Structural Reforms in a Monetary Union: The Role of The ZLB*

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Abstract

Structural reforms that increase competition in product and labor markets may have large effects on the long-run level of output. We find that, in a medium scale DSGE model, a 10 percent reduction in product and labor markups increases output by nearly 7 percent after 5 years. The short-run transmission of these reforms, however, depends critically on the presence of the zero lower bound (ZLB). When monetary policy is at the ZLB, structural reforms may have perverse effects, as they increase deflationary pressures and delay the normalization of policy rates. Hence, contrary to conventional wisdom, we argue that labor market reforms should precede product market reforms.

*The views expressed in this paper do not necessarily reflect the position of the Federal Reserve Bank of New York or of the Federal Reserve System.

1 Introduction

Conventional wisdom places the origin of the European crisis in the development of macroeconomic imbalances since the adoption of the Euro (see, among others, Eichengreen, 2010). As shown in Figure 1, EMU core countries (mainly Germany, but also Austria and the Netherlands) have persistently maintained current account surpluses over the past decade, whereas EMU peripheral countries have run large deficits. Diverging external balances between core and periphery countries have also been associated with significant real exchange rate differentials (see Figure 2).[1]

Absent the possibility of devaluing their currency, policymakers in the periphery face the difficult task of finding measures that can restore competitiveness and return economic growth on a sound footing. In this perspective, the recent academic literature has, to a large extent, focused on the scope for fiscal devaluations, that is, revenue-neutral changes in the composition of the taxes that mimic an exchange rate devaluation. However, quantitatively, the potential gains brought by these policies have been shown to be limited.[2]

Figure 3(a) shows another related dimension of divergence between core and periphery. Indexes of economic flexibility obtained from the World Economic Forum indicate that peripheral economies are characterized by significantly higher structural rigidities in both product and labor markets than core countries. High rigidities in product and labor markets are associated with low levels of labor productivity (Figure 3(b)). Motivated by this observation, this paper studies the macroeconomic effects of structural reforms that increase competition in product and labor markets using a medium-scale open economy DSGE model.

Our theoretical framework features two countries, periphery and core, that share a common currency. Countries produce manufacturing goods, which are traded, and services, which are not. Firms and labor unions in each country have monopolistic power and pay a fixed cost to change prices as in Rotemberg (1982). Finally, the central bank sets monetary policy for the

[1] Corsetti and Pesaran (2012) note how inflation differentials between EMU members and Germany are a much more reliable proxy for interest rate differentials than sovereign debt-to-GDP differentials. To the extent that current account deficits are correlated with real exchange rate appreciations, the external balance of periphery countries is also tightly related to sovereign yield spreads. In sum, fiscal and external imbalances, as well as the relative competitive position, are likely to be different sides of the same underlying problem (Eichengreen, 2010).

[2] See, for example, Adao et al. (2009) and Fahri et al. (2012), as well as Lipinska and von Thadden (2012) for a critical appraisal.

currency union following a standard Taylor rule.

We model structural reforms as a permanent reduction in product and labor market markups, as typically assumed in the literature.[3] We calibrate steady-state price markups in the tradable (manufacturing) and non-tradable (service) sector of core and periphery using data from the OECD (2005). We then use the model first-order conditions together with sectoral data obtained from the EU-Klems dataset to back out the size of the after-tax wage markup. Price and wage markups tend to be higher in the periphery than in the core (and than in the United States), largely because of higher markups in the service sector. We interpret this evidence as reflecting the impact of higher regulations that limit competition in product and labor markets, particularly in the service sector. We then run deterministic simulations of reforms that reduce the monopoly power of firms and unions (i.e. their markups) in the periphery and trace out the short- and long-run response of the main macroeconomic variables.

Steady state comparative static suggests that the long-run effects of structural reforms are unambiguously positive. A 10 percent reduction of product and labor market markups in the service sector, which essentially closes the gap between core and periphery, increases the steady state level of output in the periphery by nearly 7 percent. These reforms result in a large reduction of prices in the periphery and a depreciation of its real exchange rate of 8 percent, roughly the same order of magnitude of the inflation differential between Italy and Germany.

Our main contribution consists in the analysis of the short-run transmission mechanism of reforms, with a particular focus on the role of the zero lower bound (ZLB) constraint on monetary policy. A growing literature has documented that the standard transmission channel of shocks are often overturned in frameworks where monetary policy is at the ZLB. For instance, Erceg and Linde (2012) argue that the size of fiscal multipliers are greatly affected by the presence of the ZLB. These authors find that expenditure-based consolidations are associated with larger short-run output costs than tax-based consolidations when the ZLB is binding. Eggertsson (2012) shows that the New Deal policies that granted firms and unions higher monopoly power contributed to end the Great Depression as they created inflationary expectations. As in these papers, we assume that the economy is hit by a preference shock that pushes the nominal interest rate to the ZLB. To our knowledge, however, very little attention

[3]See, for instance, Bayoumi et al. (2004) and Forni et al. (2010).

has been given to the constraints imposed by the ZLB to the implementation of structural reforms, modeled as markup shocks, in open economies.

We show that the transition dynamics associated with structural reforms in the presence of the ZLB critically depends on the balancing of two effects. On the one hand, reforms increase agents' permanent income, thus stimulating aggregate consumption and prompting a faster recovery from the crisis. On the other hand, reforms reinforce expectations for a prolonged deflation which, at the ZLB, can further depress consumption and deepen the recession. This second channel is reminiscent of the paradox of toil recently studied in Eggertsson (2011, 2012) among others.

We then show that this tradeoff becomes even more pronounced if structural reforms lack credibility. Reforms that are subsequently unwound (imperfectly credible) reduce their short-run benefits and substantially worsen their deflationary consequences in times of crisis.

Finally, our analysis of reforms at the ZLB has implications for the sequencing of reforms. Blanchard and Giavazzi (2004) and Cacciatori et al. (2011) argue that product market reforms should be implemented before labor market reforms, as they increase real wages and employment and facilitate the transition to the new steady state (see, for instance, OECD, 2012). Additionally, the reallocation of workers across industries or geographic areas may delay the short-run benefits of labor market reforms if implemented first. Our analysis, in contrast, suggests that when monetary policy is at the ZLB, the deflationary effects of product market reforms may further depress aggregate demand, resulting in larger short-run output losses. It follows that labor market reforms should be given higher priority.

2 The Model

The world economy consists of two countries Home (H) and Foreign (F) which share a common currency. Firms in each country produce an internationally-traded good and a non-traded good using labor, which is immobile across countries and sectors. Production takes place in two stages. In each sector (tradable and non-tradable), competitive retailers combine differentiated intermediate goods to produce the final consumption good. Monopolistic competitive wholesale producers set the price of each differentiated intermediate good on a staggered basis.

A representative household, composed by a continuum of members of measure 1, inhabits each country. The household derives utility from consumption of tradable and non-tradable goods and disutility from work. Each member of the household supplies a differentiated labor input. Labor agencies combine these inputs in sector-specific aggregates while the household sets the wage for each input on behalf of its members on a staggered basis. The only asset traded across countries is a one-period nominal risk-free bond denominated in the common currency. The common central bank sets monetary policy for the union as a whole following a standard interest rate rule with inertia. This section presents the details of the model from the perspective of the Home country. Foreign variables are denoted by an asterisk.

2.1 Retailers

Wholesale producers in the tradable (H) and non-tradable (N) sector combine raw goods according to a technology with time-varying elasticity of substitution $\theta_{kt} > 1$, where $k = \{H, N\}$

$$Y_{kt} = \left[\left(\frac{1}{\gamma_k} \right)^{\frac{1}{\theta_{kt}}} \int_0^{\gamma_k} Y_{kt}(j)^{\frac{\theta_{kt}-1}{\theta_{kt}}} dj \right]^{\frac{\theta_{kt}}{\theta_{kt}-1}} \tag{1}$$

where $\gamma_k = \{\gamma, 1-\gamma\}$ is the size of the tradable and non-tradable sector, respectively. The industry markup is a function of the elasticity of substitution θ_{kt}. The mapping is direct in steady state while over the cycle nominal rigidities make the markup time-varying. As in Blanchard and Giavazzi (2004), we assume that policymakers can perfectly control the elasticity of substitution. By changing the degree of substitution among varieties, structural reforms directly affect the degree of competition among firms.

Wholesale firms operate in perfect competition and maximize profits subject to their technological constraint (1)

$$\max_{Y_{kt}} P_{kt} Y_{kt} - \int_0^{\gamma_k} P_{kt}(j) Y_{kt}(j) dj \tag{2}$$

The first order condition for this problem yields the standard demand function

$$Y_{kt}(j) = \frac{1}{\gamma_k} \left[\frac{P_{kt}(j)}{P_{kt}} \right]^{-\theta_{kt}} Y_{kt} \tag{3}$$

where $P_{kt}(j)$ is the price of the j^{th} variety of the good produced in sector k. The zero profit condition implies that the price index in sector k is

$$P_{kt} = \left[\frac{1}{\gamma_k}\int_0^{\gamma_k} P_{kt}(j)^{1-\theta_{kt}} dj\right]^{\frac{1}{1-\theta_{kt}}} \tag{4}$$

2.2 Labor Agencies

Competitive labor agencies combine differentiated labor inputs supplied by household members into a sector-specific homogenous aggregate according to a technology with time-varying elasticity of substitution $\phi_{kt} > 1$.

$$L_{kt} = \left[\left(\frac{1}{\gamma_k}\right)^{\frac{1}{\phi_{kt}}} \int_0^{\gamma_k} L_{kt}(i)^{\frac{\phi_{kt}-1}{\phi_{kt}}} di\right]^{\frac{\phi_{kt}}{\phi_{kt}-1}} \tag{5}$$

As in the case of price markups, ϕ_{kt} reflects the monopoly power of workers in setting their wages. Again, we assume that policymakers control this variable so that reforms that change the degree of substitution among labor inputs have a direct impact on the degree of competition in labor markets.

Labor agencies maximize their profits

$$\max_{L_{kt}(i)} W_{kt}L_{kt} - \int_0^{\gamma_k} W_{kt}(i)L_{kt}(i)di \tag{6}$$

subject to (5), where W_{kt} is the wage index in sector k and $W_{kt}(i)$ is the wage specific to type-i labor input. The first order condition for this problem is

$$L_{kt}(i) = \frac{1}{\gamma_k}\left(\frac{W_{kt}(i)}{W_{kt}}\right)^{-\phi_{kt}} L_{kt} \tag{7}$$

The zero profit condition implies that the wage index is

$$W_{kt} = \left[\frac{1}{\gamma_k}\int_0^{\gamma} W_{kt}(i)^{1-\phi_{kt}} di\right]^{\frac{1}{1-\phi_{kt}}} \tag{8}$$

2.3 Intermediate Goods Producers

A continuum of measure γ_k of intermediate goods producers operate in each sector using the technology

$$Y_{kt}(j) = Z_{kt}L_{kt}(j) \tag{9}$$

where Z_{kt} is an exogenous productivity shock.

Intermediate goods producers are imperfectly competitive and choose the price for their variety $P_{kt}(j)$, as well as the optimum amount of labor inputs $L_{kt}(j)$, to maximize profits subject to their technological constraint (9) and the demand for their variety (3).

As customary, we can separate the intermediate goods producers problem in two steps. First, for given price, these firms minimize labor costs subject to their technology constraint. The result of this step is that the marginal costs (the Lagrange multiplier on the constraint) equals the nominal wage scaled by the level of productivity

$$MC_{kt}(j) = MC_{kt} = \frac{W_{kt}}{Z_{kt}} \tag{10}$$

This condition also shows that the marginal cost is independent of firm-specific characteristics.

Given the expression for the marginal cost, firms decide the optimal price to charge for their product. In changing the price, these firms pay a quadratic cost in units of output (Rotemberg, 1982). Their problem in real terms is

$$\max_{P_{kt+s}(j)} E_t \sum_{s=0}^{\infty} \widetilde{Q}_{t+s} \left[\left(\frac{P_{kt+s}(j)}{P_{t+s}} - \frac{MC_{kt+s}}{P_{t+s}} \right) Y_{kt+s}(j) - \frac{\kappa_p}{2} \left(\frac{P_{kt+s}(j)}{P_{kt-1+s}(j)} - 1 \right)^2 \frac{P_{kt+s} Y_{kt+s}}{P_{t+s}} \right] \tag{11}$$

subject to the demand for their variety (3), where $\widetilde{Q}_{t+s}$ is the stochastic discount factor for a real asset between period t and period $t+s$ (such that $\widetilde{Q}_t = 1$). The optimality condition for this problem yields the pricing rule

$$\begin{aligned}(1-\theta_{kt})\frac{Y_{kt}(j)}{P_t} + \theta_{kt} MC_{kt} \frac{Y_{kt}(j)}{P_{kt}(j)} - \kappa_p \left(\frac{P_{kt}(j)}{P_{kt-1}(j)} - 1 \right) \frac{1}{P_{kt-1}(j)} \frac{P_{kt} Y_{kt}}{P_t} + \\ + \kappa_p E_t \left[\widetilde{Q}_{t,t+1} \left(\frac{P_{kt+1}(j)}{P_{kt}(j)} - 1 \right) \frac{P_{kt+1}(j)}{P_{kt}(j)^2} \frac{P_{kt+1} Y_{kt+1}}{P_{t+1}} \right] = 0\end{aligned}$$

In a symmetric equilibrium, all firms within each sector choose the same price ($\widetilde{P}_{kt}(j) = P_{kt}$). Therefore, each firm hires the same amount of labor and produces the same amount of output (equal to the total amount of output per-sector divided by the size of the sector $Y_{kt}(j) = Y_{kt}/\gamma_k$), so that the index j becomes redundant. The pricing condition takes the form of a forward looking Phillips curve

$$\kappa_p \gamma_k \left(\Pi_{kt} - 1\right) \Pi_{kt} \frac{P_{kt}}{P_t} = \left(\theta_{kt} - 1\right) \left(\frac{\theta_{kt}}{\theta_{kt} - 1} MC_{kt} - \frac{P_{kt}}{P_t} \right) + \kappa_p \gamma_k E_t \left[\widetilde{Q}_{t,t+1} \frac{P_{kt+1}}{P_{t+1}} \frac{Y_{kt+1}}{Y_{kt}} \left(\Pi_{kt+1} - 1\right) \Pi_{kt+1} \right], \quad (12)$$

where $\Pi_{kt} = P_{kt}/P_{kt-1}$ is the gross inflation rate in sector k. In case of no adjustment cost (i.e., for $\kappa_p = 0$), the price Phillips curve boils down to the familiar pricing condition in monopolistic competition, that is

$$\frac{P_{kt}}{P_t} = \frac{\theta_{kt}}{\theta_{kt} - 1} MC_{kt}.$$

2.4 Households

In each country, a representative household consists of a continuum of measure one of members. Household members supply differentiated labor inputs and set their wage subject to quadratic adjustment costs à la Rotemberg (1982). Consumption and savings in bonds holdings are decided at the household level.

Aggregate consumption is a CES composite of tradable and nontradable goods with elasticity of substitution $\varphi > 0$

$$C_t = \left[\gamma^{\frac{1}{\varphi}} C_{Tt}^{\frac{\varphi-1}{\varphi}} + (1-\gamma)^{\frac{1}{\varphi}} C_{Nt}^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}} \quad (13)$$

where $\gamma \in (0,1)$ is the share of tradables in total consumption. The expenditure minimization problem is

$$P_t C_t \equiv \min_{C_{Tt}, C_{Nt}} P_{Tt} C_{Tt} + P_{Nt} C_{Nt} \quad (14)$$

subject to (13). The first order condition for this problem yields the demand for the tradable and non-tradable goods

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t} \right)^{-\varphi} C_t \quad (15)$$

$$C_{Nt} = (1-\gamma) \left(\frac{P_{Nt}}{P_t} \right)^{-\varphi} C_t \quad (16)$$

The associated price index is

$$P_t = \left[\gamma P_{Tt}^{1-\varphi} + (1-\gamma) P_{Nt}^{1-\varphi}\right]^{\frac{1}{1-\varphi}} \tag{17}$$

Consumption of tradables is further allocated between goods produced in the two countries according to a CES bundle with elasticity of substitution $\epsilon > 0$

$$C_{Tt} = \left[\omega^{\frac{1}{\epsilon}} C_{Ht}^{\frac{\epsilon-1}{\epsilon}} + (1-\omega)^{\frac{1}{\epsilon}} C_{Ft}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \tag{18}$$

where $\omega \in (0,1)$ is the share of Home tradables. We assume that the law of one price holds for internationally traded goods

$$P_{Ht} = P_{Ht}^{*} \tag{19}$$

$$P_{Ft}^{*} = P_{Ft} \tag{20}$$

The expenditure minimization problem is

$$P_{Tt} C_{Tt} \equiv \min_{C_{Ht}, C_{Ft}} P_{Ht} C_{Ht} + P_{Ft} C_{Ft} \tag{21}$$

subject to (18). The first order conditions for this problem yield the standard demand functions for domestic and foreign traded goods

$$C_{Ht} = \omega \left(\frac{P_{Ht}}{P_{Tt}}\right)^{-\epsilon} C_{Tt} \tag{22}$$

$$C_{Ft} = (1-\omega) \left(\frac{P_{Ft}}{P_{Tt}}\right)^{-\epsilon} C_{Tt} \tag{23}$$

The zero profit condition implies that the price index for traded goods is

$$P_{Tt} = \left[\omega P_{Ht}^{1-\epsilon} + (1-\omega) P_{Ft}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{24}$$

Conditional on the allocation between tradable and non-tradable goods, and between Home and Foreign-produced tradables, the problem of country H representative household is

$$\max_{C_{t+s}, B_{t+s}, W_{kt+s}(i)} E_t \left\{ \sum_{s=0}^{\infty} \beta^s \varsigma_{t+s} \left[\frac{C_{t+s}^{1-\sigma}}{1-\sigma} - \int_0^1 \frac{L_{kt+s}(i)^{1+\nu}}{1+\nu} di \right] \right\} \tag{25}$$

subject to the demand for labor input (7) and the budget constraint

$$P_t C_t + \frac{B_t}{\psi_{Bt}} = (1+i_{t-1})B_{t-1} + \int_0^1 \left[W_{kt}(i) L_{kt}(i) - \frac{\kappa_w}{2} \left(\frac{W_{kt+s}(i)}{W_{kt-1}(i)} - 1 \right)^2 P_{kt} Y_{kt} \right] di + \mathcal{P}_t \quad (26)$$

where $\mathcal{P}_t$ indicates profits from intermediate goods producers. The variable ς_t is a preference shock that makes agents more or less impatient. In reduced form, positive preference shocks (an increase in the desire to save) capture disruptions in financial markets that may force the monetary authority to lower the nominal interest rate to zero. As in Erceg, Guerrieri and Gust (2006), the intermediation cost ψ_{Bt} ensures stationarity of the net foreign asset position

$$\psi_{Bt} \equiv \exp\left[-\psi_B \left(\frac{B_t}{P_t Y_t} \right) \right] \quad (27)$$

where $\psi_B > 0$ and $P_t Y_t$ corresponds to nominal GDP

$$P_t Y_t \equiv P_{Ht} \widetilde{Y}_{Ht} + P_{Nt} \widetilde{Y}_{Nt}, \quad (28)$$

and where $\widetilde{Y}_{Ht}$ and $\widetilde{Y}_{Nt}$ are measures of output net of price and wage adjustment costs. Only domestic households pay the transaction cost while foreign households collect the associated fees. Moreover, while we assume that the intermediation cost is a function of the net foreign asset position, domestic households do not internalize this dependency.[4]

The consumption-saving optimality conditions yield

$$1 = \beta \psi_{Bt} (1+i_t) E_t \left[\frac{\varsigma_{t+1}}{\varsigma_t} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+1}} \right] \quad (29)$$

From expression (29), the stochastic discount factor for nominal assets is

$$Q_{t,t+s} = \beta^s \frac{\varsigma_{t+s}}{\varsigma_t} \left(\frac{C_{t+s}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+s}} \quad (30)$$

while the discount factor for real assets is $\widetilde{Q}_{t,t+s} \equiv Q_{t,t+s} \Pi_{t+s}$.

Finally, after substituting the labor demand equation (7) into the objective and the con-

[4] We use the intermediation cost only to ensure stationarity of the net foreign asset position. We set the parameter ψ_B small enough as to have no discernible effects on the transition dynamics.

straint, the first order condition for wage setting is

$$\phi_{wt} L_{kt}(i)^{1+\nu} \frac{1}{W_{kt}(i)} + (1-\phi_{wt}) \frac{\varsigma_t C_t^{-\sigma}}{P_t} L_{kt}(i) - \kappa_w \varsigma_t C_t^{-\sigma} \left(\frac{W_{kt}(i)}{W_{kt-1}(i)} - 1 \right) \frac{1}{W_{kt-1}(i)} \frac{P_{kt} Y_{kt}}{P_t} \\ + \kappa_w \beta E_t \left[\varsigma_{t+1} C_{t+1}^{-\sigma} \left(\frac{W_{kt+1}(i)}{W_{kt}(i)} - 1 \right) \frac{W_{kt+1}(i)}{W_{kt}(i)^2} \frac{P_{kt+1} Y_{kt+1}}{P_{t+1}} \right] = 0 \quad (31)$$

In a symmetric equilibrium, $W_{kt}(i) = W_{kt}, \forall i$, which implies that $L_{kt}(i) = L_{kt}/\gamma_k$. Therefore, the last expression simplifies to a forward-looking wage Phillips curve

$$\kappa_w \gamma_k \left(\Pi_{kt}^w - 1 \right) \Pi_{kt}^w \frac{P_{kt} Y_{kt}}{P_t L_{kt}} = (\phi_{wt} - 1) \left[\frac{\phi_{wt}}{\phi_{wt} - 1} \frac{(L_{kt}/\gamma_k)^\nu}{\varsigma_t C_t^{-\sigma}} - \frac{W_{kt}}{P_t} \right] \\ + \kappa_w \gamma_k \beta E_t \left[\widetilde{Q}_{t,t+1} \frac{P_{kt+1} Y_{kt+1}}{P_{t+1} L_{kt+1}} \frac{L_{kt+1}}{L_{kt}} \left(\Pi_{kt+1}^w - 1 \right) \Pi_{kt+1}^w \right] \quad (32)$$

where we used the definition of $\widetilde{Q}_{t,t+s}$. In case of no wage adjustment cost (i.e., for $\kappa_w = 0$), the wage Phillips curve boils down to the familiar optimality condition for labor supply in case of monopolistic competition

$$\frac{W_{kt}}{P_t} = \frac{\phi_{wt}}{\phi_{wt} - 1} \frac{(L_{kt}/\gamma_k)^\nu}{\varsigma_t C_t^{-\sigma}},$$

that is, the real wage is a markup over the marginal rate of substitution between labor and leisure.

2.5 Monetary Policy

We define the union-wide price index P_t^{MU} as an equally-weighted geometric average of the consumer price indexes in the two countries[5]

$$P_t^{MU} \equiv (P_t)^{0.5} (P_t^*)^{0.5} \quad (33)$$

The inflation rate of the union-wide price index (33) is

$$\Pi_t^{MU} = (\Pi_t)^{0.5} (\Pi_t^*)^{0.5}. \quad (34)$$

In the same spirit, using (28) and its foreign counterpart, we construct a union-wide level of

[5] This definition is the model-equivalent of the Harmonized Index of Consumer Prices (HICP), the measure of consumer prices published by Eurostat.

output as

$$Y_t^{MU} \equiv (Y_t)^{0.5}(Y_t^*)^{0.5}. \tag{35}$$

We assume that a single central bank conducts monetary policy for the entire union following a simple interest rate feedback rule of the form

$$1 + i_t = \max\left\{1, (1+i_{t-1})^{\rho}\left[(1+i)\left(\frac{\Pi_t^{MU}}{\overline{\Pi}^{MU}}\right)^{\phi_\pi}\left(\frac{Y_t^{MU}}{\overline{Y}_t^{MU}}\right)^{\phi_y}\right]^{1-\rho} e^{\varepsilon_{it}}\right\},$$

where $\rho \in (0,1)$ is the interest-smoothing parameter, $\phi_\pi > 1$ is the feedback coefficient on inflation, $\phi_y > 0$ is the feedback coefficient on real activity, $\overline{\Pi}^{MU}$ is the inflation target, $\overline{Y}_t^{MU}$ is the target level for output, and ε_{it} is a monetary policy shock.

2.6 Equilibrium

An imperfect competitive equilibrium for this economy is a sequence of quantities and prices such that the optimality conditions for households and firms in the two countries hold and all markets clear. Appendix A reports a detailed list of equilibrium conditions. Here we note that goods market clearing in the tradable and non-tradable sectors satisfies

$$\begin{aligned}
C_{Ht} + C_{Ht}^* &= \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Ht} - 1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Ht}^w - 1\right)^2\right] Y_{Ht}, & (36)\\
C_{Ft} + C_{Ft}^* &= \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Ft} - 1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Ft}^w - 1\right)^2\right] Y_{Ft}^*, & (37)\\
C_{Nt} &= \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Nt} - 1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Nt}^w - 1\right)^2\right] Y_{Nt}, & (38)\\
C_{Nt}^* &= \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Nt}^* - 1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Nt}^{*w} - 1\right)^2\right] Y_{Nt}^*. & (39)
\end{aligned}$$

Net foreign assets evolve according to

$$\frac{B_t}{\psi_{Bt}} = (1 + i_t)\, B_{t-1} + P_{Ht}C_{Ht}^* - P_{Ft}C_{Ft}. \tag{40}$$

Finally, asset market clearing requires

$$B_t + B_t^* = 0. \tag{41}$$

2.7 Calibration

Most parameters are standard in the literature. The calibration for the consumption bundles follows closely Obstfeld and Rogoff (2006). The degree of home bias α is set equal to 0.75 and the steady state share of tradable goods in total consumption γ is 0.25. The elasticity of substitution between traded and nontraded goods, instead is 0.75 (see also Stockman and Tesar (1995)) and the elasticity of substitution between home and foreign traded goods is 1.5 as in Backus et al. (1994). The discount factor β equals 0.99, implying an annualized real interest rate of about 4 percent. Preferences are logarithmic in consumption (i.e. $\sigma = 1$) and the inverse Frisch elasticity ν is equal to one.

The response of the nominal interest rate to inflation ϕ_π is 3 and the smoothing parameter is 0.7, as in Galí and Gertler (2007).[6] Following Ascari (2011), we parameterize the price adjustment cost so that the corresponding slope of the Phillips curve has an implied Calvo probability of price adjustment equal to 0.25 per quarter. The wage adjustment cost is set to this same level.

Table 1. Calibration

Firms	$\kappa_p = 144$ (*)	
Households	$\beta = 0.99$	$\varphi = 1$
	$\sigma = 1$	$\epsilon = 0.75$
	$\nu = 1$	$\omega = 0.75$
	$\gamma = 0.25$	$\kappa_w = 144$
Monetary Policy	$\rho = 0.7$	
	$\phi_\Pi = 1.5$	
	$\overline{\Pi} = 0.0$	

(*) Implied average frequecy of price adjustment is 1 year.

[6]The inflation coefficient in the policy rule is somewhat higher than the value estimated in Taylor (1993). We use this value for two reasons. First, this parameter, together with the price adjustment cost, determines the relative response of output and prices to shocks. Second, several central banks, including the ECB, have single mandates to target price stability, with secondary role assigned to output stabilization.

2.7.1 Price Markups

We set the initial levels of price markups in the home and foreign country following estimates produced by the OECD (2005) for peripheral and core EMU. We consider the manufacturing sector as a proxy for tradable sector in the model and the service sector as a proxy for the nontradable sector. For comparison, we report estimates for the U.S. as well.

The OECD estimates show a some interesting patterns. First, perhaps not suprisingly, markups are higher in European countries than in the U.S. In this paper, we assume that such differences reflect to a large extent the presence of regulations and other restrictions under control of policy makers. Second, this difference is mainly accounted for by higher markups in the service sector, whereas markups in the manufacturing sector are similar across regions in Europe and between Europe and the U.S. Third, markups in peripheral Europe are much higher than in the core Europe. This supports that view that peripheral European countries could greatly benefit from the implementation of liberalization measures in the product market, consistent with the evidence presented in Figure 3.

Table 2. OECD [2005]: Markup Estimates by Sector

	Periphery (H)	Core (F)	U.S.
Total Private Firms	1.36	1.25	1.19
Services	1.48	1.33	1.23
Manufacturing	1.17	1.14	1.14

Periphery: Greece, Ireland, Italy, Portugal, and Spain

Core: Austria, Belgium, Finland, France, Germany, and The Netherlands

Table 3 presents the corresponding values for the price elasticity (θ_k) adopted in the initial steady state.

Table 3. Price Elasticity Across Sectors (θ_k)

	Periphery (H)	Core (F)
Tradable	7.67	7.67
Non-Tradable	3.08	4.03

2.7.2 Wage Markups

Estimates for markups in the labor market are more difficult to obtain. Laxton, Bayoumi, and Pesenti (2004) use the cross-sectional variation in wage data to argue that wages are relatively higher in peripheral countries because of higher markups in the service sector. Their point estimates are in line with the figures presented in Table 3.

[This section yet to be completed. Current experiments reflect symmatry with price markups]. In this paper, we use the steady state of the model to make inference about these markups as follows. From the labor demand equation and the labor supply (wage Phillips curve) equation we can substitute for the real wage in each sector and obtain that, in steady state, the following labor market equilibrium condition holds

$$(1-\alpha)MC_k\frac{Y_k}{L_k} = \frac{\phi_k}{\phi_k - 1}\frac{(L_k/\gamma_k)^\nu}{C^{-\sigma}} \tag{42}$$

We eliminate the real marginal cost from the previous expression using the steady state pricing condition in sector k to obtain

$$\frac{\phi_k}{\phi_k - 1} = A\frac{\theta_k - 1}{\theta_k}\frac{p_k}{p}\frac{Y_k}{L_k}\frac{(L_k/\gamma_k)^\nu}{C^{-\sigma}} \tag{43}$$

We can then evaluate this expression using sectoral data on output and labor input (which we obtain from the EU-KLEMS database) together with aggregate consumption from the National Accounts. The parameters ν and σ come from our calibration. The parameter A includes the term $(1-\alpha)$ to take into account capital in the production function ($\alpha = 0$ in the current setup) and taxes $(1-\tau)$,which is another wedge entering the static FOC. For θ_k

we use the values presented in the previous section.[7] We then and use data on labor input to construct the size of each sector

$$\gamma_k = \frac{\text{Employment in sector } k}{\text{Total employment}}. \tag{44}$$

and construct time-series for wage-markup estimates for periphery and core.

3 The Effects of Structural Reforms

3.1 Long-Run Effects of Reforms

We begin our analysis by quantifying the long-run effects of structural reforms on the main macroeconomic variables. The experiment is setup as follows. In the first period, policymakers credibly announce reforms which result in a 10 percent permanent reduction of price and wage markups in the nontradable sector, thus bringing markups in the periphery to the same level as in the core. Reforms are announced in the first period, but they are then completed over three years to reflect implementation lags typically associated with the political bargaining and the legislative process. We first study the effects of product and labor liberalization separately, and then combine both reforms. In our analysis, we always consider a perfect foresight solution whereby agents at time zero find out the sequence of all exogenous variables at each point in time.

Table 4 presents the long-run effects of structural reforms on the level of output and international prices. Over the course of 5 years, a 10 percent reduction in both price and wage markups increases output (consumption and labor input) by 6.6 percent. Reforms involve a significant increase in notradable output (not shown) and a decrease in the price of nontradables relative to tradables. Thus, the real exchange rate depreciates by 8 percent, whereas the depreciation in the terms of trade is minimal.

[7] In an extension of the current model, we explicitly model capital accumulation.

Table 4. Long-Run Effects of Structural Reforms (5 Years)

Variables	Y	RER	TOT
Full liberalization $\theta_N = \theta_N^* = 11$ $\phi_N = \phi_N^* = 11$	+6.6%	+8.1%	+0.5%
Goods mkt liberalization $\theta_N = \theta_N^* = 11$ $\phi_N = 6.5$; $\phi_N^* = 11$	+3.3	+4.1	+0.25%
Labor mkt liberalization $\theta_N = 6.5$; $\theta_N^* = 11$ $\phi_N = \phi_N^* = 11$	+3.3	+4.0	+0.25%

In our benchmark, the effects of product and labor market reforms are symmetric, as shown in the bottom section of Table 4. However, preliminary results (not shown, but available upon request) suggest that this result depends critically to the presence of capital in the production function. When capital and investment are explicitly considered, the distortions created by monopoly power in the product market depresses capital accumulation, resulting in higher long-run output losses and consumer prices. In this environment, product market reforms provide a larger boost to output and larger deflation.

3.2 Short-Run Transmission: Benchmark Case

Figure 4 and Figure 5 present the response of the economy to reforms. The dynamic response of each variable is presented in percentage deviation from the (initial) steady state.

[Insert Figure 4 and 5 here]

On impact, reforms generate a boom in output across the monetary union, with both home and foreign output increasing about 3 percent in impact. This increase is permanent in the periphery but temporary in the foreign country, where markups remain unchanged. The responses of consumption follow closely output, with the difference accounted for by the temporary increase in the home country trade balance (panel 3 in Figure 5).

The bottom panels of Figure 4 present the response of inflation and policy rates. Lower markups in the home country nontradable sector result in a large decline in domestic prices. Prices in the foreign country, however, increase, due to the interaction of two forces. First, households in the home country increase consumption of all manufacturinf goods, both domestic and foreign. Thus, structural reforms in the homne country represent a positive demand shock for the foreign country. Second, consumption in the foreign country increases, as the worldwide amount of resources is expected to increase. Since the technology to produce the foreign goods has not changed, these increases in demand are associated with an increase in foreign prices, contributing to an appreciation of foreign terms of trade and real exchange rate (panel 4 of Figure 4). Inflation in the monetary union edges up in the first few quarters, triggering an increase in policy rates.

3.3 Structural Reforms when the ZLB is binding

In this section, we investigate whether the effects of structural reforms are amplified or diminuished by the presence of the ZLB. The motivation for this analysis is twofold. First, four years after the 2008-09 global financial crisis, monetary policy in many countries is still at the ZLB. This constraint may be even more relevant for the countries in the euro area, as exchange rate policies cannot be used to regain competitiveness and support output. Second, a large literature documents that the transmission of shocks in the presence of the ZLB can be qualitatively and quantitatively very different than under normal circumstances. For instance, Erceg and Linde' (2012) find that tax-based fiscal consolidations may be associated with lower short-run output losses than expediture-based fiscal consolidations, in contrast to what has been suggested in the literature (see, for instance, Alesina et al (2012)). Similarly, Eggertsson (2011) finds that policies that increased monopoly power of firms and union helped the U.S. recovery during the Great Depression, contrary to the conventional wisdom that these policies slowed the recovery (see, for instance, Cole and Ohanian (2004)). In Eggertsson (2011), the presence of the ZLB represents a key element to overturn the standard transmission of higher regulations and markups.

Motivated by these theoretical results, we next study the effects of structural reforms in a currency union when monetary policy is constrained by the ZLB. Figure 6 presents our implementation of the ZLB constraint. As typically done in the literature, we assume that an aggregate (preference) shock takes the economy to the ZLB. In our calibration, the economy contracts more than 15 percent and experiences a deep and prolonged deflation. Monetary policy remains at the ZLB for about two years.

[Insert Figure 6 and 7 here]

In this environment, we then study the response of the economy to structural reforms considered before. Specifically, we assume that the government in the home country implements reforms that permanently reduce price and wage markups by 10 percent. Figure 7 presents the effects of these reforms when the ZLB constraint binds. Structural reforms have the same long-run effects on output and other variables, independently of the prensece of the ZLB constraint. This is not surprising, since the economy eventually recovers from the crisis and slowly converges to the new steady state. However, in the short run, the ZLB creates a trade-off between inflation and output stabilization. Although the home country rebounds more quickly than in the case without reforms, the crisis is now associated with higher deflationary pressures. The large gap between output (that is, labor) and consumption suggests that a lot of resources are allocated to change prices whereas inflation takes longer to return to its long-run value. Thus, policy rates take longer to normalize than in the case without reforms. The emergence of this tradeoff is very close to the perverse effects studied in Eggertsson (2011), with some qualifications. In particular, in our model the response of output in home country is not very different from the the benchmark case, at least qualitatively.

Having established this interesting result, we next study the effects of a reduction in the price markup alone when the economy is at the ZLB. The literature seems to suggest that in implementing structural reforms governments should begin by liberalizing the product market first. These reforms, the argument goes, are likely to be more beneficial as they are associated with an increase in real wages and employment, and may make subsequent labor market reforms easier to be implemented (see, for instance, Blanchard and Giavazzi (2004)).

[Insert Figure 8]

As shown in Figure 8, we find that product market reforms are associated with a deeper deflation in the short-run, resulting in a even slower normalization of policy rates. The intuition for this result is quite straightforward. These reforms reduce the price markup charged by firms, thus resulting in higher competition and lower prices. In an environment where the ZLB is binding, however, monetary policy would like to engineer inflation to stimulate production, while reforms amplify deflationary dynamics. All told, these results support the view that labor market reforms should receive more attention than product market reforms when monetary policy is at ZLB.

4 Credibility of Reforms and the ZLB

TBA

5 Conclusions

TBA

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A Equilibrium Conditions

In this section, we list the equilibrium conditions, expressing all prices relative to the union-wide price index P_t^{MU} in lower case letters (for example, $p_{Ht} \equiv P_{Ht}/P_t^{MU}$).

- Demand for Home and Foreign tradable goods:

$$C_{Ht} = \omega \left(\frac{p_{Ht}}{p_{Tt}}\right)^{-\epsilon} C_{Tt}, \qquad C_{Ft} = (1-\omega)\left(\frac{p_{Ft}}{p_{Tt}}\right)^{-\epsilon} C_{Tt}. \tag{45}$$

$$C_{Ft}^* = \omega \left(\frac{p_{Ft}}{p_{Tt}^*}\right)^{-\epsilon} C_{Tt}^*, \qquad C_{Ht}^* = (1-\omega)\left(\frac{p_{Ht}}{p_{Tt}^*}\right)^{-\epsilon} C_{Tt}^*. \tag{46}$$

- Demand for tradable consumption bundles:

$$C_{Tt} = \gamma \left(\frac{p_{Tt}}{p_t}\right)^{-\varphi} C_t, \qquad C_{Tt}^* = \gamma \left(\frac{p_{Tt}^*}{p_t^*}\right)^{-\varphi} C_t^*. \tag{47}$$

- Demand for non-tradable goods:

$$C_{Nt} = (1-\gamma) \left(\frac{p_{Nt}}{p_t}\right)^{-\varphi} C_t, \qquad C_{Nt}^* = (1-\gamma) \left(\frac{p_{Nt}^*}{p_t^*}\right)^{-\varphi} C_t^*. \tag{48}$$

- Resource constraint for Home and Foreign tradable goods:

$$C_{Ht} + C_{Ht}^* = \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Ht}-1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Ht}^w - 1\right)^2\right] Y_{Ht}, \tag{49}$$

$$C_{Ft} + C_{Ft}^* = \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Ft}-1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Ft}^w - 1\right)^2\right] Y_{Ft}^*. \tag{50}$$

- Resource constraint for non-tradable goods:

$$C_{Nt} = \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Nt}-1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Nt}^w - 1\right)^2\right] Y_{Nt}, \tag{51}$$

$$C_{Nt}^* = \left[1 - \frac{\kappa_p}{2}\left(\Pi_{Nt}^*-1\right)^2 - \frac{\kappa_w}{2}\left(\Pi_{Nt}^{*w} - 1\right)^2\right] Y_{Nt}^*. \tag{52}$$

- Marginal costs (denote real wages as $w_{kt} \equiv W_{kt}/P_t^{MU}$)

$$MC_{Ht} = \frac{1}{Z_{Ht}}\frac{w_{Ht}}{p_t}, \qquad MC_{Nt} = \frac{1}{Z_{Nt}}\frac{w_{Nt}}{p_t}. \tag{53}$$

$$MC_{Ft}^* = \frac{1}{Z_{Ft}^*}\frac{w_{Ft}^*}{p_t^*}, \qquad MC_{Nt}^* = \frac{1}{Z_{Nt}^*}\frac{w_{Nt}^*}{p_t^*}. \tag{54}$$

- Production functions:

$$Y_{Ht} = Z_{Ht} L_{Ht}, \qquad Y_{Nt} = Z_{Nt} L_{Nt}. \tag{55}$$

$$Y^*_{Ft} = Z^*_{Ft} L^*_{Ft}, \qquad Y^*_{Nt} = Z^*_{Nt} L^*_{Nt}. \tag{56}$$

- Price Phillips curves:

$$\begin{aligned}\kappa_p \gamma \left(\Pi_{Ht} - 1\right) \Pi_{Ht} \frac{p_{Ht}}{p_t} &= \left(\theta_{Ht} - 1\right) \left(\frac{\theta_{Ht}}{\theta_{Ht} - 1} MC_{Ht} - \frac{p_{Ht}}{p_t}\right) \\ &+ \beta \kappa_p \gamma E_t \left[\frac{\varsigma_{t+1}}{\varsigma_t} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{p_{Ht+1}}{p_{t+1}} \frac{Y_{Ht+1}}{Y_{Ht}} \left(\Pi_{Ht+1} - 1\right) \Pi_{Ht+1}\right].\end{aligned} \tag{57}$$

$$\begin{aligned}\kappa_p (1-\gamma) \left(\Pi_{Nt} - 1\right) \Pi_{Nt} \frac{p_{Nt}}{p_t} &= \left(\theta_{Nt} - 1\right) \left(\frac{\theta_{Nt}}{\theta_{Nt} - 1} MC_{Nt} - \frac{p_{Nt}}{p_t}\right) \\ &+ \beta \kappa_p (1-\gamma) E_t \left[\frac{\varsigma_{t+1}}{\varsigma_t} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{p_{Nt+1}}{p_{t+1}} \frac{Y_{Nt+1}}{Y_{Nt}} \left(\Pi_{Nt+1} - 1\right) \Pi_{Nt+1}\right].\end{aligned} \tag{58}$$

$$\begin{aligned}\kappa_p \gamma \left(\Pi^*_{Ft} - 1\right) \Pi^*_{Ft} \frac{p^*_{Ft}}{p^*_t} &= \left(\theta^*_{Ft} - 1\right) \left(\frac{\theta^*_{Ft}}{\theta^*_{Ft} - 1} MC^*_{Ft} - \frac{p^*_{Ft}}{p^*_t}\right) \\ &+ \beta \kappa_p \gamma E_t \left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t} \left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma} \frac{p^*_{Ft+1}}{p^*_{t+1}} \frac{Y^*_{Ft+1}}{Y^*_{Ft}} \left(\Pi^*_{Ft+1} - 1\right) \Pi^*_{Ft+1}\right].\end{aligned} \tag{59}$$

$$\begin{aligned}\kappa_p (1-\gamma) \left(\Pi^*_{Nt} - 1\right) \Pi^*_{Nt} \frac{p^*_{Nt}}{p^*_t} &= \left(\theta^*_{Nt} - 1\right) \left(\frac{\theta^*_{Nt}}{\theta^*_{Nt} - 1} MC^*_{Nt} - \frac{p^*_{Nt}}{p^*_t}\right) \\ &+ \beta \kappa_p (1-\gamma) E_t \left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t} \left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma} \frac{p^*_{Nt+1}}{p^*_{t+1}} \frac{Y^*_{Nt+1}}{Y^*_{Nt}} \left(\Pi^*_{Nt+1} - 1\right) \Pi^*_{Nt+1}\right].\end{aligned} \tag{60}$$

- Wage Phillips curves:

$$\begin{aligned}\kappa_w \gamma \left(\Pi^w_{Ht} - 1\right) \Pi^w_{Ht} \frac{p_{Ht} Y_{Ht}}{p_t L_{Ht}} &= \left(\phi_{wt} - 1\right) \left[\frac{\phi_{wt}}{\phi_{wt} - 1} \frac{(L_{Ht}/\gamma)^{\nu}}{C_t^{-\sigma}} - \frac{w_{Ht}}{p_t}\right] \\ &+ \kappa_w \gamma \beta E_t \left[\frac{\varsigma_{t+1}}{\varsigma_t} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{p_{Ht+1} Y_{Ht+1}}{p_{t+1} L_{Ht+1}} \frac{L_{Ht+1}}{L_{Ht}} \left(\Pi^w_{Ht+1} - 1\right) \Pi^w_{Ht+1}\right].\end{aligned} \tag{61}$$

$$\kappa_w(1-\gamma)\left(\Pi^w_{Nt}-1\right)\Pi^w_{Nt}\frac{p_{Nt}Y_{Nt}}{p_t L_{Nt}} = (\phi_{wt}-1)\left[\frac{\phi_{wt}}{\phi_{wt}-1}\frac{(L_{Nt}/(1-\gamma))^{\nu}}{C_t^{-\sigma}} - \frac{w_{Nt}}{p_t}\right]$$
$$+\kappa_w(1-\gamma)\beta E_t\left[\frac{\varsigma_{t+1}}{\varsigma_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{p_{Nt+1}Y_{Nt+1}}{p_{t+1}L_{Nt+1}}\frac{L_{Nt+1}}{L_{Nt}}\left(\Pi^w_{Nt+1}-1\right)\Pi^w_{Nt+1}\right]. \quad (62)$$

$$\kappa_w\gamma\left(\Pi^{*w}_{Ft}-1\right)\Pi^{*w}_{Ft}\frac{p^*_{Ft}Y^*_{Ft}}{p^*_t L^*_{Ft}} = (\phi^*_{wt}-1)\left[\frac{\phi^*_{wt}}{\phi^*_{wt}-1}\frac{(L^*_{Ft}/\gamma)^{\nu}}{(C^*_t)^{-\sigma}} - \frac{w^*_{Ft}}{p^*_t}\right]$$
$$+\kappa_w\gamma\beta E_t\left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t}\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{p^*_{Ft+1}Y^*_{Ft+1}}{p^*_{t+1}L^*_{Ft+1}}\frac{L^*_{Ft+1}}{L^*_{Ft}}\left(\Pi^{*w}_{Ft+1}-1\right)\Pi^{*w}_{Ft+1}\right]. \quad (63)$$

$$\kappa_w(1-\gamma)\left(\Pi^{*w}_{Nt}-1\right)\Pi^{*w}_{Nt}\frac{p^*_{Nt}Y^*_{Nt}}{p^*_t L^*_{Nt}} = (\phi^*_{wt}-1)\left[\frac{\phi^*_{wt}}{\phi^*_{wt}-1}\frac{(L^*_{Nt}/(1-\gamma))^{\nu}}{(C^*_t)^{-\sigma}} - \frac{w^*_{Nt}}{p^*_t}\right]$$
$$+\kappa_w(1-\gamma)\beta E_t\left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t}\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{p^*_{Nt+1}Y^*_{Nt+1}}{p^*_{t+1}L^*_{Nt+1}}\frac{L^*_{Nt+1}}{L^*_{Nt}}\left(\Pi^{*w}_{Nt+1}-1\right)\Pi^{*w}_{Nt+1}\right]. \quad (64)$$

- Price index for tradable consumption bundles:

$$p_{Tt} = \left[\omega p_{Ht}^{1-\epsilon} + (1-\omega)p_{Ft}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \qquad p^*_{Tt} = \left[\omega p_{Ft}^{1-\epsilon} + (1-\omega)p_{Ht}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \quad (65)$$

- Consumer price index:

$$p_t = \left[\gamma p_{Tt}^{1-\varphi} + (1-\gamma)p_{Nt}^{1-\varphi}\right]^{\frac{1}{1-\varphi}}, \qquad p^*_t = \left[\gamma (p^*_{Tt})^{1-\varphi} + (1-\gamma)(p^*_{Nt})^{1-\varphi}\right]^{\frac{1}{1-\varphi}}. \quad (66)$$

- Euler equations for bonds:

$$1 = \beta\psi_{Bt}(1+i_t)E_t\left[\frac{\varsigma_{t+1}}{\varsigma_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\right], \quad (67)$$

$$1 = \beta(1+i_t)E_t\left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t}\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{1}{\Pi^*_{t+1}}\right], \quad (68)$$

$$\psi_{Bt} = \exp\left[-\psi_B\left(\frac{b_t}{p_t Y_t}\right)\right], \quad (69)$$

where $b_t \equiv B_t/P^{MU}_t$.

- Evolution of net foreign assets

$$\frac{b_t}{\psi_{Bt}} = \left(\frac{1+i_t}{\Pi_t^{MU}}\right) b_{t-1} + p_{Ht} C_{Ht}^{*} - p_{Ft} C_{Ft}, \tag{70}$$

$$b_t^{*} = \left(\frac{1+i_t}{\Pi_t^{MU}}\right) b_{t-1}^{*} + p_{Ft} C_{Ft} - p_{Ht} C_{Ht}^{*} + \left(\frac{1}{\psi_{Bt}} - 1\right) b_t, \tag{71}$$

where the last term in the evolution of net foreign assets for country F measures the profits from the financial intermediation activity in international asset transactions (note that by Walras' law this last equation is always satisfied).

- Asset market clearing:

$$b_t + b_t^{*} = 0. \tag{72}$$

- GDP

$$p_t Y_t = p_{Ht} Y_{Ht} + p_{Nt} Y_{Nt}, \tag{73}$$

$$p_t^{*} Y_t^{*} = p_{Ft}^{*} Y_{Ft}^{*} + p_{Nt}^{*} Y_{Nt}^{*}. \tag{74}$$

- Union-wide inflation:

$$\Pi_t^{MU} = (\Pi_t)^{0.5} (\Pi_t^{*})^{0.5}. \tag{75}$$

- Monetary policy rule:

$$1 + i_t = \max \left\{ 1, (1+i_{t-1})^{\rho} \left[(1+i) \left(\frac{\Pi_t^{MU}}{\overline{\Pi}^{MU}} \right)^{\phi_\pi} \left(\frac{Y_t^{MU}}{\overline{Y}_t^{MU}} \right)^{\phi_y} \right]^{1-\rho} e^{\varepsilon_{it}} \right\}. \tag{76}$$

A.1 Additional Variables of Interest

- Terms of trade:

$$TOT_{Ht} = \frac{p_{Ft}}{p_{Ht}}. \tag{77}$$

- Real exchange rate

$$RER_{Ht} = \frac{p_t^{*}}{p_t}. \tag{78}$$

- Net exports (in % of GDP)

$$NX_t = \frac{p_{Ht}C^*_{Ht} - p_{Ft}C_{Ft}}{Y_t}. \tag{79}$$

- Net exports (at constant prices, in % of GDP)

$$RNX_t = \frac{p_H C^*_{Ht} - p_F C_{Ft}}{Y_t}. \tag{80}$$

B Steady State

In this section, we list the equations that characterize a symmetric steady state equilibrium.

- Demand for Home and Foreign tradable goods:

$$C_H = \omega \left(\frac{p_H}{p_T}\right)^{-\epsilon} C_T, \qquad C_F = (1-\omega)\left(\frac{p_F}{p_T}\right)^{-\epsilon} C_T. \tag{81}$$

$$C^*_F = \omega \left(\frac{p_F}{p^*_T}\right)^{-\epsilon} C^*_T, \qquad C^*_H = (1-\omega)\left(\frac{p_H}{p^*_T}\right)^{-\epsilon} C^*_T. \tag{82}$$

- Demand for tradable consumption bundle:

$$C_T = \gamma \left(\frac{p_T}{p}\right)^{-\varphi} C \qquad C^*_T = \gamma \left(\frac{p^*_T}{p^*}\right)^{-\varphi} C^*. \tag{83}$$

- Demand for non-tradable goods:

$$C_N = (1-\gamma)\left(\frac{p_N}{p}\right)^{-\varphi} C, \qquad C^*_N = (1-\gamma)\left(\frac{p^*_N}{p^*}\right)^{-\varphi} C^*. \tag{84}$$

- Resource constraint for Home and Foreign tradable goods:

$$C_H + C^*_H = Y_H, \tag{85}$$

$$C_F + C^*_F = Y^*_F. \tag{86}$$

- Resource constraint for non-tradable goods:

$$C_N = Y_N, \tag{87}$$

$$C^*_N = Y^*_N. \tag{88}$$

- Marginal costs (denote real wages as $w_{kt} \equiv W_{kt}/P_t^{MU}$)

$$MC_H = \frac{1}{Z_H}\frac{w_H}{p} \qquad MC_N = \frac{1}{Z_N}\frac{w_N}{p} \tag{89}$$

$$MC_F^* = \frac{1}{Z_F^*}\frac{w_F^*}{p^*} \qquad MC_N^* = \frac{1}{Z_N^*}\frac{w_N^*}{p^*} \tag{90}$$

- Production functions:

$$Y_H = Z_H L_H, \qquad Y_N = Z_N L_N. \tag{91}$$

$$Y_F^* = Z_F^* L_F^*, \qquad Y_N^* = Z_N^* L_N^*. \tag{92}$$

- Price setting:

$$\frac{\theta_H}{\theta_H - 1} MC_H = \frac{p_H}{p} \qquad \frac{\theta_N}{\theta_N - 1} MC_N = \frac{p_N}{p} \tag{93}$$

$$\frac{\theta_F^*}{\theta_F^* - 1} MC_F^* = \frac{p_F^*}{p^*} \qquad \frac{\theta_N^*}{\theta_N^* - 1} MC_N^* = \frac{p_N^*}{p^*} \tag{94}$$

- Wage setting:

$$\frac{w_H}{p} = \frac{\phi_w}{\phi_w - 1}\frac{(L_H/\gamma)^\nu}{C^{-\sigma}} \qquad \frac{w_N}{p} = \frac{\phi_w}{\phi_w - 1}\frac{(L_N/(1-\gamma))^\nu}{C^{-\sigma}} \tag{95}$$

$$\frac{w_F^*}{p^*} = \frac{\phi_w^*}{\phi_w^* - 1}\frac{(L_F^*/\gamma)^\nu}{(C^*)^{-\sigma}} \qquad \frac{w_N^*}{p^*} = \frac{\phi_w^*}{\phi_w^* - 1}\frac{(L_N^*/(1-\gamma))^\nu}{(C^*)^{-\sigma}} \tag{96}$$

- Price index for tradable consumption bundles:

$$p_T = \left[\omega p_H^{1-\epsilon} + (1-\omega) p_F^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \qquad p_T^* = \left[\omega p_F^{1-\epsilon} + (1-\omega) p_H^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{97}$$

- Consumer price index:

$$p = \left[\gamma p_T^{1-\varphi} + (1-\gamma) p_N^{1-\varphi}\right]^{\frac{1}{1-\varphi}}, \qquad p^* = \left[\gamma (p_T^*)^{1-\varphi} + (1-\gamma)(p_N^*)^{1-\varphi}\right]^{\frac{1}{1-\varphi}}. \tag{98}$$

- Euler equations for bonds:

$$1 = \beta(1+i) \tag{99}$$

- Balanced trade:

$$p_H C_H^* = p_F C_F \tag{100}$$

- Relation between CPIs:

$$p = \frac{1}{p^*} \tag{101}$$

Figure 1. Current Account Balances

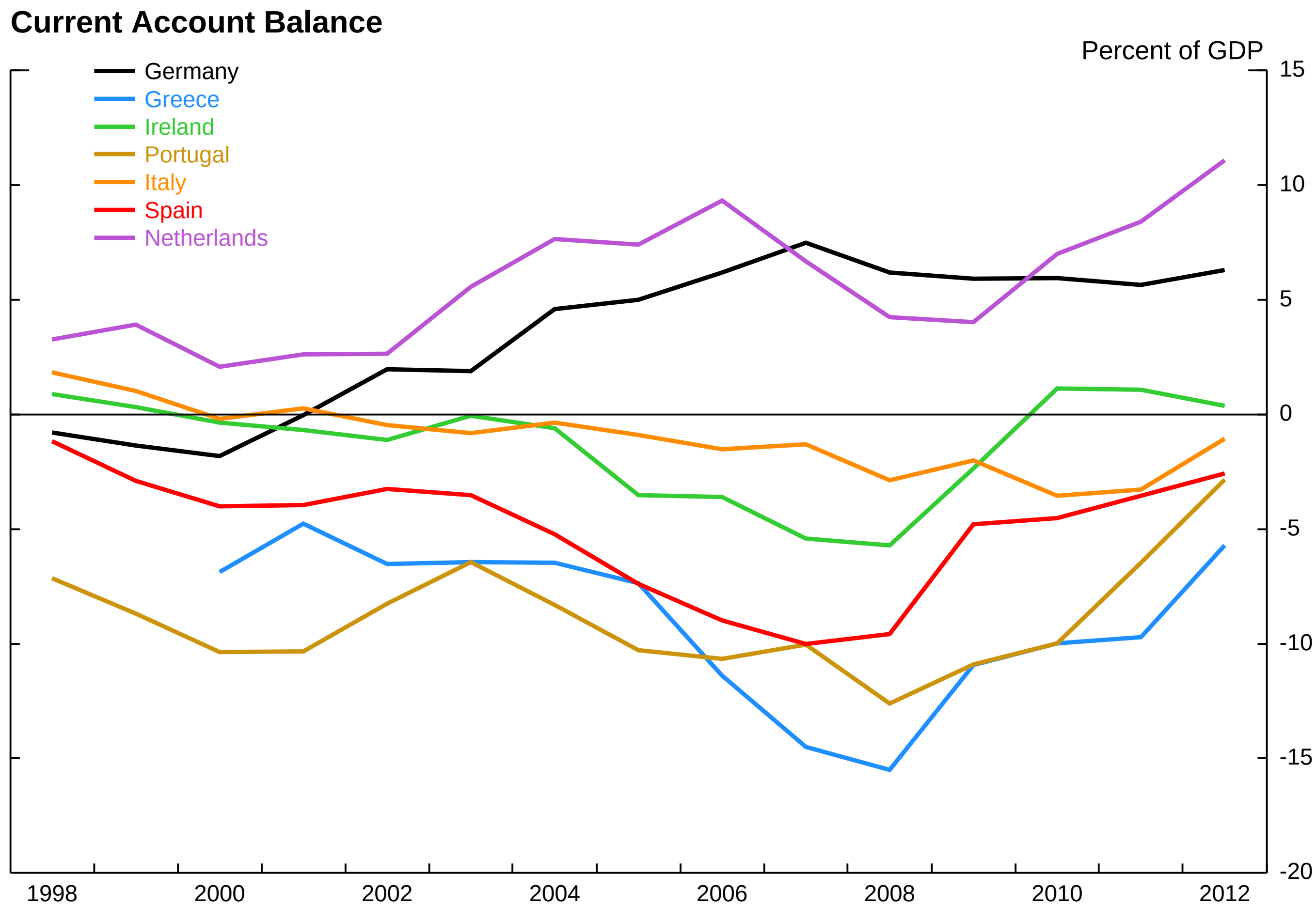


Figure 2. Real Exchange Rates

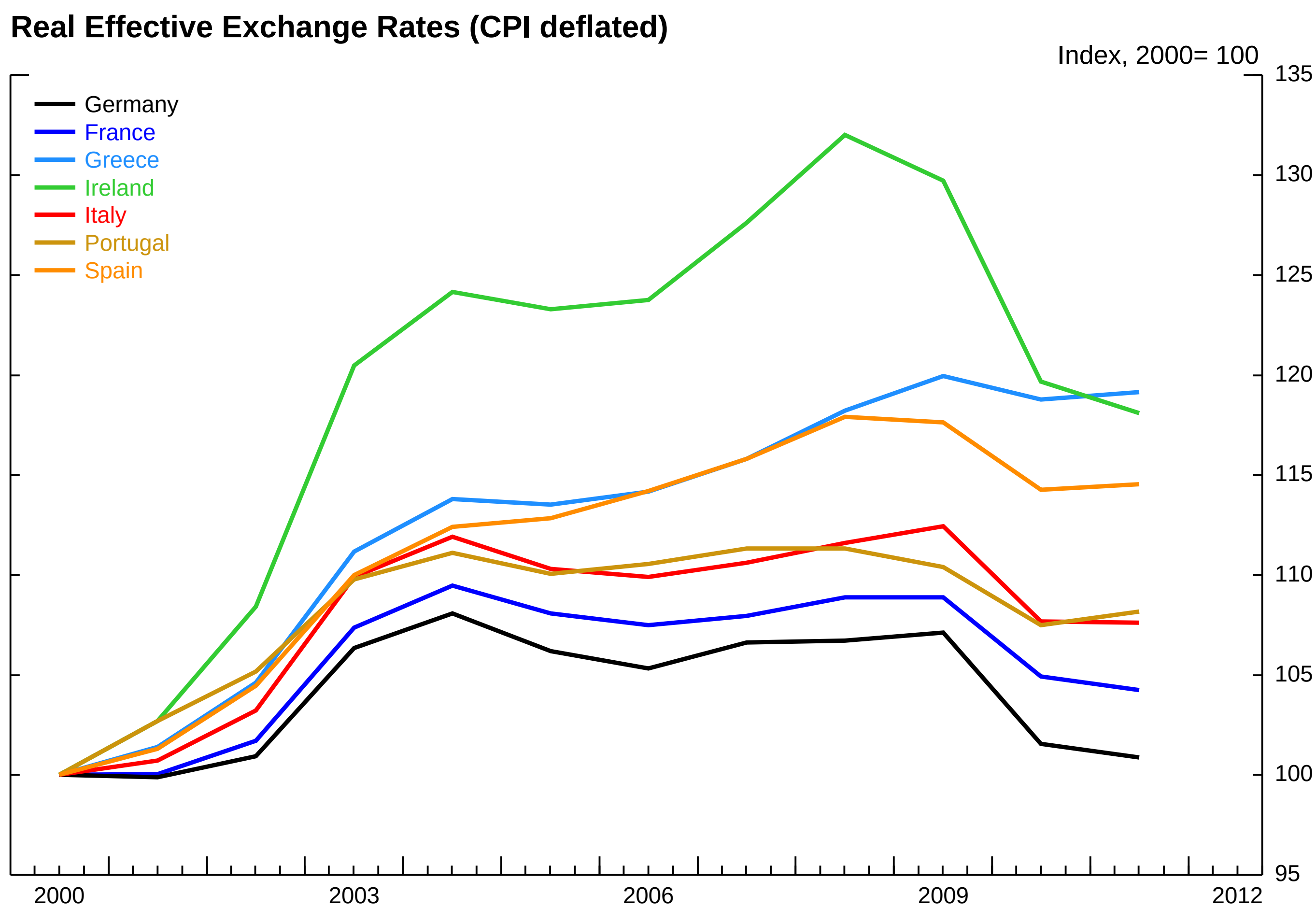
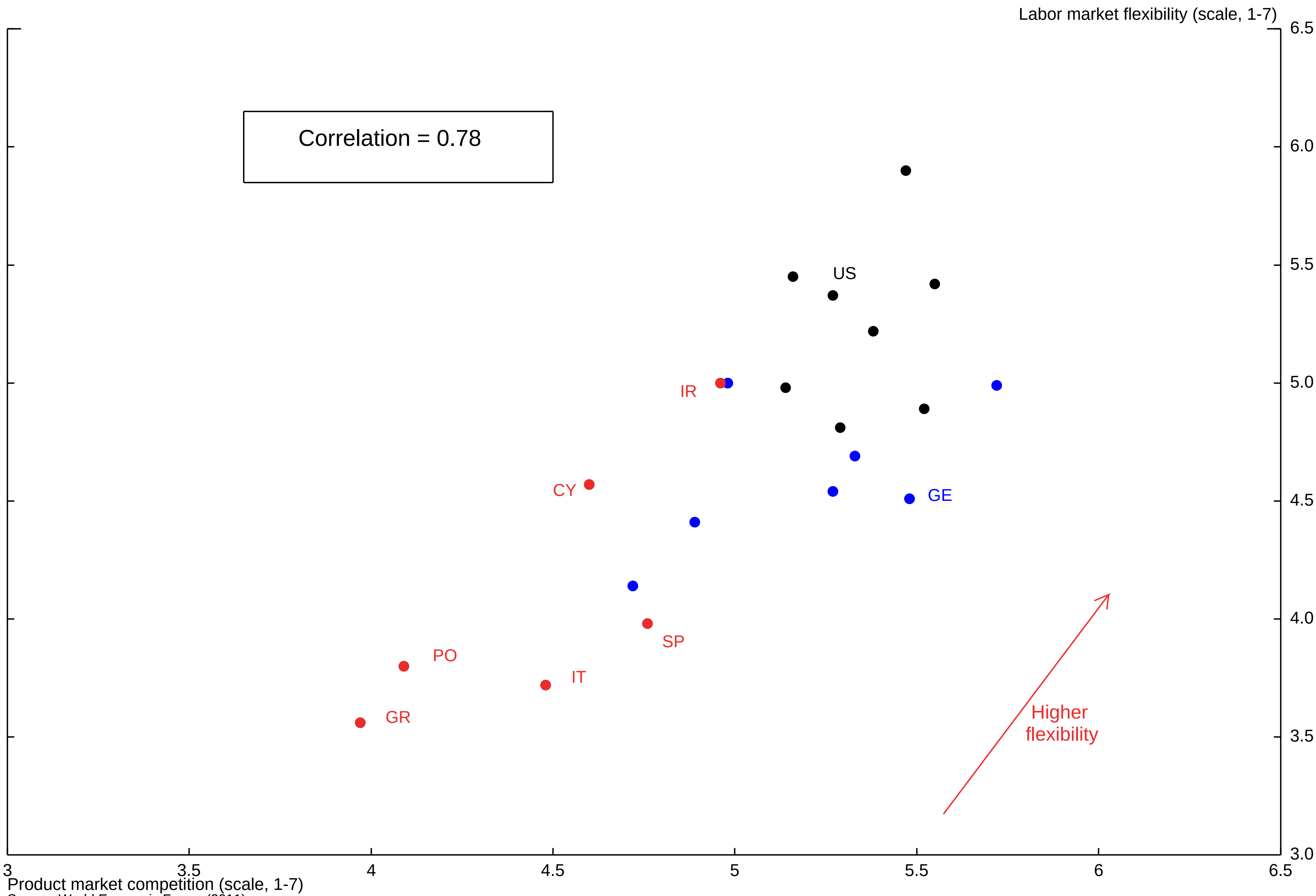


Figure 3. Product and Labor Market Flexibility



Source: World Economic Forum (2011).

Figure 4. Benchmark

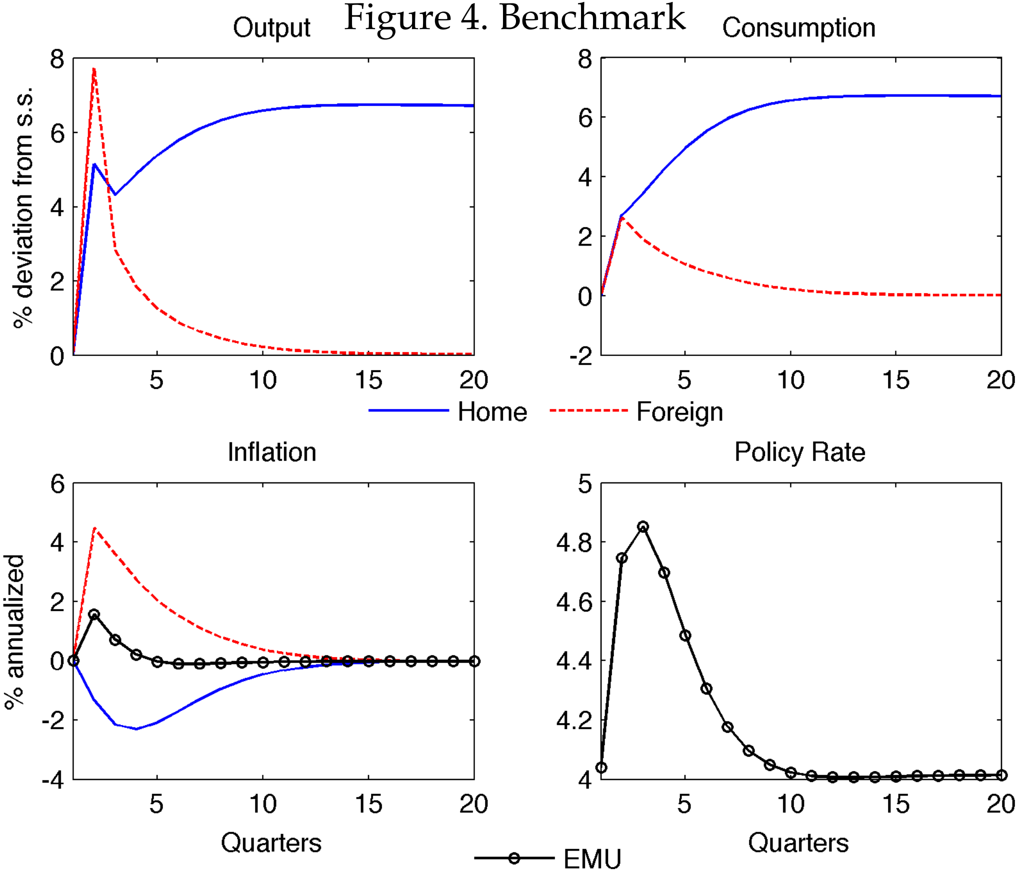


Figure 5. Benchmark (2)

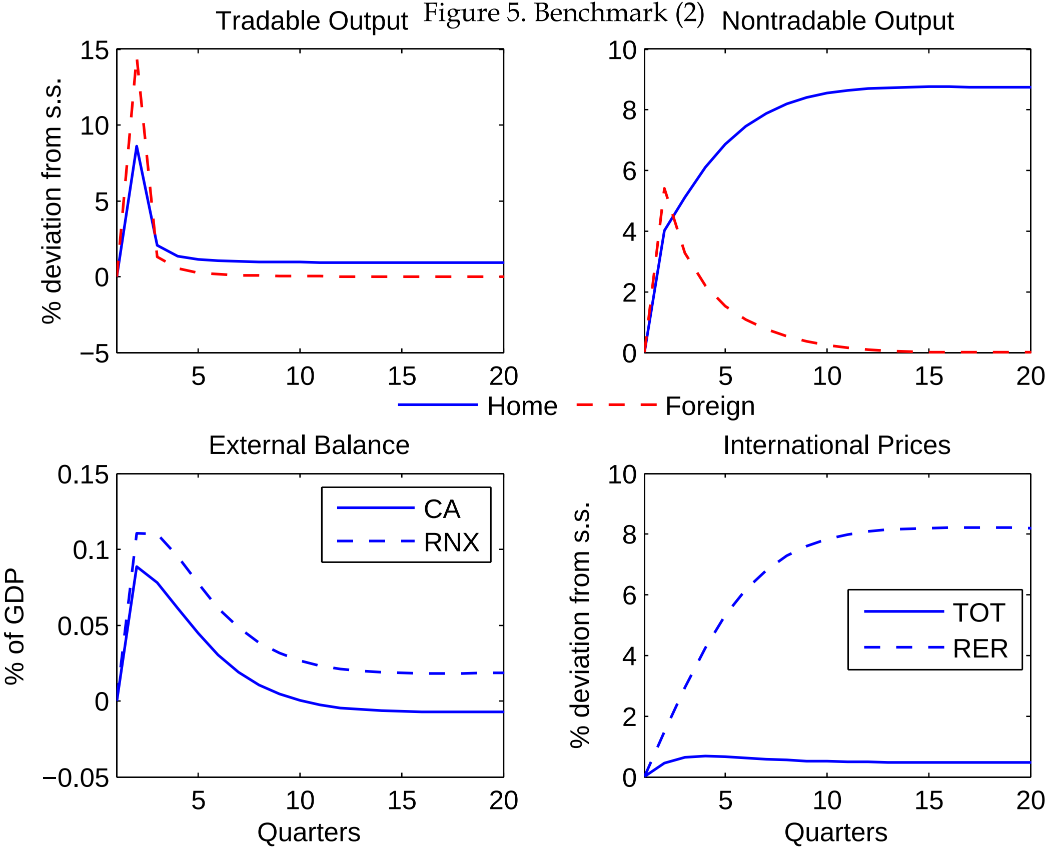


Figure 6. ZLB-Crisis

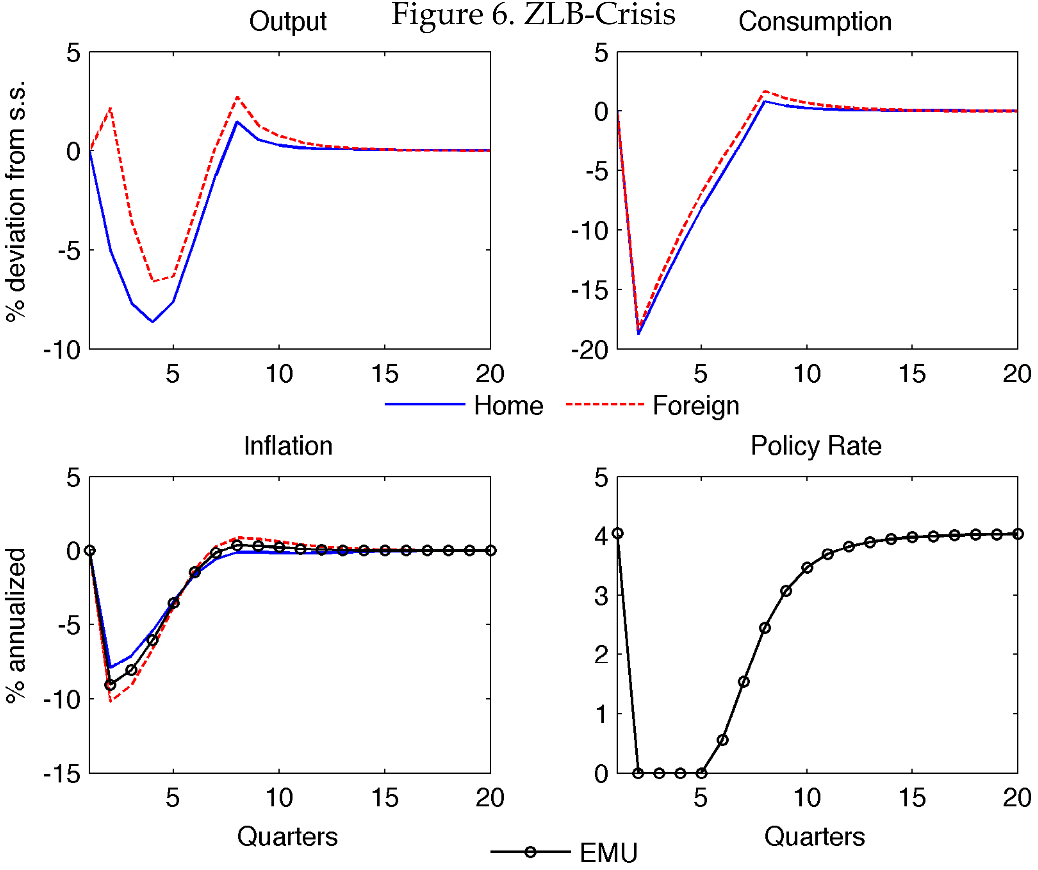


Figure 7. ZLB-Crisis and Reforms

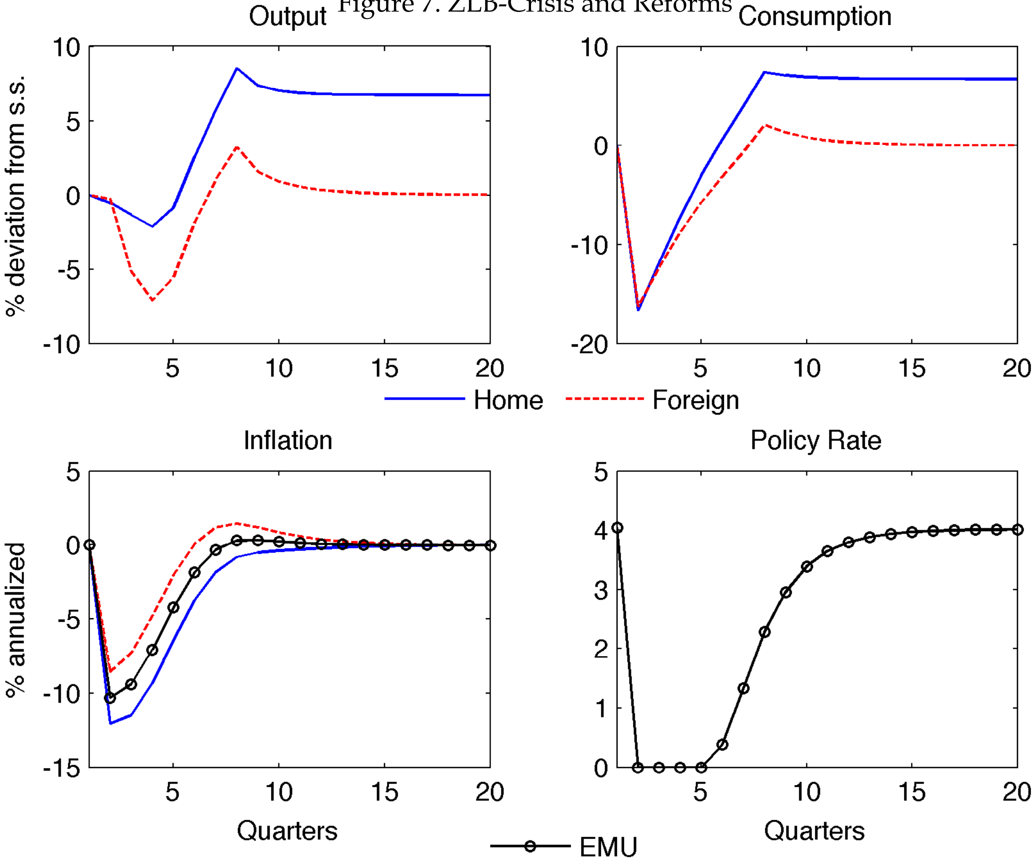


Figure 8. ZLB-Crisis and Product Reforms