Fiscal policy in EMU with downward nominal wage rigidity

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Abstract

There is considerable empirical evidence for downward nominal wage rigidity in EMU countries in the recent bust episode. We use a three region (EA periphery-RoEA-RoW) DSGE model to analyse two alternative fiscal strategies for an individual country in EMU, namely an increase in government expenditure vs. a reduction in revenues, via a cut in employers' social security contributions. Both fiscal strategies have been advocated as possible instruments in the current juncture. An expenditure increase can especially be effective under a ZLB constraint since it raises inflation. A cut in SSC is targeting the constraint on wage inflation and facilitates labour market clearing. It is shown that for an open economy in EMU the latter fiscal strategy is superior along two dimensions. First the fiscal multiplier is larger and second, the budgetary costs are smaller because the adjustment of the economy to a SSC reduction is more tax rich. These two features strongly reduce the budgetary cost and make this policy measure attractive for a number of periphery countries which suffer from very limited fiscal space.

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Introduction

One of the policy dilemmas in the Eurozone in the aftermath of the financial crisis was that countries which required a fiscal impulse, i. e. countries with the highest output gaps, did not have large fiscal space and suffered from high and rising government debt. One fiscal strategy often discussed to deal with this problem is to ask countries with fiscal space within the eurozone, to conduct more expansionary fiscal policies and rely on fiscal spillover effects (see IMF and G7, G20 meetings). As shown by recent research (see In't Veld, 2016, Blanchard, Erceg and Lindé, 2016) such a strategy can indeed have stronger spillover effects within a monetary union under a ZLB constraint for monetary policy. However, such proposals only have very limited prospects for being implemented, since countries with fiscal space often have policy preferences in favour of reducing government debt or judge that their current fiscal stance is adequate from a purely domestic perspective. This raises the question whether fiscal measures exist which could be pursued directly by periphery countries. Any policy with a realistic prospect of being implemented should ideally meet two requirements, given the specific circumstances these countries are in. First it should have large multiplier effects and, second, it should minimise budgetary costs. Though the first requirement goes a long way in also meeting the second criterion, the latter does not automatically follow from the first. Suppose for example that there are two alternative fiscal strategies with identical multiplier effects, they can nevertheless have different budgetary cost if they affect tax, transfer and benefit bases differently. What are these specific circumstances one should care about when designing fiscal measures? For periphery countries the post-2009 period is characterised by a large loss in output (large output gap), low price inflation, low productivity growth and wage adjustment needs due to a loss of competitiveness in the pre-2009 boom period. As will be shown below, because of these specific circumstances, there is one additional friction relevant for periphery countries in a low/negative inflation and low/negative productivity growth environment, namely a zero bound constraint on nominal wage growth (ZBWG). This constraint prevents a rapid adjustment of nominal unit labour cost in periphery countries.

Fiscal policy discussions at the current juncture usually focus on the ZLB constraint on the policy rate and advocate raising government expenditure because of the higher fiscal expenditure multiplier implied by the ZLB (see Coenen et al., 2012, Christiano et al., 2011). Coenen et al. (2012) show that an expenditure increase yields larger multipliers compared to a revenue reduction. However, there remains uncertainty about the inflationary impact of such measures (see discussion of Blanchard et al. (2016) by Uhlig (2016) and Linde and Trabandt (2016)). Second, the multiplier effect is often discussed in a closed economy context and disregards open economy aspects such as detrimental effects of inflation on competitiveness. Because of the latter, Farhi and Werning (2014) argue that the fiscal spending multiplier in open economies within a monetary union is likely to be smaller than one, since the real interest rate reducing effect of spending will be largely offset by competitiveness losses.

In this paper, we extent the discussion of fiscal policy in individual countries of EMU by also taking into account the ZBWG constraint. In this context we take up the discussion again on the relative effectiveness of an increase in spending vs a cut in revenues. In particular, we compare two types of policies to each other, namely an increase in government purchases and a reduction of employer's social security contributions (SSC). The ZBWG constraint will likely have ambiguous consequences for the open economy spending multiplier. On the one hand, it reduces the inflation effect of the fiscal shock and therefore further reduces the domestic demand stimulus via the expected real interest rate channel, on the other hand, it mitigates adverse competitiveness effects.

Wage subsidies for firms has been proposed by Schmitt-Grohe and Uribe (2015). This policy measure targets the wage adjustment friction in the labour market directly but does not exploit the ZLB constraint. However, since inflation has ambiguous effects on the fiscal multiplier in open economies, a policy which targets the ZBWG friction instead of the ZLB constraint may be more efficient for an open economy in a monetary union.

We take up this issue and compare the effects of a temporary expenditure increase vs. a temporary reduction of social security contributions paid by firms in the context of a fully specified 3-region DSGE model of the eurozone periphery, the rest of the eurozone and the rest of the world. The model features a standard wage setting rule, which exhibits nominal and real

wage adjustment frictions. We add to these wage frictions a downward nominal wage rigidity. We model this friction as a partially binding constraint. In order to implement this we create a deflationary crisis baseline with a fall in output and inflation similar to what has been experienced in the EA periphery.

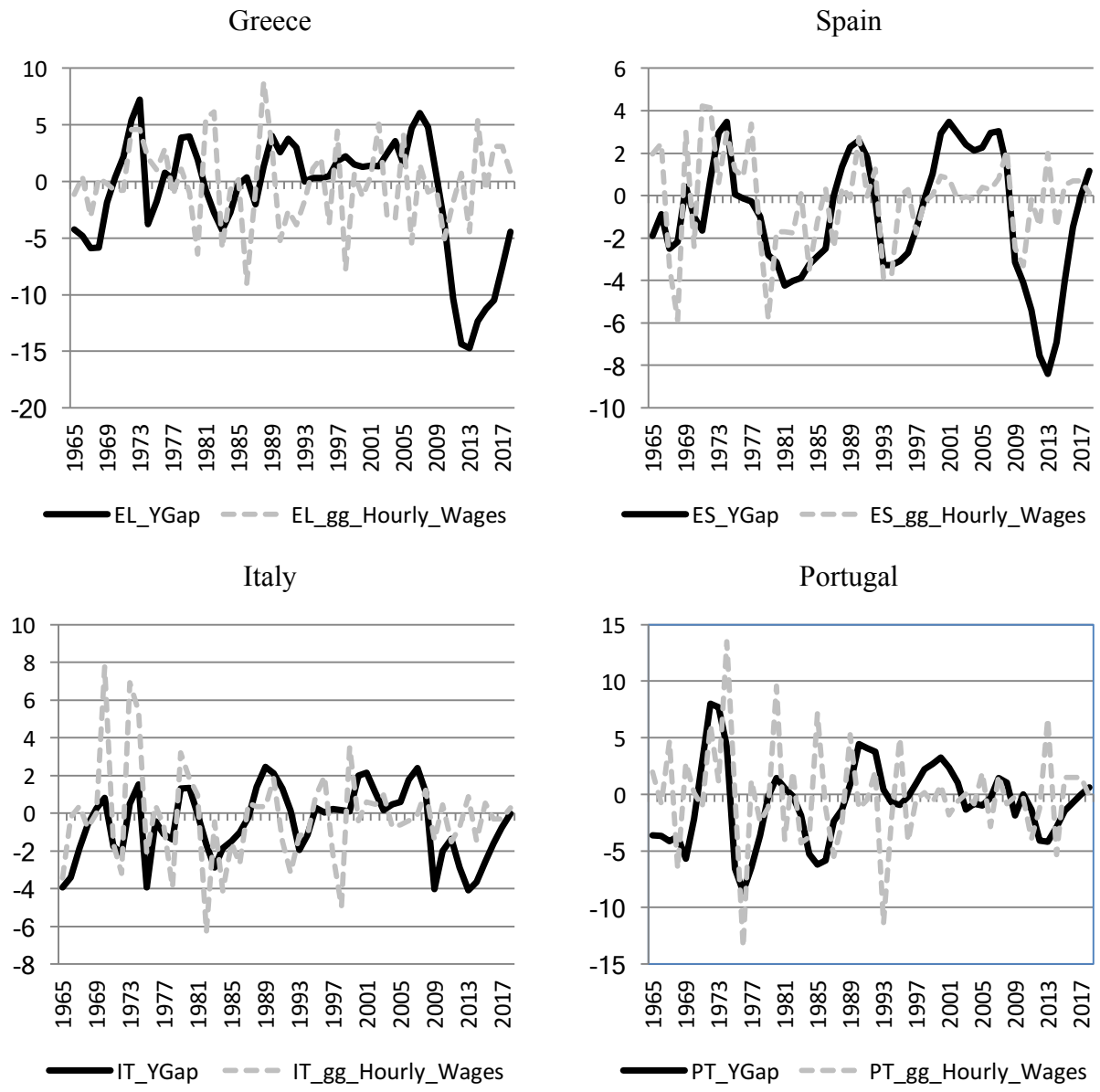
The structure of the paper is as follows. Section 1 provides some empirical evidence that wage inflation is constrained around zero in EA periphery countries. Section 2 presents the model and discusses the type of wage frictions we are considering. Section 3 presents a baseline scenario, where we give positive and negative demand shocks, in order to generate a boom and a bust in the order of magnitude as observed for EA periphery countries. Section 4 discusses fiscal policy options for periphery countries within EMU. Essentially we compare GDP effects and budgetary costs of a temporary increase in public consumption with a temporary reduction of employers' social security contributions. Both measures are ex ante identical. In order to identify the impact of the wage friction we compare both policies with and without zero bound on wages. Section 5 concludes.

1. Empirical Evidence on downward nominal wage rigidity

The presence of downward nominal wage rigidity is often discussed in the economics literature. For example, Holden and Wulfsberg (2008) provide evidence for downward nominal wage rigidity for OECD countries in the pre-2009 period. Given the low inflation in the aftermath of the 2009 financial crisis this phenomenon appears more acute now. Schmitt-Grohe and Uribe (2016) provide empirical evidence that nominal rigidity may have indeed been prevalent in the post-2009 years. Using Data on nominal average hourly labour cost in manufacturing, construction and services they show positive wage growth in Ireland, Italy, Spain and Portugal over the period 2008Q1 to 2011Q2 despite strongly rising unemployment rates over the same period. The OECD economic outlook 2014 also provides micro evidence for increased nominal downward wage rigidity in Greece, Portugal and Spain. Using administrative data for Spain it is shown that the incidence of wage freezes at zero increased from 3% in 2008 to 22% in 2012. A survey conducted in 2009 by the Wage Dynamics Network (WDN) of European central banks also comes to the conclusion that downward wage rigidity is prevalent. Only a small percentage of firms reported cuts in base wages (see ECB 2012). Figure 1 shows output gaps and the first

difference of nominal wage growth for EA periphery countries. These graphs illustrate that relative to the large output gap in periphery countries, deceleration of wage inflation remained benign after 2009. It is interesting to notice that initially (around 2009) there is a drop in wage inflation, however the deceleration of wage inflation does not continue as the output gap increases.

Figure 1: Output gap and nominal wage growth acceleration in EA periphery countries



Source: AMECO, European Commission

Taking Italy as an example, compared to previous recessions around 1982 and 1993, which were associated with a deceleration of nominal wage growth, such a deceleration did not occur after 2008, despite the large and long output gap Italy experienced.

2. Model and Wage rule

For our analysis we use a three region DSGE model and we distinguish between a representative EA periphery country, the rest of the Euro area and the rest of the world. A detailed model description and calibration is contained in the appendix of this paper. In this section we concentrate on the description of the wage Phillips curve and the non-linearity imposed by the ZBWG.

We assume that trade union set wages according to the standard Phillips curve mechanism. They target real consumption wages (W_t/P_t^C) in the medium term to be consistent with the marginal rate of substitution between leisure and consumption of a weighted average of constrained and unconstrained households. There are two types of adjustment frictions which prevent a rapid adjustment of real wages. First, because of wage contracts with duration of more than one quarter there is a nominal wage friction. In addition, there is often habit persistence in wage setting which restricts fluctuations of real wage growth (adjusted for trend productivity growth) (see Blanchard et al., 2015). Both constraints are operative in the standard model. In this paper we consider an additional constraint on nominal wage adjustment, namely a floor on nominal wage growth at zero, which is likely to be relevant for a number of periphery countries with high wage adjustment needs in an environment with very low or even negative inflation. The wage Phillips curve is given by the following equation, where $U^i_{1-L_t}$ and $U^i_{C_t}$, (i=r,c) are the marginal utility of leisure and consumption of the two households, $\beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor of the unconstrained household. The slope coefficient id a function of labour demand (θ) and wage adjustment cost (γ_w) parameters. The degree of real wage rigidity is denoted by (ϕ) and π_t^w is wage inflation.

$$\pi_t^w = \frac{\beta\lambda_{t+1}}{\lambda_t} E_t \pi_{t+1}^w + \frac{(\theta-1)}{\gamma_w} \log\left((1 + mup_t^w) \left(\frac{(s^r U_{1-L_t}^r + s^c U_{1-L_t}^c)}{(s^r U_{C_t}^r + s^c U_{C_t}^c)} \right)^{1-\phi} \left(\frac{W_{t-1}}{P_{t-1}^C} \right)^{\phi} \frac{P_t^C}{W_t} \right) \quad (1)$$

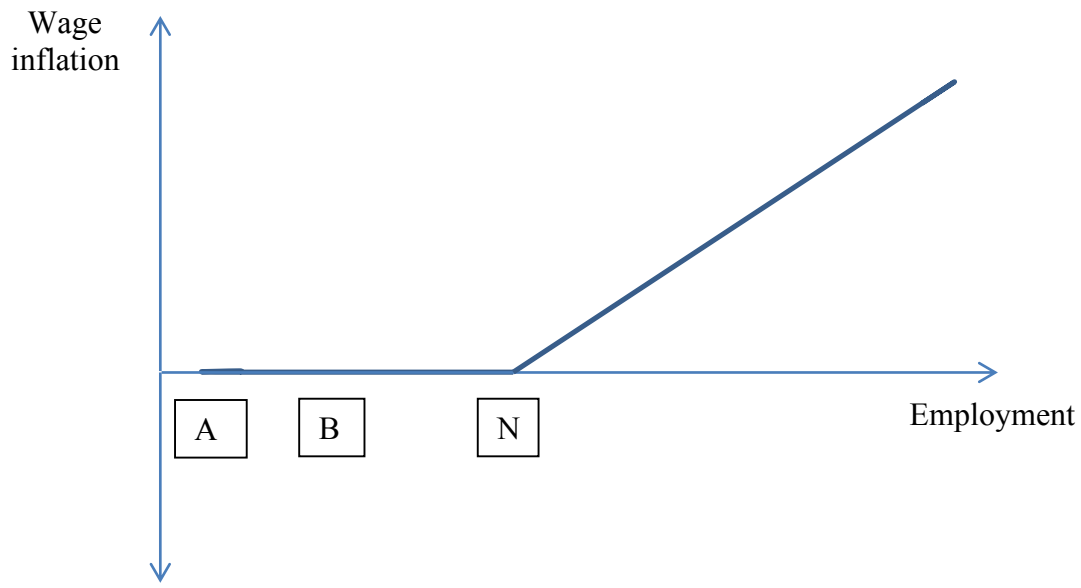
The non-linearity of the ZBWG can be characterised as follows

$$\pi_t^W = Max\{0, f(C_t, L_t, E\pi_{t+1}^W)\} \quad (2)$$

where $f(.)$is the RHS of eq (1). In the New Keynesian model this wage rule is derived form a monopolistically competitive trade union which sets wages for workers (supplying varieties of labour). The zero bound on wage growth is not the result of utility maximisation on behalf of workers but is an additional (ad hoc) constraint. Knowing that this constraint exist there could be strategic wage behaviour in order to avoid the wage constraint (see Elsby, 2009), such as for example wage restraint in the boom phase in order to avoid strong downward wage adjustments in the bust. As pointed out by Schmitt-Grohe and Uribe (2016) the strong increase in nominal wages in the EA periphery (despite modest inflation and low TFP growth) suggests that such strategic considerations did not play a dominant role.

The properties of wage inflation and employment in the presence of a ZBWG are illustrated in Figure 2. In the inflation employment space we get a positive relationship between wage inflation and employment. The wage inflation-employment schedule has a kink at point N since nominal wage growth cannot fall below zero. Suppose the economy is in the constrained regime with employment level A. Any policy which moves employment up from point A to B will not be inflationary. Only policies which move employment beyond point N will be inflationary.

Figure 2: Wage inflation and employment



3. Boom Bust Cycle in EA periphery

Our starting point consists in generating a boom and bust baseline which generates a decline of economic activity and inflation. As shown in Table 1 the output loss as measured by the output gap was enormous. As a consequence of the financial crisis nature of the recession, the main driver of the output loss was a drop in the investment rate. The bust also caused a fall in inflation and an increase in government debt, which leaves little fiscal space for periphery countries.

Table 1: Bust in EA periphery countries

	Output Gap (difference between peak and trough)*	Investment to GDP ratio (difference between pre crisis peak and post 2009 trough)*	Inflation (difference between pre crisis and after 2009 trough)**	Debt to GDP ratio (difference between pre crisis and post 2009 level)**
Italy	-6.5	-5.9	-1.9	32.9
Spain	-11.4	-11.9	-3.0	64.4
Greece	-19.2	-15.6	-5.1	73.9
Portugal	-5.6	-7.8	-2.7	61.8

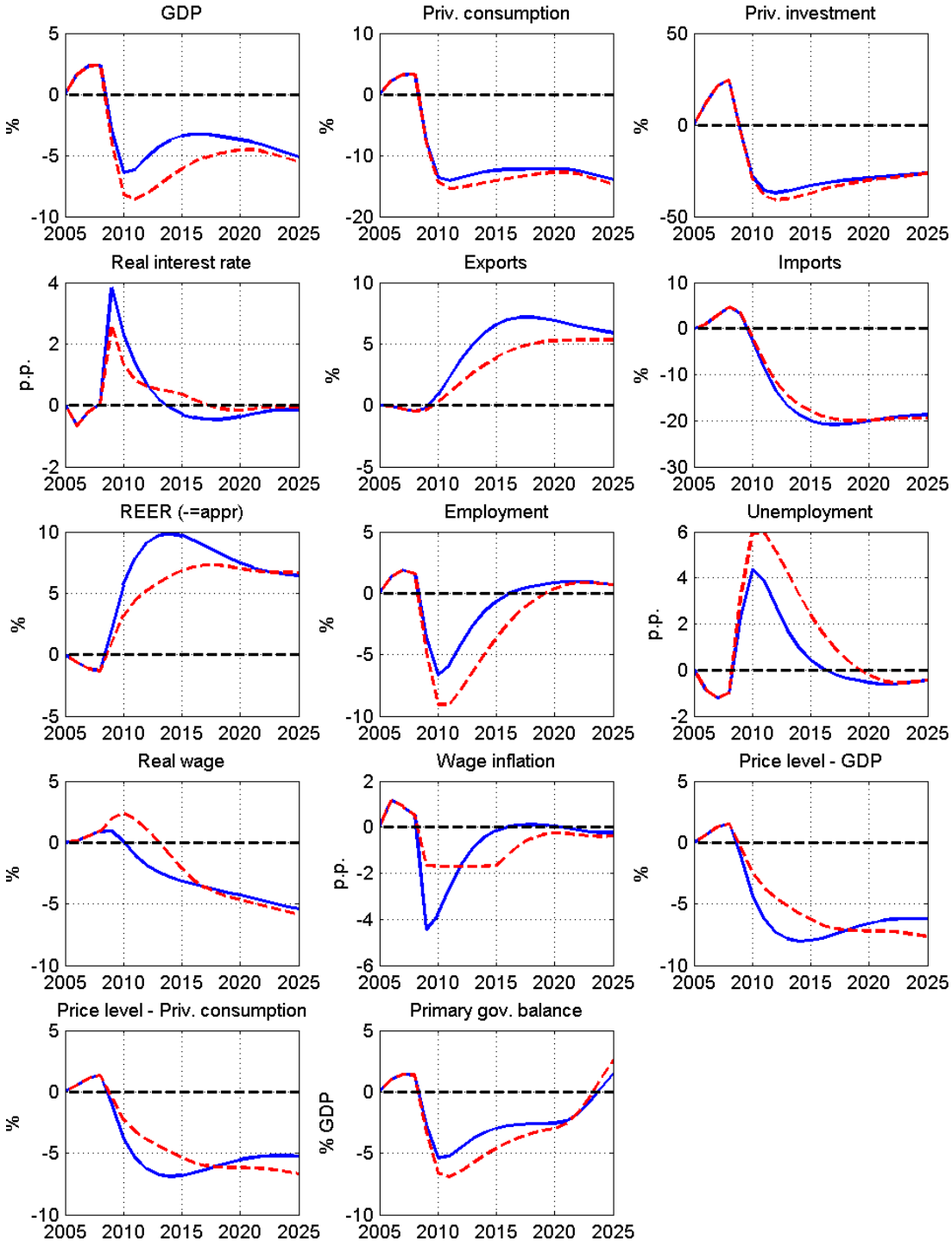
*) peak: 2007, trough: 2013; **) peak: 2007, trough 2014; ***) pre-crisis: 2007, post 2009:2015

Source: AMECO, European Commission

As shown in figure 1 the boom-bust cycle in the EA periphery was quite asymmetric, with positive output gaps in the range between 5% and 1% around 2007 and negative gaps in the range between 4% and 15% after 2008. We generate an investment and consumption boom via a persistent reduction in investment risk premia and a reduction in the rate of time preference in order to mimic the credit loosening towards the periphery countries in the first years of EMU. We generate a recession in 2009 by assuming that economic agents become aware about overoptimistic risk assessments and financial markets reverting risk premia. This is implemented by a reversal of the risk premium shock, starting in the first quarter of 2009 and by starting a new simulation, conditional on initial values of state variables in 2008Q4 generated by the boom shock. These types of shocks are often identified in estimated macroeconomic models as crucial for explaining the boom and bust cycle (see for example In'tVeld et al. (2014)).

Figure 3 shows the boom bust cycle generated by the model without fiscal policy intervention with and without a ZBWG constraint (baseline scenario). A first interesting observation is that the wage adjustment friction makes the recession worse. Without zero bound on wage growth (ZBWG), GDP falls by about 6% below pre crisis trend, while with ZBWG it falls by more than 8% and the zero bound on nominal wage growth binds from 2009 to 2015. This difference is mostly explained by a larger increase in the unemployment rate (+6% instead of +4%). There is also a noticeably smaller real depreciation, resulting from a more gradual decline of inflation in the periphery. In all simulations the government debt rule is turned off until 2021. Starting from 2012, debt stabilisation is invoked by assuming that the periphery government is gradually raising labour taxes to reach the debt target in the long run. Distortionary tax financing also explains why GDP slightly falls relative to the baseline around 2020.

Figure 3: Boom-bust baseline



Note: Without (solid line) and with (dashed line) zero bound on wage inflation. Because we report results with trend inflation and trend TFP removed the zero bound of wage inflation is at -1.8% (2% trend inflation minus 0.2% trend TFP)

4. Fiscal stabilisation: expenditure increase vs. cut in social security contributions

Two alternative fiscal stabilisation strategies can be distinguished, namely an increase in spending or a reduction in taxation. Advocates of a spending increase point towards the beneficial effects on the real interest rate if the policy generates some inflation. In a recent paper Schmitt Grohe and Uribe suggest a temporary wage subsidy as an optimal policy. They argue that such a policy is directly targeting the labour market inefficiency. In this section we compare variants of such policies, namely a reduction of social security contributions paid by firms to an increase in government expenditure. In order to highlight the importance of the ZBWG for the outcome of fiscal policy we present two alternative cases. We compare the two fiscal strategies with and without ZBWG.

Case 1: No ZBWG

In order to make both strategies comparable to each other, they both amount to ex ante fiscal shocks of 1% of GDP over 3 years (gradually phased out). In order to study the degree of self-financing in the medium term, we assume that the debt stabilisation rule is turned off for 12 years (until 2021). As can be seen from Figures 4a and 4b, both stabilisation strategies have similar GDP multipliers of around 0.6. A temporary increase of expenditure crowds out private domestic demand (inflation effect is positive but small) and worsens the trade balance because of the real appreciation relative to the rest of the Euro area. In contrast, a reduction of SSC increases domestic demand (consumption via an increase in real wages and employment and investment via a reduction in wage costs for firms). Because wage costs and therefore prices decline, there is a real depreciation which improves the trade balance. Even though prices decline initially the impact on expected real rate is not very different in both stabilisation strategies. With the expenditure increase the real rate falls on impact and is expected to increase in the following years (as prices return to base), while with the SSC reduction, the real interest rate rises initially but falls in the following years as prices move above base.

Though the overall GDP effects from both strategies is not very different, the distribution across public private and domestic foreign demand components differs substantially. The expenditure shock is crowding out private demand and worsens the trade balance, the SSC shock increases

private demand and imprioves the trade balance. The latter resembles more closely closely the composition effect in case the EA periphery would have a monetary policy instrument available.

That both fiscal strategies yield similar GDP effects is of course due to specific elasticities and should not be seen as a general result. For example, the expansionary effect of an expenditure based expansion could be higher/smaller if the competitiveness effect was smaller/larger (i. e. a lower/higher price elasticity of exports and imports)).

Figure 4a: Fiscal stabilisation via expenditure increase (without ZBWG)

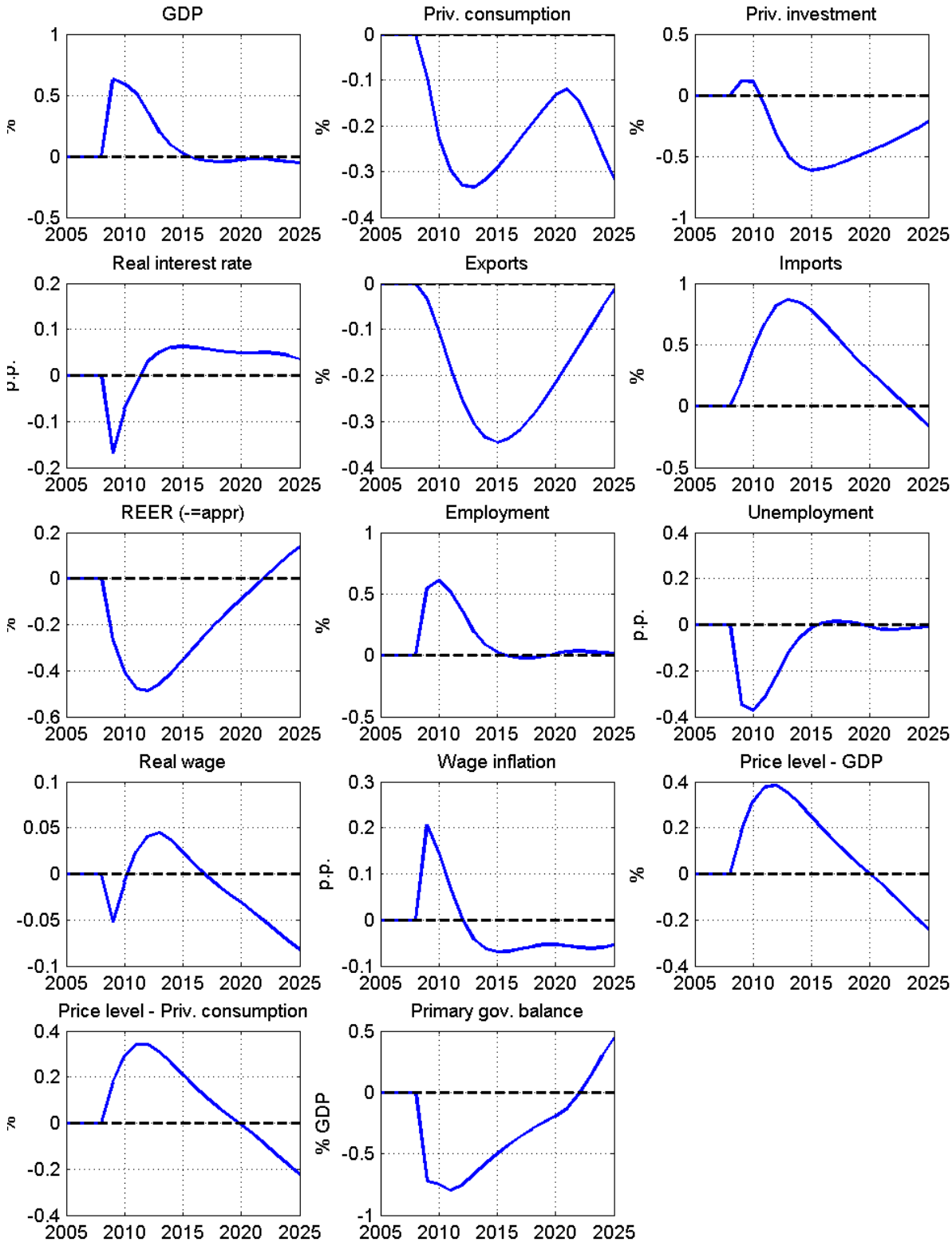
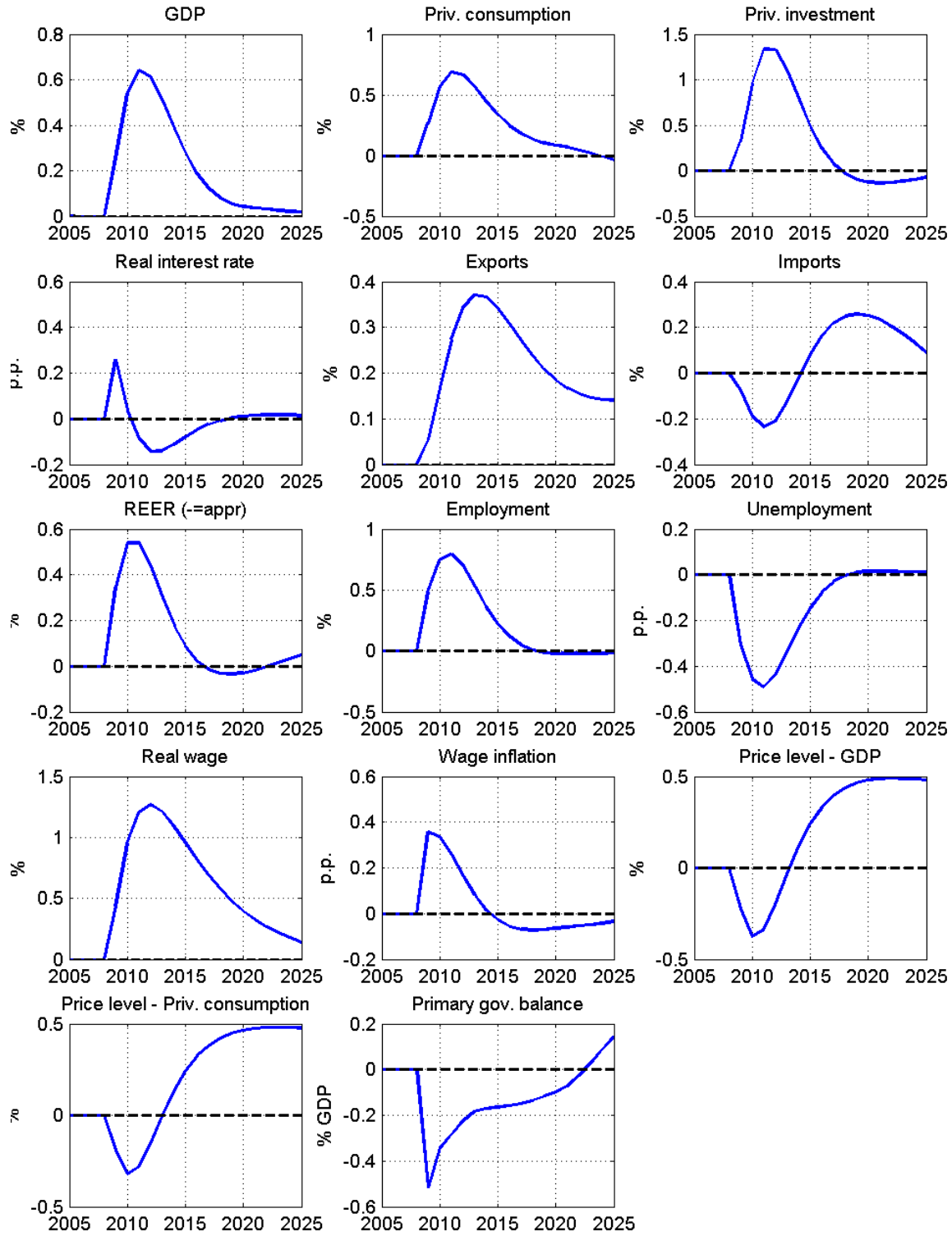


Figure 4b: Fiscal stabilisation via SSC reduction (without ZBWG)



Case 2: With ZBWG

This section shows that the fiscal multiplier of an SSC reduction can be substantially increased in presence of a binding nominal wage constraint. As can be seen by comparing wage adjustment in the baseline scenarios (Figure 3), without binding constraint, the nominal wage would decline more. Therefore, if a fiscal expansion resulting in an increase in labour demand is undertaken in a constrained wage regime, there is little upward pressure on nominal wages. As a result (comparing Figure 5b to Figure 4b) the SSC reduction achieves a substantially larger reduction of wage costs for firms in the constrained wage regime compared to the unconstrained wage regime. Thus the increase in labour demand is stronger. Even though real wages increase less in the constrained regime, real wage income increases more because of the positive employment effect, this increases consumption demand. Also because nominal wage costs fall more, there is a larger increase of investment. Because prices fall more (stronger decline of wage costs) exports rise more. This pushes the SSC multiplier above one. Because of the persistent increase of GDP, consumption and employment (higher labour taxes, lower benefits), the fiscal shock turns out to be self-financing over the medium term as can be seen from the movement of the primary balance, with an initial deficit followed by a surplus.

Figure 5a shows that also the public spending multiplier increases under ZBWG, but remains below 1 (around 0.75). Because of wages being constrained, nominal wage costs initially do not increase which increases the employment effect of the fiscal expansion, this reduces the crowding out of private domestic demand. The employment effect thus dominates the real interest rate effect (smaller decline of the real rate because of lower inflation). However, since the demand expansion does not directly exploit the fact that nominal wages will remain constant over a range of increasing demand for labour it is less effective in stabilising the economy than the SSC reduction. Finally it also appears less efficient in terms of financing properties. Because of crowding out of domestic demand (in particular consumption) and a smaller increase in corporate profits, plus a smaller employment effect, public purchases are less tax rich. This together with the smaller multiplier prevents self-financing of the fiscal measure.

Figure 5a: Fiscal stabilisation via expenditure increase (ZBWG)

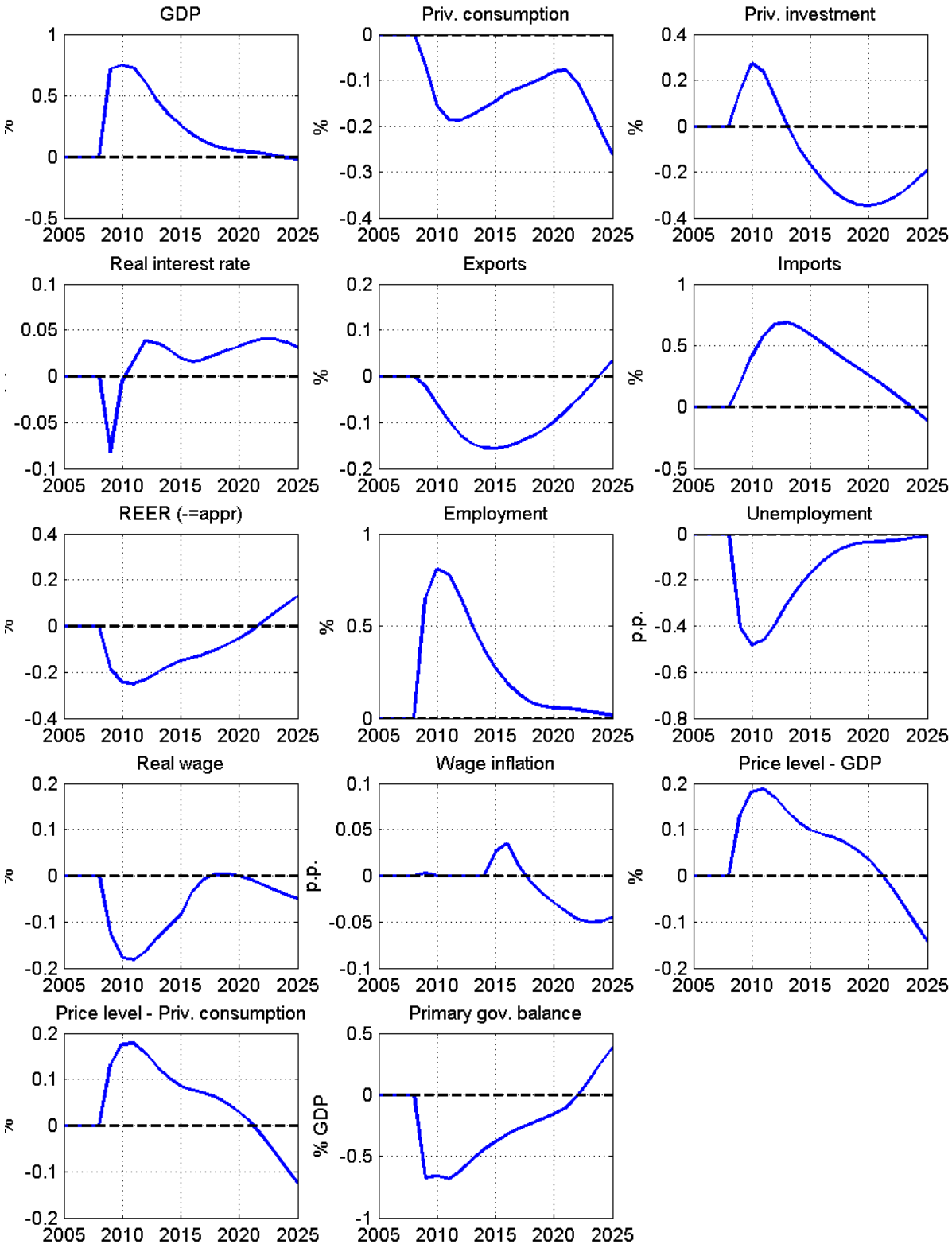
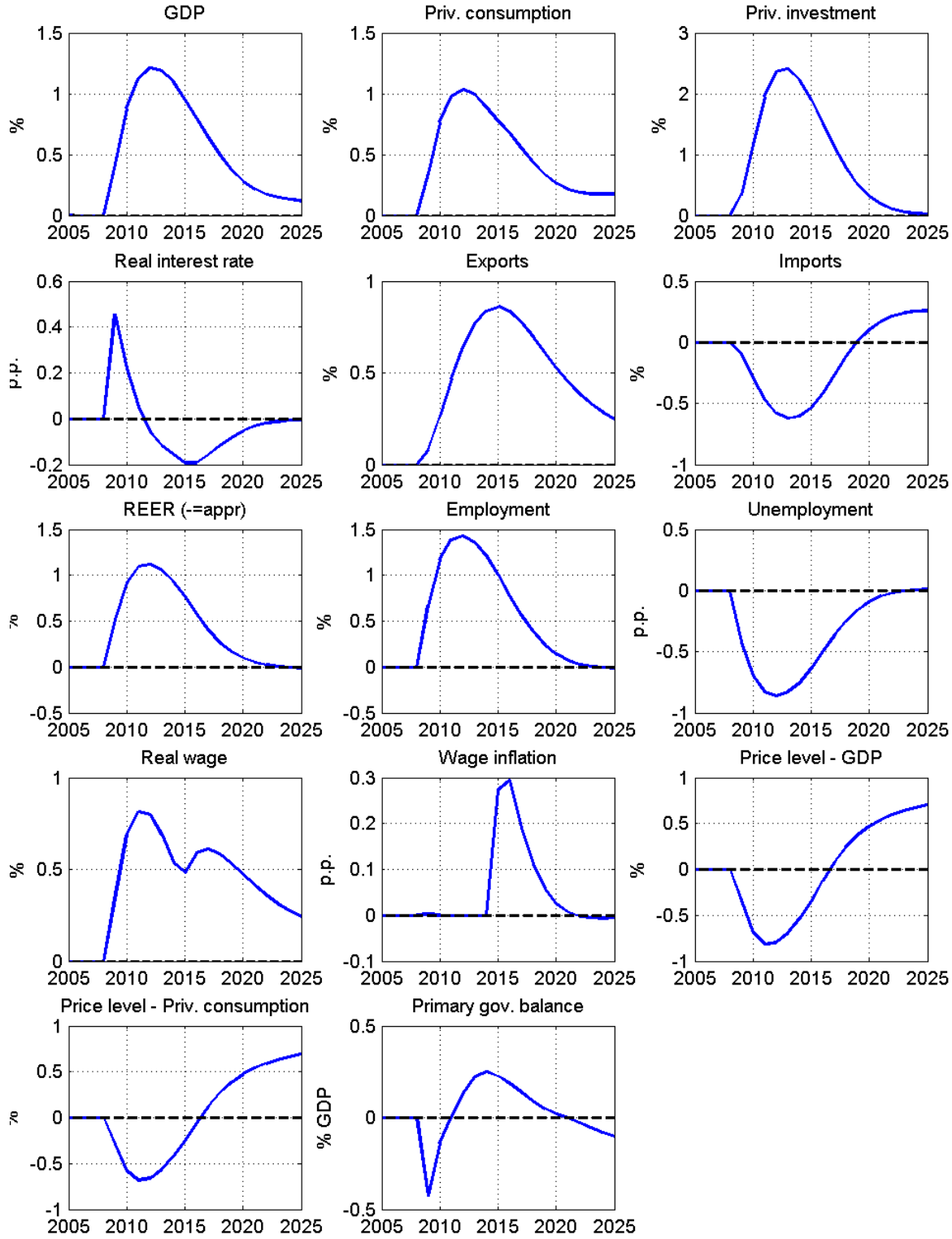


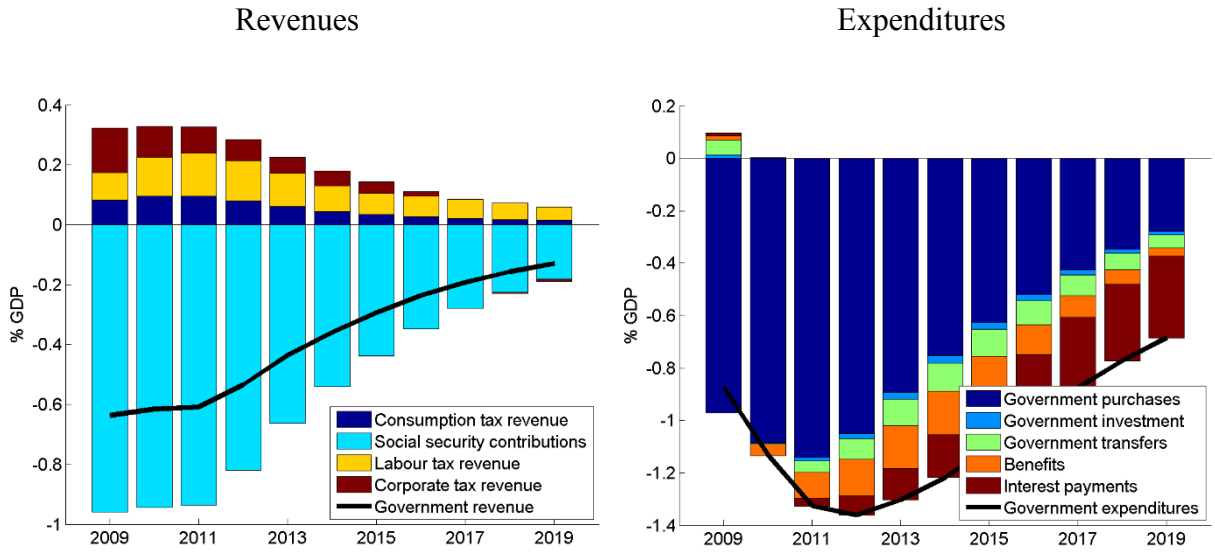
Figure 5b: Fiscal stabilisation via SSC reduction (ZBWG)



Self-financing properties of expenditure increase vs. reduction in social security contributions

Figure 6 compares the budgetary effects of a SSC reduction and an expenditure increase. The figure displays the difference between the budgetary effects of a social security contribution reduction and an expenditure increase for all revenue and expenditure components in the model. Hence, in the left panel *positive* values are indicative of relatively more positive effects on the budget balance of the SSC reduction, whereas in the right panel *negative* values are indicative of relatively more positive effects on the budget balance by the SSC reduction.

Figure 6: Budgetary effect social security contribution reduction vs. expenditure increase



Note: Bar charts display difference between budgetary effects of a social security contribution reduction and an expenditure increase. Positive revenues and negative expenditures highlight the budgetary superiority of the former.

On the revenue side consumption tax, labour tax as well as corporate tax revenue rise relatively more strongly when social security contributions are lowered. The positive consumption tax revenue is driven by the effect the fiscal shock has on its tax base, private consumption. While private consumption is crowded out by the government expenditure shock, it increases when social security contributions are lowered owing to an increase in household income as wages and employment increase strongly (compare Figures 5a and 5b). This increase in the wage sum is also at the source of relatively more labour tax revenues. Furthermore, the comparably strong

increase in the wage sum is causing that social security contribution revenues do not drop one-to-one with the reduction in its statutory rate. Corporate tax revenues also increase relatively more strongly as the reduction in social security contributions lowers firm's costs translating also into a profit increase. Ex ante the difference in total government revenue in both scenarios is -1% of GDP by design. Ex post this effect increases to close to -0.6% (solid line in Figure 6, left panel) in the first year. On the revenue side the reduction in social security contributions is clearly preferable to an increase in government expenditures.

How the two policies affect the expenditure side depends strongly on the expenditure rules. For example, if government expenditure is fixed as a share of GDP, then the two policies would have identical budgetary effects. Here we assume that expenditures (government purchases, government investment and transfers are fixed in real terms. Therefore there there are two offsetting effects resulting on the one hand from differences in the size of the GDP effect and on the other hand from differences in the sign of the real exchange rate effect. Because the SSC reduction has a larger GDP effect, expenditure as a share of GDP declines more strongly, which makes the SSC reduction more self-financing. However, this is partly offset by the real devaluation associated with the SSC reduction, while an expenditure increase leads to real appreciation. Nevertheless the GDP effect slightly dominates the real exchange rate effect. There are two additional beneficial effects on the expenditure side. First, because the SSC reduction reduces unemployment more strongly, unemployment benefit payments are reduced by this policy. With regards to the relatively stronger negative contribution of interest payments on the government budget in case of the SSC reduction, it is explained by a significantly smaller increase in government debt in case of the SSC reduction. Again, ex post the effect on total government expenditures of the social security contribution reduction is much away from -1% signalling a comparably stronger self-financing when SSC are reduced compared to when government expenditures are increased.

5. Conclusion

Boom bust cycles are often characterised by large wage adjustment needs in the bust episode because of excessive wage growth during the boom, generated by optimistic expectations about

future income and employment growth. This is coupled with low demand due to deleveraging pressures and elevated risk premia in financial markets. These developments can lead to a strong decline of inflation and generally require a downward adjustment of nominal unit labour costs. Downward nominal wage rigidities can thus severely slow down the adjustment of the economy.

We find compelling empirical evidence that downward nominal wage rigidity has been a relevant an adjustment friction in the recent slump episode. Because of wage adjustment frictions it is often argued (see Uribe et al.) that adjustment in monetary unions can be painful given the absence of an exchange rate instrument which could move relative prices to their respective equilibrium levels relatively quickly.

In this paper we compare two fiscal policy strategies for an individual country in EMU which is hit by a negative demand shock and faces a ZBWG constraint, namely an increase in government expenditure and reduction in revenues, via a cut in SSC paid by employers. Both fiscal strategies have been advocated as possible instruments in the current juncture. An expenditure increase can especially be effective under a ZLB constraint since it raises inflation. A cut in SSC is targeting the ZBWG constraint and facilitates labour market clearing. It is shown in the paper that for an open economy in EMU the latter fiscal strategy is superior along two dimensions. First the fiscal multiplier is larger and the budgetary costs are smaller because the adjustment of the economy to a SSC reduction is more tax rich. These two features strongly reduce the budgetary cost and makes this policy measure attractive for a number of periphery countries which suffer from very limited fiscal space.

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Appendix: Model Description

3 countries, tradables and non tradables

There are two types of households: liquidity-constrained households *s* and unconstrained Ricardian households *r*. All households consume and supply labour. In addition, Ricardian households invest into domestic productive capital, domestic government bonds and an internationally tradable bond and they own the firms. There is no cross-border mobility of labour. The government levies taxes and spends its revenue on consumption, public investment, unemployment benefits, transfers, and debt service.

A.1. Production

There is a continuum of firms operating in the T and NT sectors. Individual firms in T and NT are indexed by the superscript *j*. Each firm produces a variety of the T or NT good that is an imperfect substitute for varieties produced by other firms. Sectoral output O_t^J with *J=(T, NT)* is a CES aggregate of the varieties $O_t^{j,J}$:

$$(1) \qquad O_t^J \equiv \left[\int_0^1 \left(O_t^{j,J} \right)^{(\sigma_J - 1)/\sigma_J} dj \right]^{\sigma_J/(\sigma_J - 1)}$$

where σ_J is the elasticity of substitution between varieties *j* in sector J. The elasticity can differ between T and NT, implying sector-specific price mark-ups.

The firms in sector T sell consumption and investment goods and intermediate inputs to domestic and foreign private households and firms and consumption and investment goods to domestic and foreign governments. The NT sector sells consumption goods to domestic households, consumption and investment goods to the domestic government, and intermediate inputs to domestic firms. Hence, all private investment in physical capital consists of T goods.

Output is produced with a CES technology that combines value-added (Y_t^j) and intermediate inputs (INT_t^j). It nests a Cobb-Douglas technology with capital (K_t^j), production workers ($L_t^j - LO_t^j$) and public capital (KG_t) for the production of Y_t^j:

$$(2) \qquad O_t^j = \left[\left(1 - s_{in}^j\right)^{\frac{1}{\sigma_{in}}} \left(Y_t^j\right)^{(\sigma_{in}-1)/\sigma_{in}} + \left(s_{in}^j\right)^{\frac{1}{\sigma_{in}}} \left(INT_t^j\right)^{(\sigma_{in}-1)/\sigma_{in}} \right]^{\sigma_{in}/(\sigma_{in}-1)}$$

$$(3) \qquad Y_t^j = A_t^j (ucap_t^j K_t^j)^{1-\alpha} (L_t^j - LO_t^j)^{\alpha} KG_t^{\alpha_g} - FCY_t^j$$

where s_{in}^j and σ_{in} are, respectively, the share parameter of intermediates in output and the elasticity of substitution between intermediates and value-added, and A_t^j, $ucap_t^j$, LO_t^j and FCY_t^j are total factor productivity (TFP), capacity utilisation, overhead labour and fixed costs of producing.[1]

Firm-level employment L_t^j is a CES aggregate of variants of labour services:

$$(4) \qquad L_t^j = \left[\int_0^1 L_t^j(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} \quad \text{with } \theta > 1$$

where θ indicates the degree of substitutability between the different types of labour i.

The firm hires workers, rents capital and buys intermediate inputs. The demand for inputs and pricing decisions result from profit (Pr_t^j) maximisation subject to adjustment costs for changing prices ($adj_t^{P,j}$), employment ($adj_t^{L,j}$) and capacity ($adj_t^{ucap,j}$):

$$(6) \qquad Pr_t^j = p_t^j O_t^j - p_t^{INT,j} INT_t^j - \left(1 + ssc_t^J\right) w_t L_t^j - i_t^J p_t^I K_t^j - \left(adj_t^{P,j} + adj_t^{L,j} + adj_t^{ucap,j}\right)$$

where ssc_t^J, w_t, i_t^J and p_t^I are the employer social security contributions, the real wage, the rental rate of capital, and the price of capital. Adjustment costs are quadratic:

$$(7a) \qquad adj_t^{L,j} \equiv \gamma_L w_t (\Delta L_t^j)^2 / 2$$

$$(7b) \qquad adj_t^{P,j} \equiv \gamma_P (\pi_t^j)^2 Y_t^j / 2 \text{ with } \pi_t^j \equiv P_t^j / P_{t-1}^j - 1$$

[1] Lower case letters denote ratios and rates. In particular, $p_t^j \equiv P_t^j / P_t$ is the price of good j relative to the GDP deflator, $w_t \equiv W_t / P_t$ is the real wage, $ucap_t^j$ is actual relative to steady-state (full) capital utilisation, and e_t is the nominal exchange rate defined as the price of foreign in domestic currency.

(7c) $adj_t^{ucap,j} \equiv p_t^I K_t^j [\gamma_{ucap,1}(ucap_t^j - 1) + \gamma_{ucap,2}(ucap_t^j - 1)^2] / 2$

A.2. Households

The household sector consists of a continuum of households $h \in [0,1]$. There are $s^l \leq 1$ households which are liquidity-constrained and indexed by *l*. These households do not trade on asset markets and consume their disposable income each period. A fraction s^r of all households are Ricardian and indexed by *r*. The period utility function is identical for Ricardian and liquidity-constrained households and separable in consumption (C_t^h), and leisure ($1 - L_t^h$). We also allow for habit persistence in consumption (h^c).

(8) $U(C_t, L_t(i)) = \sum_{t=0}^{\infty} \beta^t \left[\log(C_t - h^c \bar{C}_{t-1}) + \frac{\omega}{1-\kappa} (1 - \int_0^1 L(i)_t di)^{1-\kappa} \right]$

The two types of households supply differentiated labour services to unions which maximise a joint utility function for each type of labour *i* on behalf of households. It is assumed that types of labour are distributed equally over the two household types. Nominal rigidity in wage setting is introduced by assuming that the household faces adjustment costs for changing wages. These adjustment costs are borne by the household.

A.2.1. Ricardian households

Ricardian households have full access to financial markets. They hold domestic government bonds (B_t^G) and bonds issued by other domestic and foreign households (B_t^r, $B_t^{F,r}$), real capitals (K_t^j) of the tradable and non-tradable sector. The household receives income from labour (net of adjustment costs on wages), financial assets, rental income from lending capital to firms, plus profit income from firms owned by the household (tradables, non-tradables, and residential construction). The unemployed (1-*npart-L*) receive benefits *ben*, while in addition there is income from general transfers *TR*. Income from labour is taxed at rate t^w. We allow for taxes on corporate profits, t^k. Finally, households pay lump-sum taxes T^{LS}. Domestic bonds yield risk-free nominal return equal to i_t. Foreign bonds are subject to (stochastic) risk premia linked to net foreign indebtedness.

Household members offer different types of labour, indexed by i. These variants of labour are imperfectly substitutable by firms in production. This gives rise to monopoly rents of workers.

Households face a budget constraint which is standard, apart from the fact that households bear wage adjustment costs which rise to the square as wage growth deviates from target inflation and trend labour efficiency growth:

(9) $$A_t + p_t^C C_t^r = \int_0^1 w_t(i)(1-t^w)L_t^r(i)di + (1+r_{t-1})A_{t-1} - adj_t^W - adj_t^K - adj_t^I$$

with $\Pi_t = (1+\pi^{tar})(1+gtfp^T)$ where $\pi^{tar}, gtfp^T$ are the inflation target and trend growth of labour augmenting technical progress. The term A_t is the household portfolio of financial and real assets

(10) $$A_t = B_t^G + B_t^F + p_t^I(K_t^T + K_t^N)$$

and r is the average real return from asset holding

where the adjustment costs have the functional forms:

(13a) $$adj_t^{W,J} = \frac{\gamma_{W,J}}{2}\sum\left[\frac{W_t(i)}{\Pi_t W(i)_{t-1}} - 1\right]^2 w_t L_t$$

(13b) $$adj_t^{K,J} \equiv \gamma_{K,J}(I_t^J / K_{t-1}^J - \delta^J)^2 K_{t-1}^J / 2$$

(13c) $$adj_t^{I,J} \equiv \gamma_{I,J}(\Delta I_t^J)^2 / 2$$

A.2.3. Liquidity-constrained households

Liquidity-constrained households do not optimise the intertemporal consumption path, but simply consume their entire disposable income at each date. Real consumption of household c is thus determined by the net wage and transfer income minus the lump-sum tax:

(9) $$p_t^C C_t^r = \int_0^1 w_t(i)(1-t^w)L_t^r(i)di + TR_t - adj_t^W - adj_t^K - adj_t^I$$

The labour supply behaviour of liquidity-constrained households is determined by the utility function (11) which also applies to Ricardian households and is described next.

A.2.4. Wage setting

A trade union is maximising a joint utility function for each type of labour i. The trade union sets wages by maximising a weighted average of the utility functions of these households. The wage rule is obtained by equating a weighted average of the marginal utility of leisure to a weighted average of the marginal utility of consumption times the real consumption wage of the two household types

Optimising w. r. t. $W_t(i)$ across the two household types and assuming symmetry yields

$$(s^r U^r_{1-L_t} + s^c U^c_{1-L_t})(-\theta) = (s^r U^r_{C_t} + s^c U^c_{C_t})\frac{W_t}{P_t}\left((1-\theta) - \gamma\left[\frac{W_t}{\Pi_t W_{t-1}} - 1\right]\left(\frac{W_t}{\Pi_t W_{t-1}}\right) + \frac{\beta\lambda_{t+1}}{\lambda_t}\gamma\left[\frac{W_{t+1}}{\Pi_{t+1} W_t} - 1\right]\left(\frac{W_{t+1}}{\Pi_{t+1} W_t}\right)\right)$$

Linearising adjustment costs and defining $(1 + mup_t^w) = \frac{\theta}{\theta-1}$ yields the wage Phillips curve

$$\pi_t^w = \frac{\beta\lambda_{t+1}}{\lambda_t}\pi_{t+1}^w + \frac{(\theta-1)}{\gamma}\log\left((1 + mup_t^w)\frac{(s^r U^r_{1-L_t} + s^c U^c_{1-L_t})}{(s^r U^r_{C_t} + s^c U^c_{C_t})}\frac{P_t^C}{W_t}\right)$$

Fluctuations arise from wage stickiness and shocks to the wage mark-up (ε_t^W). In the presence of wage stickiness, the fraction *1-sfw* of workers ($0 \le sfw \le 1$) indexes wage growth π_t^W to price inflation in the previous period:

(30) $\eta_t^W = 1 - 1/\theta - \varepsilon_t^W - \beta\gamma_W / \theta E_t[\lambda_{t+1}^r / \lambda_t^r (\pi_{t+1}^W - (1-sfw)\pi_t) - (\pi_t^W - (1-sfw)\pi_{t-1})]$

A.2.5. Aggregation

Aggregate consumption is given by:

(31) $C_t = s^r C_t^r + s^c C_t^c$

and aggregate employment by:

(32) $L_t = s^r L_t^r + s^c L_t^c$ with $L_t^r = L_t^c$.

A.3. Fiscal and monetary policy

We assume that except for explicit discretionary interventions, governments keep consumption and investment constant in real terms. Thus nominal government purchases (G_t) and investment (I_t^G) are kept constant in real terms.

(33) $G_t = \bar{g} p_t^C$

(34) $I_t^G = \overline{\imath^G} p_t^C$

Also the real consumption value of transfers are kept constant (TR_t)

(35) $TR_t = \overline{tr} p_t^C$

The nominal benefits paid to the non-employed part of the labour force correspond to the exogenous replacement rate ($\overline{ben}$) times the nominal wage:

(36) $BEN_t = \overline{\overline{ben} w_t}(L_t - LF_t)$

The government receives consumption tax, labour tax, corporate tax and lump-sum tax revenue as well as social security contributions. Nominal government debt (B_t) evolves according to:

(37) $B_t = (1 + i_{t-1})B_{t-1} + G_t + I_t^G + TR_t + BEN_t - T_t^{LS} - t_t^C P_t^C C_t - (t_t^W + ssc_t) W_t L_t - t_t^K PR_t$

Labour taxes are used to stabilise the debt-to-GDP ratio:

(38) $\Delta t_t^W = \tau^B \left(\frac{B}{P_t Y_t} - b \right) + \tau^d \Delta B_t$

with b being the target government debt to GDP ratio. The consumption tax, corporate income tax and personal income tax rates and the rate of social security contributions are exogenous.

Monetary policy follows a Taylor rule that allows for a smoothing of the interest rate response to inflation and the output gap:

(39) $$i_t = \rho_i i_{t-1} + (1-\rho_i)\left(\bar{r} + \pi^{tar} + \tau_\pi(\pi_t^C - \pi^{tar}) + \tau_y ygap_t\right)$$

The central bank has an inflation target π^{tar}, adjusts its policy rate when actual CPI inflation deviates from the target and also responds to the output gap (*ygap*). The output gap is not calculated as the difference between actual and efficient output, but derived from a production function framework, which is the standard practice of output gap calculation for fiscal surveillance and monetary policy. More precisely, the output gap is defined as deviation of factor utilisation from its long-run trend:

(40) $$ygap_t \equiv \alpha \ln(L_t / L_t^{ss}) + (1-\alpha)\ln(ucap_t / ucap_t^{ss})$$

The variables L_t^{ss} and $ucap_t^{ss}$ are moving averages of employment and capacity utilisation rates:

(41a) $$L_t^{ss} = \rho^L L_{t-1}^{ss} + (1-\rho^L)L_t$$

(41b) $$ucap_t^{ss} = \rho^{ucap} ucap_{t-1}^{ss} + (1-\rho^{ucap})ucap_t^j$$

The moving averages are restricted to move slowly in response to actual values.

A.4 Trade and financial linkages

In order to facilitate aggregation, private households and the government are assumed to have identical CES preferences across goods used for consumption and investment. (42)

$$Z_t = \left[\left(1-s^T\right)^{1/\sigma_{tnt}}\left(Z_t^{NT}\right)^{(\sigma_{tnt}-1)/\sigma_{tnt}} + \left(s^T\right)^{1/\sigma_{tnt}}\left(Z_t^T\right)^{(\sigma_{tnt}-1)/\sigma_{tnt}}\right]^{\sigma_{tnt}/(\sigma_{tnt}-1)}$$

where $Z_t \epsilon \{C_t, G_t, I_t^T, I_t^N, I_t^G\}$ and Z_t^{NT} and Z_t^T is an index of demand across the NT and T varieties. Concerning, Z_t^T households and the government have identical CES preferences regarding domestically produced and imported goods ($Z_t^{T,D}$) and ($Z_t^{T,M}$) respectively:

(43) $$Z_t^T = \left[(1-s_m)^{1/\sigma_x}\left(Z_t^{T,D}\right)^{(\sigma_x-1)/\sigma_x} + s_m{}^{1/\sigma_x}\left(Z_t^{T,M}\right)^{(\sigma_x-1)/\sigma_x}\right]^{\sigma_x/(\sigma_x-1)}$$

The elasticity of substitution between the bundles of NT and T goods is σ_{tnt}. The elasticity of substitution between the bundles of domestically produced and imported T goods is σ_x. The steady-state shares of T goods in Z_t and of imports Z_t^T are s^T and s_m, respectively. All investment in physical capital in the T and NT sectors consists of T goods.

The intermediate inputs in sector J=(T, NT) are also composites of T and NT analogously to equations (42) and (43) with T either domestically produced or imported:

$$(45) \qquad INT_t^J = \left[(1-s_{\text{int}}^J)^{1/\sigma_{tnt}} (INT_t^{NT,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}} + (s_{\text{int}}^J)^{1/\sigma_{tnt}} (INT_t^{T,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}} \right]^{\sigma_{tnt}/(\sigma_{tnt}-1)}$$

$$(46) \qquad INT_t^{T,J} = \left[(1-s_m)^{1/\sigma_x} (INT_t^{T,D,J})^{(\sigma_x-1)/\sigma_x} + s_m^{1/\sigma_x} (INT_t^{T,M,J})^{(\sigma_x-1)/\sigma_x} \right]^{\sigma_x/(\sigma_x-1)}$$

Exporters sell domestically produced tradable goods in world markets. It is assumed that exporters engage in domestic currency pricing.

A.5 Calibration

Behavioural parameters are based on a range of estimates of earlier version of the QUEST model.[2] Table 2 summarises common values and Table 3 block-specific values. In the absence of detailed evidence on the behavioural differences between the blocks represented in our model, we opted for a common calibration of behavioural parameters. Only when we judged it particularly necessary or when we had firm evidence for behavioural differences, we opted for a block-specific calibration. Irrespective of that, macroeconomic aggregates like private and public consumption and investment, as well as trade openness and linkages are calibrated on block-specific data

The discount factor for Ricardian households, β^r, is set at 0.997 in order to be consistent with a global long-run real interest rate. Habit persistence in consumption is set at 0.85 and in line with evidence from estimated versions of the QUEST model. The labour supply elasticity is set at 0.2,

[2] See for example Kollmann, Ratto, Roeger, in 't Veld (2013), Kollmann, Ratto, Roeger, in 't Veld, Vogel (2015), In 't Veld, Pagano, Raciborski, Ratto, Roeger (2015) and In 't Veld, Raciborski, Ratto, Roeger, 2011.

which lies at the lower end of the range of estimation results from the QUEST model. This is in line with evidence from Chetty (2012). Concerning adjustment costs on labour, goods and capital we broadly follow earlier estimations of the QUEST model. The shares of forward looking wage and price setters, sfp and sfw, is calibrated to 0.9 reflecting the extent to which agents base their decisions on model consistent expectations. The elasticity of substitution between tradables and non-tradables σ_{tnt} is set following evidence from the IMF's GIMF model (see Kumhof et al., 2010).

The output elasticity for public capital α_g is set at 0.09, such that the marginal product of public capital equates that of private capital (Gramlich, 1994). Setting the elasticity of substitution between types of labour, θ, at 6 induces a wage mark-up of 20%. Tax rule parameters τ^b and τ^{def} are chosen to assure a smooth transition to the long-run debt target. In setting the reaction coefficient to inflation in the Taylor rule, τ_π, at 2 we closely follow the literature.

Table 2: Calibration – common values

Parameter	Value	Description
β^r	0.997	Discount factor Ricardian households
h^c	0.85	Habit persistence in consumption
$1/\kappa$	0.2	Labour supply elasticity
γ^L	25	Head-count adjustment costs parameter
γ^P	20	Price adjustment costs parameter
$\gamma^{ucap,1}$	0.04(T) 0.03(NT)	Linear capacity-utilisation adjustment cost
$\gamma^{ucap,2}$	0.05	Quadratic capacity-utilisation adjustment cost
γ^K	20	Capital adjustment cost
γ^I	75	Investment adjustment cost
γ^W	120	Wage adjustment cost
γ^H	40	Adjustment costs to the housing stock
sfp	0.9	Share of forward looking price setters
γ^X	5	Adjustment cost parameter export prices
sfw	0.9	Share of forward looking wage setters
σ_{tnt}	0.5	Elasticity of substitution T-NT
σ_x	1.2	Elasticity of substitution in total trade
σ_f	0.99	Elasticity of substitution between import sources
α	0.65	Cobb-Douglas labour parameter
α_g	0.09	Cobb-Douglas public capital stock parameter
σ_{in}	0.5	Elasticity of substitution between value added and intermediates
θ	6	Elasticity of substitution between types of labour
δ^T	0.015	Depreciation rate T capital stock
δ^{NT}	0.005	Depreciation rate NT capital stock
δ^g	0.013	Depreciation rate public capital stock
ρ_L	0.95	Persistence of potential employment
ρ_{ucap}	0.99	Potential capacity utilisation persistence
τ^b	0.01	Tax rule parameter on debt
τ^{def}	0.1	Tax rule parameter on deficit
ρ_i	0.6	Interest rate smoothing in Taylor rule

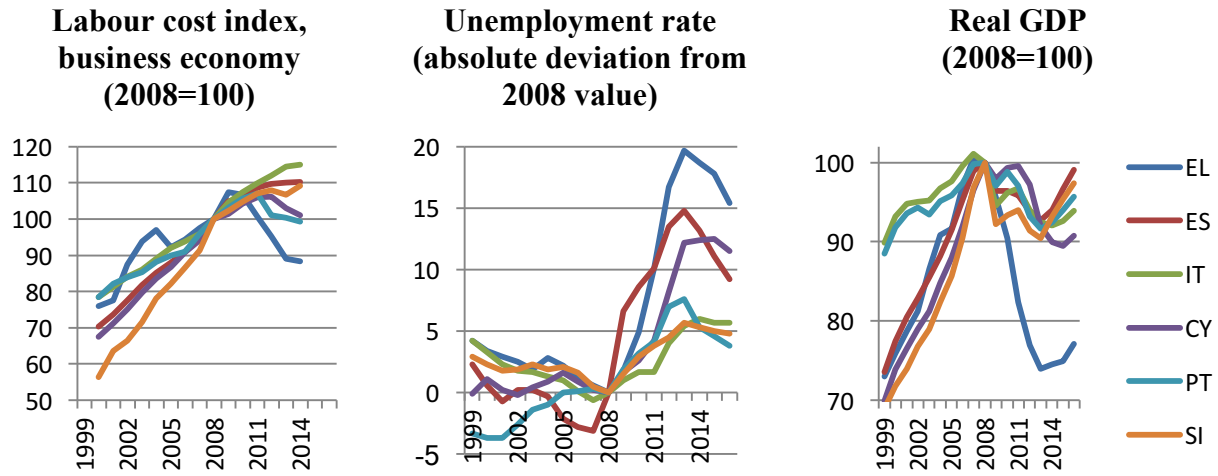
Parameter	Value	Description
τ_π	2	Reaction coefficient to inflation in Taylor rule

Table 3 features block-specific values of the calibration. Concerning financial market frictions in advanced economies, we assume 60 percent of households to have full access to financial markets, which corresponds closely to our estimates (Ratto et al., 2009). Labour force to total population and employment shares are taken from national sources and are aggregated for the corresponding block. Steady-state consumption shares of imports, the share of intermediates in the tradable and non-tradable sector are based on input-output tables from the GTAP database (see Narayanan and Walmsley, 2008). The share of bilateral imports are compiled from the direction of trade statistics provided by the IMF and aggregated netting out intra-block. The baseline debt-to-GDP ratio is based on an average debt-to-GDP ratios observed over the last 5 to 10 years. The mildly higher reaction coefficient to output in the Taylor rule of the US compared to other regions is motivated by the mandate of the Federal Reserve which suggests a relatively stronger focus on economic activity.

Table 3: Calibration - block-specific values

Parameter	Value			Description
	EA Periphery	EA Core	RoW	
s^r	0.6	0.6	0.6	Share of Ricardian households
s^l	0.4	0.4	0.4	Share of liquidity-constrained households
$1 - npart$	0.71	0.71	0.71	Labour force to population
L	0.64	0.64	0.70	Steady state employment to population
$1/\sigma_T$	0.12	0.12	0.12	Mark-up T sector
$1/\sigma_{NT}$	0.24	0.24	0.2	Mark-up NT sector
s^T	0.4	0.4	0.3	Steady-state share of T
s_m	0.22	0.33	0.24	Steady-state consumption share of imports
s_{in}^T	0.73	0.76	0.62	Steady-state share of intermediates in output T
s_{in}^{NT}	0.50	0.59	0.45	Steady-state share of intermediates in output NT
s_{int}^T	0.67	0.61	0.72	Steady-state T intermediate share in T
s_{int}^{NT}	0.47	0.43	0.44	Steady-state T intermediate share in NT
$s^{EA-P,f}$	-			Share of bilateral imports of EA periphery
$s^{EA-C,f}$		-		Share of bilateral imports of EA core
$s^{Row,f}$			-	Share of bilateral imports of RoW
$btar$	0.8	0.7	0.8	Baseline government debt-to-GDP ratio
τ_y	0.1	0.1	0.15	Reaction coefficient to output gap in Taylor rule

Figure 7: Wages, unemployment rate and GDP in selected EA countries



Source: Eurostat (LCI), AMECO (other variables)