for most EU countries (see Eurostat website).

[18] Prepared by Lisa Rodano.

Since population projections differ across these groups, the overall population structure will be transformed. Therefore even assuming constant participation rates within each group, changes in population composition will affect aggregate participation rates and therefore labour force projections.

The standard growth accounting framework estimates potential output by assuming the following aggregate production function (Cobb-Douglas with constant returns to scale):

$$Y_t^* = A_t K_t^{\alpha} L_t^{1-\alpha},$$

where Y_t^* is potential output at time t, A_t is trend Total Factor Productivity (TFP), K_t is the capital stock (the flow of capital services used in production are assumed proportional to this stock, although sometimes variable capacity utilisation is also considered) and L_t is trend labour input (abstracting from cyclical variations in participation and unemployment). Assuming competitive factor markets, the parameter α is usually calibrated as one minus the share of employee compensation in nominal GDP.

Demographic change affects the labour input component. This can be disaggregated as follows:

$$L_t = (1-U_t^*)LF_t^* = (1-U_t^*)PR_t^*POP_t,$$

where U_t^* is a time-varying structural unemployment rate and LF_t^* is the trend labour force. The latter can be decomposed into the product of the (trend) participation rate (PR_t^*) and population in working age (POP_t). Unemployment and participation rates need to be stripped of their cyclical component in order to arrive at a measure of the trend (or sustainable) level of labour input that determines potential output. Often this simply means replacing observed unemployment and participation rates by their Hodrick-Prescott filtered version. More rigorous studies replace the unemployment rate with the non-accelerating inflation unemployment rate (NAIRU) that is estimated separately using the information from cyclical movements in inflation.

Projections of aggregate labour input can be obtained by combining assumptions on the structural unemployment rate, the participation rate and the population of working age. The path of potential output can then be obtained by using the aggregate production function to combine aggregate labour input with capital input (based on assumed path of future investment, usually chosen to stabilise the investment-output ratio or the capital-output ratio) and with assumed Total Factor Productivity (usually the most judgment-based component of the three).

Some National Central Banks disaggregated labour input by considering different groups within the population. Thus it is possible to separate participation rates for men and women or for immigrants and natives. Consider the following:

$$LF_t = \sum_a \sum_s \sum_c pr_{a,s,c} POP_{a,s,c} \ ,$$

where $POP_{a,s,c}$ is the population of working age within a given category of age, sex and citizenship (educational attainment can be an additional dimension) and $pr_{a,s,c}$ is the participation rate within this category.

The official long-term population projections are disaggregated by age and sex (citizenship can be recovered from assumptions about net migration flows). Labour Force Survey data can be used to extract trends from past participation rates in these different categories. Scenarios can then be constructed by extending the category-specific participation rates using different assumptions. The simplest scenario is to assume that participation rates remain constant at the last observed value. This abstracts from past trends (for example, female participation is rising in most countries) and also from changes that can be anticipated given the ageing process (participation among older agents is likely to rise in response to pension reforms). A second possible scenario is to consider participation rates converging to some target levels (for example national targets set within the EU2020 growth strategy that has followed the Lisbon strategy). A third scenario could focus on the impact of immigrants, either assuming no immigration by setting their participation to zero or assuming that native participation rates slowly converge to immigrant levels. Finally, the impact of reforms raising the retirement age can be simulated by increasing participation rates among older workers.

3.1. Data

The following refers to the official long-term projections of the Italian population, but the method and the overall picture is applicable to most EU countries facing shifts in population structure.

According to the NSI projections released in 2011, over the next 50 years the Italian population should remain more or less stable at its current level around 61 million. However this assumes considerable migrant inflows (255 thousand new arrivals per year). In Figure 6, population net of migration flows appears to be shrinking monotonically over the projection horizon. Moreover, persistent increases in projected life expectancy combined with only moderate increases in fertility rates lead to a significant ageing process: the share of young people (25–55) is projected to shrink by 10 percentage points, while the share of those aged 55 and more is expected to increase by approximately the same amount (panel 2 of Figure 6)

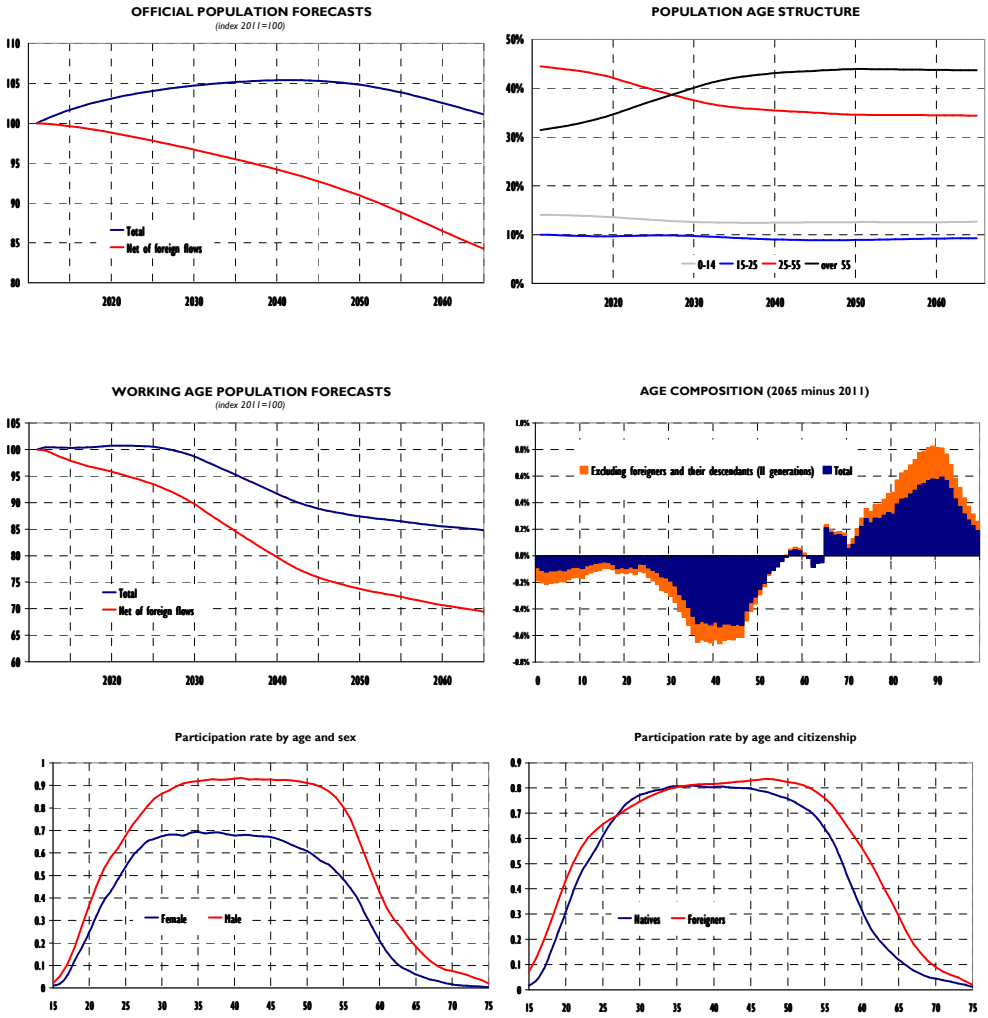


Figure 6: Official long-term forecasts

As a result, the native population of working age is projected to decrease at progressively faster rates. Migration helps to counter the ageing process, as on average foreigners are 10 years younger than natives and they have relatively higher fertility rates. Thus, the migration flows embedded in the official projections provide a strong positive contribution to working age population (Panels 3 and 4 of Figure 6).

Participation rates are rather heterogeneous across ages and population groups. In Italy, female participation rates are much lower at all ages and immigrant participation rates are higher at younger and older ages (panels 5 and 6 of Figure 6).

3.2. Results

This section reports results from scenario analysis using alternative assumptions for participation rates at the disaggregate level; refer to Figure 7. Under the baseline scenario, potential output is calculated using aggregate population and aggregate participation rates.

Scenario 1: Potential output is computed by assuming constant participation rates within each subgroup of the population. The population is disaggregated by sex and age and the participation rate specific to each group is extended by assuming it remains constant for the next 20 years at its current level. This yields an alternate path for labour force and therefore for labour input and potential output. The impact of changing population structure on potential growth can be evaluated by comparing results under this scenario to the projection assuming a constant average participation rate for the aggregate population. Results suggest that ageing may reduce annual potential growth by around 0.2% on average over the next 20 years.

Scenario 2: Potential output is computed assuming no net migration from 2012 onwards. Population projections under this scenario exclude new migrants and also their descendants (but not the children of those who immigrated before 2012). Again, the population is disaggregated into groups by sex and age and group-specific participation rates are kept constant at current levels for the rest of the projection. The impact of migration on potential growth can be evaluated by comparing the results under this scenario to the baseline that includes migration. Results suggest that migration (as assumed by the NSI) may raise potential growth by 0.2% on average over the next 20 years.

Scenario 3: Potential output is computed assuming that native participation rates rise to match those of immigrants in each sex and age group. Immigrant participation rates are higher for younger and older groups in particular (see panel 6 of Figure 6). This scenario assumes that native participation rates (in each sex and age group) linearly converge to the corresponding level among immigrants over the next 20 years. Results for the aggregate labour force suggest that average participation would rise to 76%, which is 13 percentage points above the current level. Assuming a NAIRU of 6.2% (the euro area average), this participation rate would allow Italy to meet its EU2020 target employment rate of 70%. Thus results suggest that increasing participation rates to meet the EU2020 target may raise annual potential growth by 0.1% on average over the next 20 years.

Scenario 4: Potential output is computed assuming higher participation rates for the elderly following an increase in the retirement age as envisaged in the recent pension reform. In 2011, the Italian parliament approved a pen-

sion reform that will likely raise participation rates among older workers. Estimates suggest that retirement age would increase by 3 years on average. Thus, this scenario assumes an increase in participation rates for both men and women above 50 years of age (earliest possible retirement age), effectively shifting the profile of participation rates across age groups to postpone their decline by three years. Results suggest that an increase in elderly participation rates of this form may raise annual potential growth by nearly 0.1 percentage points on average over the next twenty years.

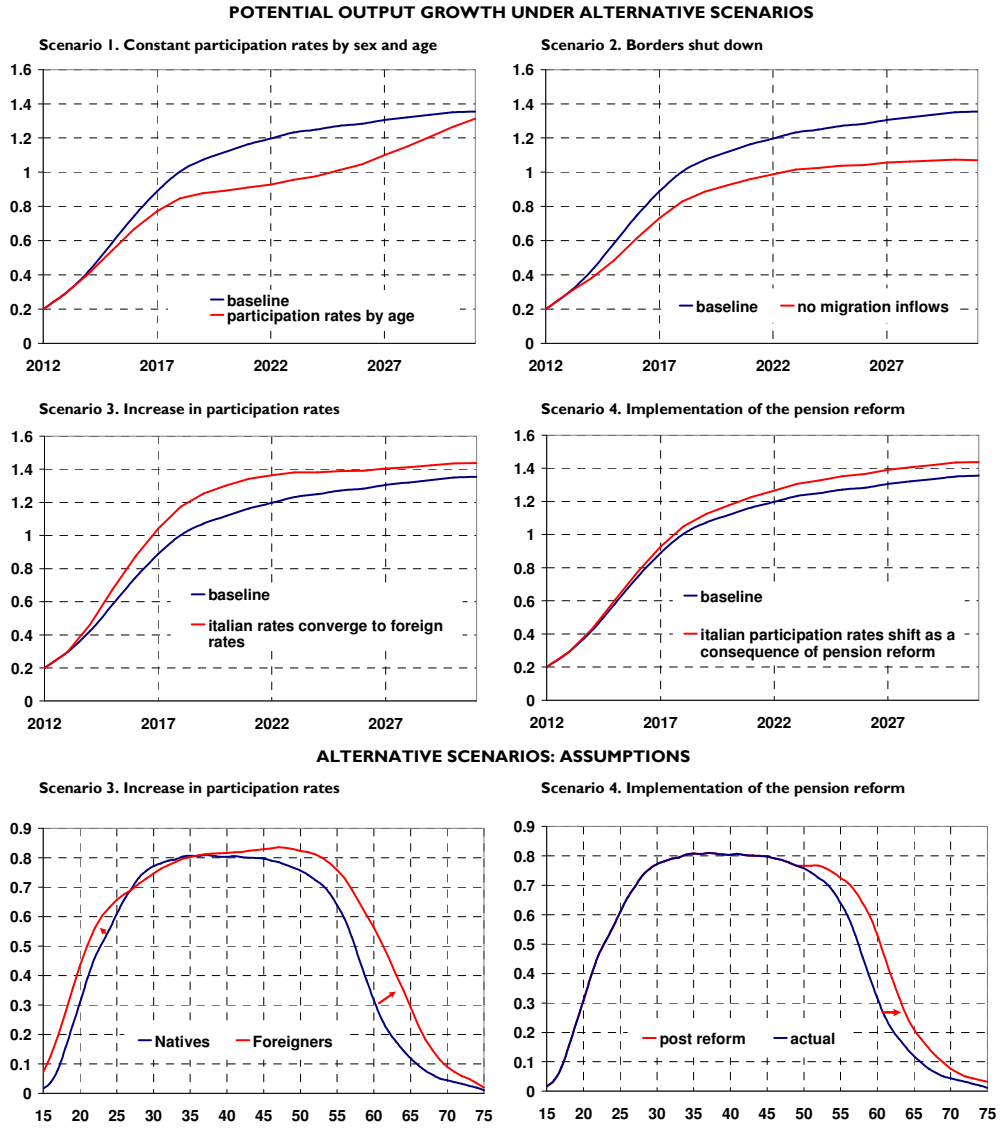


Figure 7: Alternative scenarios

3.3. Summary

The proposed disaggregation of labour input provides several interesting perspectives on potential growth; refer to Figure 8. First, results suggest that changing population structure will significantly affect average participation rates. Potential growth estimates that ignore composition effects may suffer an upward bias of 0.2 percentage points in the Italian case. Second, immigration assumptions are crucial as they affect participation rates as well as population levels. Results for Italy suggest that immigration flows represent an additional 0.2 percentage points in projected potential growth. Third, efforts to increase native participation rates to match those of immigrants would allow Italy to meet its EU2020 target employment rate. Results suggest this represents an additional 0.1 percentage points in projected potential growth. Finally, recent reforms aimed at raising elderly participation rates should increase the retirement age by three years. Results suggest this represents an additional 0.1 percentage points in projected potential growth.

By quantifying the impact of different policies, the disaggregated analysis reveals that policies aimed at increasing participation rates will have the desired positive impact on potential output, but that this will be insufficient to offset the effect of ageing. Pension reforms increasing the retirement age by three years only make a limited contribution to potential growth. Instead, the immigration assumptions in official projections account for a much larger contribution to potential growth. This is now threatened by the hostile attitude to immigration taken by recent policy discussions in Italy.

The following picture provides a range for Italian potential growth projections based on the disaggregated exercise: the upper limit of the shaded area represents potential growth when native participation rates converge to immigrant rates and at the same time elderly participation rates increase as a consequence of the pension reform (overall +0.2% per year), the lower limit represents potential growth under the zero immigration assumption (–0.2%). The solid line represents the baseline computed from aggregate participation rates and population projections.

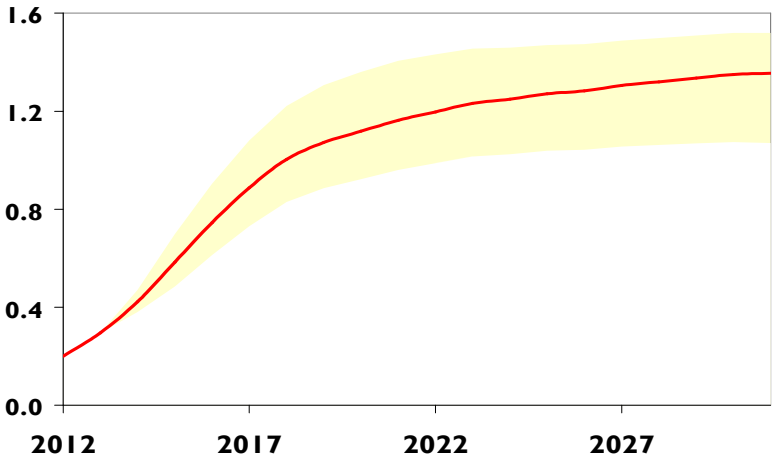


Figure 8: Range of potential growth estimates

Box 4: Research on structural reforms[19]

The persistent effects of the financial crisis, the fiscal consolidation effort required by increasing debt, and the effects of population ageing all combine to lower the medium-term prospects for output growth. In this perspective, it is natural to consider structural reforms as additional measures to foster growth by raising productivity or labour utilisation. Box 4 provides a brief survey of the associated literature.

Structural reforms include: (i) labour market reforms, (ii) product market reforms to boost competition, (iii) tax reforms, (iv) improved capital market regulation, (v) measures to boost innovation (e.g. investment in R&D) and (vi) education reforms.

Over the last decades structural reforms have differed across countries both with regard to timing and extent. For certain sectors in particular there was some convergence across countries in the regulatory framework. Some reforms appeared in waves across countries and most took place gradually (see, inter alia, IMF (2004)). Structural heterogeneity in the euro area is well documented (see, inter alia, Allard and Evaert (2010), Irac and Lopez (2013))[20]. Thus, the required reforms differ across euro area economies.

[19] Prepared by Maria Albani, Delphine Irac and Dimitris Sideris.

[20] Irac and Lopez (2013) rank EA countries using structural indicators in the fields: (i) regulations and qualities of institutions, (ii) knowledge economy and (iii) labor mobilization –see Appendix for details. This ranking is subject to change, especially given measures adopted during the crisis (see OECD (2012a)).

Structural reforms launched by some euro area countries during the crisis may contribute to a more homogeneous economic environment within the monetary union (see e.g. OECD (2012a)).

Cross-country evidence

Research at the European Commission, OECD, IMF, and the World Bank confirms that structural reforms can raise growth in the long run. For example, D'Auria et al. (2009) use a dynamic stochastic general equilibrium (DSGE) model calibrated to individual EU member states to study the impact of several reforms. Results suggest an increase in employment and output in the long run, although the impact differs across countries, depending on specific features. Bayoumi et al. (2004) reach similar conclusions using a general equilibrium model calibrated to capture spillovers between the euro area aggregate and a foreign country aggregating other developed economies. Evaraert and Schule (2006) confirm the positive effect using a version of the IMF GEM model that is calibrated to split the EU into four blocks: one of the euro area countries, the rest of the euro area, the three non-euro area EU15 members and the new EU member states. Gomes et al. (2011) perform a similar exercise using the Euro Area and Global Economy model (EAGLE), which is a multi-country DSGE model with four country blocks: one calibrated to match either Germany or Portugal, another for the rest of the euro area, a third block for the United States and the last for the rest of the world.

A more empirical literature using cross-country regressions also confirms the positive effects of structural reforms on growth. Here, many articles focus on the effects of labour market and product market reforms. A variety of labour market rigidities (e.g. higher levels of employment protection, minimum wages, severance pay, labour taxes and wage bargaining inefficiencies) are associated with lower employment and productivity (Nickell et al. (2005), Bassanini and Duval (2006), Annett (2007), Fialová and Schneider (2008), Jaumotte (2011), World Bank (2012)). Excessive regulation of the product market is also associated with lower growth in production, employment and investment (Berger and Danninger (2007), Pérez and Yao (2012), World Bank (2012)).

Germany, Sweden, Denmark and Finland, who all reformed their labour market over the last decade, performed relatively well on various labour measures, such as employment and unemployment (Räisänen et al. (2012)). On product market reforms, Wölfl et al. (2009) found significant cross-country heterogeneity, with anti-competitive restrictions significantly below the OECD average in some countries (the UK, the US, Iceland, Canada, Denmark and the Netherlands), and significantly above in others (Luxembourg, Czech Republic, Mexico, Turkey and Poland).

Irac and Lopez (2013) propose a clustering method that classifies euro area countries according to differences in (i) regulations and quality of institutions; (ii) knowledge economy and (iii) labour mobilization. The resulting classification separates euro countries into a Southern Countries Group (Greece, Italy, Portugal, Spain) and an Other Countries Group. The classification is broadly unchanged between 1995 and 2007, which suggests that countries that implemented structural reforms early during this decade (e.g. Germany) were in a better initial position and maintained this advantage despite structural reform elsewhere. The clustering is robust to dropping individual variables, but also if the algorithm is applied to variables from only one of the three domains. This suggests little convergence in labour market and product market institutions within the euro area. However, the analysis ignores recent labour and product market reforms enacted by Greece, Ireland, Portugal and Spain during the crisis. OECD (2012) reports that these four countries responded most strongly to reform recommendations from 2008–2009 to 2010–2011. Instead, the response to reform recommendations was weakest in Germany, Switzerland, Luxembourg and Belgium.

The implementation of structural reforms

Many studies focus on the effects of structural reforms in individual economies. Forni et al. (2010), Almeida et al. (2010) and Kilponen and Ripatti (2006) study the impact of labour and product market reforms on output and welfare in Italy, Portugal and Finland respectively. In these three papers the authors use DSGE models to quantify the effects of competition-enhancing reforms that reduce mark-ups in the product and/or labour markets. The main qualitative conclusions are similar across the three studies. Stronger competition boosts output, consumption and investment, and fosters employment. Still, short-run costs include a temporary reduction in consumption and an increase in the interest rate. Gomes et al. (2011) find that mark-up reductions in Portuguese labour and service markets generate long-run gains in the main macroeconomic components. For Greece, IOBE (2010) suggests that product and labour market reforms and public sector reforms have important effects on productivity and growth. This study emphasizes the need to address high mark-ups and price rigidities in Greek product markets. For Spain, Gavilan et al. (2011) propose simultaneous implementation of structural reforms on labour and product markets.

In fact, several authors argue that product market and labour market reforms are complementary. Everaert and Schule (2006), Berger and Danninger (2007), Aghion et al. (2009), Allard and Everaert (2010), Gomes et al. (2011), Bouis and Duval (2011), Pérez and Yao (2012), Turner and Nicoletti (2012) find a positive impact from synchronizing reforms on the two mar-

kets. Annett (2007) finds that the benefits of wage moderation are higher in countries where labour and product markets are less regulated. Berger and Danniger (2007) find that product market deregulation is more effective when labour market regulation is less stringent. However, Fiori et al. (2012) reach the opposite conclusion when taking into account political economy linkages between policies. Productivity and potential growth are also affected by product and labour market deregulation, the level of education of the labour force and the technology level of the economy (Aghion et al. (2009), Sideris (2010)).

Some authors (Annett (2007), Pérez and Yao (2012)) stress the virtuous circle of labour market reforms: the increase in labour supply allows fiscal consolidation, paving the way for further structural reforms. Ostry, Prati and Spilimbergo (2009) stress the importance of reform sequencing. Structural reforms often have transition costs because benefits only materialise slowly (higher firm/job creation, higher innovation), while costs are immediate (wage moderation, decreased consumption, structural reallocation, reduction in government size, etc.). Cacciatore et al. (2012) suggest that a broad package of labour and product market reforms can mitigate transition costs. The short-run contractionary effects of structural reforms may be due to adjustment costs, increased uncertainty and other factors. However, reforms may also carry short-run benefits as mark-ups fall in product markets (Blanchard and Giavazzi (2003)) or adjustment improves in the labour market (Bassanini and Duval (2006)). Several models assume that product market reforms immediately reduce mark-ups of prices and wages (see, e.g. Everaert and Schule (2006), Gomes et al. (2011)).

Structural reforms in times of crisis

Recent empirical articles focussing on structural reforms in times of crisis reach several conclusions. First, the impact of reform depends on the state of the economy (Bouis et al. (2012), OECD (2012b)). The contractionary short-term effect may be amplified if structural reforms increase uncertainty about future income and therefore precautionary savings. Second, successful implementation depends on a number of political economy factors. Based on a sample of ten OECD countries, Tompson (2009) argues that success requires clearly communicated goals, perceived fairness, support from a cohesive government, appropriate governance and consensus among social partners. OECD (2012b) notes that these conditions may have been lacking in Greece, contributing to output decline and political tensions. Third, only a comprehensive approach can revive growth over the medium term, so reforms need to monitor demand as long as the recovery remains fragile (Allard et al. (2010)). Fourth, synergies between labour market and service sector reforms

should be exploited to promote job growth (Allard et al. (2010), OECD (2012b)). The contractionary effect of employment losses following labour market reforms could be partly offset if product market reforms lower prices and profit margins, boosting real disposable income (Blanchard and Giavazzi (2003), IOBE (2010)). Labour and product market reforms may also improve competitiveness by reducing wages and prices. However, for highly indebted countries, lower prices may also raise the burden of debt (OECD (2012b)). Competitiveness can also be enhanced by measures to improve productivity. Fifth, structural reforms are more likely to succeed if expectations of future gains feed back into current demand through consumption and investment (OECD (2012b)). This also requires a robust and effective banking system to finance investment and allow income smoothing in anticipation of future gains and to offset temporary income losses (OECD (2012b), Allard et al. (2010)).

4. Ageing and pension reform in General Equilibrium Models[21]

This section analyses population ageing and alternative pension reforms using three national general equilibrium models incorporating demographic features. A harmonised population shock is used to provide comparable results across models. These confirm that increases in social contributions or labour taxes alone cannot cover anticipated pension costs without unrealistic adjustments. Combining these measures with lower pension replacement rates or a higher retirement age raises labour supply, mitigating the impact of ageing on public finances and economic growth. Box 5 reviews the research literature studying ageing, welfare and pensions in general equilibrium.

Conventional debt sustainability analysis as discussed in ECB (2012) is limited as "the standard debt accumulation equation does not capture interdependencies between the variables driving debt sustainability ... ". Only general equilibrium models capture these interdependencies, providing a theoretically consistent framework to evaluate the direct and indirect impacts of ageing on the economy.

However, for general equilibrium models to remain tractable they require some simplification of the complex ageing process. As indicated in the survey on ageing, welfare and pensions in Box 5, much of the existing literature uses closed economy fully-fledged overlapping generation models (Ludwig, Schelkle and Vogel (2012), Altig, Auerbach, Kotlikoff, Smetters and Wal-

[21] Prepared by Ricardo Mourinho Felix, Juha Kilponen and Luca Marchiori.

liser (2001), Auerbach and Kotlikoff (1987)). There is also an open economy literature on ageing but these models focus on international capital flows in multi-country frameworks (e.g. Börsch-Supan, Ludwig and Winter (2006) or Domeij and Flodén (2006)). These models usually abstract from trade and exchange rate dynamics in order to preserve tractability.

Instead, this section analyses ageing within the New Open Economy Macroeconomics (NOEM) framework developed by Obstfeld and Rogoff (1995). This approach analyses trade and capital mobility by modelling the current account and exchange rate dynamics while treating the foreign economy as completely exogenous. Three euro area central banks separately developed small open-economy DSGE models with demographic features to study the general equilibrium impact of ageing and pension reform. Each model represents a euro area member state, implying that monetary policy and nominal exchange rate are exogenous.

The demographic structure in these models breaks Ricardian equivalence in an intuitive and very elegant manner by explicitly modelling finite lifetimes. In the workhorse DSGE model, the more common solution to generate non-trivial effects of fiscal policy is to assume rule-of-thumb consumers (Gali (2007)). While standard, this approach is more ad hoc and only allows for non-neutral fiscal policy at business cycle frequencies, not in the steady-state. Since the demographic shock will have permanent effects on fiscal variables, a more genuine non-Ricardian framework is required to study ageing in general equilibrium. Finally, the new open economy framework determines the net foreign asset position endogenously, while the workhorse open economy DSGE model needs to pin it down exogenously to rule out explosive paths (Schmitt-Grohe and Uribe (2003)).

Although the three models share a number of features, they differ somewhat in how they model ageing. Table 3 compares the main differences across models. The following paragraphs describe each model in more detail.

Table 3: Overview of model features

	PESSOA	**LOLA**	**AINO**
Country calibration	Portugal	Luxembourg	Finland
Demographic structure	OLG à la Blanchard-Yaari and hand-to-mouth pensioners	OLG à la Auerbach-Kotlikoff	OLG à la Blanchard-Yaari and Gertler
Number of age classes	2 age classes coexist at each period	16 generations coexisting at each period	2 age classes coexist at each period
Periodicity	Quarterly	5-year	Quarterly
Agent heterogeneity	Two household types within one age class: asset holders and hand-to-mouth households	One household type (but distinction between residents and non-residents)	Two household types: retirees and workers
Labour market structure	Monopolistic, wage rigidities à la Rotemberg	Search and Matching	Monopolistic, wage rigidities à la Calvo
Labor supply decisions at the *intensive* margin	Yes	No	Yes, including workers and retirees
Labor supply decisions at the *extensive* margin	No	Yes, retirement decisions for the 55 and 65 years old	No
Economic Openness	New open economy macroeconomics	New open economy macroeconomics	New open economy macroeconomics
Other key features	Old-age pensions linked to demographic structure. Age related spending exogenous.	Benefits for unemployment, early-retirement and retirement	Age related expenditures linked to demographic structure

PESSOA (Almeida, Castro and Félix (2010)) is a small-open economy version of Kumhof and Laxton (2007). Households follow a stochastic finite lifetime overlapping generation scheme (Blanchard (1985), Yaari (1965), Buiter (1988), Weil (1989)). However, Braz, Castro, Félix and Maria (2012)

extended PESSOA by including an overlapping-generations demographic structure to study the impact of ageing. As in the original version, households belong to one of two types during their working life: the asset holders, who hold all the assets in the economy, or the hand-to-mouth households, who cannot access asset markets. In the modified version of the model, these households are subject to an exogenous instant probability of retiring next period. At the beginning of their working life, asset holders take out an income insurance contract which allows the insurance company to seize all their assets when they retire. In exchange, the insurance company provides households that remain in the workforce with a share of the assets from households that retire. When households retire, they become hand-to-mouth consumers irrespective of their previous type and are subject to an exogenous constant death probability. This implies that unlike in Gertler (1999), asset holder households in PESSOA do not save for retirement during their working life. Since old-age pensions are largely funded by pay-as-you-go systems, this assumption is not too unrealistic. In PESSOA, retirees can also supply labour, but they attach a larger disutility to work, so their labour supply elasticity is much lower. The version of PESSOA used in this section also includes a slightly modified treatment of the Government. In particular, old-age pensions show up separately in public spending and are set as an exogenous replacement rate on the average wage level, implying that wage fluctuations are fully passed on to pensions. The model is of the new Keynesian type, featuring monopolistic competition in labour, intermediate and final goods markets and price and wage rigidities. The latter play a minor role in the analysis of ageing, whose effect on the economy is at frequencies lower than the business cycle.

LOLA is a dynamic general equilibrium model calibrated to the Luxembourg economy that combines overlapping generations, cross-border workers, endogenous retirement, frictions in the labour market and new open economy macroeconomics. These characteristics are now described in turn. First, LOLA features overlapping generations (OLG) à la Auerbach and Kotlikoff (1987). There are 16 generations coexisting each period to represent age classes from 20–24 to 95–99. This means that one period in the model corresponds to 5 years in the ageing process. The population pyramid evolves according to fertility and mortality rates as well as migration flows as taken from official population projections. Second, LOLA models early retirement decisions. From age 20 to 55 individuals are active (employed or unemployed) and they must retire at age 65 at the latest. However, between 55 and 64 they can decide to take early retirement. Third, the model also features non-resident workers, who currently represent 40% of Luxembourg employment. The share of these cross-border workers is calibrated to match official projections over the coming decades. Fourth, LOLA departs from the perfectly competitive labour market to consider a more realistic Diamond-

Mortensen-Pissarides labour market (see Pissarides (2000)). Firms post vacancies and job-seekers can be either residents or non-residents. Finally, LOLA combines the OLG structure with the Obstfeld and Rogoff (1995) New Open Economy Macroeconomics (NOEM) framework to model trade and capital mobility. Results presented here are based on the second version of LOLA (Marchiori and Pierrard (2012)), which is a NOEM extension of the original (Pierrard and Sneessens (2009), see also de la Croix, Pierrard and Sneessens (2013)).

AINO depicts the Finnish economy as dynamically optimizing small open economy with an internationally fixed real interest rate and a non-stochastic balanced growth path. On the balanced growth path, economic growth is determined by exogenous labour-saving technology progress and population growth. Accumulation of financial assets and physical capital reflect optimal intertemporal decisions of households and firms. Optimal consumption and labour supply decision are based on the Gertler (1999) tractable overlapping generations model, and extended to allow distortionary taxes, and time-varying retirement and death probabilities. In addition, age-related expenditures are indexed to the demographic structure. Since the Finnish pension system is partially funded, it is represented as a contractual saving part (assets accumulated by the pension fund) and a PAYG part (monetary transfer from workers to pensioners). The monetary transfers are financed by collecting pension contributions from firms and workers. These social security contributions adjust to balance the budget of the pension system. Households have finite lives separated in two distinct periods ("workers" and "retirees", following Gertler (1999)). In order to capture the changing labour supply incentives of the elderly, we assume that "retirees" participate in the labour market. However, their labour efficiency is lower, to capture greater reliance on part-time work and possibly lower productivity. More generally, an elastic labour supply allows demographic change to feed through to capital and investment through capital-labour substitution effects.

Since labour income is reduced on retirement, workers discount future income at a higher rate, reducing consumption and increasing saving. In this sense, workers save for retirement. This reflects results in Gourinchas and Parker (2002), who find that observed saving patterns are consistent with forward-looking optimizing behaviour in a life-cycle setup with income uncertainty. Their study suggests that in early life 60–70 percent of non-pension wealth is due to precautionary saving. Finally, in AINO pensioners have a shorter planning horizon due to the constant periodic probability of death. Therefore they have a greater propensity to consume out of wealth. Gourinchas and Parker (2002) estimate retirees' marginal propensity to consume out of liquid assets at 6–7 percent. Finite lifetime and distortionary taxes break Ricardian equivalence, so that fiscal policy affects optimal allocations.

Individuals receive transfers from both the central government and the pension fund, reflecting the structure of the Finnish social security system. To preserve analytical tractability, pensions are related to the aggregate wage level and not to individual characteristics. The supply side (production structure) is based on a CES production technology with factor augmentation in the underlying technological processes and nominal and real rigidities. The model is closed by fiscal rules. Since central government and the pension fund are separate, one fiscal rule determines the long-term net lending rate of the pension fund, while the other ensures that the central government "debt ratio" returns to its long-run equilibrium after a shock. The model captures three factors underlying demographic dynamics: length of working careers, life expectancy and growth in the working-age population. These parameters define the changes in the old-age dependency ratio and allow the ageing process to be modelled as an exogenous change to work-retirement profiles. The parameters can be adjusted to match official projections of the population structure.

4.1. Scenario description

The model simulations analyze ageing as a permanent shock to the economy. Key parameters have been calibrated to reflect the main features of the respective economies.

Table 4 provides a description of the different scenarios. In the baseline scenario, the ageing (demographic) shocks in different models have been calibrated in such a way as to produce a 15 percentage point increase in the old-age dependency ratio, roughly in line with the average European ageing trend.

To assess the extent to which various policy measures could alleviate the macro-economic effects of ageing, the following policy experiments have been considered. In scenario Policy 1, the retirement age increases by 2 years, reflecting recent pension reforms implemented in various advanced countries (IMF (2010)). In scenario Policy 2, the pension replacement ratio is reduced by 15 percentage points. Finally, in order to assess the impact of different tax distortions caused by ageing, in scenario Policy 3, the consumption tax is increased by 1 percentage points. The results are reported in five-year intervals, assuming that the policies are implemented within the next 5 years. Results are shown over the medium-term, i.e. a 30-year interval. Appendix 3 reports results for selected macroeconomic variables for the different models. For the baseline simulation, results are expressed in differences compared to year 0, i.e. compared to the initial state. For the scenarios, results are expressed in differences compared to the values in the baseline.

Table 4: Scenario description

Scenario label	Scenario description
Baseline scenario	Gradual increase in dependency ratio by 15 percentage points over the next 30 years combined with increased contribution rates (taxes on labour income) to keep debt ratio at sustainable levels (initial steady state in PESSOA and AINO, below 60% in LOLA).
Policy 1	Permanent increase in the retirement age by 2 years (implemented within the next 5 years)
Policy 2	Permanent reduction of the gross replacement ratio by 15 percentage points (implemented within the next 5 years), in addition to Policy 1
Policy 3	Permanent increase in consumption taxes by 1 percentage point (implemented within the next 5 years), in addition to Policy 2

4.2. Simulation results from the Portuguese model

In PESSOA, the baseline scenario implies a substantial increase in social security contributions paid by employers and employees, raising the tax wedge on labour and therefore reducing labour supply. The required increase in the social security contribution rate is close to 25 percentage points (from a baseline level close to 35%). The incentive effects of such a tax adjustment suggest that ageing will jeopardize debt sustainability. Given the dramatic increase in the tax wedge on labour, the new steady state sees households consuming more leisure and consumption declining as a share of GDP. Simulation results suggest a protracted fall in real output growth in the range –0.5 to –0.3 per year over the first 30 years after the shock. All the simulated policy measures contribute to alleviate the impact of ageing on real GDP per capita, private consumption and hours worked.

The first policy measure, a 2-year increase in the retirement age, permanently reduces the share of the population entitled to old-age pensions and increases overall social security contributions as it enlarges their base. This reduces the required increase in the tax wedge on labour, attenuating the impact on labour supply, per capita consumption and real GDP. In the medium term, the impact on real GDP is also slightly less severe, only declining –0.3 to –0.2 per year. Nevertheless, while increasing the retirement age provides some relief, it cannot be the sole policy to tackle ageing.

The second policy measure – a permanent cut in the pension replacement ratio by 15% – contributes more to limit the impact of ageing. Since agents are allowed to work during retirement, their labour supply increases as old-age pensions are reduced. The impact is twofold. On the one hand, a permanent cut in the replacement ratio reduces old-age pension expenditure and therefore reduces government spending and the required increases in social security contribution rates. This mitigates the increase in the tax wedge on labour, encouraging labour supply, investment in more labour intensive technologies and employment. In addition, the cut in retiree income creates a further incentive for these households to supply labour, keeping down wages and contributing to a real exchange rate depreciation that limits the deterioration in net foreign assets. If this policy is combined with the 2-year increase in retirement age, the impact of ageing might be close to nil over the medium run and even positive in the short-run, as retirees continue to participate in the labour market.

Finally, the third policy measure – an increase in the consumption tax by 1 percentage point – further reduces the required increase in social security contribution rates, limiting the increase in the tax wedge on labour. This measure exploits the nominal rigidities in the economy to reduce real wages more rapidly, but also replaces taxes on labour with taxes on consumption, creating an incentive to save and reducing tax distortions. The impacts are visible in the level of output and employment, but the impacts on growth rates dissipate as soon as nominal rigidities stop playing a role and wages and prices return to the flexible price equilibrium. Therefore, the simulation does not provide convincing evidence that consumption taxes can play an important role in financing pensions.

4.3. Simulation results from the Luxembourg model

The baseline scenario ("Baseline" panel in Appendix 3) indicates that labour income taxes (including social security contributions by employers and employees) need to increase by up to 8 percentage points (pp) compared to current levels to keep the debt level below 60% of GDP within a 30-year horizon (current debt-to-GDP level about 20%). As explained below, LOLA incorporates official demographic projections that anticipate increases in both resident population and non-resident workforce, so total employment is increasing in the medium run despite ageing and higher taxes. However, the increase in labour taxes raises labour costs and therefore unemployment. The increase in labour taxes only delays the debt explosion, since in the longer run debt exceeds 60% of GDP (see line "Final SS").

Scenario Policy 1 raises the retirement age by two years, reducing the dependency ratio[22]. As a result, labour taxes need to increase by only 7.29 percentage points in the medium term (0.71 pp less than in the baseline). Employment is actually above baseline (unemployment falls – not shown), encouraging investment (consumption per capita and net foreign assets are lower). In the first five years per capita income accelerates and it remains above baseline in the long run.

In addition to the increased retirement age, scenario Policy 2 also reduces the pension replacement ratio by 15 percentage points. This significantly reduces the required increase in labour taxes to only 5.19 percentage points after 30 years (2.81 percentage points below the baseline). Investment is further boosted (at the expense of consumption) and employment also improves. Policy 2 leads to even higher income per capita in the long run.

In addition to the two previous policy changes, scenario Policy 3 also adds a 1 percentage point increase in the consumption tax rate. This reduces the required increase in labour tax rates by almost 4 percentage points compared to the baseline. Policy 3 further improves labour market outcomes (employment and unemployment).

4.4. Simulation results from the Finnish model

In the AINO simulations[23] we assume that labour income tax and pension contributions adjust to keep government debt close to 60% of GDP and the assets in the pension funds around 50% of GDP. The economic effect of ageing is usually analysed in terms of higher pension costs. However, population ageing will also increase public expenditure for health care, long-term care and social welfare services. In the AINO simulations, the supply of public services expands to meet the resulting increases in age-related expenditures. The evolution of public consumption expenditure reflects changes in the old-age dependency ratio. Growth of public spending related to the changing demographic structure lead to an increase in the share of public consumption in GDP. Estimates of the EU Working Group on Ageing are used to derive changes in age-related public consumption, assuming that the need for services will remain unchanged by age category. In other respects, the public services-to GDP ratio is assumed to remain constant, i.e. the rising standard

[22] In LOLA, the increase in retirement age is approximated by decreasing the leisure parameter that controls the early retirement decision. This raises the effective retirement age rather than the statutory retirement age.

[23] For details, see Kilponen, Kinnunen and Ripatti (2006).

of living resulting from economic growth will be fully reflected in the costs of public services[24].

In AINO, public consumption growth in response to ageing initially represents a positive demand shock, boosting total demand and leading to temporarily stronger growth. GDP growth per capita averages about 0.3% higher during the first 5 years of the simulation, but then falls below the balanced growth path. However, the expansion of public services leads to output losses in the private sector and higher labour costs due to employment increases in ageing-related services.

The dominant macro-economic effect of ageing remains a considerable increase in the tax burden. In the baseline (where the long-run old age dependency ratio increases by 15 percentage points), the labour income tax rate increases by more than 15 percentage points, while the pension contribution rate rises by 3 percentage points. The need to tighten tax rates is amplified by labour market responses since wages are higher than in the baseline, but total employment rates and the capital share are lower. Since productivity growth is slower in the public sector, overall labour productivity will decline. Growing demand for labour in the public sector also raises the price of public consumption.

Although increasing the retirement age and reducing the pension replacement rate (Policy 1 and Policy 2) stimulate labour supply with respect to baseline, this is not enough to offset the decline in total employment rates and in the long run the capital share and GDP fall well below the baseline. Therefore, taxes must rise substantially to stabilise debt-to-GDP ratios. The demographic shock also slows GDP growth in the medium term, since the increase in demand for ageing-related services is only a temporary stimulus. A 1 percentage point increase in the consumption tax rate (Policy 3) mitigates the required increase in labour taxes and contribution rates, which in turn attenuates the negative effect on GDP per capita. Overall, increasing the retirement age by 2 years, lowering the pension replacement ratio by 15 percentage points and increasing the consumption tax rate by 1 percentage point reduces the required increase in labour tax by roughly 7 percentage points. This provides substantial relief, reducing the negative impact of ageing on private consumption per capita. However, the overall increase in taxation still seems unreasonable given the already very high level of taxation in Finland.

[24] For details, see Kinnunen and Railavo (2011).

4.5. Results across models

It is important to note that PESSOA and AINO simulate the demographic shock at the steady state, while LOLA constructs its baseline scenario from the official long-term population projections. These envisage cross-border workers increasing their share of total employment at a slower pace than in the past (it rose from less than 10% in the 80s to 40% in 2012 and is expected to peak at 55%). Migration flows will contribute to an increase in the resident population, so that resident employment also grows over the next 50 years. As a result, total employment and debt both rise substantially in LOLA's baseline scenario, unlike in PESSOA and AINO. Employment growth would be even stronger without the tax increases required to stabilise the debt-to-GDP ratio.

In PESSOA and AINO, a labour tax increase around 10 percentage points is sufficient to keep debt close to the baseline (after 30 years). In LOLA, even larger tax increases will be required in the future to offset the additional retirement costs of the growing labour force. To keep results comparable across models, the baseline tax increase in LOLA is calibrated to match the ones in PESSOA and AINO, allowing debt to grow in the LOLA baseline.

AINO and PESSOA adopt essentially different strategies to model retirees, who play a crucial role in the analysis. In AINO, asset holding households save for retirement as in a partially-funded pension system. In PESSOA, retirees do not save for retirement, mimicking a pay-as-you-go pension system. Despite these differences, results are qualitatively similar at the aggregate level. Nevertheless, these may conceal different underlying behaviour of workers and pensioners in the two models, reflecting the different incentives to save for retirement.

4.6. Policy implications

The above analysis used three general equilibrium models to compare alternative policies to stabilize the debt-to-GDP ratio over the medium run (30 years). Although the modelling frameworks differ in their structure, calibration and results, they arrive at a common conclusion. To stabilise debt following a realistic demographic shock, labour taxes would have to rise to unacceptable levels. Higher labour taxes reduce labour supply and therefore medium-term growth. When this policy is combined with a 2-year increase in the retirement age (Policy 1), total pension expenditure is reduced and social contributions are increased by longer working lives. This reduces the cost of financing pensions and therefore requires a smaller increase in labour taxes to stabilise debt. The 2-year increase in the retirement age also increases labour

supply. However, this is insufficient to avoid the substantial drop in medium-term growth. When, in addition, the pension replacement ratio is cut 15 percentage points (Policy 2) this stimulates labour supply, offsetting the negative effects of the increase in contribution rates and the drop in medium-term growth is much more contained. An additional increase in consumption taxes (Policy 3) further reduces the required increase in social contributions and its negative impact on labour supply. In all three models both Policy 2 and Policy 3 outperform the baseline scenario and Policy 1 in terms of the outcome for employment, growth and GDP per capita.

Model results suggest a significant medium-term impact of ageing on the debt-to-GDP ratio. The 2012 Ageing Report by the European Commission indicates that the impact of ageing will differ across countries not only in terms of magnitude, but also in timing and dynamics. As a result, heterogeneous fiscal positions will pose a new challenge for European policy coordination. Ageing needs to be considered properly in any debt sustainability analysis (ECB (2012)).

Results also suggest that ageing dynamics will reduce medium and long term growth prospects. This is particularly challenging since many countries need higher growth to reduce debt. Box 4 surveys the literature on structural reforms as a means to foster medium-term growth. However, the simulations above suggest that timely policy action may improve the situation substantially, in particular if the required increase in social security contributions is complemented by extending the working life and reducing the pension replacement ratio.

Finally, the results suggest that a combination of policy instruments is best suited to mitigate the negative growth effects of aging. A 20 percentage point increase in social security contributions is unrealistic, even for economies where this tax rate is relatively low[25]. When the increase in social security contributions is accompanied by a 2-year increase in the retirement age, the negative impact on labour supply is reduced and medium-term growth benefits. Delayed retirement raises the level of GDP in the long term by only 3.8% in PESSOA, 6.0% in LOLA and 3.2% in AINO[26]. This is clearly not sufficient to offset the increase in the old-age dependency ratio over a 30-year horizon.

[25] According to national accounts data, social security contributions represent 28% of compensation of employees on average across euro area countries. Only in Ireland, Malta and Cyprus is this rate below 24%, and only in Greece, France and Slovakia it is above 33%.

[26] Barrell et al. (2011) found a 1% GDP increase from a 1-year increase in retirement age and Karam et al. (2010) found a 4.25% GDP increase from a 2-year increase in retirement age.

It should be kept in mind that social security contributions are a specific tax that households perceive as saving that entitles them to a future old-age pension. Thus, a substantial cut in the replacement ratio could be perceived as a form of default, with government reneging on its past promises, affecting credibility and realigning incentives. Some of the measures considered to cope with ageing could trigger changes in agent behaviour well beyond the decline in labour supply predicted by DSGE models, namely increased tax evasion and/or undeclared hours. Massive cuts in benefits risk provoking social unrest and may raise costs of providing public social and health systems.

The country-specific response to cope with ageing largely depends on current level of social contributions, income taxes and pension benefits. For countries where contributions and taxes are already high, a further increase may be counter-productive, leading to an ineffective policy response. The choice between increased contributions/tax rates and lower benefits is also a redistribution of the burden between current and future generations. This involves a trade-off between efficiency and equity in intergenerational terms and is therefore a political decision on which economists can only clarify the issues at stake to guide the policymaker. The kind of standard welfare analysis familiar from models with infinitely-lived representative agents is not directly applicable to OLG models, since generations will differ in size, endowments and utility levels each period. Nevertheless, labour and consumption developments can provide an informal welfare assessment. For example, the LOLA model has been used to compare different possible pension reforms in terms of their impact on the public deficit, economic growth and consumption[27].

Summing up, the adverse effects of ageing populations require comprehensive policy measures in many European countries. At the European level, coordination of fiscal policies and strengthening of free movement of labour are important measures that can mitigate the negative effects of ageing on growth and debt.

Box 5: Research on ageing, welfare and pensions in general equilibrium[28]

Box 5 provides a broader survey of the literature on ageing, welfare and pensions. This raises several issues that are complementary to the simulations

[27] See Box 4, pp.85-91 in Bulletin 2013-1 of the Banque centrale du Luxembourg.
[28] Prepared by Edgar Vogel.

in the previous section. Population ageing is a change in the population structure that leads to an increase in the population share of the elderly and a reduction in the population share of working age. Labour supply falls as longer lives increase life-cycle savings and therefore the capital stock[29]. The increase in the capital-labour ratio leads to a fall in the interest rate and an increase in wages. Most studies conclude that this will penalise the currently old (who are asset-rich) and benefit the young (through higher wages). Auerbach and Kotlikoff (1987) developed the workhorse model in this quantitative literature. Some studies also use the perpetual youth approach in Blanchard (1985) and Yaari (1965).

Below the literature is grouped in three parts. First, papers dealing with the effect of an ageing population on the accumulation of capital, international capital movements, factor prices, and welfare. Second, papers analysing the impact of ageing on pay-as-you-go (PAYGO) social security systems and the appropriate policy response. Third, endogenous growth models which link the change in the population structure to the endogenous long-run growth rate.

In the *open-economy literature on ageing*, Domeij and Flodén (2006) calibrate a model to OECD countries to show that different population structures can account for a small but significant portion of international capital flows. Rapidly ageing countries export capital to relatively young countries. They conclude that part of the observed external imbalances can be attributed to temporarily different population structures and will be reversed as young countries also enter the demographic transition.

Börsch-Supan, Ludwig, and Winter (2006) calibrate a large scale multi-country model to simulate alternative pension adjustment scenarios. They confirm the substantial capital flows from old to young countries and their reversal once young countries mature. Furthermore, they find that general equilibrium feedback effects can account for a drop in interest rates by as much as 200 basis points as the population ages. Finally, they show that a shift from a PAYGO pension system to a funded pension system has a substantially different effect depending on the openness of capital markets.

Attanasio, Kitao, and Violante (2007) use a similar model to quantify the effects of pension reforms in open economies. They find welfare differences are rather small although cross-border capital movements due to different population dynamics have large effects on capital accumulation, labour supply and factor prices. Adding idiosyncratic risk to the open-economy frame-

[29] See Sheshinski (2006), Sheshinski (2009) and Bloom, Canning, and Graham (2003) for papers linking population structure and aggregate savings in various setups.

work, Krüger and Ludwig (2007) find that US interest rates will drop by about 100 basis points. Fehr, Jokisch, and Kotlikoff (2005) focus on China's population dynamics and high savings rate, noting that these will raise world supply of capital and output. They warn that other open economy models that relegate China to the "Rest of the World" may produce misleading results.

Turning to the *literature on reforming PAYGO pension systems*, De Nardi, İmrohoroğlu, and Sargent (1999) warn that "back-of-the-envelope" attempts to evaluate the sustainability of US social security can provide very misleading results since they ignore general equilibrium feedback effects. In a closed-economy OLG framework, they find that current levels of generosity cannot be maintained without dramatic increases in contributions or taxes, which will generate large distortions.

Huang, İmrohoroğlu, and Sargent (1997) find that moving from pay-as-you-go to a funded system carries long-run benefits. They compare two policy experiments: eliminating social security immediately but compensating pensioners by increasing debt ("buy-out") or preparing the transition by temporarily raising labour taxes to build up a fund to finance future pensions. Their simulations suggest that the second policy is more efficient. The difference is mostly because government provides insurance against two risks: higher labour income taxes reduce labour income risk, while social security benefits insure against longevity risk.

Nishiyama and Smetters (2007) and Fehr, Habermann and Kindermann (2008) use similar models to simulate transition to a fully funded system in the US and Germany. As in the rest of the literature, they find that moving to a fully funded system would deliver welfare gains for households born after pay-as-you-go is phased out. However, after accounting for transition costs, this reform does not always deliver efficiency gains[30]. Both papers find that the reform is only efficient if labour taxation loses its role as a partial insurance mechanism (Nishiyama and Smetters (2007)). Furthermore, reducing social security carries larger efficiency losses in the US than in Germany, where benefits are more closely linked to contributions[31].

Conesa and Krüger (1999) simulate potential reforms of the US pension system in a model with heterogeneous agents. They find that under plausible assumptions, there is no reform which would be accepted by majority voting. The share of agents supporting the reform is also reduced if the labour

[30] The reform is "efficient" if savings equal the hypothetical lump-sum transfers required to leave all households indifferent between the two steady states (see Nishiyama and Smetters (2007) or Auerbach and Kotlikoff (1987).

[31] In other words, the US system is more redistributive. See also Diamond and Gruber (1999).

income process becomes more risky. This finding confirms the result above: the pensions system acts as an important insurance mechanism against a series of "unlucky" draws in the labour market.

Fuster, İmrohoroğlu and İmrohoroğlu (2007) take a different approach by modeling two-sided altruism. In this setting parents care about children (and vice versa), so potential welfare gains can be optimally redistributed within a family (over time) which should facilitate the move to a funded pension system. They suggest decreasing contributions but compensating pensioners by issuing debt financed by higher consumption taxes. In such a setting, welfare increases for 58% of agents, who would then support the reform. A flexible labour market is crucial for this result.

Ludwig, Schelkle and Vogel (2012) show that investment in human capital can reduce welfare losses during the demographic transition for both current and future generations. However, as in Fuster, İmrohoroğlu, and İmrohoroğlu (2007), distortions must be kept low (i.e. cutting pensions while keeping contribution rates constant) or they will affect incentives for human capital accumulation as well as labour supply. In a companion paper, Vogel, Ludwig, and Börsch-Supan (2012) find that raising the retirement age is a good alternative to cutting pensions. If labour supply and human capital are endogenous, increasing the retirement age has large positive welfare effects compared to increasing contributions.

Storesletten (2000) examines the contribution of immigration to relieving pressure on the US pension system. He finds that past immigration rates are not sufficient to solve the problem. Not even the most favorable immigration policy (i.e. selection of young and highly educated agents) can avoid a fundamental pension reform.

Finally, the *endogenous growth literature* has reached a consensus that higher life expectancy will increase growth. Unlike the quantitative literature reviewed above, the literature on ageing and endogenous growth usually relies on the framework developed by Blanchard (1985) and Yaari (1965). This delivers elegant and tractable solutions in endogenous growth models but provides less scope for quantitative exercises.

Boucekkine, de la Croix, and Licandro (2002) and de la Croix and Licandro (1999) focus on endogenous human capital accumulation. As life expectancy increases, agents devote more time to accumulating human capital and retire later, raising aggregate human capital and growth. The relationship is not monotonic, as human capital is assumed to be generation-specific and less productive among older agents. Therefore, if the population grows too old the growth rate falls as an increasing share of the workforce is

less productive. Echevarría and Iza (2006) develop a similar model but add a link from past earnings to pension payments. All else equal, a more generous pension system encourages investment in human capital and therefore growth. However, in general equilibrium more generous social security requires higher contribution rates, discouraging labour supply and investment in human capital. Only for very low contribution rates will the positive effect outweigh losses due to distortions.

In summary, it is well established that an older population will raise the capital-output ratio, cut the marginal product of capital and increase wages. Exporting capital to countries with higher returns (i.e. developing countries with younger populations) will only temporarily decouple domestic demographics from general equilibrium prices. Eventually, younger countries are also expected to enter demographic transition, reversing international capital flows.

To continue financing PAYGO pensions as the population ages, governments must raise contributions or cut benefits. New debt may temporarily finance expenditures but cannot be a long-run solution. Maintaining current pension levels will discourage capital accumulation by limiting incentives to save. Increasing contributions will reduce labour supply. Therefore, in the long run the ageing process will impose large welfare losses if pension benefits are maintained at current levels. There will be additional negative effects from distortions on human and physical capital accumulation. One possible compromise is to keep pensions constant but increase the retirement age. Higher migration only provides a partial and temporary solution.

Reducing the pay-as-you-go component may provide long-run benefits, but public pensions are also welfare-enhancing as they provide insurance against longevity and income risk. Therefore, a shift to a fully funded system is not necessarily optimal. In addition, social security reform faces political obstacles since current retirees (and agents close to retirement age) will incur welfare losses. Reform will only benefit current retirees under special assumptions (strong externalities, altruism, etc.).

In the endogenous growth literature, increased life expectancy should raise investment in human capital and therefore economic growth. This result relies on the assumption that agents will respond to longer lifetimes by raising investment. However, these models are highly stylized and the quantitative literature is still in its infancy.

5. Conclusions

The weak and protracted recovery following the Great Recession has brought medium-term prospects more sharply into focus. From this perspective, high public debt and ageing populations pose a number of challenges for economic growth. This paper analysed them from several angles.

Starting with public debt, the theoretical literature (Box 1) suggests that while government debt can have beneficial effects, increasing public debt also crowds out private sector investment and hampers economic growth. Cross-country evidence from the empirical literature (Box 2) suggests a possible threshold beyond which increases in public debt lead to lower economic growth. Furthermore, the relationship between debt and growth is unlikely to be one-way, since sovereign debt yields are likely to react to growth prospects (Box 3). The model simulations in Section 2 suggest that reductions in risk premia my help to attenuate the contractionary effects of fiscal consolidation, in particular if policy is credible and financial markets are forward-looking.

Longer-term growth prospects are also affected by structural characteristics of the economies. Box 4 surveys the research on structural reforms, which suggests that short-term costs are offset by long-term gains. Section 3 analyses the impact of population ageing on economic growth by extending the standard growth accounting exercise from a partial equilibrium perspective. The proposed growth accounting approach disaggregates labour input into categories by age, sex citizenship and education. The results emphasise that changing population structures will have important composition effects on potential growth, which could be mitigated by structural reforms boosting labour force participation.

Finally, Section 4 analyses the effects of ageing from a general equilibrium perspective. The economic literature surveyed in Box 5 suggests that ageing will reduce the marginal product of capital, increasing wages and the financial burden of pay-as-you-go public pension systems. The section uses three different macro-economic models to evaluate the impact of demographic change on economic growth and public finances. The simulation results confirm that the increased cost of public pensions cannot be met solely by raising social contributions/labour taxes without requiring unrealistic adjustments and substantial falls in medium-term growth. Better solutions must combine different reforms with offsetting incentive effects on agents' labour supply in order to mitigate the impact on medium-term growth.

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Appendix

Appendix 1: Section 2 – Debt sustainability equations

Government Debt accumulation:

$$\Delta b(t) = \left[\frac{i(t) - g(t)}{1 + g(t)}\right] \cdot b(t-1) - pb(t) + dda(t),$$

where *b* is the debt-to GDP ratio, *i* is the nominal effective/implicit interest rate, *g* is the nominal GDP growth, *pb* is the primary balance-to-GDP ratio and *dda* are deficit-debt adjustments (in % of GDP), i.e. changes in government debt that are not recorded in the deficit (e.g. asset purchases).

Fiscal rule:

As households are non-Ricardian, the path of government debt and taxes matter for the evolution of the economy. Therefore governments aim to insure stability of the public debt stock. The fiscal policy rule is based on a reaction of personal income taxes to the deviation of the government's debt to GDP ratio from its predetermined target and which contributes to adjustment towards the stock-flow equilibrium in the long-run.

$$\Delta \tau_t = \phi_1 \left(b_{t-1} - b^{t\arg et}\right) + \phi_2 \Delta b_{t-1},$$

where τ_t is the personal income tax rate and and b^{target} is the target debt-to-GDP ratio. The parameters ϕ_1 and ϕ_2 are calibrated to 0.003 and 0.03 respectively.

Interest payments on debt:

$$i(t) = \left(1 - alpha/4\right) \cdot i(-1) + \left(alpha/4\right) \cdot \left(i^l + RP/100\right),$$

where i^l is the marginal interest rate determined from a term structure of the short-term interest rate, RP is the sovereign risk premium (see below) and alpha is the proportion of debt which is rolled-over each year.

Yearly share of maturing debt (average over last 5 years):

Country	FR	DE	IT	ES	NL	Smaller countries
Share	0.209	0.188	0.273	0.186	0.208	0.179

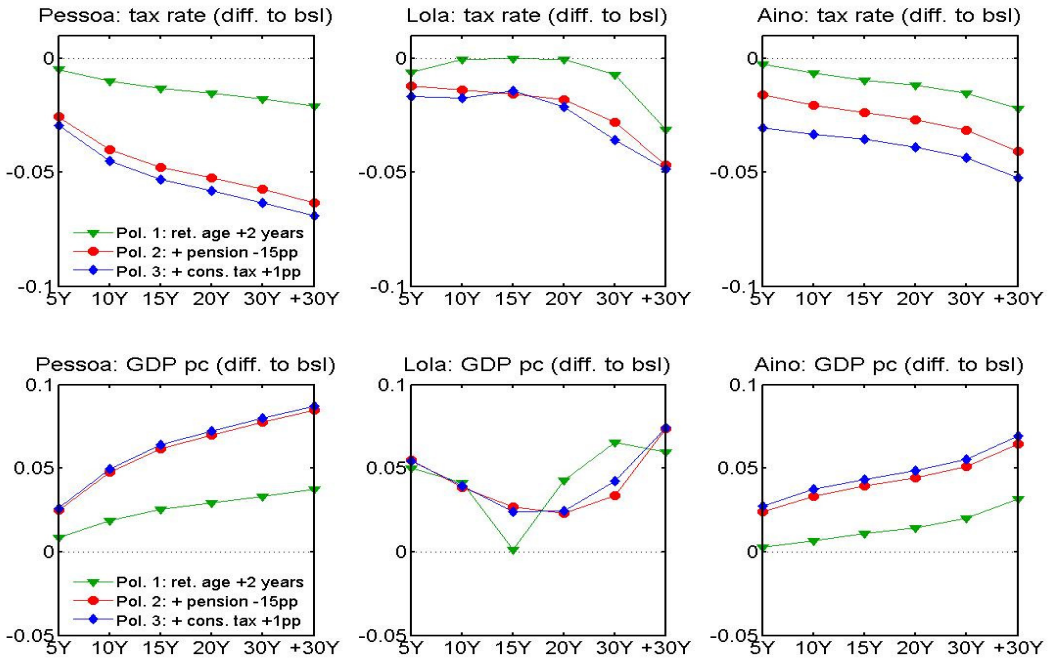
Non-linear Sovereign Risk Premia:

$$RP = \left(0.00087 \cdot b^3 - 0.1014 \cdot b^2 + 3.90941 \cdot b - 24.492\right) - RP_{base},$$

where RP is risk premium, and RP_{base} is base level.

Appendix 2: Section 4 - Simulation charts and table

Simulation results (deviations from baseline)[32]



[32] The value +30y on the x-axis is a long-term average. See Table 4.4 for explanations.

Appendix 3: Simulation results from the three DSGE models

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		Dependency ratio			Labour Income Tax			GDP/capita			Employment			Annual Debt/GDP			Growth/Capita		
		PESSOA	LOLA	AINO	PESSOA	LOLA	AINO	PESSOA	LOLA	AINO	PESSOA	LOLA	AINO	PESSOA	LOLA	AINO	PESSOA	LOLA	AINO
Baseline					**Pure Demographic Shock (longevity shock leading to 15 pp increase in old age dependency ratio)**														
	5Y	0.0273	0.0255	0.0291	0.0361	0.0098	0.0263	-0.0179	0.0203	-0.0230	-0.0214	0.0413	-0.0169	0.0410	0.0428	0.0132	-0.0036	-0.0035	-0.0046
	10Y	0.0517	0.0560	0.0530	0.0625	0.0154	0.0546	-0.0440	0.0375	-0.0505	-0.0505	0.0746	-0.0481	0.0295	0.0823	0.0152	-0.0045	-0.0041	-0.0052
	15Y	0.0715	0.0754	0.0722	0.0794	0.0308	0.0744	-0.0649	0.0647	-0.0756	-0.0694	0.0926	-0.0732	0.0174	0.0931	0.0116	-0.0045	-0.0023	-0.0052
	20Y	0.0875	0.0884	0.0876	0.0915	0.0517	0.0896	-0.0804	0.0614	-0.0965	-0.0824	0.0991	-0.0925	0.0077	0.1028	0.0093	-0.0042	-0.0082	-0.0051
	30Y	**0.1107**	**0.1070**	**0.1100**	**0.1071**	**0.0800**	**0.1129**	**-0.0999**	**-0.0176**	**-0.1274**	**-0.0977**	**0.1384**	**-0.1202**	**-0.0066**	**0.2980**	**0.0066**	**-0.0035**	**-0.0169**	**-0.0045**
	Final SS	0.1502	0.1500	0.1505	0.1290	0.1150	0.1566	-0.1243	-0.0550	-0.1848	-0.1143	0.1987	-0.1735	-0.0313	0.6114	-0.0009	-0.0005	-0.0153	-0.0006
Policy 1					**Increase in retirement age by 2 years (changes compared to evolution in the Baseline)**														
	5Y	-0.0034	-0.0664	-0.0034	-0.0048	-0.0062	-0.0025	0.0085	0.0501	0.0027	0.0060	0.0756	0.0022	-0.0097	0.0000	-0.0014	0.0017	0.0100	0.0005
	10Y	-0.0066	-0.0508	-0.0069	-0.0100	-0.0006	-0.0065	0.0189	0.0414	0.0068	0.0119	0.0889	0.0067	-0.0063	-0.0026	-0.0022	0.0019	-0.0017	0.0007
	15Y	-0.0093	-0.0221	-0.0097	-0.0131	-0.0002	-0.0095	0.0256	0.0014	0.0108	0.0153	0.0625	0.0107	-0.0032	0.0067	-0.0019	0.0017	-0.0079	0.0007
	20Y	-0.0115	-0.0053	-0.0119	-0.0152	-0.0005	-0.0118	0.0295	0.0427	0.0145	0.0174	0.1051	0.0140	-0.0010	-0.0390	-0.0015	0.0014	0.0082	0.0007
	30Y	**-0.0147**	**-0.0128**	**-0.0152**	**-0.0177**	**-0.0071**	**-0.0154**	**0.0334**	**0.0656**	**0.0201**	**0.0198**	**0.1234**	**0.0189**	**0.0019**	**-0.0379**	**-0.0011**	**0.0011**	**0.0219**	**0.0007**
	Final SS	-0.0205	-0.0571	-0.0210	-0.0210	-0.0311	-0.0221	0.0377	0.0596	0.0315	0.0227	0.0601	0.0288	0.0063	0.0114	0.0001	0.0001	0.0003	0.0001
Policy 2					**Policy 1 + Reduction in pension replacement ratio by 15 pp (changes compared to evolution in the Baseline)**														
	5Y	-0.0034	-0.0734	-0.0034	-0.0257	-0.0120	-0.0160	0.0250	0.0550	0.0238	0.0270	0.0852	0.0315	-0.0208	-0.0165	-0.0070	0.0049	0.0109	0.0047
	10Y	-0.0066	-0.0623	-0.0069	-0.0400	-0.0139	-0.0206	0.0476	0.0386	0.0334	0.0445	0.0954	0.0390	-0.0107	-0.0042	-0.0034	0.0046	-0.0032	0.0033
	15Y	-0.0093	-0.0414	-0.0097	-0.0477	-0.0155	-0.0238	0.0617	0.0272	0.0395	0.0531	0.1018	0.0437	-0.0028	0.0070	-0.0025	0.0040	-0.0022	0.0026
	20Y	-0.0115	-0.0215	-0.0119	-0.0524	-0.0182	-0.0270	0.0698	0.0232	0.0444	0.0578	0.0891	0.0476	0.0024	0.0001	-0.0023	0.0034	-0.0008	0.0022
	30Y	**-0.0147**	**-0.0238**	**-0.0152**	**-0.0575**	**-0.0281**	**-0.0314**	**0.0775**	**0.0339**	**0.0511**	**0.0621**	**0.0825**	**0.0530**	**0.0088**	**-0.0062**	**-0.0016**	**0.0025**	**-0.0007**	**0.0017**
	Final SS	-0.0205	-0.0720	-0.0210	-0.0633	-0.0466	-0.0406	0.0848	0.0736	0.0645	0.0663	0.1110	0.0635	0.0177	-0.0069	-0.0001	0.0003	0.0076	0.0002
Policy 3					**Policy 2 + Increase in consumption tax by 1 pp (changes compared to evolution in the Baseline)**														
	5Y	-0.0034	-0.0749	-0.0034	-0.0293	-0.0168	-0.0305	0.0260	0.0547	0.0275	0.0283	0.0881	0.0365	-0.0198	-0.0073	-0.0120	0.0051	0.0109	0.0054
	10Y	-0.0066	-0.0637	-0.0069	-0.0450	-0.0175	-0.0333	0.0494	0.0394	0.0375	0.0465	0.0986	0.0439	-0.0097	0.0094	-0.0032	0.0048	-0.0029	0.0037
	15Y	-0.0093	-0.0395	-0.0097	-0.0533	-0.0142	-0.0355	0.0639	0.0242	0.0434	0.0554	0.0975	0.0480	-0.0018	0.0035	-0.0022	0.0041	-0.0030	0.0028
	20Y	-0.0115	-0.0238	-0.0119	-0.0582	-0.0214	-0.0389	0.0722	0.0245	0.0485	0.0602	0.0935	0.0520	0.0036	-0.0081	-0.0025	0.0035	0.0001	0.0024
	30Y	**-0.0147**	**-0.0305**	**-0.0152**	**-0.0634**	**-0.0357**	**-0.0435**	**0.0799**	**0.0423**	**0.0554**	**0.0644**	**0.0962**	**0.0575**	**0.0102**	**0.0015**	**-0.0016**	**0.0026**	**0.0011**	**0.0018**
	Final SS	-0.0205	-0.0721	-0.0210	-0.0691	-0.0485	-0.0524	0.0872	0.0741	0.0692	0.0684	0.1117	0.0688	0.0192	0.0016	0.0000	0.0003	0.0060	0.0002

Note: - The Baseline results expressed in percent (Employment and GDP/capita) or percentage point (Dependency ratio, taxes, annual debt/GDP, and Growth/capita) deviation to the model's initial steady state (year 0). The model's steady state is balanced growth path steady state where the demographic structure of the economy is unchanged.

- Results for Policy 1, 2 and 3 are expressed in percent or percentage point change compared to the Baseline values.

- Growth/Capita indicates GDP per capita growth. For Luxembourg (LOLA model), the dependency ratio, GDP per capita, employment and growth/capita exclude cross-border workers.

Occasional Papers of Eesti Pank 2015

No 1
Liina Malk. Labour Cost Adjustment in Estonia During and After the Crisis