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Fixed exchange rate –
a friend or foe of labor cost adjustments?

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Abstract: This paper examines the effectiveness of labor cost reductions as a means to stimulate economic activity and assesses the differences which may occur with the prevailing exchange rate regime. We develop a medium-scale three-region DSGE model and show that the impact of a cut in employers' social security contributions rate does not vary significantly under different exchange rate regimes. We find that both the interest rate and the exchange rate channel matters. Furthermore, the measure appears to be effective even if it comes along with a consumption tax increase to preserve long-term fiscal sustainability. Finally, we assess whether obtained theoretical results hold up empirically by applying the local projection method. Regression results suggest that changes in employers' social security contributions rates have statistically significant real effects – a one percentage point reduction leads to an average cumulative rise in output of around 1.3 percent in the medium term. Moreover, the outcome does not differ significantly across the different exchange rate regimes.

Keywords: Structural policies, Labor cost adjustments, Exchange rate regime, Local projection, DSGE

JEL Classification: C53, C54, E32, E37, E61, E62, F41, F45, F47

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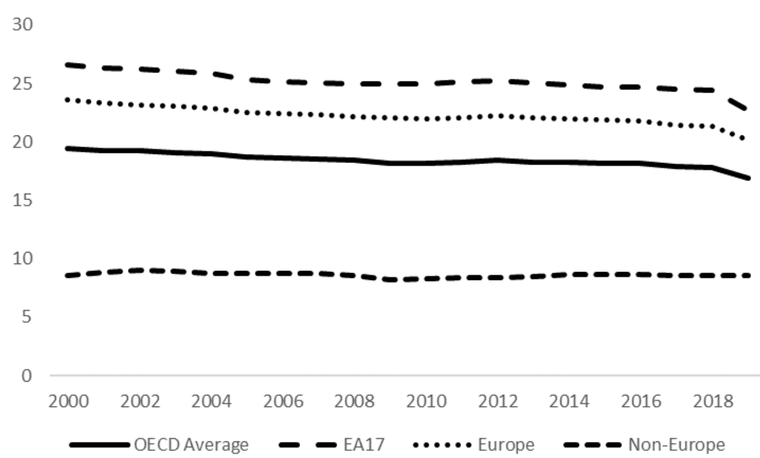
1 Introduction

Restoring competitiveness is widely regarded as a main pillar of reform measures necessary to re-ignite economic growth in countries facing subdued prospects. The recent Global Financial Crises and the subsequent sovereign debt crisis exposed fundamental structural weaknesses in a number of euro area economies. In particular, several member states have been facing persistent competitiveness issues due to high labor costs relative to underlying productivity.[1] Increased labor costs, embodied not only in wage inflation considerably outpacing productivity growth but also in excessive tax and social contribution rates for firms, represent a significant burden for already overloaded economies.

The loss of competitiveness due to high labour costs is particularly sensitive in a fixed exchange rate environment, such as a currency union.[2] In a single currency area depreciation in nominal terms is not available as a policy instrument and real exchange rate dynamics is driven solely by inflation differentials. Moreover, traditional policy measures designed for long-lasting productivity enhancement such as investments in infrastructure, education and research, improving competition in products markets or exploiting new areas of growth as green and digital transition, might materialize slowly at best. On the contrary, lowering labor costs and consequently relative prices may help to swiftly regain price competitiveness. Structural reforms aimed at alleviating firms' burdens and reducing market distortions ought to result in real depreciation, aggregate demand stabilization, as well as in an increase of output and employment. Potential benefits of the aforementioned channel steered to cuts in employers' social security contribution rates in eight OECD member countries in 2010.[3]

Two major components drive a wedge between employers' costs of labor and net remuneration received by workers: income taxes and social security contributions (both employers' and employees'). Total social security contributions represent more than half of the total tax on labor income in OECD member states, being the lion's share of the wedge.[4]

Figure 1: Average employers' social security contribution rates over time



Note: Authors' calculations. Source OECD (2011) and (2020). Considered values are average statutory rates of employers' social security contribution as a percent of gross wage earnings, similar for both family type categories: single person at 100 percent of average earnings with no child and one-earner married couple at 100 percent of average earnings with 2 children.

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[1] See e.g. Thimann (2015).

[2] Discussions related to difficulties for economic policy and adjustment processes induced by fixed exchange rate regimes and benefits of flexible exchange rates date back at least to Friedman (1953).

[3] See e.g. De Mooij and Keen (2012).

[4] See e.g. OECD (2020) and Almosova et al. (2020).

Figure 1 suggests significantly higher employers' contribution rates in the euro area in comparison to the OECD average and non-European economies. European institutions identified lowering labor taxes as a high policy priority that should be implemented without deterioration of already unsolid fiscal positions.[5]

This paper examines the effects of a reduction in social security contributions paid by employers based on both a theoretical modeling framework and an empirical regression analysis. We develop a medium scale three-region DSGE model to simulate a temporary and a permanent cut in firms' contribution rates. Furthermore, we study the consequences of a simultaneous consumption tax increase to preserve long-term fiscal sustainability. In all scenarios we explicitly compare the impact and the propagation mechanism under three different exchange rate regimes: a flexible regime, a hard peg and in a currency union. This approach addresses concerns that the effects of labor cost adjustments might be smaller for an economy with a fixed exchange rate compared to an economy with an autonomous monetary policy. More specifically, these adjustments work to a large extent through their induced effect on the endogenous reaction of the nominal interest rate, as it decreases in response to lower inflationary pressures (Gali and Monacelli (2016)). If this channel is absent, as in a monetary union, the effect on aggregate demand and employment will be muted. The opposite views, instead, emphasize the so-called exchange rate channel, according to which a nominal appreciation under the flexible regime may fully eliminate this regime's effect on quantities (Lane and Perotti (2003)). According to our model-based simulations the outcome does not differ substantially across the considered exchange rate regimes. Resulting impulse responses imply the importance of two underlying mechanisms - the interest rate channel that leads to larger initial effects in a flexible regime and the nominal exchange rate channel that partially offsets these benefits in the subsequent periods. To scrutinize obtained theoretical results we provide empirical evidence by conducting a local projection based regression analysis, introduced by Jorda (2005). Our empirical results suggest that changes in social security contributions rates paid by employers have a statistically significant effect on economic activity. A one percent rate reduction leads on average to a cumulative rise in output of around 1.3 percentage points after four years, with similar effects under fixed and flexible exchange rate arrangements.

The remainder of the paper is organized as follows. In Section II we discuss the related literature and link our work to previous findings. Section III explains the DSGE model used in our analysis. Section IV elaborates on model-based simulation results and policy implications, whereas Section V considers several extensions. In Section VI we present empirical results obtained from estimations based on the local projection method. Section VII concludes the paper.

2 Related literature

Existing literature finds strong evidence that labor taxation may be harmful to employment and economic growth (Kneller et al. (1999), Daveri and Tabellini (2000), Bassanini and Duval (2006), OECD (2011)). Coenen et al. (2008) use a DSGE environment to analyze a reduction of European tax distortions to levels comparable to the US and find significant long-run benefits in terms of total hours worked and GDP increase. Similarly, Duval and Furceri (2018) show that a labor tax wedge reduction of one percent raises the level of output in OECD countries by about 0.6 percent in the medium term, with considerably larger effects during periods of slack.

Lane and Perotti (2003) examine the effectiveness of labor taxation under different exchange rate regimes. They consider the effects of personal income tax, social security, and payroll tax changes on

[5] See Eurogroup (2014) and European Commission (2016).

the tradable sector and compare them for fixed and floating exchange rates. They rely on a theoretical model and panel regression estimates for 17 OECD countries from 1964 to 1993. Obtained results suggest that the impact of tax increases on output is negative and not significantly different across regimes, implying the importance of the exchange rate channel.

Gali and Monacelli (2016) mainly examine the gains from increased wage flexibility. However, they also find in that context that the impact of labor cost reductions on employment is considerably smaller in a currency union than under a flexible exchange rate regime. In particular, they exploit a small open economy model with staggered price and wage setting and conclude that the latter result is mainly driven by the absence of an endogenous monetary policy response. Similarly, simulations in the multi-country model by Decressin et al. (2015) suggest that the impact of internal devaluation through wage moderation on output in the short run depends on several factors in addition to competitiveness increase. They highlight the importance of the monetary policy response and the real interest rate channel, with the larger effects obtained when monetary policy is not constrained.

The above considerations became progressively relevant after the Global Financial Crisis, but with the limitation that they may undermine fiscal consolidation objectives. This led to proposals of so-called fiscal devaluation[6] – a revenue-neutral combination of labor cost reductions and higher consumption taxation. Numerous model simulations have recently discussed such tax shifts with a focus on international competitiveness and recovery of the euro area. Lipinska and von Thadden (2009) develop a tractable two-country DSGE model to show that a shift in the tax structure towards indirect taxes generates only limited quantitative effects. Farhi et al. (2014) use a New Keynesian open economy DSGE model to explain possible implementations of fiscal devaluation and show that plausible changes in tax rates do not lead to considerable improvements. On the other hand, ECB (2012) uses three different multi-country models to analyze these effects from the perspective of a euro area small open economy. It finds that fiscal devaluation implies a hump-shaped output response with a peak of 0.2-0.5 percent. Additionally, the European Commission (2013) QUEST multi-country model suggests a modest impact of a fiscal devaluation on GDP in the short to medium term and significant effects in the long run. Attinasi et al. (2016) propose a DSGE model for several euro area countries which implies beneficial effects of a decrease in labor taxation financed by an increase in consumption taxes, with large output gains and reductions in unemployment. Similarly, Engler et al. (2017) employ a DSGE model calibrated to the euro area to quantify the international effects of a fiscal devaluation implemented as a revenue-neutral shift from employers' social contributions to the value-added tax and find that a fiscal devaluation carried out in the South has a strong positive effect on output (more than 1 percent), but only mild effects on the trade balance and the real exchange rate.

Existing empirical studies focus mostly on the trade impact of a fiscal devaluation. De Mooij and Keen (2012) find no significant evidence of the measure in the European Union, whereas Holzner et al. (2018) show that the effect varies significantly across countries depending mostly on their trade openness. Lambertini and Proebsting (2019) examine empirically the effects of internal devaluations instead, through government spending reductions, and find this measure more efficient. They find evidence of a decline in nominal wages in some euro area countries, a real exchange rate depreciation and current account improvements, but mostly driven by lower import stemming from faltering domestic demand.

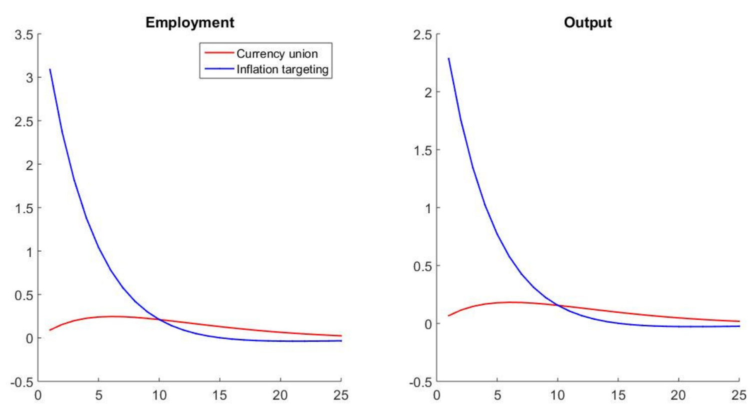
[6] The idea of fiscal devaluatuion dates back to Keynes (1931): "Precisely the same effects as those produced by a devaluation of sterling by a given percentage could be brought about by a tariff of the same percentage on all imports together with an equal subsidy on all exports, except that this measure would leave sterling international obligations unchanged in terms of gold".

Another stream of the literature explores empirically the role of the exchange rate regime when it comes to the size of fiscal multipliers, mostly focussing on demand-side fiscal policies. Results from Acconcia et al. (2011) and Nakamura and Steinsson (2011) imply that regional spending multipliers within monetary unions are sizeable. Similarly, Ilzetzki et al. (2011) and Born et al. (2013) find that multipliers tend to be sizeable in countries with fixed exchange rates and much smaller under flexible regimes. Their estimations suggest that these differences play out mostly via adjustments in the level of private expenditures, rather than through redirections in trade flows. Theoretical work by Corsetti et al. (2011), Nakamura and Steinsson (2011), Born et al. (2013) illustrates how fiscal transmission mechanism varies across exchange rate regimes. Additionally, Christiano et al. (2011) and Woodford (2011) show that the multiplier is considerably larger in periods when monetary policy is constrained by the zero lower bound.

Our contribution to existing literature is twofold. First, from the modeling perspective, we exploit a rich three-region DSGE setup with nominal and real rigidities under three different exchange rate regimes. Thereby, we examine the differences in the impact of a cut in employers' social security contribution rate on economic activity under a flexible exchange rate regime, a proper currency peg and in a currency union. Second, we intend to fill the gap in the empirical literature by conducting a regression based empirical assessment to scrutinize the results obtained from the model-based analysis.

As regards the modeling perspective, to a certain extent we complement the work of Gali and Monacelli (2016) that compares the impact of a reduction in payroll taxes in a currency union and under an autonomous central bank with a full price stability mandate. However, results from their small-scale model (Figure 2) appear to be sensitive to the monetary policy rule applied. As presented in Figure 3, the implementation of other policy rules, in line with existing literature (e.g. considered in Gali and Monacelli (2005) and a rule with interest rate smoothing), yields less considerable divergence in the effects of a temporary payroll tax cut.[7]

Figure 2: Impulse response functions to a temporary payroll tax cut in Gali and Monacelli (2016)

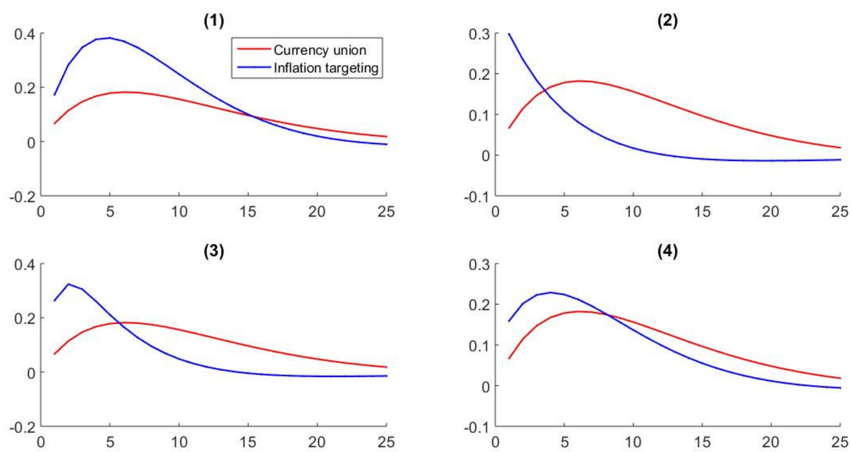


Note: Replicated from Gali and Monacelli (2016) using the original code provided by the authors. Monetary policy rule aims at full stabilisation of CPI inflation ($\pi_t = 0$).

[7] We thank the authors for providing the codes of both of their papers. The model codes are publicly available in the Macroeconomic Model Data Base (MMB, Wieland et al. (2012) and (2016)).

Naturally, these rules determine the nominal interest rate response to inflation dynamics and consequently affect the inflation and real interest rate, resulting in different output levels. Impulse responses for permanent cuts shown in Figure A1 in the Appendix confirm that under these alternative policy rules, a fixed exchange rate regime does not necessarily lead to a significantly muted outcome. Furthermore, our analysis benefits from four additional features worth mentioning. First, instead of a New Keynesian two-country model, we introduce the third region, given that a significant part of trade materializes outside the currency union. Second, we calibrate our model to resemble a specific country, the Italian economy, the Rest of the Euro Area, and the Rest of the World. Third, we allow for detailed exchanged rate arrangements, suitable for the euro area perspective, instead of pegging the exchange rate indefinitely (or to a certain degree) to another currency. Last, we also consider the aspect of a fiscal devaluation in case fiscal space is limited, e.g. in an economy significantly hit by a crisis.

Figure 3: Impulse response functions of output to a temporary payroll tax cut under alternative policy rules



Note: Authors' calculations based on the original model in Gali and Monacelli (2016). For the calculations the original model code with alternative policy rules was used: (1) full stabilization of domestic inflation ($\pi_{H,t} = 0$), (2) the CPI inflation-based Taylor rule ($i_t = 1.5\pi_t$), (3) domestic inflation-based Taylor rule ($i_t = 1.5\pi_{H,t}$), and (4) Taylor rule with interest rate smoothing ($i_t = 0.9i_{t-1} + (1 - 0.9)1.5\pi_t$).

From the empirical perspective, we study the effects of employers' social security contribution rates reductions and compare them across exchange rate regimes. Our local projection specification setup follows Jorda and Taylor (2016), and resembles Duval and Furceri (2018), who apply a similar approach to examine tax wedge cut effects on economic activity and its interaction with macroeconomic conditions and policies.

3 A structural approach

We employ a rich-in-structure three-region DSGE model to explore the dynamics and transmission mechanisms that may be important for the question of our interest. In this section we outline briefly the modeling framework used for the analysis which builds on the New Area-Wide model developed in Coenen et al. (2008). A more detailed description can be found in the Appendix.

3.1 Model

The model consists of two structurally symmetric economies, with different parametrization, in particular Economy A and Economy B, with size s and $1-s$, respectively, and the Rest of the World (ROW). The economies of Economy A and Economy B are populated by two different types of households, Ricardian and non-Ricardian, by intermediate and final goods producers and by the fiscal and the monetary authorities. The ROW economy is modeled parsimoniously using the standard textbook three-equation New Keynesian framework. For Economy A and Economy B, it is assumed that a fixed share of the households, ω, among the entire population is of non-Ricardian type and has neither access to capital nor to the bond markets. Nevertheless, the non-Ricardian agents can adjust cash balance holdings in each period to smooth consumption. The other part of the households, with share $1-\omega$, is of Ricardian type and has access to both capital and bonds markets and is also able to hold cash balances. In the production sector of the economy, intermediate goods producing firms operate in a monopolistically competitive environment and sell tradable goods in both the domestic and foreign markets. The final goods producing firms are fully competitive and transform domestic and imported intermediate goods into three different types of non-tradable final goods: private consumption goods, investment goods, and public consumption goods. In the following, unless not explicitly noted, all equations refer to both the Economy A and Economy B.

Ricardian Households

Ricardian households, indexed with i, maximize lifetime utility by optimizing the allocation of consumption goods $C_{i,t}$, investment goods $I_{i,t}$, capital stock $K_{i,t}$ and the extent of its utilization $u_{i,t}$, domestic and foreign bond holdings $B_{i,t}$ and $B_{i,t}^{F}$, and cash balances $M_{i,t}$ over time. The lifetime utility function is separable in consumption and individually supplied labor $N_{i,t}$ and takes the following form:

$$E_t\left[\sum_{k=0}^{\infty}\beta^k\left(\frac{1}{1-\sigma}\left(C_{i,t+k}-\kappa C_{i,t+k-1}\right)^{1-\sigma}-\frac{1}{1+\zeta}\left(N_{i,t+k}\right)^{1+\zeta}\right)\right],$$

where β denotes the discount factor, σ the relative risk aversion, ζ is the inverse of the elasticity of labor supply and κ controls the persistence of the external habit formation. Ricardian households have access to foreign bonds, $B_{i,t}^{F}$, which are internationally traded and denominated in ROW currency. Consequently, Ricardian households face the following budget constraint at each period *t*:

$$\begin{aligned}\left(1+\tau_t^C+\Gamma_v(v_{i,t})\right)P_{C,t}C_{i,t}+P_{I,t}I_{i,t}+R_t^{-1}B_{i,t+1}+((1-\Gamma_{B^F}(B_{i,t}^F))R_t^F)^{-1}S_t^{ROW}B_{i,t+1}^F+M_{i,t}+\ \Xi_{i,t}\\ +\ \Phi_{i,t}\\ =\ (1-\tau_t^N-\tau_t^{W_h})W_{i,t}N_{i,t}+(1-\tau_t^K)(R_{K,t}u_{i,t}-\Gamma_u(u_{i,t})P_{I,t})K_{i,t}\\ +\tau_t^K\delta P_{I,t}K_{i,t}+(1-\tau_t^D)D_{i,t}+TR_{i,t}-T_{i,t}+B_{i,t}+S_t^{ROW}B_{i,t}^F+M_{i,t-1}\quad,\end{aligned}$$

$P_{C,t}$ and $P_{I,t}$ denote hereby the price of domestic final consumption goods and investment goods, respectively, R_t and $R_t^{F,ROW}$ are the nominal interest rates paid on the domestic and internationally traded bonds.[8] When engaging in international bond holdings, agents are required to pay an external risk premium, also referred to as participation costs, and characterized by the function

[8] To retain the model as general as possible, internationally traded bonds are denoted in ROW currency and therefore international bond holdings have to be multiplied by the nominal exchange rate S_t^{ROW} defined as home currency per ROW currency.

$\Gamma_{B^{F,ROW}}(B_{i,t}^{F,ROW})$[9]. The premium to be paid, denoted by $\Xi_{i,t}$, is rebated back to the Ricardian households in a lump-sum manner. The individual labor service provided by households is rewarded by the nominal wage rate $W_{i,t}$. On the effective amount of capital rented out to firms the rental price $R_{K,t}$ is paid. The costs associated with the supply of the effective amount of capital service rented by altering the intensity of utilization are captured by the function $\Gamma_u(u_{i,t})$. In addition, Ricardian households receive dividends $D_{i,t}$ from firms that they own.

Ricardian households are subject to different types of distortionary taxes. In particular, consumption tax τ_t^C is levied on the nominal consumption while the tax rates τ_t^N, τ_t^K and τ_t^D are levied on the wage, capital and dividend income obtained, respectively. Besides, social security contributions are also collected by the fiscal authorities and modeled in the form of an additional tax rate $\tau_t^{W_h}$ on wage income. Simultaneously, Ricardian households pay lump-sum taxes $T_{i,t}$, yet they receive transfers $TR_{i,t}$ from the government. In addition to distortionary taxes, transaction costs to Ricardian households' consumption are introduced by the function $\Gamma_v(v_{i,t})$[10] and depend on the consumption-based velocity given by

$$v_{i,t} = \frac{(1+\tau_t^C)P_{C,t}C_{i,t}}{M_{i,t}}$$

To ensure herself against wage income risk, household i trades state-contingent securities, $\Phi_{i,t}$, with other Ricardian households $i' \in I$. Finally, the dynamics of the capital stock owned by household i is described as follows:

$$K_{i,t+1} = (1-\delta)K_{i,t} + (\Gamma_I(I_{i,t}/I_{i,t-1}))I_{i,t}$$

where δ is the depreciation rate and the function $\Gamma_I(I_{i,t}/I_{i,t-1})$[11] refers to the investment adjustment costs depending on the investments compared with those from the previous period.

Ricardian households provide differentiated labor services in monopolistic competition and act as wage setters. Wages are permitted to adjust only gradually by assuming a Calvo (1983) scheme with partial adjustment of the wage contracts to past inflation. In a given period t, each Ricardian household receives a signal with probability $1-\xi_I$ to reoptimize her wage. Households which cannot reoptimize wages are allowed though to adjust wages along with the geometric average of past inflation and the steady state inflation

$$W_{i,t} = \left(\frac{P_{C,t-1}}{P_{C,t-2}}\right)^{\chi_I} \pi_C^{1-\chi_I} W_{i,t-1}$$

where χ_I denotes the weight parameter.

[9] The external risk premium function is defined as follows:
$\Gamma_{B^{F,ROW}}(B_{i,t}^{F,ROW}) := \gamma_{B_1}\left(\exp\left(S_t^{ROW}P_{t-1}^{ROW}B_{i,t}^{F,ROW}/(P_t^Y Y_t)\right)-1\right)$

[10] The transaction costs are defined as $\Gamma_v(v_{i,t}) = \gamma_{v,1}v_{i,t} + \gamma_{v,2}v_{i,t}^{-1} - 2\sqrt{\gamma_{v,1}\gamma_{v,2}}$

[11] The investment adjustment costs function is defined as $\Gamma_I(I_{i,t}/I_{i,t-1}) = \frac{\gamma_1^I}{2}\left(I_{i,t}/I_{i,t-1}-1\right)^2$

Non-Ricardian households

Non-Ricardian households, denoted by j, are excluded from capital and bond markets, yet they can adjust their cash balances. These households act as 'quasi' wage setters, that is, it is assumed that they actually do not optimize, but instead choose to set each period a constant percentage share, here 75 percent, of the optimal wage set by the Ricardian households. As a result, non-Ricardian households choose optimal allocations of consumption $C_{i,t}$ and cash balances $M_{i,t}$ by maximizing a similar lifetime utility function as Ricardian agents subject to the following constraint:

$$\left(1+\tau_t^C+\Gamma_v(v_{j,t})\right)P_{C,t}C_{j,t}\ +M_{j,t}=\ (1-\tau_t^N-\tau_t^{W_h})W_{j,t}N_{j,t}+TR_{j,t}-T_{j,t}+M_{j,t-1}+\Phi_{j,t}$$

where $\Gamma_v(v_{j,t})$ are the transaction cost of consumption purchases. Similarly, non-Ricardian agents receive transfers $TR_{j,t}$ and pay lump-sum taxes $T_{j,t}$, additionally, they trade state-contingent securities, $\Phi_{j,t}$, with other non-Ricardian households $j' \in J$ to insure themselves against wage income risk.

Intermediate Goods Producers

There exists a continuum of intermediate goods producers indexed by $f \in [0,1]$ using a Cobb-Douglas technology with non-zero fixed costs described by the following production function:

$$Y_{f,t}\ =max\left[z_t\,K_{f,t}^{\alpha}N_{f,t}^{1-\alpha}-\psi,0\right]$$

where the input factors are physical capital $K_{f,t}$ rented from Ricardian households in fully competitive markets and a composite of labor services, $N_{f,t}$, consisting of the bundled individual labor supply, $N_{f,t}^I$ and $N_{f,t}^J$, of both types of households, Ricardian and non-Ricardian. ψ denotes real fixed costs occurring at each period t and z_t is the total factor productivity which is similar across all firms and evolves according to the following process

$$ln(z_t)\ =(1-\rho_z)ln(z)+\rho_z ln(z_{t-1})+\epsilon_{z,t}\ .$$

The cost function of intermediate goods producers is given by

$$\mathcal{C}\left(K_{f,t},N_{f,t}\right)=R_{K,t}K_{f,t}+(1+\tau_t^{W_f})W_tN_{f,t}\ .$$

W_t stands for the overall wage index and $\tau_t^{W_f}$ for the payroll tax rate where the latter is intended to capture social security contributions paid by firms. From the first order conditions it follows that marginal costs for intermediate goods producers equal to

$$MC_{f,t}=\frac{1}{z_t\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\left(R_{K,t}\right)^{\alpha}((1+\tau_t^{W_f})W_t)^{1-\alpha}.$$

The overall labor input $N_{f,t}$ used by the firms is defined by using a CES-aggregator function

$$N_{f,t}\ =\left((1-\omega\varsigma)^{\frac{1}{\eta}}\left(N_{f,t}^I\right)^{\frac{\eta-1}{\eta}}+(\omega\varsigma)^{\frac{1}{\eta}}\left(N_{f,t}^J\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}\ ,$$

where $N_{f,t}^I$ and $N_{f,t}^J$ are bundles of individually supplied labor services of Ricardian and non-Ricardian households, respectively. η denotes the intratemporal elasticity of substitution between the different labor bundles and ς is a parameter influencing the relative contribution of the different labor types to the overall labor input. In addition to choosing the optimal amounts of the two different labor bundles, firms also choose the optimal input of the individually supplied labor by households $i \in I$ and $j \in J$ to construct the two labor bundles $N_{f,t}^{I}$ and $N_{f,t}^{J}$. In particular, $N_{f,t}^{I}$ and $N_{f,t}^{J}$ are defined as follows:

$$N_{f,t}^{I} = \left(\left(\frac{1}{1-\omega} \right)^{\frac{1}{\eta_I}} \int_{0}^{1-\omega} \left(N_{f,t}^{i} \right)^{\frac{\eta_I - 1}{\eta_I}} di \right)^{\frac{\eta_I}{\eta_I - 1}} ,$$

$$N_{f,t}^{J} = \left(\left(\frac{1}{\omega} \right)^{\frac{1}{\eta_J}} \int_{1-\omega}^{1} \left(N_{f,t}^{j} \right)^{\frac{\eta_J - 1}{\eta_J}} dj \right)^{\frac{\eta_J}{\eta_J - 1}} ,$$

where η_I and η_J denote the elasticity of substitution between the labor services supplied by the individual households $i \in I$ and $j \in J$, respectively.

Similarly to wages, prices can only adjust gradually in Calvo style. All firms sell intermediate goods in both the domestic and foreign markets. On the markets of Economy A and Economy B prices are always charged in local currency while on the ROW markets producer currency pricing is assumed and the law of one price holds. Each period firms receive a signal with probability $1 - \xi_H$ and $1 - \xi_X$ to reset the price of their individual products on the home market and on the market of the other country, respectively. Firms which are not allowed to reset prices in a given period will index their prices to the geometric average of the past period and the steady state inflation on the local market, respectively:

$$P_{H,f,t} = \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\chi_H} \pi_H^{1-\chi_H} P_{H,f,t-1} ,$$

$$P_{X,f,t} = \left(\frac{P_{X,t-1}}{P_{X,t-2}} \right)^{\chi_X} \pi_X^{1-\chi_X} P_{X,f,t-1} .$$

Final goods producers

Final goods producers operate under perfect competition and use CES-technology to transform bundles of domestic and foreign intermediate goods into non-tradable final consumption goods Q_t^C and investment goods Q_t^I:

$$Q_t^C = \left(\begin{array}{c} \nu_C^{\frac{1}{\mu_C}} (H_t^C)^{\frac{\mu_C - 1}{\mu_C}} + (1 - \nu_C - \nu_{C,ROW})^{\frac{1}{\mu_C}} \left(\left(1 - \Gamma_{IM^C} \left(\frac{IM_t^C}{Q_t^C} \right) \right) IM_t^C \right)^{\frac{\mu_C - 1}{\mu_C}} \\ + \nu_{C,ROW}^{\frac{1}{\mu_C}} \left(\left(1 - \Gamma_{IM^C}^{ROW} (IM_t^{C,ROW} / Q_t^C) \right) IM_t^{C,ROW} \right)^{\frac{\mu_C - 1}{\mu_C}} \end{array} \right)^{\frac{\mu_C}{\mu_C - 1}} ,$$

$$Q_t^I = \left(\begin{array}{c} \nu_I^{\frac{1}{\mu_I}} (H_t^I)^{\frac{\mu_I - 1}{\mu_I}} + (1 - \nu_I - \nu_{I,ROW})^{\frac{1}{\mu_I}} \left(\left(1 - \Gamma_{IM^I} \left(\frac{IM_t^I}{Q_t^I} \right) \right) IM_t^I \right)^{\frac{\mu_I - 1}{\mu_I}} \\ + \nu_{I,ROW}^{\frac{1}{\mu_I}} \left(\left(1 - \Gamma_{IM^I}^{ROW} (IM_t^{I,ROW} / Q_t^I) \right) IM_t^{I,ROW} \right)^{\frac{\mu_I - 1}{\mu_I}} \end{array} \right)^{\frac{\mu_I}{\mu_I - 1}} .$$

where μ_C and μ_I denote the elasticity of substitution, ν_C and ν_I the home bias, $\nu_{C,ROW}$ and $\nu_{I,ROW}$ the weights of the ROW inputs, while the remaining part of inputs stems from the other economy (Economy A or Economy B), respectively. Both the final consumption and investment goods producers face adjustment costs when altering the share of imported intermediate goods bundles used for production. The latter costs are captured by the functions Γ_{IM^C}, Γ_{IM^I}, $\Gamma_{IM^C}^{ROW}$ and $\Gamma_{IM^I}^{ROW}$[12].

The bundles of intermediate goods, H_t^C, IM_t^C and H_t^I, IM_t^I are defined as follows:

$$H_t^C = \left(\int_0^1 \left(H_{f,t}^C\right)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \quad IM_t^C = \left(\int_0^1 \left(IM_{f^*,t}^C\right)^{\frac{\theta^*-1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}},$$

$$H_t^I = \left(\int_0^1 \left(H_{f,t}^I\right)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \quad IM_t^I = \left(\int_0^1 \left(IM_{f^*,t}^I\right)^{\frac{\theta^*-1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}}.$$

where $H_{f,t}^C$, $H_{f,t}^I$, $IM_{f^*,t}^C$, $IM_{f^*,t}^I$ denote the use of intermediate goods produced by domestic firms f and foreign firms f^* in the other economy, respectively, and $\theta, \theta^* > 1$ are the corresponding substitution elasticities. As the ROW produces only one single good, $IM_t^{C,ROW}$ and $IM_t^{I,ROW}$ are identical to the bundle of goods produced in the ROW. Final goods producers take prices as given, set by the intermediate goods producers in a monopolistic competitive environment, to minimize costs of producing one unit of a final good. For non-tradable final public consumption goods the home bias is unity, that is, this goods bundle is produced only using home intermediate goods. Hence, the technology constraint is

$$H_t^G = \left(\int_0^1 \left(H_{f,t}^G\right)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}$$

Fiscal Authories

The fiscal authorities collect taxes levied on consumption, capital, dividend, and wage income. Furthermore, payroll taxes are raised in the form of social contributions from both employers and employees. The fiscal authorities also levy lump-sum taxes and obtain seignorage income where the latter is forwarded by the monetary authority. The revenues are expensed on public consumption goods and transfers paid to households. To refinance its outstanding debt, the government issues bonds each period. Consequently, the fiscal budget constraint is described as follows:

$$\begin{aligned} &P_{G,t}G_t + TR_t + B_t + M_{t-1} \\ &\qquad = \tau_t^C P_{C,t} C_t + (\tau_t^N + \tau_t^{W_h}) \left(\int_0^{1-\omega} W_{i,t} N_{i,t} \, di + \int_{1-\omega}^1 W_{j,t} N_{j,t} \, dj \right) + \tau_t^{W_f} W_t N_t \\ &\qquad + \tau_t^K \left(R_{K,t} u_{i,t} - \left(\Gamma_u(u_{i,t}) + \delta\right) P_{I,t}\right) K_t + \tau_t^D D_t + T_t + R_t^{-1} B_t + M_t \quad , \end{aligned}$$

Expenses on public consumption goods expressed as the fraction of steady state nominal output follow an AR(1) process with mean *g*:

[12] Import share adjustment costs are defined as $\Gamma_{IM^i}\left(IM_t^i \,/\, Q_t^i\right) := \frac{\gamma_{IM^i}}{2}\left(\frac{IM_t^i/Q_t^i}{IM_{t-1}^i/Q_{t-1}^i} - 1\right)$ for $i = C, I$

$$g_t = (1-\rho_g)g + \rho_g g_{t-1} + \epsilon_{g,t} \qquad \text{with } g_t = P_{G,t}\, G_t/P_Y Y$$

Naturally, the price level for public consumption $P_{G,t}$ will equal to the price of intermediate goods $P_{H,t}$ as only intermediate goods produced in the home country are used for the production of public consumption goods. Transfers to households are defined as the fraction of steady state nominal output and are modeled similarly by an AR(1) process with mean *tr:*

$$tr_t = (1-\rho_{tr})tr + \rho_{tr} tr_{t-1} + \epsilon_{tr,t} \quad \text{with } tr_t = TR_t/P_Y Y$$

Lump-sum taxes are levied each period according to the following rule:

$$\tau_t = \phi_{B_Y}\left(\frac{B_t}{P_Y Y} - B_Y\right) \qquad \text{with } \tau_t = T_t/P_Y Y$$

where B_Y is the target debt to output ratio in steady state. All distortionary tax rates follow an exogenous AR(1) process unless otherwise stated:

$$\tau_t^X = (1-\rho_{\tau^X})\tau^X + \tau_{t-1}^X + \epsilon_{\tau^X,t} \quad \text{for} \quad X = C, D, K, N, W_h, W_f$$

Monetary Policy Regimes

The model allows for an easy assessment and comparison of the dynamics under three different settings – flexible exchange rates, currency peg of Economy A to Economy B and a monetary union between the two countries – which can be implemented by adjusting the monetary policy rules.

a) Flexible Exchange Rates: In this scenario, the monetary authorities in both regions operate independently and follow a standard Taylor rule with interest rate smoothing:

$$(R_t^A)^4 = \rho^A (R_{t-1}^A)^4 + (1-\rho^A)\left((r^{*,A}\Pi^{*,A})^4 + \phi_\pi^A\left(\frac{P_{C,t}^A}{P_{C,t-4}^A} - (\Pi^{*,A})^4\right) + \phi_Y^A(Y_t^A - Y^A) + \epsilon_{R,t}^A\right)$$

$$(R_t^B)^4 = \rho^B (R_{t-1}^B)^4 + (1-\rho^B)\left((r^{*,B}\Pi^{*,B})^4 + \phi_\pi^B\left(\frac{P_{C,t}^B}{P_{C,t-4}^B} - (\Pi^{*,B})^4\right) + \phi_Y^B(Y_t^B - Y^B) + \epsilon_{R,t}^B\right)$$

where ρ is the smoothing parameter, r^* is the steady state real interest rate equaling $1/\beta$, Π^* is the inflation target, ϕ_π is the reaction to the deviation from the consumer-price inflation target and ϕ_y is the reaction to the output gap. Additionally, we assume that monetary policy shocks are uncorrelated. In this set-up the FOCs of the Ricardian households with respect to B_t and B_t^F imply that the uncovered interest rate parity (UIP) to the ROW, including the risk premium $\Gamma_B(B_{i,t}^F)$ depending on the foreign bond position, will hold. The triangle no-arbitrage equation for the currencies, as postulated further below, will imply that the UIP between Economy A and Economy B will also hold, up to the difference in the risk premia.

b) Unilateral Peg: In order to model Economy A pegging unilaterally its currency to the anchor currency of Economy B the monetary policy rule of Economy A needs to be altered. To guarantee that the exchange rate remains constant we follow the textbook example and add a reaction to nominal depreciation being sufficiently large that deviations in the exchange rate compared with that of one period before are negligibly small:

$$(R_t^A)^4 = (r^{*,A}\Pi^{*,A})^4 + \phi_e\left(\frac{S_t}{S_{t-1}} - 1\right) + \epsilon_{R,t}^A$$

where S_t stands for the nominal exchange rate and ϕ_e is the reaction to fluctuations in the exchange rate. The monetary authority in Economy B follows a similar rule as in the flexible exchange rate scenario. In case it can be assumed that $\epsilon_{R,t}^{A} = 0$ for all t, then the exchange rate is fixed which will lead to a de facto nominal interest rate parity (except for the differences in the risk premia $\Gamma_B(B_{i,t}^F)$ of the two countries, following from the UIP).

c) Currency Union: To assess the dynamics in a currency union the model can be slightly tweaked by introducing a new equation which sets the ratio S_t/S_{t-1} to unity and canceling the monetary policy rule of Economy A at the same time. The central bank of Economy B will serve as the common monetary authority by reacting to the weighted averages of Economy A and Economy B inflation and output gap:

$$
\begin{aligned}
(R_t^{CU})^4 = \; & \rho^{CU}(R_{t-1}^{CU})^4 \\
& + (1-\rho^{CU}) \Bigg(s(r^{*,A}\Pi^{*,A})^4 + (1-s)(r^{*,B}\Pi^{*,B})^4 \\
& + \phi_\pi^{CU}\left(s\left(\frac{P_{C,t}^A}{P_{C,t-4}^A} - (\Pi^{*,A})^4\right) + (1-s)\left(\frac{P_{C,t}^B}{P_{C,t-4}^B} - (\Pi^{*,B})^4\right)\right) \\
& + \phi_Y^{CU}\left(s(Y_t^A - Y^A) + (1-s)(Y_t^B - Y^B)\right) + \epsilon_{R,t}^{CU} \Bigg)
\end{aligned}
$$

Consequently $R_t^{CU} = R_t^{A,B}$ and the FOCs of the Ricardian households in Economy A and Economy B with respect to B_t and B_t^F together with the currency triangle no-arbitrage condition will directly imply that interest parity holds as under the unilateral peg. The de facto difference to the unilateral peg case is that monetary policy is conducted by taking also Economy A into account.

The Rest of the World

The rest of the world is modeled using the textbook three equation New Keynesian model extended by feedback on the output gap and the inflation from Economy A and Economy B:

$$Y_t^{GAP,ROW} = E_t Y_{t+1}^{GAP,ROW} + \frac{1}{\sigma^{ROW}}(\tilde{R}_t^{ROW} - E_t \tilde{\Pi}_{t+1}^{ROW}) + g_t^{ROW}$$

$$\tilde{\Pi}_t^{ROW} = \beta^{ROW} E_t \tilde{\Pi}_{t+1}^{ROW} + \gamma^{ROW} Y_t^{GAP,ROW} + u_t^{ROW}$$

$$\tilde{R}_t^{ROW} = \phi_\pi^{ROW} \tilde{\Pi}_t^{ROW} + \phi_y^{ROW} Y_t^{GAP,ROW} + \epsilon_t^{R,ROW}$$

where

$$g_t^{ROW} = \tilde{g}_t^{ROW} + \eta_{y,A} Y_t^{GAP,A} + \eta_{y,B} Y_t^{GAP,B}$$

$$u_t^{ROW} = \tilde{u}_t^{ROW} + \eta_{\pi,A}(\Pi_t^A - \Pi^{*,A}) + \eta_{\pi,B}(\Pi_t^B - \Pi^{*,B})$$

$$\tilde{g}_t^{ROW} = \rho_g^{ROW} \tilde{g}_{t-1}^{ROW} + \epsilon_t^{g,ROW}$$

$$\tilde{u}_t^{ROW} = \rho_u^{ROW} \tilde{u}_{t-1}^{ROW} + \epsilon_t^{u,ROW}$$

The variables $Y_t^{GAP,ROW}$, $\tilde{\Pi}_t^{ROW}$ and $\tilde{R}_t^{ROW}$ stand for the output gap, the inflation, and the nominal interest rate, respectively. The parameters σ^{ROW}, β^{ROW}, ϕ_π^{ROW} and ϕ_y^{ROW} are the risk aversion, the time preference, and the reaction of the monetary authority to inflation and the output gap. The disturbance terms g_t^{ROW} and u_t^{ROW} are the summation of the indigenous demand and cost-push shocks, $\tilde{g}_t^{ROW}$ and $\tilde{u}_t^{ROW}$, and the feedback from Economy A and Economy B with the elasticities $\eta_{y,A}$, $\eta_{y,B}$, $\eta_{\pi,A}$ and $\eta_{\pi,B}$.

Since it is assumed that firms in the ROW price their products in producer currency and that the law of one price holds, trivially, the import price for products from the ROW can be expressed as

$$P_t^{IM,ROW} = S_t^{ROW} P_t^{Y,ROW}$$

and the inflation dynamics in the ROW is defined as

$$\widetilde{\Pi}_t^{ROW} = \frac{P_t^{Y,ROW}}{P_{t-1}^{Y,ROW}} - 1$$

To remain consistent with respect to the dimension of key variables throughout the model we define Π_t^{ROW} as the gross inflation being

$$\Pi_t^{ROW} = \Pi^{*,ROW}\left(1 + \widetilde{\Pi}_t^{ROW}\right)$$

where $\Pi^{*,ROW}$ is the gross inflation target in the ROW. Similarly, we define the gross nominal interest rate R_t^{ROW} as

$$R_t^{ROW} = R^{*,ROW}\left(1 + \widetilde{R}_t^{ROW}\right)$$

where $R^{*,ROW}$ is the nominal gross steady state interest rate in the ROW being defined as the product of the real gross steady state interest rate and the gross inflation target. Finally, the demand for imported intermediate goods by the ROW, equalling the exports of Economy A and Economy B, respectively, is given by

$$X_t^{ROW} = \left(1 + \phi_X^{ROW} Y_t^{GAP,ROW}\right)\psi^{ROW}\left(\frac{P^H}{S_t^{ROW} P^{Y,ROW}}\right)^{-\eta^{ROW}}$$

where ψ^{ROW} is a country-specific scaling constant, η^{ROW} is the elasticity with respect to the relative price and ϕ_X^{ROW} is the demand elasticity with respect to the output gap.

Equilibrium

In equilibrium, domestic bond holdings are pinned down by the budget constraint of the fiscal authority. To clear the internationally traded bonds market, holdings issued in ROW currency have to sum up to zero:

$$s^A B_t^{F,A} + s^B B_t^{F,B} = -B_t^{F,ROW}$$

where s^A and s^B are the relative weights of Economy A and Economy B compared with the ROW. Technically speaking, the latter equation does not impact the ROW economy as it is described by a parsimonious three equations system where trade is not explicitly modeled. The dynamics of the holdings of the internationally traded bonds can be expressed as

$$(R_t^{ROW})^{-1} B_{t+1}^F = B_t^F + \frac{TB_t + TB_t^{ROW}}{S_t^{ROW}}$$

For both Economy A and Economy B, the trade balance with the other country, TB_t, is defined as

$$TB_t = P_{X,t}X_t - P_{IM,t}IM_t$$

The trade balance with the ROW, TB_t^{ROW}, is defined in a similar manner:

$$TB_t^{ROW} = P_{H,t}X_t^{ROW} - S_t^{ROW}P_t^{Y,ROW}IM_t^{ROW}$$

where $IM_t^{ROW} = IM_t^{C,ROW} + IM_t^{I,ROW}$.

The terms of trade is defined as the ratio of import to export prices expressed in home currency:

$$ToT_t = \frac{P_{IM,t}}{S_t P_{X,t}} \quad , \qquad ToT_t^{ROW} = \frac{S_t^{ROW}P_t^{Y,ROW}}{P_{H,t}}$$

Finally, to close the model, we explicitly require that the triangle no-arbitrage condition for the currencies holds:

$$S_t^{A,ROW} = S_t^{A,B}S_t^{B,ROW}$$

As the model can be rewritten up in a manner that instead of exchange rate levels only depreciation terms show up in the equations, the above classical triangle arbitrage equation transforms into

$$\frac{S_t^{A,ROW}}{S_{t-1}^{A,ROW}} = \frac{S_t^{A,B}}{S_{t-1}^{A,B}}\frac{S_t^{B,ROW}}{S_{t-1}^{B,ROW}}.$$

To clear the money market, the monetary authority will supply the amount of money demanded by the households – pinned down by the optimality conditions of the households – as monetary policy uses the interest rate as a policy instrument.

3.2 Calibration

In order to assess the dynamics under all three different exchange rate regimes, Economy A and Economy B are calibrated to roughly reflect the Italian economy and the Rest of the Euro Area, respectively. For the ROW standard textbook parameter values were taken. In general, we intend to strike the right balance between matching the average figures in the data for the period following the year 2010 and commonly set values from the literature.

The country weights were set to 0.178 for Economy A and to 0.822 for Economy B, mirroring the shares of the population within the euro area over the past decade. To pin down the investment to output ratio to 20.5 and 20.9 percent for Economy A and Economy B, respectively, we calibrate for both economies the elasticity of capital in intermediate goods production to 0.3, capital depreciation to 1.5 percent per period, β to 0.995 implying a yearly steady-state real interest rate of approximately 2 percent and τ^K to 0.275 for Economy A and to 0.225 for Economy B.[13] When it comes to the consumption to GDP ratio,

[13] The implied investment to output ratio for Economy A turns out to be to some extent lower than the average value in the national accounts in the past decade. Yet, after the second wave of the past financial crises investment has failed to recover thus it might be not far-fetched that the Italian economy has now been out of equilibrium for a longer period. To achieve a significantly lower investment to output ratio for Economy A, one would need to set the capital tax to significantly higher values which cannot be justified anymore by existing data on government revenue. In general, measuring the taxation of capital income is a challenging task in practice and different measures calculated by the European Commission exist, yet these are volatile.

it equals 60.5 percent for Economy A, which fairly matches the data from the national accounts and 58 percent for Economy B being to some extent above the figure calculated from the national accounts. However, given that the euro area is running a massive trade surplus it might be realistic that the steady state consumption to GDP ratio of Economy B is higher than present data would suggest. Historical data also suggests that the consumption to GDP ratio has been higher in Italy than in the euro area, although the difference used to be smaller earlier.[14] Investment adjustment costs are set to 3 and the capital utilization cost parameter calibrated to 0.007, both in line with Coenen et al. (2008).

To reflect trade interdependencies we calibrate the model to match the import to output ratios compiled from the statistics on international trade in goods provided by Eurostat, the Extended Balance of Payments Services (EBOPS) statistics of the OECD and the national accounts. The ratios of imported consumption goods and investment goods to GDP for the model are calculated by adding up the value of all imported goods – capital goods, consumption goods, and intermediate goods – and weighting the total sum with the relative ratio of the imports in consumption goods to imported capital goods from the trade statistics. Thus, imported intermediate goods are assumed to be used for the production of final goods in the same proportion as the relative ratio of imported capital goods to imported consumption goods according to the trade statistics. Moreover, trade in services is also accounted for by adding imported services to imported goods. Based on the EBOPS dataset, it can be assumed that 20 percent of imported services in Economy A from both the ROW and Economy B is used for the production of the final investment goods bundle and the rest for the consumption goods bundle. Similarly, we assume that 20 percent of the imported services in Economy B from Economy A is channeled into the production of final investment goods and the rest into the production of final consumption goods. Moreover, the share of imported services from the ROW directed to final investment goods production amounts to 25 percent, while the remaining part is used by assumption in the production of the final consumption goods bundle. Finally, calculated nominal values are divided by nominal GDP. Overall, for Economy A the import to GDP ratio was calibrated at approximately 3.4 and 9.6 percent for the investment and the consumption goods from Economy B, and to 4.1 and 11.2 percent from the ROW. Import to GDP ratios of Economy B with respect to Economy A total in approximately 0.7 and 1.6 percent, while the import to GDP ratios with regard to the ROW add up to 9.2 and 16.4 percent, respectively. In Economy A the above ratios translate into 0.665 and 0.164 for the parameters ν_C and ν_C^{ROW}, respectively, and ν_I and ν_I^{ROW} are set to 0.6385 and 0.179. For Economy B ν_C and ν_C^{ROW} are calibrated to 0.7285 and 0.2435, while ν_I and ν_I^{ROW} are set to 0.5802 and 0.3895. The intratemporal substitution elasticities between domestic and foreign intermediate goods, μ_C and μ_I are set to 1.5 for both economies. The parameter specifying the costs incurring with respect to the variation in the imported intermediate goods to final consumption goods ratio, γ_C, is set to 2.5 while the variation for the investment goods is not subject to any costs, similar to Coenen et al. (2008).

We set the substitution elasticity of individually supplied intermediate goods to 6 for both economies, implying a markup of 20 percent. On the home market the price rigidity is equal to 0.75, while on the export market this parameter takes value 0.3 for both economies. In both markets and economies the indexation parameter is calibrated to 0.5. Moreover, the fixed costs of the firms, ϕ, are set in a manner that the steady state profit of the intermediate goods producers equals zero.

The rest of the behavioral parameters is calibrated to be in line with common values applied in existing literature, see e.g. Coenen et al. (2008) or Forni et al. (2009). The intertemporal elasticity of substitution,

[14] Alternatively, one could also set the parameter for capital depreciation differently, however, we would like to stick to existing literature where it is common to set these parameters uniformly across different economies in the euro area.

σ, is calibrated to 2, the habit persistence, κ, to 0.7 and the inverse of the elasticity of labour supply, ζ, to 2. The share of non-Ricardian consumers is uniformly set to 25 percent. As regards wage setting, the elasticity parameter is equal to 4 for Economy A and 5 for Economy B, implying a markup of 33 and 25 percent, respectively.[15] For both consumer types the wage rigidity and the indexation parameter are set to 0.75 uniformly for Economy A and Economy B, see also Coenen et al. (2008).

To reflect the ratios of the different nominal expenditure aggregates to nominal output from the national accounts, we calibrate the steady state ratios of government consumption to GDP, G/Y, to 0.19 for Economy A and to 0.21 for Economy B. The steady state debt to GDP ratio, B/Y, is calibrated to 2.4 to match the public debt target from the Maastricht Treaty by setting the transfer to GDP ratio accordingly. This can be forced by setting the steady-state transfer to output ratio accordingly, that is, to approximately 25.7 percent for Economy A and to slightly above 22 percent for Economy B. We also assume that transfers received by a non-Ricardian agent are 50 percent higher than transfers channeled to Ricardian agents. Regarding lump-sum taxes, we assume that Ricardian consumers bear the burden entirely and the reaction parameter to the deviation from the steady state debt to output ratio in the fiscal rule, ϕ_{B_Y}, is set to 0.1. Finally, the remaining tax rates, τ^C, τ^N , $\tau^{W_h}$and τ^{W_f}, are calibrated to match the government revenue statistics. That is, τ^C is set to 16.5 and 17.7 percent, τ^N to 27.9 and 20.6 percent, τ^{W_h} to 7.4 and 12.4 percent for Economy A and Economy B, respectively, and τ^{W_f} is set to 21.7 percent for both economies. To calculate τ^{W_h} and τ^{W_f}, we assume that half of the social security contributions of self-employed is paid by firms and the other half is paid by households. Furthermore, to account for imputed compensation of the self-employed, we use the adjusted gross operating surplus series provided in AMECO.

Regarding the parameters linked to cash balances, those related to consumption transaction costs, Γ_{v_1} and Γ_{v_2}, are calibrated such that the steady state cash balance to consumption spendings, $\frac{1}{v}$, is equal to 4/3, and the implicit semi-elasticity of money demand to -0.75.

The monetary policy authority follows a Taylor-type rule without interest rate smoothing and the reaction coefficient to inflation, ϕ_π, is set to 2.[16] Yet, the reaction coefficient to the output gap on the yearly interest rate is set to zero as the mandate of the ECB is price stability.

To ensure that the steady state foreign net asset position is zero, we set the parameter Γ_{B_1} to 0.0001 which is sufficiently small that the effects of increasing participation premium are negligible. The value of the autoregressive (AR(1)) coefficients of the shocks in the model is calibrated to 0.9.

The parameters for the ROW are standard: σ^{ROW} is set to 2, β^{ROW} to 0.995, γ^{ROW} to 0.025, ϕ_π^{ROW} and ϕ_y^{ROW} to 1.5 and 0.5 and the AR(1) coefficients to 0.9. The demand scaling parameter ψ^{ROW} for Economy A goods is set in a way that the real exchange rate versus the ROW reflects roughly the observable trade-weighted real exchange rates between Economy A and the ROW, being approximately 0.78. Overall, the model calibration implies a real exchange rate between Economy A and Economy B of slightly above 1.05 which is in line with the trade-weighted real exchange rate of approximately 1.08, calculated from available empirical data (Penn World Table 9.1). Furthermore, the demand scaling parameter ψ^{ROW} for Economy B goods is calibrated such that in the steady state the triangle no-

[15] These values, in line with existing literature, reflect however structural weaknesses in the labor market of Economy A. For example, Annicchiarico et al. (2013) use a fairly low value of 2.65 for the elasticity parameter for Italy implying a markup of 60 percent.

[16] We also carried out simulations with a a smoothing parameter where ρ is set to 0.85. In general, the difference in the output responses was diminished due to the decreased reaction of the domestic central bank.

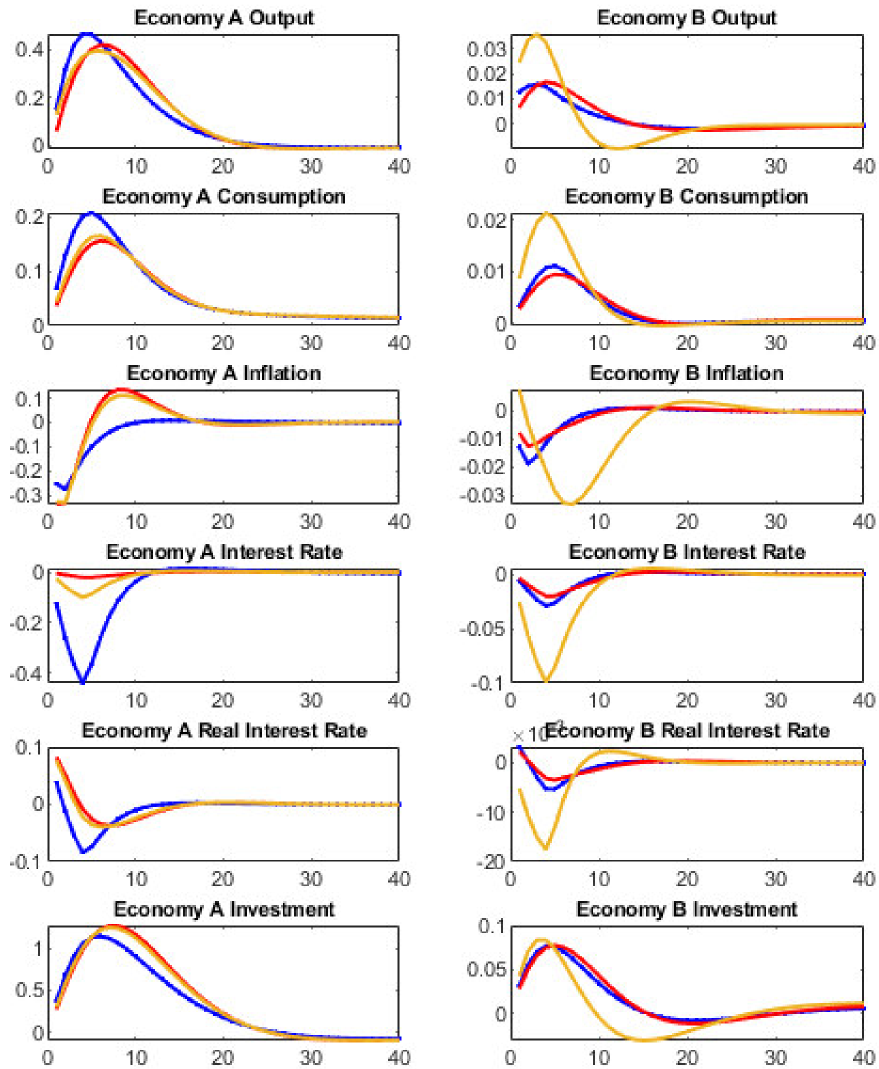
arbitrage condition in real terms also holds. The ROW output demand elasticity for Economy A and Economy B export goods, ϕ_X^{ROW} equals 0.1, that is, a one percent higher output gap in the ROW will increase import demand ceteris paribus by 0.1 percent. The demand elasticity with respect to the relative prices, η^{ROW}, is set to 0.5 for both economies. Finally, for simplicity we will assume that changes in output and inflation in Economy A and the Economy B do not impact the ROW economies, that is, η_y and η_π are equal to zero.

4 Simulation results

This section compares impulse response functions from the model under three different exchange rate regimes. In particular, we examine to what extent the dynamics of key aggregates (1) under a flexible exchange rate regime, (2) under a peg to the anchor currency of the larger economy, and (3) in a monetary union with a common central bank differ. Additionally, we aim to specify the losses suffered due to the transfer of monetary policy.

We compare the impulse responses to a temporary one percentage point negative shock in the social security contributions rate paid by firms where the real effects are summarized in Figure 4. An employers' social security contributions rate shock in Economy A has its largest effect on output under a flexible exchange rate regime which is expected as the central bank can counter-steer the decline in inflation arising due to the decrease in firms' marginal costs. Consequently, the decline in the interest rate in Economy A is the largest under the flexible exchange rate regime. When Economy A pegs its currency to the currency of Economy B, the dynamics is almost similar to that in a currency union. Yet, in the latter two cases, when the exchange rate is fixed, the output responses of Economy A in the first six periods remain significantly below the outcome that would prevail under the flexible exchange rate regime. The impact on output in Economy A in a currency union is slightly higher than in the case of a one-sided peg at the beginning. This can be attributed to the feature that in Economy B the rise in output is approximately twice as high in a currency union as under the other two exchange rate regimes, hence the spillover effect to Economy A is the largest in a currency union. The key driver of the output dynamics in Economy B is that in a currency union the common central bank reacts to the weighted inflation from both economies. The policy rate is decreased in Economy B significantly more than it would be under a flexible exchange rate regime and in the currency peg scenario. The inflation spillover effects to Economy B are in general very small as the import share of Economy A goods in Economy B is only slightly higher than 2 percent, therefore the effects on the inflation in Economy B are minor. Consequently, the response of the central bank in Economy B would turn out to be very moderate under a flexible regime or when the currency of Economy A is pegged to Economy B. Under a currency peg, the interest rate parity will hold due to the no-arbitrage condition and the participation premium paid on international bonds is negligible. Therefore, once the currency is pegged, the central bank in Economy A will not be able to boost output and cushion the decrease in inflation by a more expansionary monetary policy as it would under a flexible exchange rate regime with an independent national central bank. In Economy B the dynamics in output and inflation are fairly similar under the flexible regime and the currency peg scenario as the monetary authority aims to stabilize inflation only in the home economy. The reason that the increase in output in Economy B in the first three periods is larger under the flexible regime than under the currency peg can be attributed to the feature that in Economy A output reacts more strongly to the shock which results then in a higher demand for import goods from Economy B.

Figure 4: Impulse response functions of headline variables to a temporary one percent negative SSCR shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

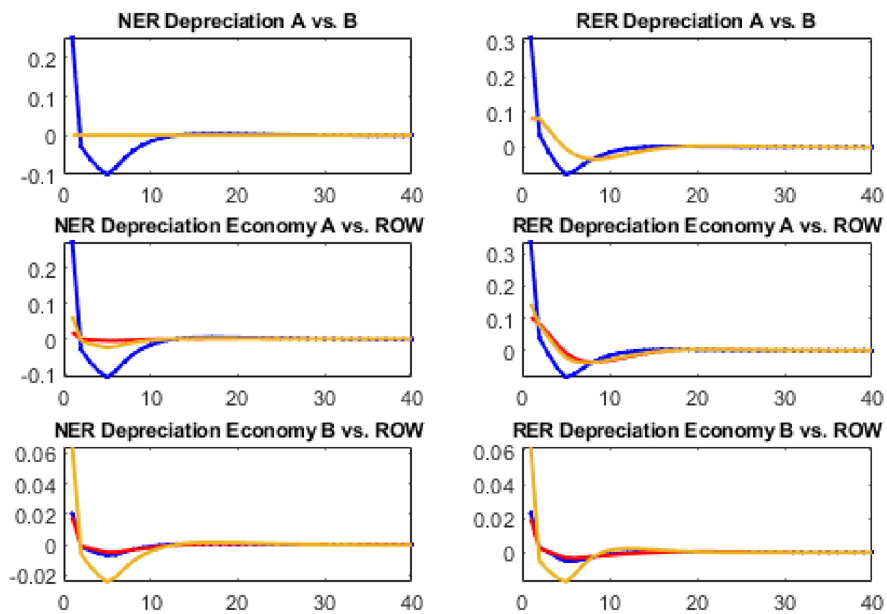
The response in consumption exhibits in both economies a very similar pattern when compared with the output dynamics.[17] Yet, the main difference between the dynamics in consumption and output is that in Economy A the relatively strong impact in output at the beginning under the flexible exchange rate regime fades out faster than under a currency peg or in a currency union while consumption under a flexible regime falls only marginally below the trajectory which would prevail under the other two regimes.[18] The reason for consumption responses being more aligned is that individuals have the desire for smoothing and therefore shift resources into the future by saving relatively more at the beginning.

[17] In Economy A the response is the largest under the flexible regime while in Economy B the increase in consumption is twice as high in a currency union as under the remaining two currency regimes.

[18] Under the flexible regime output undercuts the path which would prevail under the other two regimes after approximately six periods and remains lower until the temporary effect fades out. In Economy B the strongest response in output at the beginning arises in a currency union, yet the effect fades out much more rapidly and

In order to understand the mechanism underlying the protracted output dynamics of Economy A under the one-sided peg and in a currency union, one needs to have a look at the overall picture from a broader perspective. A negative shock reducing firms' marginal costs in Economy A causes inflation to decline and under the flexible regime the central bank would react accordingly to push inflation gradually back to target. However, under a one-sided peg or in a currency union, inflation will overshoot the target due to the lack of capability to control the policy rate. This results in a lower real interest rate than which would prevail under the flexible regime. Consequently, the lower real interest rate from the eighth period onwards will have a positive effect on both consumption and investment and hence on output which leads to a less rapid decline in output after the peak is reached.

Figure 5: Impulse response functions of exchange rates to a temporary one percent negative SSCR shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

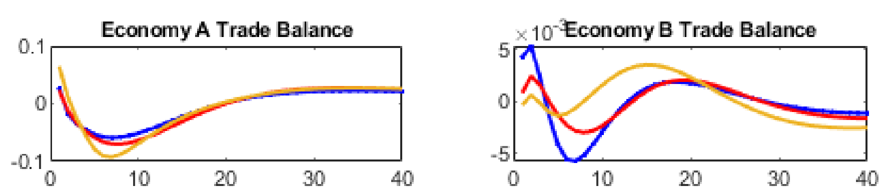
The reason for the inflation overshooting in Economy A is that under a flexible exchange rate regime the initial decrease in the interest rate and the resulting depreciation of the currency against both Economy B and the ROW is followed by a phase of gradual appreciation. This will have a negative impact on inflation, yet the exchange rate effect is absent under a one-sided peg or in a currency union. Under the latter two scenarios, the initial decrease in the interest rate is very small thus both the depreciation on impact and the appreciation afterwards versus the ROW is small. Therefore, there is no negative impact on the inflation arising from changes in the exchange rate while the nominal exchange rate versus Economy B is anyway fixed. The difference between the interest rate responses in the latter two scenarios is relatively small if compared to the difference in the policy response of the indigenous central bank under a flexible exchange rate regime. Consequently, the difference in the output dynamics under a peg and in the currency union will be moderate, yet in a currency union the impact is initially

turns even into slightly negative, being well below the path outcome would enter under both the flexible and pegged regimes. Despite the relatively sharp output contraction after the initial upswing in a currency union, consumption remains higher in Economy B for a few more periods than under a flexible regime or a one-sided peg by Economy A and then undercuts only very slightly the paths which prevail in the latter two scenarios.

slightly larger on the back of a higher demand from Economy B. In a currency union the common central bank will lower interest rates more than the central bank of Economy B would in the peg scenario. This creates a strong output response on impact in Economy B triggering also a higher demand for import goods from Economy A which will also positively influence output in Economy A at the beginning. Noting that from the perspective of Economy B the largest response in the policy rate occurs in a currency union as otherwise monetary policy would only aim to counterbalance spillover effects from Economy A, the fluctuation in the exchange rate versus the ROW will be also the largest in a currency union. Therefore the initially strong output response of Economy B in the currency union will fall rapidly and undershoot the output paths which would arise in a flexible regime or the one-sided peg scenario as the gradual appreciation versus the ROW will also result in less demand for Economy B goods from the ROW. Finally, the declining output in Economy B will spill over to Economy A which will affect the economy negatively.

An additional factor prompting the more rapid fade out of the initial output increase in Economy A under the flexible regime is that similar to Economy B fluctuations in the exchange rate will have an impact on export demand. From the perspective of Economy A, the largest response in the interest rate occurs under the flexible regime which will also result in the largest exchange rate fluctuations. Again, the initial decline in the interest rate and the resulting depreciation of the currency will first boost the economy due to higher demand from both Economy B and the ROW, yet the following gradual appreciation will hamper export demand. Under the flexible regime, the pace of the appreciation versus the ROW will be much higher than under both regimes where the nominal exchange rate versus Economy B is fixed, such that the export demand from the ROW will drop below the levels it would prevail under the peg or currency union scenarios. The exchange rate dynamics with respect to Economy B exhibits a similar pattern as versus the ROW under the flexible regime. However, in case the nominal exchange rate is fixed the real exchange rate is determined solely by the inflation difference between Economy A and Economy B. As the inflation response in Economy A is mostly higher by an order of magnitude than in Economy B the resulting change in the real exchange rate will be driven by the inflation in Economy A. Hence, the currency depreciates in real terms initially by much less and also for a couple of periods longer than it does under the flexible regime and starts appreciating gradually afterwards. Overall, when comparing the real exchange rate dynamics from the perspective of Economy A the pattern across the exchange rate regimes is very similar irrespective of whether it is considered versus Economy B or the ROW. Under the flexible regime, the currency devaluates first by more than it does under the fixed exchange rate regimes, yet the appreciation occurs at a higher pace such that a few periods later the real exchange rate will undershoot the path which prevails under the fixed regimes and will have a relatively larger negative drag on output.

Figure 6: Impulse response functions of trade balances to a temporary one percent negative SSCR shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

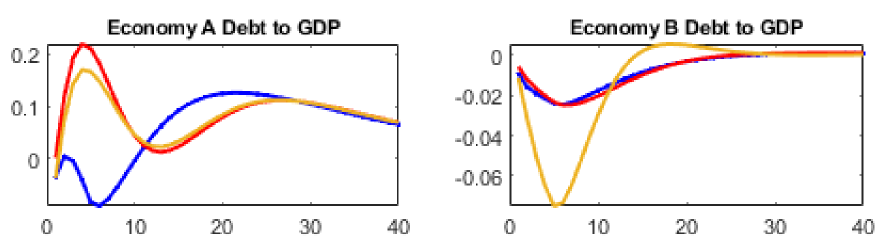
An additional key variable is the overall trade balance which exhibits a J-curve dynamics in Economy A, where initially the trade balance increases in all three scenarios and only then turns into negative.

For Economy B the overall trade balance is fluctuating but is lower by an order of magnitude than in Economy A.[19]

As regards the production factors, investments and capital stock rise only marginally more at the beginning under the flexible regime than under both fixed regimes, despite the larger increase in output, see Appendix. The straightforward reason for this feature is that investments can only increase gradually due to investment adjustment costs. However, after the initial rise in output, the relatively faster output contraction results in less demand for capital. This paired with sluggish wage adjustment, it will be more beneficial to utilize installed capital more or to substitute with labor. Furthermore, following the initial period, a relatively higher real interest rate under the flexible exchange rate will have a further negative impact on capital. When the exchange rates are fixed it is more beneficial to accumulate capital, as the positive impact on output is longer lasting. Consequently, hours worked closely follow the output pattern, since more labor input is needed if output rises. Finally, nominal wages show a hump-shaped dynamics similar to output and hours worked, yet the difference in the impulse response functions is negligible, as wages are relatively sticky. Also, nominal wages rise less than output for the reason that inflation decreases.

Finally, an important aspect of the adjustment process is the dynamics of the debt-to-GDP ratio in Economy A. A negative shock in social security contributions leads to a slight decrease under a flexible regime and an increase under the fixed exchange rate scenarios. The biggest upswing at the beginning arises when the exchange rate to Economy B is pegged, as output rises the least in this scenario. The difference in the dynamics if compared with a currency union is not substantial. Under the flexible regime, not only the higher output but also the smaller decrease in inflation contributes to a more favorable outcome at the beginning. However, the relatively sharp rise in the debt under both fixed exchange rate regimes is followed by a rapid decrease as inflation rises at a much higher pace than under the flexible regime. Moreover, also the protracted output dynamics contributes to the decrease such that after approximately twelve periods the debt-to-GDP ratio will become lower under the fixed exchange rate regime than it will be under the flexible regime. Afterwards the trajectories close and return gradually to their steady state values as the impact of the shock fades out.

Figure 8: Impulse response functions of debt-to-GDP ratios to a temporary one percent negative SSCR shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

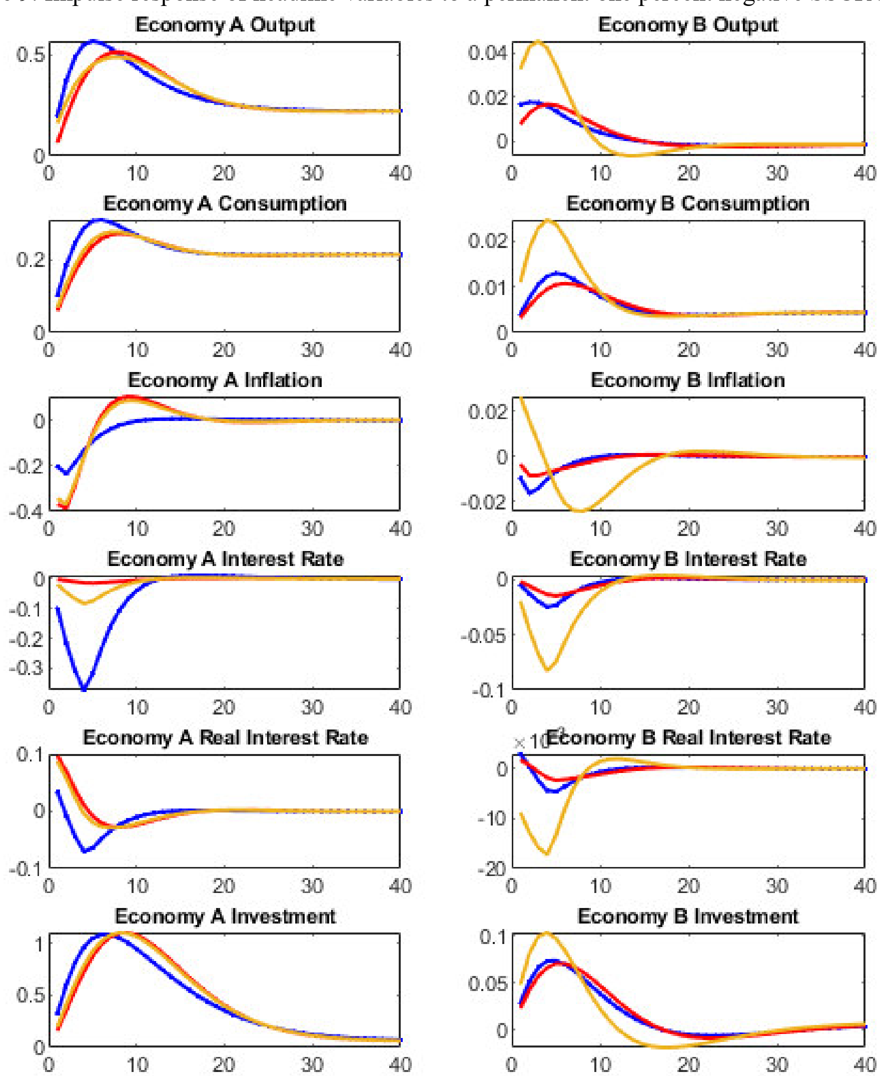
[19] A more detailed analysis of the dynamics is provided in the Appendix.

5 Extensions

5.1. Permanent Effects

In the previous sections, we have seen how a temporary negative shock to firms' social security contributions impacts key macroeconomic aggregates. However, structural reforms are typically aimed at correcting supply-side derailments, and measures of this sort intend to impact the economy permanently. Although DSGE models provide an appropriate framework to assess short- and midterm effects of temporary shocks, results concerning long term developments should be interpreted with caution. Policy measures that aim to change the structure of the economy would translate into the model by altering its steady state. Yet, we believe that the present approach is still warranted for the assessment of the transition dynamics until the economy reaches its new steady state, similarly to Forni et al. (2014).

Figure 9: Impulse response of headline variables to a permanent one percent negative SSCR shock

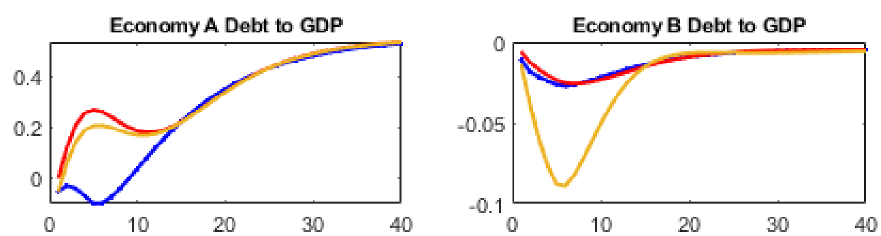


Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

Since the main goal of this paper is to evaluate the short- to midterm effects of supply-side measures under different exchange rate regimes, we provide a brief assessment of the impacts when shocks are permanent, that is, the autoregressive term of the shock process, ρ, equals to unity. As also stated by Forni et al. (2014), a permanent change in the shock process does not lead to an immediate jump from one steady-state to the other, due to the presence of nominal and real rigidities.

As Figure 9 suggests, the difference in the shape of the headline economic variables' trajectories is almost negligible. The key difference is that aggregate variables do not converge back to their steady states, but to another level. However, the magnitude of the change in output is larger. This result is straightforward as the shock is not only longer-lasting but also larger in size in the midterm which will influence the short term dynamics. It is also important to remark that the impulse responses of all displayed variables intertwine in the longer run and stabilize at the same level. As concerns the debt to GDP ratio which plays a crucial role when designing structural reforms, it can be seen that a permanent negative shock to social security contributions will result in a permanent rise on the back of lower contributions and negative price effects. This is rather unsatisfactory as in many cases these measures have to be carried out in a weak fiscal environment without deteriorating the sustainability of sovereign debt in the long run. Hence, a decrease in social security contributions is not self-financing in this model and further fiscal measures are required to at least maintain a similar debt-to-GDP ratio as at the time when the measure was implemented. It is noteworthy that the latter result is independent of the prevailing exchange rate regime. Thus, in the longer term the economy will converge to the same debt-to-GDP ratio and a more flexible exchange rate regime is not preferable in that sense. However, when the exchange rate is fixed, during the transition phase the debt to GDP ratio increases more abruptly shortly after the shock.

Figure 10: Impulse response of the debt to GDP ratio to a one percent permanent negative shock

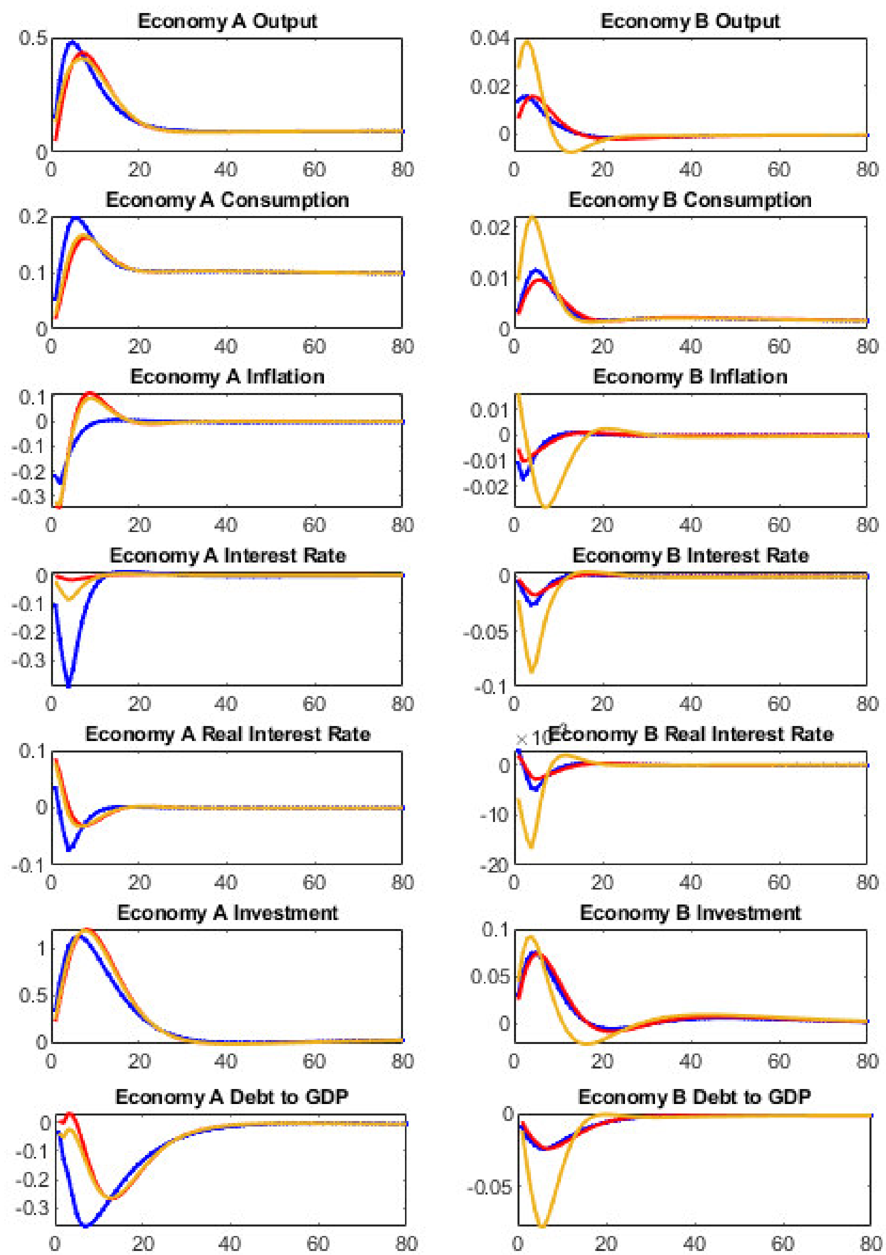


Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

5.2. Fiscal sustainability

At times of a weak fiscal position further action is needed to offset a rise in the debt-to-GDP ratio following a decrease in social security contributions to guarantee the sustainability of public debt in the long run. Consumption tax adjustment is a straightforward measure to improve the fiscal balance and keep the debt-to-GDP ratio at the same level as initially. We incorporate this into the model by shocking the consumption tax process and adjusting its magnitude such that the debt-to-GDP ratio remains unchanged in the long run. To guarantee the persistence of the latter measure, the autoregressive term of the consumption tax process is set to unity as well. Figure 11 shows the dynamics which emerges once both measures are carried out simultaneously. For a decrease in the social security contributions rate by one percent, a rise in the consumption tax rate by 0.44 percent is approximatively needed to offset the long run effect on debt. As the taxation of consumption is permanent, it does not influence the trade-off between present and future consumption, yet it still has an overall negative effect. Agents will prefer consuming fewer goods but working less, as the relative price of consumption increases, which affects the intratemporal consumption-leisure decision of agents. Consequently, the output will peak at a slightly lower level as fewer goods have to be produced. However, in the long term, the cumulative effect of the simultaneous shocks on output will still be positive. In the short term, the fiscal balance also improves significantly irrespective of the exchange rate regime. Due to the protracted output dynamics, the improvement in the fiscal balance will occur slightly later though when the exchange rates are fixed.

Figure 11: Impulse response of headline variables to a simultaneous SSCR and consumption tax shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

6 Empirical assessment

6.1 Methodology

To estimate the dynamic response of output to changes in the social security contribution rate, we rely on the local projection method introduced by Jorda (2005). This approach does not impose restrictions on variables' dynamics and is considered to be more robust to misspecifications making it more suitable in comparison to alternative vector autoregression specifications.[20] The local projection method calculates IRFs by estimating sequential regressions of the dependent variable shifted several steps ahead, instead of a recursive application of the initial set of estimated coefficients. Our baseline specification takes the following form:

$$y_{t+k,i} - y_{t-1,i} = c_i + \beta_k S_{i,t} + \theta_k' X_{i,t+k} + \varepsilon_{i,t} \tag{1}$$

where the left-hand side denotes real cumulative output growth from period *t-1* to *t+k*, β_k measures the impact of a one percentage point change in the SSCR to the cumulative output growth up to each k-th year, c_i denotes country fixed effects to take account of differences in average growth rates across the countries included in the regression and $S_{i,t}$ stands for the negative change in the SSCR.[21] Instead of revenue-based measures we use statutory rates to avoid endogeneity which may arise through the effect of common shocks on tax bases.[22] Additionally, $X_{i,t+k}$ defines a vector of control variables for the *k*-th year ahead regression and θ_k is the associated vector of coefficients.

In the initial setup $X_{i,t+k}$ comprises the following control variables: to correct for the potential bias described in Teulings and Zubanov (2014) we include the changes in the SSCR for each period between *t+1* and *t+k*; we also include the first lag of output growth as it is likely to be correlated over time; to capture global time-varying trends and external demand we use world real GDP growth for each period between *t* and *t+k*. However, as described in Jorda and Taylor (2016), there may be other macroeconomic variables that are correlated with the dependent variable or able to predict changes in the SSCR. To assess whether to add them to the regression, we examine the relevance by performing two additional tests. First, we examine whether the dependent variable is predictable with the 1-year ahead local projection from Equation (1), with the additional explanatory variable and its lag. Estimation results presented in Table D1 in the Appendix suggest that several additional control variables need to be considered: government net lending, current account balance, and short-term real interest rate. Second, using the same approach, we examine whether excluded controls predict changes in the SSCR, including them one by one, but also all together. Tables D2 and D3 in the Appendix imply that changes in rates are exogenous to a set of common control variables, also proposed in Jorda and Taylor (2016). The observed high persistence of the shock is not surprising, given its definition – the change in statutory rates that are mostly stable over time. Following our scrutiny results in accounting for the stance of the monetary, fiscal, and external sector in our specification. Finally, in the robustness analyses, we consider additional control variables that turn out not to be statistically significant but may affect our conclusions in order to address the potential remaining endogeneity and omitted variable bias.

[20] Auerbach and Gorodnichenko (2013) and Romer and Romer (2015)
[21] For didactical purposes $S_{i,t}$ is defined as $S_{i,t} = -(SSCR_{i,t} - SSCR_{i,t-1})$, that is, a positive $S_{i,t}$ defines a reduction in the SSCR
[22] De Mooij and Keen (2012) and Riera-Crichton et al. (2016)

Equation (1) is estimated using OLS for $k=0,..,4$, that is, up to four years after the change in the SSCR occurred. Impulse response functions are computed using the standard deviations associated with the estimated coefficients, based on country-clustered robust standard errors.

To scrutinize our theoretical results obtained above, we apply the regression framework separately to countries with fixed exchange rates and those with flexible regimes. That is, we separate our complete sample into different subsamples[23], depending on existing exchange rate regime classifications, and thereby allow for different effects that exchange rate flexibility may account for. We turn to estimate the following equation:

$$y_{t+k,i} - y_{t-1,i} = c_i + \beta_k^{ER} S_{i,t} + \theta_k' X_{i,t+k} + \varepsilon_{i,t} \qquad (2)$$

where the β_k^{ER} is the exchange rate specific reaction coefficient to a change in the SSCR while all other variables are defined similarly as in (1).

6.2 Data

Our dataset covers a balanced sample of 36 OECD economies over the period between 2000 and 2019. In our analysis, the change in firms' side social security contribution rates is measured as the annual change in the average statutory rate of employers' social security contribution rate in percent of gross wage earnings, published in the OECD Taxing Wages report.[24] Standard macroeconomic variables used in the regression framework as real GDP growth, world real GDP growth, GDP deflator, consumer price index, government net lending, and current account balances were taken from the IMF World Economic Outlook (WEO) Data Base.[25] The time series on short-term interest rates, expected economic growth and VAT rates stem from different OECD sources, in particular from the Statistics, Economic Outlook and the Consumption Tax Trends data bases. To classify countries with respect to their exchange rate regimes over the entire sample period, in our benchmark analysis we rely on the classification available in the Annual Report on Exchange Arrangements and Exchange Restriction (AREAER) data base provided by the IMF. In particular, we consider as a fixed regime all up to and including the category "crawling peg", that is category 5 out of 8 according to the classification prevailing until 2007.[26] Regarding the classification prevailing from 2008 onwards, we consider all categories up to including "pegged exchange rate within horizontal bands", that is, category 7 out of 10, as fixed regimes. We also double-check the resulting separation into fixed and flexible exchange rate regimes by superimposing it with the classification obtained based on the de facto exchange rate regimes available in the Ilzetzki et al. (2019) data base. When using the latter data set we regarded all up to including category 8, that is "de facto crawling band that is narrower than or equal to +/-2 percent", as the fixed regime, and all other regimes as flexible regimes, in line with Corsetti et al. (2012). We can

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[23] A similar approach was proposed in Jorda and Taylor (2016) in a different research context.

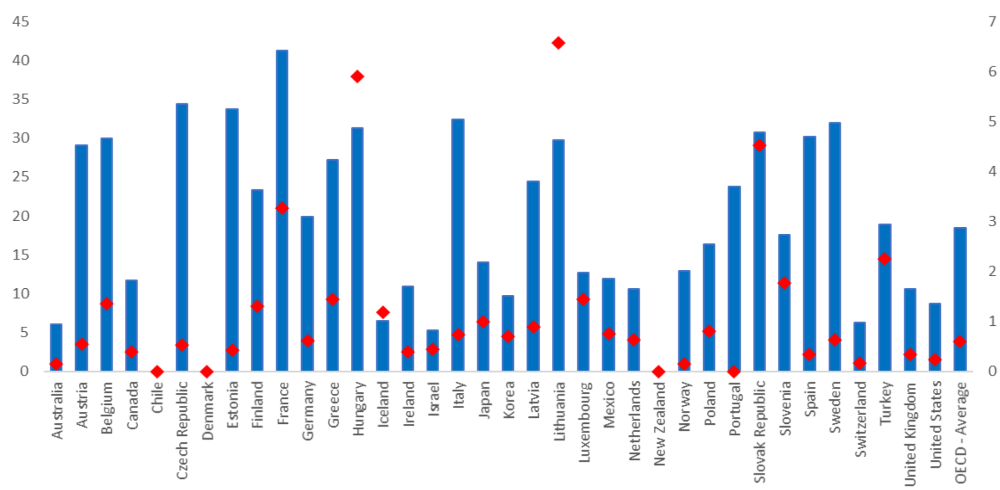
[24] These average rates paid by the employer are the same for both family type categories: single person at 100 percent of average earnings with no child and one-earner married couple at 100 percent of average earnings with 2 children.

[25] For the reason that fiscal balance series available in the OECD data bases were incomplete and real GDP growth series also differed slightly from those reported to the IMF, we use the WEO data base for standard macroecomic series. For Ireland we use instead of the GDP series the corrected GNI series which accounts for the distortion of Irish GDP data driven by tax accounting flows and reached its climax when Irish GDP rose by over 25 percent in the year 2015.

[26] The IMF AREAER data base classifies all euro area member states as countries with a flexible exchange rate regime for the reason that the European Central Bank adopted a free float exchange rate regime versus all other currencies in the world. In our analysis the latter countries are naturally regarded as countries with a fixed exchange rate regime.

conclude that with a limited number of exceptions the obtained classifications correspond. Yet, considering descriptions and explanations available we believe that the classification according to the IMF AREAER data base is significantly more consistent and therefore more suitable for the regression framework. Moreover, in the IMF AREAER data set in a handful of cases where a country changed its regime, such that it would have reclassified it from the flexible regime group into the fixed regime group or vice versa for a shorter period than four years, we remain with the same classification throughout the entire sample.[27] Overall, we end up with approximately half of the sample being classified as fixed and the other half as flexible exchange rate regimes.[28] Additionally, we also consider and run regressions separately for the subsample including twelve euro area countries participating in the European Monetary Union since the beginning together with Denmark, as this group of countries undisputedly features fixed rates throughout the whole sample period. In the robustness section, we discuss the possible impact of reclassifications on our results. Moreover, we compare the regression results if relying solely on the classification based on Ilzetzki et al. (2019).

Figure 12: Average employers' social security contribution rates and standard deviations by country



Note: Authors' calculations. Source OECD (2011) and (2020). Average values (blue bars, left axis) and standard deviations (red diamonds, right axis) of the average statutory rates of employers' social security contribution as a percent of gross wage earnings (2000-2019).

[27] For example the Czech Republic was retroactively reclassified as "Stabilized arrangement" from 2014 to 2016 although the de jure regime was floating, as the Czech National Bank announced to intervene in the foreign exchange market to weaken the koruna in order to respond to below target inflation and expected continued undershooting. Moreover, based on Ilzetzki et al. (2019) the country was classified clearly as flexible regime throughout the entire sample. Similarly the de facto regime of Switzerland in 2013-2014 was reclassified to "Crawl-like arrangement" although the de jure regime was was free floating as the Swiss National Bank (SNB) set a minimum exchange rate vs. the euro to contain deflationary risks and to stop a sharp appreciation of the franc. Based on the Ilzetzki et al. (2019) data base Switzerland was also classified as fixed regime for this period. In 2001-2002, Slovenia had a flexible regime before it pegged its currency to the euro.

[28] The group of countries characterized by a fixed exchange rate regime over the entire sample are the EA12 countries, Denmark, Estonia, Latvia, Lithuania and Slovenia as these countries either pegged their exchange rates or maintained a currency board throughout the sample period. Slovakia was included in the group with fixed regime from 2005 onwards when it entered the ERM II and consequently joined the EMU in 2009. All other countries were included in the group with flexible regimes. Comparing the classifications with respect to Hungary from both data sources turned out to be entirely contradictory, therefore based on the historical development of the exchange rate regime and the monetary policy strategy, Hungary was included into the flexible regime group.

Contributions paid by employers vary considerably across countries, from 0 percent in New Zealand and Chile to 44 percent in France in 2012, averaging 18.6 percent in the whole sample. Figure 12 shows the average values and standard deviations for every country since 2000, implying a large variability within the sample.

Table 1 shows that the episodes of SSCR changes were implemented in 6-12 percent of total observations throughout the considered period, with slightly more cases of rate cuts. The countries with the most frequent changes in the sample were Finland, Hungary, and the Netherlands.

Table 1: Frequency of changes in single country SSCR, in percent of total observations

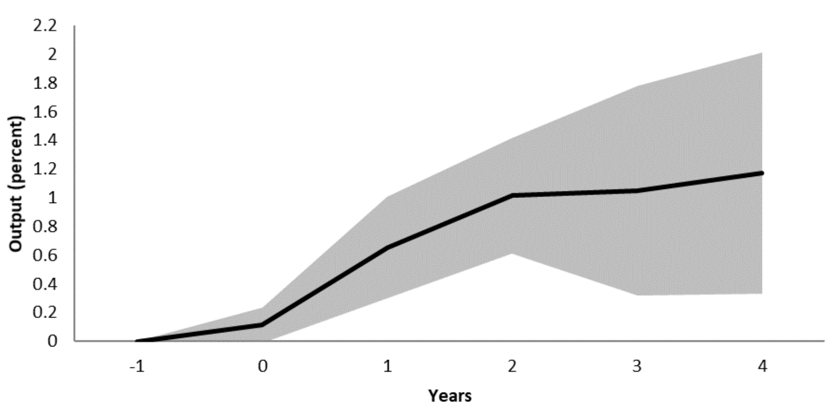
	≥ 1 p.p.	≥ 0.5 p.p.
SSCR absolute change	6.1	11.7
SSCR cut	4.8	8.5

Note: Authors' calculations based on data from OECD (2011) and (2020).

6.3 Baseline results

Figure 13 shows the effects of a one percentage point cut in firms' SSCR on economic activity over the four-year period along with 95 percent confidence intervals. Obtained results in the baseline model[29] imply statistically significant effects after the initial year with acumulative output growth of almost 1.2 percent in the medium term. Detailed results are presented in Table D4 in the Appendix.

Figure 13: Impulse response of cumulative output growth to a one percent reduction in SSCR



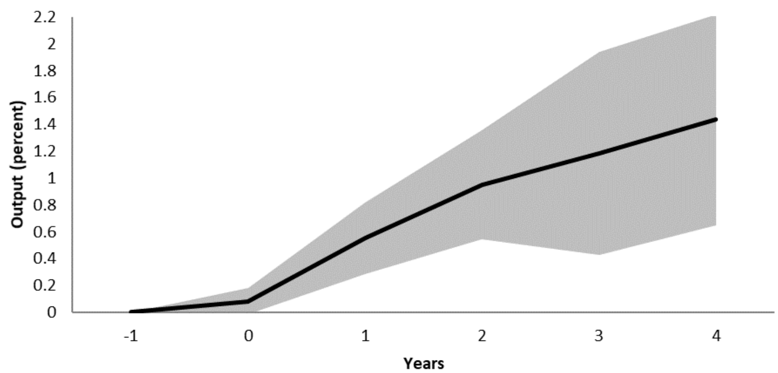
Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, future values of shocks, and country fixed effects.

The results obtained from the baseline setup come with the potential limitation that considered adjustments are not pure shocks, since they could be anticipated or correlated with previous changes in

[29] In the baseline setup we included future changes in the SSCR, lagged real output growth, contemporaneous and future real world output growth, and country-fixed effects.

economic activity. We address this issue by including additional control variables that seem to be statistically significant, as already pointed out in the methodological description. The results for the setup with additional control variables[30], shown in Figure 14 and Table D5 in the Appendix, suggest a similar outcome in the medium term, with slightly higher effects over the years, totaling in a 1.3 percent cumulative output growth.

Figure 14: Impulse response of cumulative output growth to a one percent reduction in SSCR



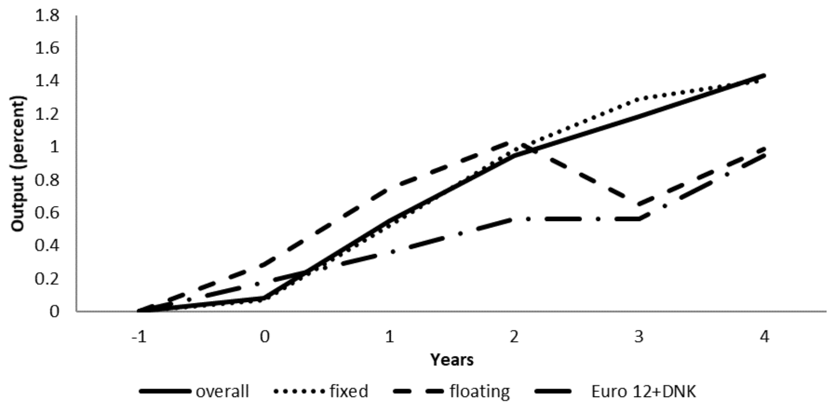
Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, government net lending, current account balance, real short-term interest rate, future values of shocks, and country fixed effects.

The subsequent analysis assesses the interaction of the prevailing exchange rate regime with the impact of a reduction in the SSCR on cumulative output growth. More particularly, we separate the sample into buckets of countries with fixed and flexible exchange rate regimes, respectively, and estimate the regression setup with additional control variables from above. We find that the impact appears to be larger for countries with flexible exchange rate regimes in the beginning while for countries with fixed exchange rates the impact is more protracted (Figure 15). These results are also in line with our findings from the theoretical model-based assessment. Additionally, we estimate the impact for a group consisting only of the twelve euro area countries (EA12) and Denmark, as explained before. The effects at the beginning are to a certain extent lower than for the group of economies with flexible exchange rate, yet after four years it appears that the impact reaches similar levels.[31] The difference across exchange rate regimes turns out not to be statistically significant according to the test statistics. These results also hold up for the baseline specification.

[30] We add to the variables from the baseline setup lagged general government net lending and current account in percentage points of GDP, as well as the real short-term interest rate.

[31] The contribution of Denmark to the regression results is limited as the SSCR was constant throughout the sample period.

Figure 15: Impulse response of cumulative output growth to a one percent reduction in SSCR – Comparison across different exchange rate regimes



Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional control variables: world real GDP growth contemporaneous and future values, lagged output growth, government net lending, current account balance, real short-term interest rate, future values of shocks, and country fixed effects.

6.4 Extensions and robustness checks

In addition to common macroeconomic control variables we also include Value Added Tax (VAT) shocks in the regression, given their simultaneous introduction with social contributions cuts after the Global Financial Crisis. We find econometric evidence that VAT shocks are likely to predict future shocks in social security contributions and therefore include their contemporaneous and future values in the regression. Obtained results imply a slightly higher impact for all regimes and a relatively higher effect for the EA12 group.[32] In general, we can conclude that the difference in the real effects across the different exchange rate regimes will diminish if we control for VAT changes.

We additionally assess the robustness of our empirical results with respect to the measure used to calculate changes in the SSCR. More specifically, we re-estimate the regression equations using changes in the marginal rate, also provided by the OECD, instead of the change in the average statutory employers' social security contribution rate. We find that the pattern of our results does not change, yet it appears that the overall impact is slightly lower irrespective of the exchange rate regime. Besides, our results also hold up if we account for changes in the VAT.

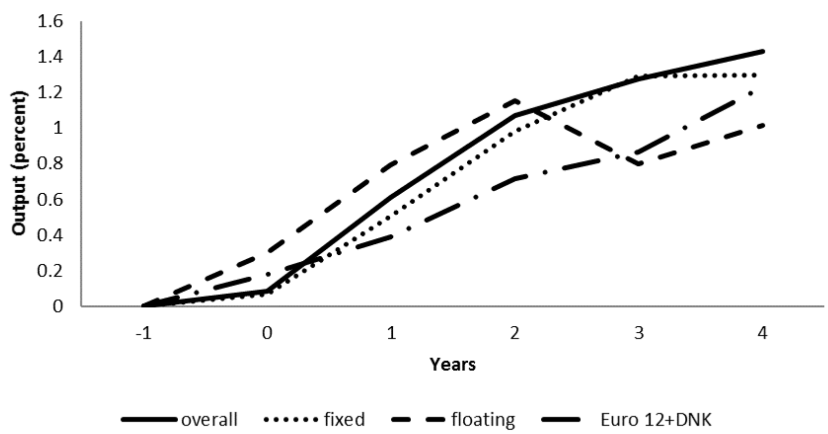
To examine whether different lag specifications alter results we include a second lag for real output growth, government net lending, the current account, and the real short-term interest rate.[33] Main conclusions do not change except that the effect for the flexible exchange rate group weakens. Results do not alter if VAT shocks are added as well. Furthermore, we re-estimate the regression including the

[32] Including the lag of the VAT shock leads to a significantly muted effect for the flexible regime group yet otherwise results remain similar. However, this feature is attributable to the smaller sample size and hence to the missing information on some significant changes in social security contribution rates in a few countries with flexible regimes and also to the relatively larger standard deviation of the estimates especially for the periods *t+3* and *t+4*. In year 2001, for example, Hungary reduced the SSCR by over 2 percent while Turkey and Iceland increased rates by 3 percent and approximately 0.5 percent, respectively. For detailed results see Appendix.

[33] To be able to use the information from the entire sample general government net lending data for Turkey in 1999 had to be complemented from earlier vintages of the OECD Economic Outlook data base by chainlinking them with the main source therefore full consistency cannot be guaranteed.

first lag of the change in SSCR. Results remain similar with the exception that the impact for economies with flexible exchange rate regimes diminishes, yet this result features the fact that the sample size shortens by one period and therefore important information is ignored.

Figure 16: Impulse response of cumulative output growth to a one percent reduction in SSCR – Comparison across different exchange rate regimes – Value Added Tax shocks included



Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, government net lending, current account balance, real short-term interest rate, future values of SSCR shocks, VAT shocks with their future values, and country fixed effects.

To address the possible impact of reclassifications resulting from a short temporary switch between fixed and flexible regimes, we move Czech Republic for the period 2014-2016 and Switzerland in the years 2013-2014 to the fixed exchange regime group. Furthermore, we move Slovenia for the period 2001-2002 to the country group with flexible regimes. Our results change only marginally. A reclassification of the Slovak Republic into the fixed exchange rate group for the entire sample period has also very little effect. Finally, we run the regression relying on the classification provided in Ilzetzki et al. (2019) and define the fixed exchange group in line with Corsetti et al. (2012). Using the latter classification scheme leads to a significant change in results in favor of countries with a flexible exchange rate regime at first sight. However, these results are mainly driven by the fact that the classification for Hungary[34] and Latvia[35] according to Ilzetzki et al. (2019) sharply contradicts the classification found in the IMF AREAER data base and also seems to stand in contrast to available

[34] Hungary can be regarded as a fixed regime at most before 2008 when the currency was officially fixed to the euro with a band of +/- 15%, yet from monetary policy strategy reports it follows that the main goal was price stability which the central bank aimed to achieve by adjustments in the main refinancing rate. In our view it is well justified that Hungary should be regarded as a flexible regime for the entire sample period as in contrast to the Slovak Republic it did not enter the ERM II and finally in February 2008 the exchange rate band was abolished while the Slovak Republic joined the EMU. Considering Hungary as a fixed regime for the period 2001-2007 would shift results in favour of the fixed regimes.

[35] Prior to joining the EMU the de jure exchange rate regime in Latvia was "conventional pegged arrangement" and the currency was officially pegged to the SDR ('Special Drawing Rights' is an international reserve asset created by the IMF and its value is determined by a basket of currencies) and later to the euro, therefore it might be again challenging to defend its classification as a flexible regime.

information on monetary policy strategy.[36] Once the sample is purged from these inconsistencies results remain similar as before except that the impact in the EA12 group is increased.

In our extended setup, we account for the stance of fiscal policy by including general government net lending. Robustness can be tested further by explicitly controlling for the effect of a change in public debt on fiscal space and hence on output growth. Therefore, instead of net lending we include the lagged primary balance and lagged net interest expenses of the government. We find that our results hold up and the pattern remains similar albeit for the EA12 group results become borderline insignificant. However, including VAT shocks diminishes again the differences in the impact and renders the estimated coefficients significant.

Given the data frequency, one may raise concerns regarding the endogenous policy response within the same year – when output growth values lead to contemporaneous changes in SSCR. We believe however that the potential bias is small due to long implementation lags that characterize fiscal policy. Furthermore, we consider the real GDP forecast from *t-1* as an indicator of the expected growth that might partly capture such changes, but show in tables D2 and D3 in the Appendix that the shock variable is exogenous to its dynamics.

To address the sensitivity of the results to the data source considered, we re-estimate our regression using the OECD data where missing values are complemented with the original data source. We find that the effect in the EA12 group is slightly lower, yet the pattern is repeated again. As in the previous cases, adding VAT to the regression decreases the gap in the results.

To sum up, our empirical evidence seems to be sufficiently robust and supportive of the claim that a change in employers' SSCR has significant real effects that do not differ due to the prevailing exchange rate regime. We acknowledge that the impact in the EA12 group might be slightly smaller or at least protracted, yet the smaller outcome might be attributed to generally lower growth rates in these countries in comparison to the rest of the sample. Finally, this gap closes even more if VAT shocks are included in the regression.

7 Conclusion

In this paper, we examine the impact of a change in employers' social security contribution rate under different exchange rate regimes. We depart from a baseline small open economy DSGE model exploited in Gali and Monacelli (2016) and show that the use of monetary policy rules common in literature leads to limited differences in the effect of a change in employers' social security contribution rate on output under fixed and flexible exchange rate regimes. We also develop a medium-scale three-region DSGE model and show that a reduction in employers' social security contributions rate results in lower employers' costs and consequently relative prices which boost output and may help to swiftly regain competitiveness. These measures are effective despite different levels of exchange rate flexibility. This

[36] The results are mainly driven by the fact that from 2009 onwards Hungary will be included in the fixed exchange rate regime subsample and prior to 2010 Latvia will belong to the country group with flexible regime for some years. A brief glance into the monetary policy strategies of the countries suggests though that according to the IMF AREAER data base both the de jure and the de facto exchange rate regime in Hungary is floating during that time, furthermore the main goal of the Hungarian National Bank is price stability and the currency has significantly depreciated versus the euro, therefore it might be challenging to argue that Hungary should be regarded as a fixed regime. Since prior to joining the EMU Latvia pegged its currency first to the SDR and then to the euro we believe that it is warranted to regard Latvia throughout the entire period as a fixed exchange regime.

is particularly important in cases where nominal depreciation is not available as a policy instrument and real exchange rate dynamics is driven solely by inflation differentials. Although the endogenous monetary policy channel in the flexible case matters and amplifies the impact in initial periods, the nominal appreciation that follows subsequently has an offsetting effect reducing the observed difference between regimes. Additionally, our simulations imply that labor cost reductions may be effective even if introduced together with an increase in consumption tax, to address concerns of fiscal sustainability. Again, different regimes account for a small difference only.

We also conduct an empirical assessment and apply the local projection method introduced by Jorda (2005) in order to examine whether the obtained theoretical results hold up. Based on regression results we can conclude that the impact of a reduction in employers' social security contribution rate does not significantly vary across different exchange rate regimes. We acknowledge that there are signs of a protracted effect in the EA12 countries, yet there is no significant difference as regards the mid-term cumulative effect. Including changes in VAT in our regression framework leads to a further reduction of the aforementioned differences.

Moving towards sustainable economic growth must rely on a widespread increase in the productivity and competitiveness levels across euro area economies. Higher labor costs relative to trade partners, embodied in heavy tax and social insurance burdens for companies, seem to undermine this quest. Overall, the considered measure should not be understood as a silver bullet, but as a short-term bridge to necessary structural reforms. As a part of a wider package of economic policy reforms aimed at increasing productivity and competitiveness, including product and labor market reforms, further investments in infrastructure, green and digital transition, and education, it may help distressed euro area economies to return to higher growth prospects.

Bibliography

Acconcia, A., Corsetti, G. and Simonelli, S., 2014. Mafia and public spending: Evidence on the fiscal multiplier from a quasi-experiment. *American Economic Review*, *104*(7), pp.2185-2209.

Almosova, A., Burda, M.C. and Voigts, S., 2020. Social Security Contributions and the Business Cycle. *Journal of Macroeconomics*, pp.103-209.

Annicchiarico, B., Di Dio, F., Felici F., Monteforte, L., 2013. IGEM: a Dynamic General Equilibrium Model for Italy, Working Papers 4, Department of the Treasury, Ministry of the Economy and of Finance.

Attinasi, M.G., Prammer, D., Stähler, N., Tasso, M. and van Parys, S., 2019. Budget-Neutral Labour Tax Wedge Reductions: A Simulation-Based Analysis for the Euro Area. *International Journal of Central Banking*, *15*(4), pp.1-54.

Auerbach, A.J. and Gorodnichenko, Y., 2012. Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, *4*(2), pp.1-27.

Auerbach, A.J. and Gorodnichenko, Y., 2013. Output spillovers from fiscal policy. *American Economic Review*, *103*(3), pp.141-46.

Bassanini, A. and Duval, R., 2006. Employment Patterns in OECD Countries: Reassessing the Role of Policies and Institutions. OECD Economics Department Working Papers No. 486. *OECD Publishing (NJ1)*.

Born, B., Juessen, F. and Müller, G.J., 2013. Exchange rate regimes and fiscal multipliers. *Journal of Economic Dynamics and Control*, *37*(2), pp.446-465.

Calvo, G.A., 1983. Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, *12*(3), pp.383-398.

Christiano, L., Eichenbaum, M. and Rebelo, S., 2011. When is the government spending multiplier large?. *Journal of Political Economy*, *119*(1), pp.78-121.

Coenen, G., McAdam, P. and Straub, R., 2008. Tax reform and labour-market performance in the euro area: A simulation-based analysis using the New Area-Wide Model. *Journal of Economic Dynamics and Control*, *32*(8), pp.2543-2583.

Corsetti, G., Kuester, K. and Müller, G.J., 2011. Floats, pegs and the transmission of fiscal policy. CEPR Discussion Papers 8180, *C.E.P.R. Discussion Papers.*

Corsetti, G., Meier, A. and Müller, G.J., 2012. What determines government spending multipliers?. *Economic Policy*, *27*(72), pp.521-565.

Daveri, F. and Tabellini, G., 2000. Unemployment, growth and taxation in industrial countries. *Economic policy*, *15*(30), pp.48-104.

Decressin, J., Espinoza, R., Halikias, I., Kumhof, M., Leigh, D., Loungani, P., Medas, P., Mursula, S., Spilimbergo, A. and Xu, T., 2015. Wage moderation in crises: policy considerations and applications to the Euro area. *Journal Issue*, *2015*, p.22.

De Mooij, R. and Keen, M., 2012. "Fiscal Devaluation" and Fiscal Consolidation: The VAT in Troubled Times. In *Fiscal Policy after the Financial Crisis* (pp. 443-485). University of Chicago Press.

Duval, R. and Furceri, D., 2018. The effects of labor and product market reforms: the role of macroeconomic conditions and policies. *IMF Economic Review*, *66*(1), pp.31-69.

Engler, P., Ganelli, G., Tervala, J. and Voigts, S., 2017. Fiscal devaluation in a monetary union. *IMF Economic Review*, *65*(2), pp.241-272.

European Central Bank, 2012. "Competitiveness and External Imbalances Within the Euro Area," ECB Occasional Paper series.

European Commission, 2013. "Tax Reforms in EU Member States - Tax Policy Challenges for Economic Growth and Fiscal Sustainability", European Economy, No. 5/2013, Brussels.

European Commission, 2014. "Taxation Trends in the European Union", 2014 edition.

Farhi, E., Gopinath, G. and Itskhoki, O., 2014. Fiscal devaluations. *Review of Economic Studies*, *81*(2), pp.725-760.

Feenstra, R. C., Inklaar R. and Timmer, M. P., 2015, The Next Generation of the Penn World Table *American Economic Review*, 105(10), 3150-3182, available for download at www.ggdc.net/pwt

Forni, L., Monteforte, L., Sessa L., 2009. The general equilibrium effects of fiscal policy: Estimates for the Euro area. *Journal of Public Economics*, 93, pp.559-585.

Forni, L., Gerali, A., Pisani, M., 2010. The macroeconomics of fiscal consolidations in euro area countries. *Journal of Economic Dynamics and Control*, 34(9), pp. 1791-1812, September.

Friedman, M., 1953. The case for flexible exchange rates. *Essays in positive economics*, *157*(203), pp.157-203.

Gali, J. and Monacelli, T., 2005. Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies*, *72*(3), pp.707-734.

Galí, J. and Monacelli, T., 2016. Understanding the gains from wage flexibility: the exchange rate connection. *American Economic Review*, *106*(12), pp.3829-68.

Granger, C.W. and Terasvirta, T., 1993. Modelling non-linear economic relationships. *OUP Catalogue*.

Holzner, M., Tkalec, M., Vizek, M. and Vukšić, G., 2018. Fiscal devaluations: evidence using bilateral trade balance data. *Review of World Economics*, *154*(2), pp.247-275.

Ilzetzki, E., Mendoza, E.G. and Végh, C.A., 2013. How big (small?) are fiscal multipliers? *Journal of Monetary Economics*, *60*(2), pp.239-254.

Ilzetzki, E., Reinhart, C.M. and Rogoff, K.S., 2019. Exchange arrangements entering the twenty-first century: Which anchor will hold?. *The Quarterly Journal of Economics*, *134*(2), pp.599-646.

Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. *American Economic Review*, *95*(1), pp.161-182.

Jordà, Ò. and Taylor, A.M., 2016. The time for austerity: estimating the average treatment effect of fiscal policy. *The Economic Journal*, *126*(590), pp.219-255.

Keynes, J.M., 1931. Addendum to: Great Britain. Committee on finance and industry report. *London: His Majesty's Stationery Office*, pp.190-209.

Kneller, R., Bleaney, M.F. and Gemmell, N., 1999. Fiscal policy and growth: evidence from OECD countries. *Journal of Public Economics*, *74*(2), pp.171-190.

Laeven, M.L. and Valencia, M.F., 2018. *Systemic banking crises revisited*. International Monetary Fund.

Lambertini, L. and Proebsting, C., 2019. Does Austerity Go Along with Internal Devaluations?. *IMF Economic Review*, *67*(3), pp.618-656.

Lane, P.R. and Perotti, R., 2003. The importance of composition of fiscal policy: evidence from different exchange rate regimes. *Journal of Public Economics*, *87*(9-10), pp.2253-2279.

Lipinska, A. and von Thadden, L., 2009. Monetary and fiscal policy aspects of indirect tax changes in a monetary union.

Nakamura, E. and Steinsson, J., 2014. Fiscal stimulus in a monetary union: Evidence from US regions. *American Economic Review*, *104*(3), pp.753-92.

OECD, 2011. Taxation and Employment, OECD Tax Policy Studies, No. 21, OECD Publishing

OECD, 2020. Taxing Wages 2020, OECD Publishing, Paris

Riera-Crichton, D., Vegh, C.A. and Vuletin, G., 2016. Tax multipliers: Pitfalls in measurement and identification. *Journal of Monetary Economics*, *79*, pp.30-48.

Smets, F. and Wouters, R., 2003. An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, *1*(5), pp.1123-1175.

Smets, F. and Wouters, R., 2007. Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, *97*(3), pp.586-606.

Teulings, C.N. and Zubanov, N., 2014. Is economic recovery a myth? Robust estimation of impulse responses. *Journal of Applied Econometrics*, *29*(3), pp.497-514.

Thimann, C., 2015. The microeconomic dimensions of the Euro area crisis and why European politics cannot solve them. *Journal of Economic Perspectives*, *29*(3), pp.141-64.

Wieland, V., Cwik, T., Müller, G.J., Schmidt, S. and Wolters, M., 2012. A new comparative approach to macroeconomic modeling and policy analysis. *Journal of Economic Behavior & Organization*, *83*(3), pp.523-541.

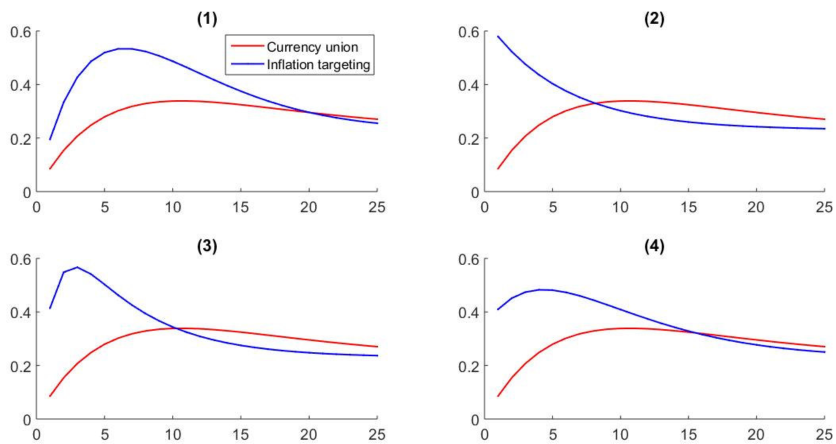
Wieland, V., Afanasyeva, E., Kuete, M. and Yoo, J., 2016. New methods for macro-financial model comparison and policy analysis. *Handbook of Macroeconomics 2*, pp.1241-1319.

Woodford, M., 2011. Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics*, *3*(1), pp.1-35.

Appendix

A Additional IRFs

Figure A1: Impulse responses of output to a permanent payroll tax cut under alternative policy rules



Note: Gali and Monacelli (2016) original model with alternative policy rules: (1) full stabilization of domestic inflation ($\pi_{H,t} = 0$), (2) the CPI inflation-based Taylor rule ($i_t = 1.5\pi_t$), (3) domestic inflation-based Taylor rule ($i_t = 1.5\pi_{H,t}$), and (4) Taylor rule with interest rate smoothing ($i_t = 0.9i_{t-1} + (1 - 0.9)1.5\pi_t$).

B Structural model

The model consists of two symmetric economies in their structures, that is Economy A and Economy B, with size s and $1 - s$, respectively, and the Rest of the World (ROW). Economy A and Economy B are populated by two different types of households, by intermediate and final goods producers and by the fiscal and the monetary authorities. The ROW economy is modeled parsimoniously using the standard textbook three-equation New-Keynesian framework. For the REA and DE economies it is assumed that a fixed part of the households with weight ω among the entire population is of non-Ricardian type and has neither access to capital nor to the bond markets, yet non-Ricardian agents are able to adjust cash balance holdings in each period to smooth consumption. The other part of the households, with weight $1 - \omega$, is of Ricardian type and has access to both capital and bonds markets and is also able to hold cash balances. In the production sector of the economy intermediate goods producing firms operate in monopolistic competition and sell tradable goods in both the domestic and the foreign markets. The final goods producing firms are fully competitive and transform domestic and imported intermediate goods into three different types of non-tradable final goods: private consumption goods, investment goods and public consumption goods. In the following, unless not explicitly noted, all equations refer to both the Economy A and Economy B economies.

Ricardian Households

Ricardian households, indexed with i, maximize lifetime utility by optimizing the allocation of consumption goods $C_{i,t}$, investment goods $I_{i,t}$, capital stock $K_{i,t}$ and the extent of its utilization $u_{i,t}$, domestic and foreign bond holdings $B_{i,t}$ and $B^F_{i,t}$, and cash balances $M_{i,t}$ over time. The lifetime utility function is separable in consumption and individually supplied labour $N_{i,t}$ and takes the following form:

$$E_t\left[\sum_{k=0}^{\infty}\beta^k\left(\frac{1}{1-\sigma}\left(C_{i,t+k}-\kappa C_{i,t+k-1}\right)^{1-\sigma}-\frac{1}{1+\zeta}\left(N_{i,t+k}\right)^{1+\zeta}\right)\right],$$

where β denotes the discount factor, σ the relative risk aversion, ζ is the inverse of the elasticity of labour supply and κ controls the persistence of the external habit formation. Ricardian households have access to foreign bonds, $B^F_{i,t}$, which are internationally traded and denominated in ROW currency. Consequently, Ricardian households face the following budget constraint at each period *t*:

$$\begin{aligned}\left(1+\tau_t^C+\Gamma_v(v_{i,t})\right)P_{C,t}C_{i,t}+P_{I,t}I_{i,t}+R_t^{-1}B_{i,t+1}+((1-\Gamma_{B^F}(B^F_{i,t}))R^F_t)^{-1}S_t^{ROW}B^F_{i,t+1}+M_{i,t}+\ \Xi_{i,t}\\ +\ \Phi_{i,t}\\ =\ (1-\tau_t^N-\tau_t^{W_h})W_{i,t}N_{i,t}+(1-\tau_t^K)(R_{K,t}u_{i,t}-\Gamma_u(u_{i,t})P_{I,t})K_{i,t}\\ +\tau_t^K\delta P_{I,t}K_{i,t}+(1-\tau_t^D)D_{i,t}+TR_{i,t}-T_{i,t}+B_{i,t}+S_t^{ROW}B^F_{i,t}+M_{i,t-1}\quad,\end{aligned}$$

$P_{C,t}$ and $P_{I,t}$ denote hereby the price of domestic final consumption and investment goods, respectively, R_t, and $R_t^{F,ROW}$ are the nominal interest rates paid on the domestic and the internationally traded bonds.[37] When engaging in international bond holdings, agents are required to pay an external risk premium, also referred to as participation costs, characterized by the function $\Gamma_{B^{F,ROW}}(B^{F,ROW}_{i,t})$[38] where the premium depends on the actual net asset position. The premium assures that in the non-stochastic steady state Ricardian households will have no incentive to hold internationally traded bonds. The premium to be paid, denoted by $\Xi_{i,t}$, is rebated back to the Ricardian households in a lump-sum manner.

The individual labour service provided by households is rewarded by the nominal wage rate $W_{i,t}$. On the effective amount of capital rented out to firms the rental price $R_{K,t}$ is paid. The costs associated with the supply of the effective amount of capital service rented by altering the intensity of utilization are captured by the function $\Gamma_u(u_{i,t})$. In addition, Ricardian households receive dividends $D_{i,t}$ from firms which they own.

Ricardian households are subject to different types of distortionary taxes. In particular, consumption tax τ_t^C is levied on the nominal consumption while the tax rates τ_t^N, τ_t^K and τ_t^D are levied on the wage, capital and dividend income obtained, respectively. In addition, social security contributions are collected as well by the fiscal authorities which is modeled in form of an additional tax rate $\tau_t^{W_h}$ on wage income. Simultaneously, Ricardian households pay lump-sum taxes $T_{i,t}$, yet they receive transfers $TR_{i,t}$ from the government.

[37] To retain the model as general as possible internationally traded bonds are denoted in ROW currency and therefore international bond holdings have to be multiplied by the nominal exchange rate S_t^{ROW} defined as home currency per ROW currency.

[38] The external risk premium function is defined as follows:
$\Gamma_{B^{F,ROW}}\left(B^{F,ROW}_{i,t}\right):=\gamma_{B_1}\left(\exp\left(S_t^{ROW}P_{t-1}^{ROW}B^{F,ROW}_{i,t}/(P_t^Y Y_t)\right)-1\right)$

In addition to distortionary taxes, transaction costs with respect to Ricardian households' consumption arise as well which are defined by the function $\Gamma_v(v_{i,t})$[39] and depend on the consumption based velocity given by

$$v_{i,t} = \frac{(1+\tau_t^C)P_{C,t}C_{i,t}}{M_{i,t}}$$

To insure herself against wage income risk, household member i trades state contingent securities, $\Phi_{i,t}$, with other household members from I. This assures that marginal consumption equals across all Ricardian households and therefore identical equilibrium allocations are chosen.

Finally, the dynamics of the capital stock owned by household i is described as follows:

$$K_{i,t+1} = (1-\delta)K_{i,t} + (\Gamma_I(I_{i,t}/I_{i,t-1}))I_{i,t}$$

where δ is the depreciation rate and the function $\Gamma_I(I_{i,t}/I_{i,t-1})$[40] refers to the investment adjustment costs depending on the change of the investment compared with that from the previous period.

Ricardian households provide differentiated labour services in monopolistic competition and act as wage setters. Wages are permitted to adjust only gradually by assuming a Calvo (1983) scheme with partial adjustment of the wage contracts to past inflation. In a given period *t*, each Ricardian household receives a signal with probability $1-\xi_I$ to reoptimize her wage. Households which cannot reoptimize wages are allowed though to adjust wages along with the geometric average of past inflation and the steady state inflation

$$W_{i,t} = \left(\frac{P_{C,t-1}}{P_{C,t-2}}\right)^{\chi_I} \pi_C^{1-\chi_I} W_{i,t-1}$$

where χ_I denotes the weight parameter.

Non-Ricardian households

Non-Ricardian households, denoted by j, are excluded from capital and bond markets. Yet, to smooth consumption, they are allowed to save by adjusting their cash balances. These households act as 'quasi' wage setters, that is, we assume that they actually do not optimize, but instead choose to set each period a constant percentage share of the optimal wage set by the Ricardian households. In particular, this scheme implies that non-Ricardian households take wages as given and are forced to supply the individual labour demanded by firms. As a result, non-Ricardian households choose optimal allocations of consumption $C_{i,t}$ and cash balances $M_{i,t}$ by maximizing a similar lifetime utility function as Ricardian agents subject to the following constraint:

$$\left(1+\tau_t^C+\Gamma_v(v_{j,t})\right)P_{C,t}C_{j,t} + M_{j,t} = (1-\tau_t^N-\tau_t^{W_h})W_{j,t}N_{j,t} + TR_{j,t} - T_{j,t} + M_{j,t-1} + \Phi_{j,t}$$

where $\Gamma_v(v_{j,t})$ are the transaction cost of consumption purchases. Similarly, non-Ricardian agents receive transfers $TR_{j,t}$ and pay lump-sum taxes $T_{j,t}$, additionally, they trade state contingent securities, $\Phi_{j,t}$, with other household members from J to insure themselves against wage income risk.

[39] The transaction costs are defined as $\Gamma_v(v_{i,t}) = \gamma_{v,1}v_{i,t} + \gamma_{v,2}v_{i,t}^{-1} - 2\sqrt{\gamma_{v,1}\gamma_{v,2}}$

[40] The investment adjustment costs function is defined as $\Gamma_I(I_{i,t}/I_{i,t-1}) = \frac{\gamma_1^I}{2}\left(I_{i,t}/I_{i,t-1}-1\right)^2$

Firms

The economies are populated by two different types of firms. Firstly, tradable intermediate goods producers operate in a monopolistically competitive environment and sell intermediate goods on both the domestic and the foreign markets to final goods producers, respectively. Secondly, fully competitive final goods producers transform intermediate goods purchased from domestic producers and imported intermediate goods into final consumption, investment and public consumption goods.

Intermediate Goods Producers

There exists a continuum of intermediate goods producers indexed by $f \in [0,1]$ using a Cobb-Douglas technology with non-zero fixed costs described by the following production function:

$$Y_{f,t} \ = max\left[z_t \, K_{f,t}^{\alpha} N_{f,t}^{1-\alpha} - \psi, 0\right]$$

where the input factors are physical capital $K_{f,t}$ rented from Ricardian households in fully competitive markets and a composite of labour services, $N_{f,t}$, consisting of the bundled individual labour supply, $N_{f,t}^{I}$ and $N_{f,t}^{J}$, of both types of households, Ricardian and non-Ricardian. ψ denotes real fixed costs occurring at each period t and z_t is the total factor productivity which is similar across all firms and evolves according to the following process

$$ln(z_t) \ = (1-\rho_z) ln(z) + ln(z_{t-1}) + \epsilon_{z,t} \ .$$

The cost function of intermediate goods producers is given by

$$C\left(K_{f,t}, N_{f,t}\right) = R_{K,t} K_{f,t} + (1+\tau_t^{W_f}) W_t N_{f,t}.$$

W_t stands for the overall wage index and $\tau_t^{W_f}$ for the payroll tax rate where the latter is intenbded to capture social security contributions paid by firms. The first order conditions from the cost minimization problem are as follows:

$$R_{K,t} = \lambda_t \frac{Y_{f,t} + \psi}{K_{f,t}} \alpha$$

$$(1+\tau_t^{W_f}) W_t = \lambda_t \frac{Y_{f,t} + \psi}{N_{f,t}} (1-\alpha)$$

The resulting optimal factor input ratio equals to

$$\frac{N_{f,t}}{K_{f,t}} = \frac{1-\alpha}{\alpha} \frac{R_{K,t}}{(1+\tau_t^{W_f}) W_t}$$

Using the first order conditions, the cost function can be expressed as

$$c\left(Y_{f,t}, \lambda_t\right) = \lambda_t (Y_{f,t} + \psi)$$

Consequently, marginal cost, defined as $MC_{f,t} := \partial c\left(Y_{f,t}, \lambda_t\right) / \partial Y_{f,t}$ equals λ_t. By reshuffling the first order conditions and using the optimal factor input ratio marginal costs can be expressed as follows:

$$MC_{f,t} = \frac{1}{z_t \alpha^{\alpha}(1-\alpha)^{1-\alpha}} \left(R_{K,t}\right)^{\alpha} ((1+\tau_t^{W_f})W_t)^{1-\alpha} .$$

The overall labour input $N_{f,t}$ used by the firms is defined by using a CES-aggregator function

$$N_{f,t} = \left((1-\omega\varsigma)^{\frac{1}{\eta}}\left(N_{f,t}^{I}\right)^{\frac{\eta-1}{\eta}} + (\omega\varsigma)^{\frac{1}{\eta}}\left(N_{f,t}^{J}\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} ,$$

where $N_{f,t}^{I}$ and $N_{f,t}^{J}$ are bundles of individually supplied labour services of Ricardian and non-Ricardian households, respectively. η denotes the intratemporal elasticity of substitution between the different labour bundles and ς is a parameter altering the relative contribution of the different labour types.[41] Correspondingly, the optimal demand for household specific labour bundles $N_{f,t}^{I}$ and $N_{f,t}^{J}$ by firm f and the aggregate wage index W_t are given by

$$N_{f,t}^{I} = (1-\omega\varsigma)\left(\frac{W_{I,t}}{W_t}\right)^{-\eta} N_{f,t}$$

$$N_{f,t}^{J} = \omega\varsigma\left(\frac{W_{J,t}}{W_t}\right)^{-\eta} N_{f,t}$$

$$W_t = \left((1-\omega\varsigma)\left(W_{I,t}\right)^{1-\eta} + \omega\varsigma\left(W_{J,t}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

In addition to choosing the optimal amounts of the two different labour bundles, firms also choose the optimal input of the individually supplied labour by households $i \in I$ and $j \in J$ to construct the two labour bundles $N_{f,t}^{I}$ and $N_{f,t}^{J}$. In particular, $N_{f,t}^{I}$ and $N_{f,t}^{J}$ are defined as follows:

$$N_{f,t}^{I} = \left(\left(\frac{1}{1-\omega}\right)^{\frac{1}{\eta_I}} \int_0^{1-\omega} \left(N_{f,t}^{i}\right)^{\frac{\eta_I-1}{\eta_I}} di\right)^{\frac{\eta_I}{\eta_I-1}} ,$$

$$N_{f,t}^{J} = \left(\left(\frac{1}{\omega}\right)^{\frac{1}{\eta_J}} \int_{1-\omega}^{1} \left(N_{f,t}^{j}\right)^{\frac{\eta_J-1}{\eta_J}} dj\right)^{\frac{\eta_J}{\eta_J-1}} ,$$

where η_I and η_J denote the elasticity of substitution between the labour services supplied by the individual households $i \in I$ and $j \in J$, respectively. Intermediate goods producers take individual wages $W_{i,t}$ and $W_{j,t}$ as given and choose the cost minimizing allocation to construct $N_{f,t}^{I}$ and $N_{f,t}^{J}$. Consequently, the optimal demand for individually supplied labour $N_{f,t}^{i}$ and $N_{f,t}^{j}$ by firm f and the wage indices of the bundles $N_{f,t}^{I}$ and $N_{f,t}^{J}$ are given by

[41] If both the relative price of the two different labour bundles and ς were equal to unity then firms optimal choice of the two labour types would be equal to the relative weight in the population being $(1-\omega)$ and ω, respectively. Setting ς differently than unity shifts the optimal ratio of demand for the two different labour types.

$$N_{f,t}^{i} = \left(\frac{1}{1-\omega}\right)\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N_{f,t}^{I}$$

$$N_{f,t}^{j} = \left(\frac{1}{\omega}\right)\left(\frac{W_{j,t}}{W_{J,t}}\right)^{-\eta_I} N_{f,t}^{J}$$

$$W_{I,t} = \left(\frac{1}{1-\omega}\int_{0}^{1-\omega} \left(W_{i,t}\right)^{1-\eta_I} di\right)^{\frac{1}{1-\eta_I}},$$

$$W_{J,t} = \left(\frac{1}{\omega}\int_{1-\omega}^{1} \left(W_{j,t}\right)^{1-\eta_J} dj\right)^{\frac{1}{1-\eta_J}}.$$

Similarly to wages, prices can only adjust gradually in Calvo style. All firms sell intermediate goods in both the domestic and the foreign markets. On the markets of Economy A and Economy B prices are always charged in local currency while on the ROW markets producer currency pricing is assumed and the law of one price holds. Each period firms receive a signal with probability $1-\xi_H$ and $1-\xi_X$, to reset the price of their individual products on the home market and on the market of the other country, respectively. Firms which are not allowed to reset prices in a given period will index their prices to the geometric average past period and steady state inflation on the local market, respectively:

$$P_{H,f,t} = \left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_H} \pi_H^{1-\chi_H} P_{H,f,t-1},$$

$$P_{X,f,t} = \left(\frac{P_{X,t-1}}{P_{X,t-2}}\right)^{\chi_X} \pi_X^{1-\chi_X} P_{X,f,t-1}.$$

Final goods producers

Final goods producers operate under perfect competition and use CES-technology to transform bundles of domestic and foreign intermediate goods into non-tradable final consumption and investment goods:

$$Q_t^C = \left(\nu_C^{\frac{1}{\mu_C}}(H_t^C)^{\frac{\mu_C-1}{\mu_C}} + (1-\nu_C - \nu_{C,ROW})^{\frac{1}{\mu_C}}\left((1-\Gamma_{IM^C}(IM_t^C/Q_t^C))IM_t^C\right)^{\frac{\mu_C-1}{\mu_C}} + \nu_{C,ROW}^{\frac{1}{\mu_C}}\left((1-\Gamma_{IM^C}^{ROW}(IM_t^{C,ROW}/Q_t^C))IM_t^{C,ROW}\right)^{\frac{\mu_C-1}{\mu_C}}\right)$$

$$Q_t^I = \left(\nu_I^{\frac{1}{\mu_I}}(H_t^I)^{\frac{\mu_I-1}{\mu_I}} + (1-\nu_I - \nu_{I,ROW})^{\frac{1}{\mu_I}}\left((1-\Gamma_{IM^I}(IM_t^I/Q_t^I))IM_t^I\right)^{\frac{\mu_I-1}{\mu_I}} + \nu_{I,ROW}^{\frac{1}{\mu_I}}\left((1-\Gamma_{IM^I}^{ROW}(IM_t^{I,ROW}/Q_t^I))IM_t^{I,ROW}\right)^{\frac{\mu_I-1}{\mu_I}}\right)^{\frac{\mu_I}{\mu_I-1}}.$$

where μ_C and μ_I denote the elasticity of substitution, ν_C and ν_I the home bias, $\nu_{C,ROW}$ and $\nu_{I,ROW}$ the weights of the ROW inputs, while the remaining part of inputs stems from the other economy (Economy A or Economy B), respectively. Both the final consumption and investment goods producers face adjustment costs when altering the share of imported intermediate goods used for production.

These costs are captured by the functions Γ_{IM^C}, Γ_{IM^I}, $\Gamma_{IM^C}^{ROW}$ and $\Gamma_{IM^I}^{ROW}$[42]. The bundles of intermediate goods, H_t^C, IM_t^C and H_t^I, IM_t^I are defined as follows:

$$H_t^C = \left(\int_0^1 \left(H_{f,t}^C\right)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \quad IM_t^C = \left(\int_0^1 \left(IM_{f^*,t}^C\right)^{\frac{\theta^*-1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}},$$

$$H_t^I = \left(\int_0^1 \left(H_{f,t}^I\right)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \quad IM_t^I = \left(\int_0^1 \left(IM_{f^*,t}^I\right)^{\frac{\theta^*-1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}}.$$

where $H_{f,t}^C$, $H_{f,t}^I$, $IM_{f^*,t}^C$, $IM_{f^*,t}^I$ denote the use of intermediate goods produced by domestic firms f and foreign firms f^* in the other country, respectively, and $\theta, \theta^* > 1$ are the corresponding substitution elasticities. As the ROW produces only one single good, $IM_t^{C,ROW}$ and $IM_t^{I,ROW}$ are identical to the bundle of goods produced in ROW. Final goods producers take prices as given, set by the intermediate goods producers in a monopolistic competitive environment, to minimize costs of producing one unit of a final good. As a result, the optimal demand for domestic and foreign intermediate goods from the other country, supplied by firm f and firm f^*, respectively, is:

$$H_{f,t}^C = \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\theta} H_t^C, \qquad IM_{f^*,t}^C = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\theta} IM_t^C$$

$$H_{f,t}^I = \left(\frac{P_{I,f,t}}{P_{I,t}}\right)^{-\theta} H_t^I, \qquad IM_{f^*,t}^I = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\theta} IM_t^I.$$

where the corresponding aggregate price index for a bundle of domestic and imported good is

$$P_{H,t} = \left(\int_0^1 \left(P_{H,f,t}\right)^{1-\theta} df \right)^{\frac{1}{1-\theta}},$$

$$P_{IM,t} = \left(\int_0^1 \left(P_{IM,f^*,t}\right)^{1-\theta} df^* \right)^{\frac{1}{1-\theta}}.$$

To produce final goods, firms minimize their cost function

$$TC_t^X = P_{H,t} H_t^X + IM_t^X P_{IM,t} + IM_t^{X,ROW} P_{IM,t}^{ROW} \qquad \text{with } X = C, I$$

with respect to the CES-technology constraint from above. $P_{IM,t}$ and $P_{IM,t}^{ROW}$ denote the prices of the import goods bundles produced by the other economy and the ROW, respectively, both denominated in home currency.[43] The resulting optimal input of goods bundles are given by

[42] The import share adjustment costs are defined as $\Gamma_{IM^i}\left(IM_t^i \,/\, Q_t^i\right) := \frac{\gamma_{IM^i}}{2}\left(\frac{IM_t^i/Q_t^i}{IM_{t-1}^i/Q_{t-1}^i} - 1\right)$ for $i = C, I$

[43] As pointed out earlier, for goods traded with the ROW the law of one price holds, thus $P_t^{IM,ROW} = S_t^{ROW} P_t^{Y,ROW}$, where $P_t^{Y,ROW}$ denotes the price level in the ROW.

$$H_t^C = \nu_C \left(\frac{P_{H,t}}{P_{C,t}}\right)^{-\mu_C} Q_t^C$$

$$IM_t^C = (1-\nu_C - \nu_{C,ROW})\left(\frac{P_{IM,t}}{P_{C,t}\Gamma^*_{IM_t^C}}\right)^{-\mu_C} \frac{Q_t^C}{1-\Gamma_{IM^C}(IM_t^C/Q_t^C)}$$

$$IM_t^{C,ROW} = \nu_{C,ROW}\left(\frac{P_t^{IM,ROW}}{P_{C,t}\Gamma^{*,ROW}_{IM_t^C}}\right)^{-\mu_C} \frac{Q_t^C}{1-\Gamma^{ROW}_{IM^C}(IM_t^{C,ROW}/Q_t^C)}$$

$$H_t^I = \nu_I \left(\frac{P_{H,t}}{P_{C,t}}\right)^{-\mu_C} Q_t^I$$

$$IM_t^I = (1-\nu_I - \nu_{I,ROW})\left(\frac{P_{IM,t}}{P_{I,t}\Gamma^*_{IM_t^I}}\right)^{-\mu_C} \frac{Q_t^I}{1-\Gamma_{IM^I}(IM_t^I/Q_t^I)}$$

$$IM_t^{I,ROW} = \nu_{I,ROW}\left(\frac{P_t^{IM,ROW}}{P_{I,t}\Gamma^{*,ROW}_{IM_t^I}}\right)^{-\mu_C} \frac{Q_t^I}{1-\Gamma^{ROW}_{IM^I}(IM_t^{I,ROW}/Q_t^I)}$$

with

$$\Gamma^*_{IM_t^C} = 1-\Gamma_{IM^C}(IM_t^C/Q_t^C) - \Gamma'_{IM^C}(IM_t^C/Q_t^C)IM_t^C$$

$$\Gamma^*_{IM_t^I} = 1-\Gamma_{IM^I}(IM_t^I/Q_t^I) - \Gamma'_{IM^I}(IM_t^I/Q_t^I)IM_t^I$$

$$\Gamma^{*,ROW}_{IM_t^C} = 1-\Gamma^{ROW}_{IM^C}(IM_t^{C,ROW}/Q_t^C) - \Gamma^{ROW\,\prime}_{IM^C}(IM_t^{C,ROW}/Q_t^C)IM_t^{C,ROW}$$

$$\Gamma^{*,ROW}_{IM_t^I} = 1-\Gamma^{ROW}_{IM^I}(IM_t^{I,ROW}/Q_t^I) - \Gamma^{ROW\,\prime}_{IM^I}(IM_t^{I,ROW}/Q_t^I)IM_t^{I,ROW}$$

The corresponding price indices for one unit of consumption and investment good are given by

$$P_{C,t} = \left(\nu_C\left(P_{H,t}\right)^{1-\mu_C} + (1-\nu_C - \nu_{C,ROW})\left(\frac{P_{IM,t}}{\Gamma^*_{IM_t^C}}\right)^{1-\mu_C} + \nu_{C,ROW}\left(\frac{P_t^{IM,ROW}}{\Gamma^{*,ROW}_{IM_t^C}}\right)^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}}$$

$$P_{I,t} = \left(\nu_I\left(P_{H,t}\right)^{1-\mu_C} + (1-\nu_I - \nu_{I,ROW})\left(\frac{P_{IM,t}}{\Gamma^*_{IM_t^I}}\right)^{1-\mu_I} + \nu_{I,ROW}\left(\frac{P_t^{IM,ROW}}{\Gamma^{*,ROW}_{IM_t^I}}\right)^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}}$$

For non-tradable final public consumption goods, the home bias is unity, that is, it is produced only using home intermediate goods. Hence, the technology constraint is

$$H_t^G = \left(\int_0^1 \left(H_{f,t}^G\right)^{\frac{\theta-1}{\theta}} df\right)^{\frac{\theta}{\theta-1}}$$

As a result, the optimal demand for domestic intermediate goods $H^G_{f,t}$ supplied by firm f is

$$H^G_{f,t} = \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\theta} H^G_t$$

Trivially, the demand for the intermediate goods bundle corresponds to the government consumption:

$$H^G_t = Q^G_t = G_t$$

Fiscal Authority

The fiscal authorities collect taxes levied on consumption, capital, dividend and wage income. Furthermore, payroll taxes are raised in form of social contributions from both employers and employees. The fiscal levies also lump-sum taxes and obtains seignorage income where the latter is forwarded by the monetary authority. The revenues are expensed on public consumption goods and transfers paid to the households. To refinance its outstanding debt, the fiscal issues bonds each period. Consequently, the fiscal budget constraint is described as follows:

$$\begin{aligned} &P_{G,t}G_t + TR_t + B_t + M_{t-1} \\ &\qquad = \tau^C_t P_{C,t}C_t + (\tau^N_t + \tau^{W_h}_t)\left(\int_0^{1-\omega} W_{i,t}N_{i,t}\,di + \int_{1-\omega}^{1} W_{j,t}N_{j,t}\,dj\right) + \tau^{W_f}_t W_t N_t \\ &\qquad + \tau^K_t (R_{K,t}u_{i,t} - \left(\Gamma_u(u_{i,t}) + \delta\right)P_{I,t})K_t + \tau^D_t D_t + T_t + R^{-1}_t B_t + M_t \quad , \end{aligned}$$

Expenses on public consumption goods expressed as the fraction of steady state nominal output follow an AR(1) process with mean *g*:

$$g_t = \left(1 - \rho_g\right)g + \rho_g g_{t-1} + \epsilon_{g,t} \qquad \text{with } g_t = P_{G,t}\, G_t / P_Y Y$$

Naturally, the price level for public consumption $P_{G,t}$ will equal to the price of intermediate goods $P_{H,t}$ as only intermediate goods produced in the home country are used for the production of public consumption goods.

Transfers to households are defined as the fraction of steady state nominal output and are modeled similarly by an AR(1) process with mean *tr:*

$$tr_t = (1 - \rho_{tr})tr + \rho_{tr} tr_{t-1} + \epsilon_{tr,t} \quad \text{with } tr_t = TR_t / P_Y Y$$

Lump sum taxes are levied each period according to the following rule:

$$\tau_t = \phi_{B_Y}\left(\frac{B_t}{P_Y Y} - B_Y\right) \qquad\qquad \text{with } \tau_t = T_t / P_Y Y$$

where B_Y is the target debt to output ratio in steady state. All distortionary tax rates follow an exogenous AR(1) process unless otherwise stated:

$$\tau^X_t = \left(1 - \rho_{\tau^X}\right)\tau^X + \tau^X_{t-1} + \epsilon_{\tau^X,t} \quad \text{for} \quad X = C, D, K, N, W_h, W_f$$

Monetary Policy Regimes

The model allows for an easy assessment and comparison of the dynamics in three different settings – flexible exchange rates, currency peg of Economy A to Economy B and a monetary union between the two countries – which can be implemented adjusting the monetary policy rules.

a) Flexible Exchange Rates: In this scenario the monetary authorities in both regions operate independently and follow a standard Taylor rule with interest rate smoothing:

$$(R_t^A)^4 = \rho^A (R_{t-1}^A)^4 + (1-\rho^A) \left((r^{*,A}\Pi^{*,A})^4 + \phi_\pi^A \left(\frac{P_{C,t}^A}{P_{C,t-4}^A} - (\Pi^{*,A})^4 \right) + \phi_Y^A (Y_t^A - Y^A) + \epsilon_{R,t}^A \right)$$

$$(R_t^B)^4 = \rho^B (R_{t-1}^B)^4 + (1-\rho^B) \left((r^{*,B}\Pi^{*,B})^4 + \phi_\pi^B \left(\frac{P_{C,t}^B}{P_{C,t-4}^B} - (\Pi^{*,B})^4 \right) + \phi_Y^B (Y_t^B - Y^B) + \epsilon_{R,t}^B \right)$$

where ρ is the smoothing parameter, r^* is the steady state real interest rate equaling $1/\beta$, Π^* is the inflation target, ϕ_π is the reaction to the deviation from the consumer-price inflation target and ϕ_y is the reaction to the output gap. In addition, we assume that monetary policy shocks are uncorrelated. In this set-up the FOCs of the Ricardian households with respect to B_t and B_t^F imply that the uncovered interest rate parity (UIP) with respect to the ROW, including the risk premium $\Gamma_B(B_{i,t}^F)$ depending on the foreign bond position, will hold. The triangle no-arbitrage equation for the currencies, as postulated below, will imply that the UIP between Economy A and Economy B will also hold, up to the difference in the risk premia.

b) Unilateral Peg: In order to model Economy A pegging unilaterally its currency to the anchor currency of Economy B the monetary policy rule of Economy A needs to be altered. To guarantee that the exchange rate remains constant we follow the textbook example and add a reaction to depreciation being sufficiently large that deviations in the exchange rate compared with that of one period before are negligibly small:

$$(R_t^A)^4 = (r^{*,A}\Pi^{*,A})^4 + \phi_e \left(\frac{S_t}{S_{t-1}} - 1 \right) + \epsilon_{R,t}^A$$

where ϕ_e is the reaction to fluctuations in the exchange rate. The monetary authority in Economy B follows a similar rule as in the flexible exchange rate scenario. In case it can be assumed that $\epsilon_{R,t}^A = 0$ for all t then the exchange rate is fixed which will lead to a de facto nominal interest rate parity (except for the differences in the risk premia $\Gamma_B(B_{i,t}^F)$ of the two countries following from the UIP).

c) Currency Union: To assess the dynamics in a currency union the model can be slightly tweaked by introducing a new equation which sets the ratio S_t/S_{t-1} to unity and cancelling the monetary policy rule of Economy A at the same time. The central bank of Economy B will serve as the common monetary authority by reacting to the weighted averages of inflation and output gap of the Economy A and Economy B:

$$\begin{aligned}(R_t^{CU})^4 = {} & \rho^{CU} (R_{t-1}^{CU})^4 \\ & + (1-\rho^{CU}) \Bigg(s(r^{*,A}\Pi^{*,A})^4 + (1-s)(r^{*,B}\Pi^{*,B})^4 \\ & + \phi_\pi^{CU} \left(s \left(\frac{P_{C,t}^A}{P_{C,t-4}^A} - (\Pi^{*,A})^4 \right) + (1-s) \left(\frac{P_{C,t}^B}{P_{C,t-4}^B} - (\Pi^{*,B})^4 \right) \right) \\ & + \phi_Y^{CU} \left(s(Y_t^A - Y^A) + (1-s)(Y_t^B - Y^B) \right) + \epsilon_{R,t}^{CU} \Bigg)\end{aligned}$$

Consequently $R_t^{CU} = R_t^B$ and the FOCs of the Ricardian households in Economy A and Economy B with respect to B_t and B_t^F together with the currency triangle no-arbitrage condition will directly imply that interest parity holds as under the unilateral peg. The de facto difference to the unilateral peg case is that monetary policy is conducted by taking also Economy A into account.

The Rest of the World

The rest of the world is modeled using the textbook three equation New Keynesian model extended by feedback on the output gap and the inflation from Economy A and Economy B:

$$Y_t^{GAP,ROW} = E_t Y_{t+1}^{GAP,ROW} + \frac{1}{\sigma^{ROW}} (\tilde{R}_t^{ROW} - E_t \tilde{\Pi}_{t+1}^{ROW}) + g_t^{ROW}$$

$$\tilde{\Pi}_t^{ROW} = \beta^{ROW} E_t \tilde{\Pi}_{t+1}^{ROW} + \gamma^{ROW} Y_t^{GAP,ROW} + u_t^{ROW}$$

$$\tilde{R}_t^{ROW} = \phi_\pi^{ROW} \tilde{\Pi}_t^{ROW} + \phi_y^{ROW} Y_t^{GAP,ROW} + \epsilon_t^{R,ROW}$$

where

$$g_t^{ROW} = \tilde{g}_t^{ROW} + \eta_{y,A} Y_t^{GAP,A} + \eta_{y,B} Y_t^{GAP,B}$$

$$u_t^{ROW} = \tilde{u}_t^{ROW} + \eta_{\pi,A}(\Pi_t^A - \Pi^{*,A}) + \eta_{\pi,B}(\Pi_t^B - \Pi^{*,B})$$

$$\tilde{g}_t^{ROW} = \rho_g^{ROW} \tilde{g}_{t-1}^{ROW} + \epsilon_t^{g,ROW}$$

$$\tilde{u}_t^{ROW} = \rho_u^{ROW} \tilde{u}_{t-1}^{ROW} + \epsilon_t^{u,ROW}$$

The variables $Y_t^{GAP,ROW}$, $\tilde{\Pi}_t^{ROW}$ and $\tilde{R}_t^{ROW}$ stand for the output gap, the inflation and the nominal interest rate, respectively. The parameters σ^{ROW}, β^{ROW}, ϕ_π^{ROW} and ϕ_y^{ROW} are the risk aversion, the time preference and the reaction of the monetary authority to inflation and the output gap. The disturbance terms g_t^{ROW} and u_t^{ROW} are the summation of the indigenous demand and cost-push shocks, $\tilde{g}_t^{ROW}$ and $\tilde{u}_t^{ROW}$, and the feedback from Economy A and Economy B with the elasticities $\eta_{y,REA}$, $\eta_{y,DE}$, $\eta_{\pi,REA}$ and $\eta_{\pi,DE}$.

Since it is assumed that firms in the ROW economy price their products in producer currency and that the law of one price holds, trivially, the import price for products from ROW can be expressed as

$$P_t^{IM,ROW} = S_t^{ROW} P_t^{Y,ROW}$$

and the dynamics of inflation is defined as

$$\tilde{\Pi}_t^{ROW} = \frac{P_t^{Y,ROW}}{P_{t-1}^{Y,ROW}} - 1$$

To remain consistent with respect to the dimension of key variables throughout the model we define Π_t^{ROW} as the gross inflation being

$$\Pi_t^{ROW} = \Pi^{*,ROW}\left(1 + \tilde{\Pi}_t^{ROW}\right)$$

where $\Pi^{*,ROW}$ is the gross inflation target in the ROW. Similarly, we define the gross nominal interest rate R_t^{ROW} as

$$R_t^{ROW} = R^{*,ROW}\left(1 + \tilde{R}_t^{ROW}\right)$$

where $R^{*,ROW}$ is the nominal gross steady state interest rate in the ROW, given by the product of the real gross steady state interest rate and the gross inflation target. Finally, the demand for imported intermediate goods by the ROW, equaling the exports of Economy A and Economy B, respectively, is given by

$$X_t^{ROW} = \left(1 + \phi_X^{ROW} Y_t^{GAP,ROW}\right)\psi^{ROW}\left(\frac{P^H}{S_t^{ROW} P^{Y,ROW}}\right)^{-\eta^{ROW}}$$

where ψ^{ROW} is a country specific scaling constant, η^{ROW} is the elasticity with respect to the relative price and ϕ_X^{ROW} is the demand elasticity with respect to the output gap.

Aggregation

The model is closed by adding the aggregation across the agents, the market clearing conditions for labour, intermediate and final goods, the dynamics of the internationally traded bonds and the triangle no-arbitrage condition for all currencies. In particular, we have

$$X_t = (1-\omega)X_{I,t} + \omega X_{J,t} \quad \text{for } X = C, M, TR, T$$

and

$$X_t = (1-\omega)X_{I,t} \quad \text{for } X = I, K, D, B, B^F$$

To clear the labour market we aggregate first the demand across all firms $f \in [0,1]$ for individual labour varieties i to obtain

$$N_t^i = \left(\frac{1}{1-\omega}\right)\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N_t^I$$

Then it has to hold that $N_{i,t} = N_t^i \ \forall i \in I$. Using the optimal demand conditions and the corresponding wage indices after some manipulation one obtains

$$\int_0^{1-\omega} N_{i,t}\, di = \Delta_t^{W,I} N_t^I$$

where $\Delta_t^{W,I}$ is the wage dispersion of the Ricardian households which evolves according to

$$\Delta_t^{W,I} = (1-\xi_I)\left(\frac{\widetilde{W}_{I,t}}{W_{I,t}}\right)^{-\eta_I} + \xi_I\left(\frac{W_{I,t}}{W_{I,t-1}}\frac{\pi_{C,t}}{\pi_{C,t-1}^{\chi_I}\pi_C^{1-\chi_I}}\right)^{-\eta_I}\Delta_{t-1}^{W,I}$$

$\widetilde{W}_{I,t}$ is the optimal wage set by Ricardian household members and $\eta_I/(\eta_I - 1)$ is the wage markup for the Ricardian households. From the wage indices of the bundles of individually supplied labour the wage dynamics can be immediately derived:

$$W_{I,t} = (1-\xi_I)\left(\widetilde{W}_{I,t}\right)^{1-\eta_I} + \xi_I\left(\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_I}\pi_C^{1-\chi_I} W_{I,t-1}\right)$$

Furthermore, the total wage paid by the firms can be expressed as follows:

$$\int_0^{1-\omega} W_{i,t}N_{i,t}\,di = W_{I,t}N_t^I$$

As a result, the aggregate constraint for the Ricardian looks as follows:

$$\begin{aligned}\left(1+\tau_t^C+\Gamma_v(v_{I,t})\right)P_{C,t}C_{I,t} \;+\; P_{I,t}I_{I,t}+R_t^{-1}B_{I,t+1} \;+\; (R_t^{ROW})^{-1}S_t^{ROW}B_{I,t+1}^F \;+M_{I,t} \\ = \;(1-\tau_t^N-\tau_t^{W_h})(1-\omega)^{-1}W_{I,t}N_t^I+(1-\tau_t^K)(R_{K,t}u_{I,t}-\Gamma_u(u_{I,t})P_{I,t})K_{I,t} \\ +\tau_t^K\delta P_{I,t}K_{I,t}+(1-\tau_t^D)D_{I,t}+TR_{I,t}-T_{I,t}+B_{I,t}+S_tB_{I,t}^F+M_{I,t-1}\end{aligned}$$

For non-Ricardian households, aggregation is carried out in a similar way:

$$\left(1+\tau_t^C+\Gamma_v(v_{J,t})\right)P_{C,t}C_{J,t} \;+M_{J,t} = \;(1-\tau_t^N-\tau_t^{W_h})\omega^{-1}W_{J,t}N_t^J+TR_{J,t}-T_{J,t}+M_{J,t-1}$$

To clear the market for the intermediate goods, as a first step the domestic demand for domestic goods and foreign intermediate goods from the other country, f and f^*, is derived by summing up across the three sectors C, I, G:

$$H_{f,t}=H_{f,t}^C+H_{f,t}^I+H_{f,t}^G=\left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\theta} H_t$$

$$IM_{f^*,t}=IM_{f^*,t}^C+IM_{f^*,t}^I=\left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\theta^*} IM_t$$

with $H_t=H_t^C+H_t^I+H_t^G$ and $IM_t=IM_t^C+IM_t^I$. Here we use the market clearing condition that the demand for foreign intermediate good f^* has to be equal to the quantity supplied by the foreign intermediate good producer f^* from the other country. Therefore, it has to hold that

$$sIM_{f^*,t}=(1-s)X_{f^*,t}^*$$

with $X_{f^*,t}^*$ being the amount of the intermediate goods exported by the foreign intermediate good producer f^* from the other country. Naturally, the quantities have to be adjusted for the country size. Furthermore, local currency pricing is assumed, that is $P_{IM,f^*,t}=P_{X,f^*,t}^*$ and therefore it holds that $P_{IM,t}=P_{X,t}^*$. As the ROW economy is modeled in a compact manner where the aggregate goods bundle Y_t produced is exported there is no need to model the demand for goods supplied by individual firms in ROW.

Market clearing for the intermediate goods requires that $Y_{f,t}=H_{f,t}+X_{f,t}+X_{f,t}^{ROW}\ \forall f\in[0,1]$ where $X_{f,t}^{ROW}$ is the demand for the intermediate good produced by firm f by the ROW economy. Summing up across firms, then using the optimality conditions and the corresponding price indices market clearing implies that

$$Y_t \;=\Delta_t^H(H_t+X_t^{ROW})+\;\Delta_t^X X_t$$

where the price dispersions Δ_t^H and Δ_t^X evolve according to

$$\Delta_t^H=(1-\xi_H)\left(\frac{\tilde{P}_{H,t}}{P_{H,t}}\right)^{-\theta}+\;\xi_H\left(\frac{P_{H,t}}{P_{H,t-1}}\frac{\pi_{H,t}}{\pi_{H,t-1}^{\chi_H}\pi_H^{1-\chi_H}}\right)^{-\eta_I}\Delta_{t-1}^H$$

$$\Delta_t^X = (1-\xi_X)\left(\frac{\tilde{P}_{X,t}}{P_{X,t}}\right)^{-\theta} + \xi_X\left(\frac{P_{X,t}}{P_{X,t-1}}\frac{\pi_{X,t}}{\pi_{X,t-1}^{\chi_X}\pi_X^{1-\chi_X}}\right)^{-\eta_I}\Delta_{t-1}^X$$

Since the price setting for the goods exported to the ROW occurs under the assumption of producer currency pricing and that the law of one price holds, the dispersion in the ROW export markets is the same as in the domestic markets. $\tilde{P}_{H,t}$ and $\tilde{P}_{X,t}$ represent the optimal prices set on the domestic market and foreign market in the other country, respectively, when re-optimization is allowed and $\pi_{H,t} = P_{H,t}/P_{H,t-1}$ and $\pi_{X,t} = P_{X,t}/P_{X,t-1}$. The aggregated price dynamics is described by the equations

$$P_{H,t} = \left((1-\xi_H)\left(\tilde{P}_{H,t}\right)^{1-\theta} + \xi_H\left(\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_H}\pi_C^{1-\chi_H}P_{H,t-1}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}$$

$$P_{X,t} = \left((1-\xi_X)\left(\tilde{P}_{X,t}\right)^{1-\theta} + \xi_X\left(\left(\frac{P_{X,t-1}}{P_{X,t-2}}\right)^{\chi_H}\pi_X^{1-\chi_X}P_{X,t-1}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}.$$

The aggregate nominal output of intermediate goods can be obtained by summing up the nominal value of intermediate goods production

$$P_{Y,t}\,Y_t = \int_0^1 P_{H,f,t}\left(H_{f,t} + X_{f,t}^{ROW}\right) + S_t P_{X,f,t}X_{f,t}df$$

where $P_{Y,t}$ is defined as the implicit price index of the continuum of differentiated intermediate goods. Again, using the optimal demand conditions, the corresponding price indices and the relationships

$$sX_{f,t} = (1-s)IM_{f,t}^*\,,$$

$$P_{X,t} = P_{IM,t}^*$$

the aggregate nominal output of intermediate goods can be expressed as follows:

$$P_{Y,t}\,Y_t = P_{H,t}(H_t + X_t^{ROW}) + S_t P_{X,t}X_t$$

The price index $P_{Y,t}$ is therefore determined by

$$P_{Y,t} = \frac{P_{H,t}(H_t + X_t^{ROW})}{Y_t} + \frac{S_t P_{X,t}X_t}{Y_t}.$$

The market clearing on the final goods markets require:

$$Q_t^C = C_t + \Gamma_{v,t}$$

$$Q_t^I = I_t + \Gamma_u(u_t)\,K_t$$

$$Q_t^G = G_t$$

with

$$\Gamma_{\nu,t} = \int_0^{1-\omega} \Gamma_\nu(\nu_{i,t})C_{i,t}\, di + \int_\omega^1 \Gamma_\nu(\nu_{j,t})C_{j,t}\, dj = (1-\omega)\Gamma_\nu(\nu_{I,t})C_{I,t} + \omega\Gamma_\nu(\nu_{J,t})C_{J,t}$$

To clear the capital market aggregate capital demand by the intermediate goods producers has to equal the effective capital supplied by the households:

$$u_t\, K_t = \int_0^1 K_{f,t} df$$

Aggregate profits channeled back to households consist of the aggregated profits of the domestic intermediate goods producers realized on the domestic and foreign markets:

$$D_t = \int_0^1 D_{H+X^{ROW},f,t} df + \int_0^1 D_{X,f,t} df$$

Finally, for the sake of completeness, we also report the resource constraint which can be deduced from the individual constraints and replace one of the latter, if preferred:

$$\begin{aligned} P_{Y,t}Y_t = P_{C,t}\,(C_t + \Gamma_{\nu,t}) + P_{I,t}(I_t + \Gamma_u(u_t)K_t) + P_{G,t}G_t + S_tP_{X,t}X_t + P_{H,t}X_t^{ROW} \\ - P_{IM,t}(IM_t^C + IM_t^I) \quad - P_t^{IM,ROW}\left(IM_t^{C,ROW} + IM_t^{I,ROW}\right) \end{aligned}$$

In equilibrium the domestic bond holdings are pinned down by the budget constraint of the fiscal authority. To clear the internationally traded bonds market holdings issued in ROW currency have to sum up to zero:

$$s^A B_t^{F,A} + s^B B_t^{F,B} = -B_t^{F,ROW}$$

where s^A and s^B are the relative weights of Economy A and Economy B compared with the ROW. Technically speaking, the latter equation does not impact the ROW economy as it is described by a parsimonious three equations system where trade is not explicitly modeled. The dynamics of the holdings of the internationally traded bonds can be expressed as

$$(R_t^{ROW})^{-1} B_{t+1}^F = B_t^F + \frac{TB_t + TB_t^{ROW}}{S_t^{ROW}}$$

For both Economy A and Economy B, where the trade balance with the other contry, TB_t, is defined as

$$TB_t = P_{X,t}X_t - P_{IM,t}IM_t$$

and the trade balance with the ROW, TB_t^{ROW}, is defined in a similar manner:

$$TB_t^{ROW} = P_{H,t}X_t^{ROW} - S_t^{ROW}P_t^{Y,ROW}IM_t^{ROW}$$

where $IM_t^{ROW} = IM_t^{C,ROW} + IM_t^{I,ROW}$.

The terms of trade is defined as the import price over the export price expressed in home currency:

$$ToT_t = \frac{P_{IM,t}}{S_tP_{X,t}}\ , \qquad ToT_t^{ROW} = \frac{S_t^{ROW}P_t^{Y,ROW}}{P_{H,t}}$$

Finally, to close the model, we explicitly require that the triangle no-arbitrage condition between the currencies holds:

$$S_t^{A,ROW} = S_t^{A,B} S_t^{B,ROW}$$

As the model can be rewritten up in a manner that instead of exchange rate levels only depreciation terms show up in the equations the above classical triangle arbitrage equation transforms into

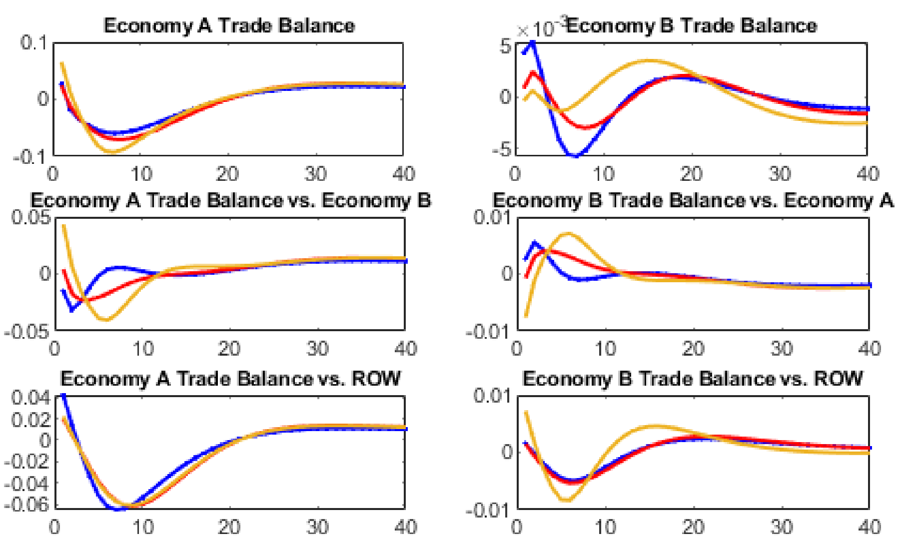
$$\frac{S_t^{REA,ROW}}{S_{t-1}^{REA,ROW}} = \frac{S_t^{REA,DE}}{S_{t-1}^{REA,DE}} \frac{S_t^{DE,ROW}}{S_{t-1}^{DE,ROW}}$$

To clear the money market, the monetary authority will supply the amount of money demanded by the households – pinned down by the optimality conditions of the households – as monetary policy uses the interest rate as policy instrument.

C Additional IRFs

C.1 Trade Balance

Figure C1: Impulse response of trade balances to SSCR one percent negative shock

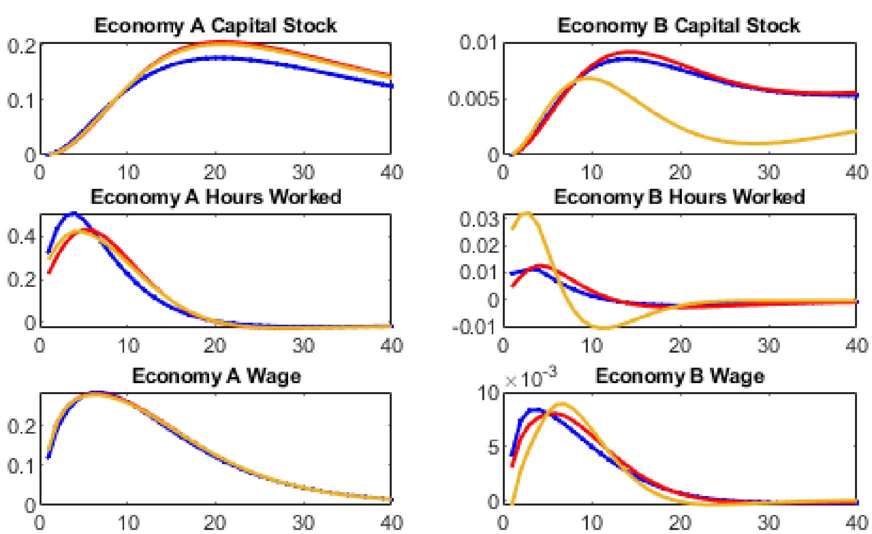


Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

As regards the trade balance with Economy B, the largest increase on impact occurs in a currency union as the nominal exchange rate versus Economy B is fixed and the large output increase in Economy B at the beginning spills over to Economy A creating a significant surplus in the trade balance. In case the exchange rate is flexible, one can indeed observe the classical J-curve effect where the trade balance turns immediately negative on impact and improves afterward. The trade balance with the ROW exhibits the same J-curve pattern, however, there is little difference in the dynamics under the three exchange rate regimes. The increase on impact is the highest under the flexible regime, given the largest devaluation in that case, which leads to higher demand for export goods and lower import demand due to substitution effects. For Economy B the overall trade balance is fluctuating but is lower by an order of magnitude than in Economy A. The largest fluctuation arises under the flexible regime which is primarily driven by the relatively large exchange rate fluctuation and the high demand on the back of the strong output growth in Economy A. At the same time the real depreciation versus the ROW will contribute to the initial positive trade balance as well. However, after the depreciation versus the ROW a phase of the real appreciation will set on and along with the vanishing demand on the back of the relatively strong output decrease in Economy A will result in a worsening of the trade balance. The improvement in the real exchange rate versus Economy A will not be able to alter the trend. For Economy B the impact on the trade balance is the smallest in a currency union. The real exchange effect versus the ROW is here the largest among the three scenarios while on the back of the strong output growth in the home economy and the fixed nominal exchange rate the trade balance versus Economy A worsens considerably, so the effects roughly offset each other. After the initial fluctuation, there is some positive rebound for a few periods which can be attributed to the real exchange rate dynamics and the output decline.

C.2 Production Factors

Figure C2: Impulse response of production factors to SSCR one percent negative shock



Note: The blue lines display the impulse responses under a flexible exchange rate regime, the red lines under a currency peg, and the yellow lines in a currency union.

D Empirical analysis

Table D1: Predictability of output growth

Output growth	*t+1*
World real GDP growth	0
Government net lending	0
Current account balance	.02
Deflator inflation	.75
Real short-term interest rate	.01

p-values presented

Note: Entries are the p-value of a test of the null hypothesis that the given variable and its lag are irrelevant in determining output given the changes in SSCR.

Table D2: Predictability of SCCR changes

$\Delta SSCR$	*t+1*
World real GDP growth	.35
Government net lending	.18
Current account balance	.48
Real short-term interest rate	.57
Deflator inflation	.68
Expected growth rate	.36
ΔSSCR	.01

p-values presented

Note: Entries are the p-value of a test of the null hypothesis that the given variable and its lag are irrelevant in determining SSCR changes.

Table D3: Predictability of SSCR changes

	ΔSSCR t+1
World real GDP growth	-0.01
	(0.03)
Government net lending	0.03
	(0.02)
Current account balance	0.02
	(0.02)
Real short-term interest rate	-0.02
	(0.03)
Deflator inflation	0.01
	(0.02)
Expected growth rate	-0.02
	(0.02)
Δ SSCR	0.18***
	(0.06)
Country fixed effects	Yes
Observations	627

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D4: Basic model estimation results

	(1)	(2)	(3)	(4)	(5)
	t	t+1	t+2	t+3	t+4
SSCR change	0.112*	0.655***	1.013***	1.047***	1.171***
	(0.0614)	(0.174)	(0.199)	(0.359)	(0.413)
Observations	684	648	612	576	540

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, future values of shocks, and country fixed effects.

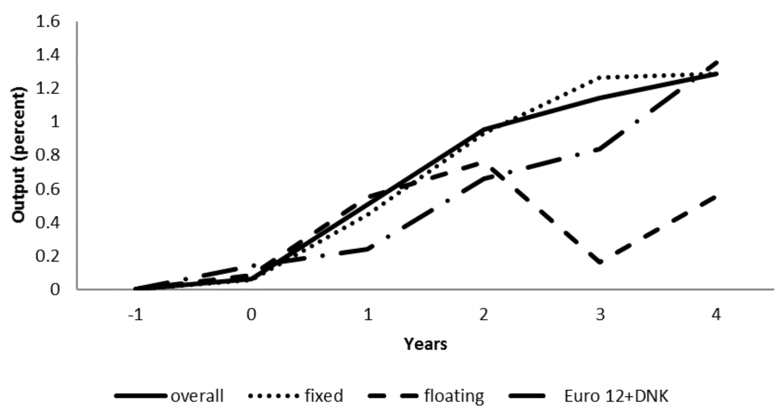
Table D5: Model with additional controls estimation results

	(1)	(2)	(3)	(4)	(5)
	t	t+1	t+2	t+3	t+4
SSCR change	0.0568	0.511***	0.881***	1.089***	1.304***
	(0.0390)	(0.155)	(0.194)	(0.393)	(0.370)
Observations	678	642	606	570	534

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, government net lending, current account balance, real short-term interest rate, future values of shocks, and country fixed effects.

Figure D1: Impulse response of cumulative output growth to a one percent reduction in SSCR – Comparison across different exchange rate regimes – Value Added Tax shocks with lag included



Note: Authors' estimates based on eq. (1). t=0 is the year of the adjustment. Standard errors are clustered by country. Additional controls: world real GDP growth contemporaneous and future values, lagged output growth, government net lending, current account balance, real short-term interest rate, future values of SSCR shocks, VAT shocks with their future values and first lag, and country fixed effects.

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