Can Structural Reforms Help Europe?*

Gauti Eggertsson	Andrea Ferrero	Andrea Raffo
Brown University	FRB New York	Federal Reserve Board

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Abstract

Structural reforms that reduce product and labor market markups in peripheral Europe by 10 percentage points can improve competitiveness in that region and boost union-wide output by almost 5%. If implemented during a crisis that takes the nominal interest rate to its lower bound, however, these reforms have short-run contractionary effects of more than 1% on impact, thus deepening the recession. Absent the appropriate monetary stimulus, reforms fuel expectations of prolonged deflation, increase the real interest rate, and depress aggregate demand. Our findings have implications for the current debate on the design of reforms in Europe.

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"...the biggest problem we have for growth in Europe is the problem of lack of competitiveness that has been accumulated in some of our Member States, and we need to make the reforms for that competitiveness.

...to get out of this situation requires...structural reforms, because there is an underlying problem of lack of competitiveness in some of our Member States."

José Manuel Durão Barroso
President of the European Commission
Closing Remarks following the State of the Union 2012
Strasbourg, September 12, 2012

1 Introduction

As the European Monetary Union (EMU) struggles to recover from the global financial crisis and the European debt crisis, conventional wisdom among academics and policymakers suggests that structural reforms that increase competition in product and labor markets are the main policy option to foster growth in the region. This paper is bad news: In a standard dynamic stochastic general equilibrium model calibrated to match salient features of the EMU economy, we show that structural reforms have near-term contractionary effects when monetary policy is constrained by the zero lower bound (ZLB). Even more disappointingly, if agents foresee that such reforms are not permanent (which may quite likely be the case, as several interest groups have strong incentives to oppose wide-ranging liberalizations), these policies can generate large short-term output losses, further deepening the current recession.

The 2008-9 global financial crisis hit the EMU hard, resulting in large and widespread output contractions (Figure 1). While core EMU countries, such as Germany and France, have mostly recovered their output losses, the aftermath has been particularly difficult for peripheral countries (Greece, Ireland, Italy, Portugal, and Spain). These countries have remained in serious recessions ever since 2008, eventually triggering doubts about the sustainability of their public finances and putting in danger the Euro project altogether. What is the reason for this asymmetric response between the core and the periphery? What kind of policies can address this situation?

A common narrative is that the periphery was particularly badly hit due to "macroeconomic imbalances" that had been accumulated ever since the introduction of the common currency

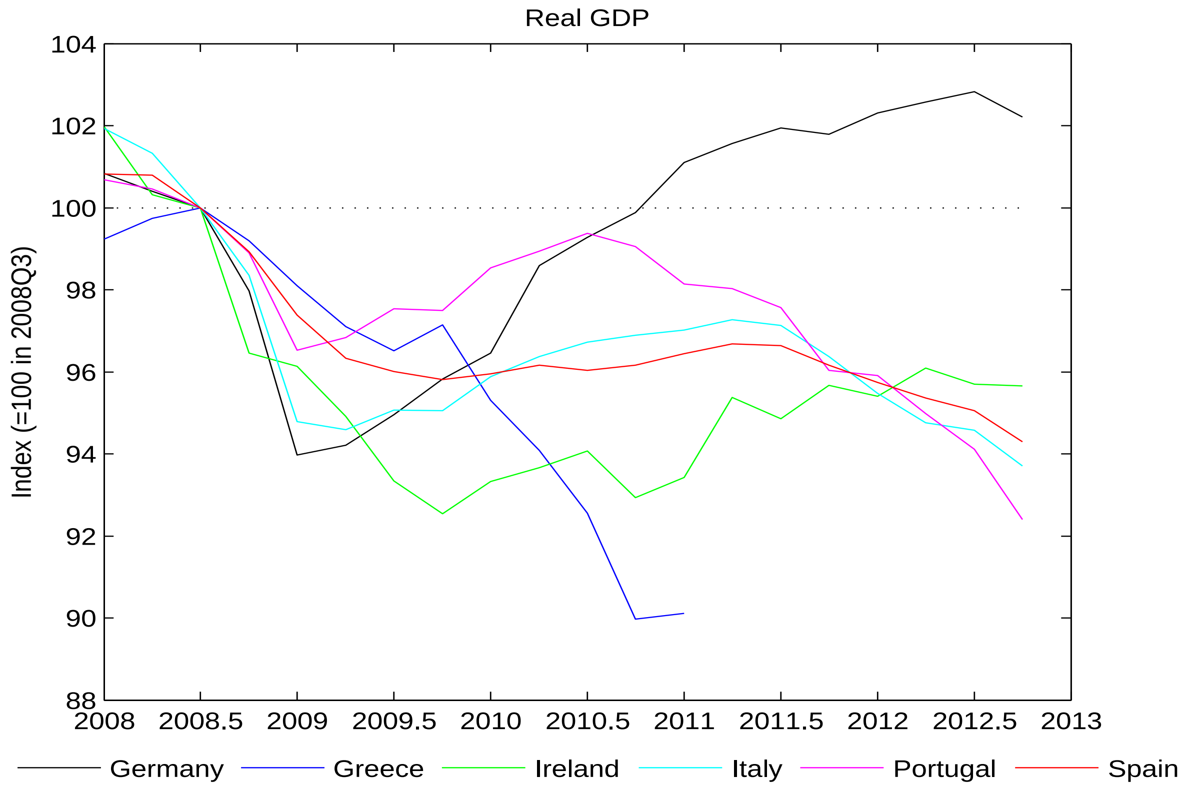

Figure 1: Real GDP (= 100 in 2008Q3) in Germany (black), Greece (blue), Ireland (green), Italy (cyan), Portugal (magenta) and Spain (red).

(see, among others, Eichengreen, 2010). As shown in the left panel of Figure 2, core euro-area countries (mainly Germany, but Austria and the Netherlands followed a similar pattern) persistently maintained current account surpluses over the past decade, whereas peripheral euro-area countries run large deficits. These large external borrowing positions have been associated with significant real exchange rate appreciation and large competitiveness losses. The right panel of Figure 2 plots the evolution of the Harmonized Index of Consumer Prices (HICP) for Germany (in black) and the European Monetary Union (EMU) periphery.[1] Relative to Germany, the real exchange rate of peripheral countries appreciated between 7 percent (Italy) and 17 percent (Greece) over the period 2000-2008. [2]

[1] The bilateral real exchange rate is the ratio of the HICP indexes between each pair of country.

[2] 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, according to this view, fiscal and external imbalances, as well as the relative competitive position, are likely to be different sides of the same underlying problem (Eichengreen, 2010).

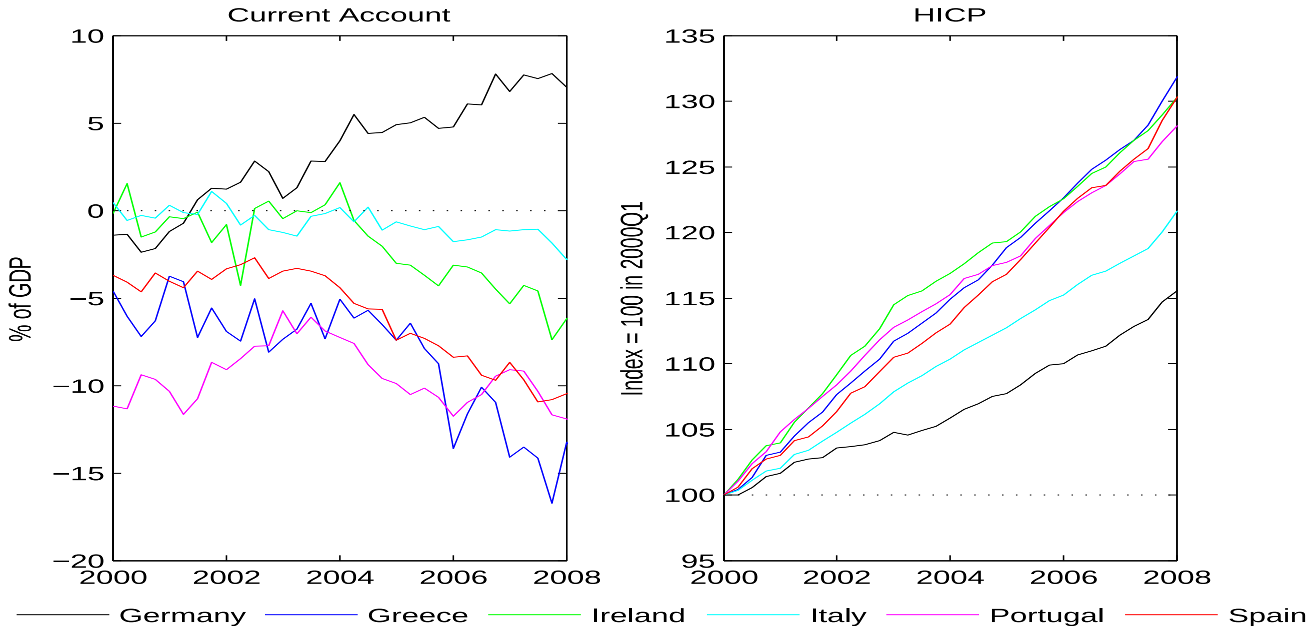

Figure 2: Balance on the current account in % of GDP (left panel) and Harmonized Index of Consumer Prices normalized to 100 in 2000Q1 (right panel) for Germany (black), Greece (blue), Ireland (green), Italy (cyan), Portugal (magenta) and Spain (red).

If one accepts this narrative for the plight of the periphery, a natural suggestion is that peripheral EMU needs to urgently adopt structural reforms that increase competition in product and labor markets, not least because empirical evidence points to significantly higher rigidities in these countries (see, for example, the indexes of economic flexibility obtained from the World Economic Forum in Figure 3).[3] Structural reforms directly aim at the source of the imbalances between core and periphery, trying to achieve two complementary objectives in the context of the current crisis. First, these reforms would effectively trigger a "real devaluation" of the periphery relative to the core, contributing to a reduction in the competitiveness gap accumulated over the past decade. Second, structural reforms would boost expectations about future growth prospects and stimulate current demand through potentially sizable wealth effects. In light of these arguments—and evidence—it is perhaps not very surprising that structural reforms are the cornerstone of both academics and international agencies' policy advice, as exemplified in the quote by the President of the European Commission Jose M.D. Barroso, reported above.

We study the effectiveness of this policy strategy in an open economy version of the standard

[3]OECD estimates of business markups and regulations burden paint a similar picture. We make explicit use of these estimates in our quantitative exercises.

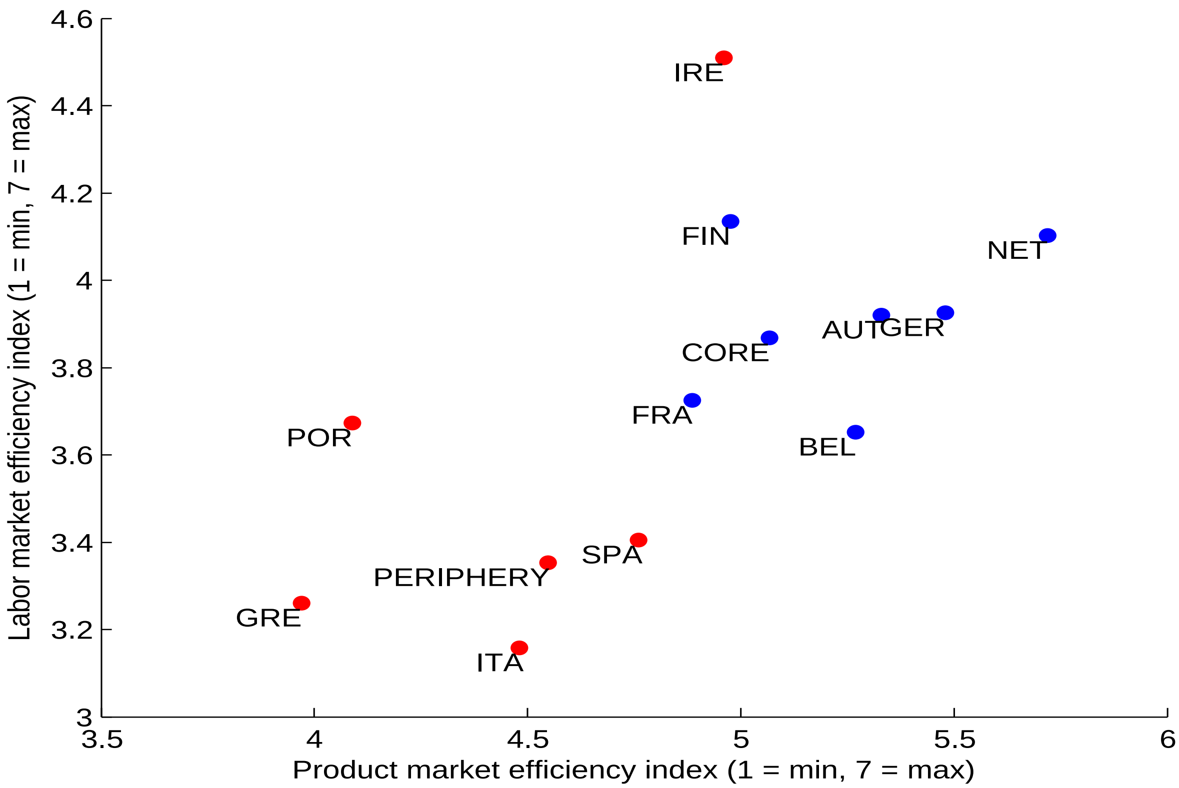

Figure 3: Scatter plot of product market (horizontal axis) and labor market (vertical axis) efficiency indexes (1 = minimum efficiency, 7 = maximum efficiency) for core (blue dots) and periphery (red dots) EMU countries.

New Keynesian model, with two sectors (tradable and non-tradable) and two countries that form a currency union. As typically assumed in the literature, we model structural reforms in one of the two countries (the "periphery") as a permanent reduction in product and labor market markups.[4]

The long-run effects of structural reforms are unambiguously positive. In the long run, a permanent reduction of product and labor market markups by 10 percentage points in the periphery service sector increases the level of output in that country by nearly 5 percent, and contributes to boost the union-wide level of output as well.[5] As output in the service sector expands and its prices fall, the home country experiences a real exchange rate depreciation of about 7 percent. These figures suggest that ambitious reforms implemented in peripheral

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

[5]These large long-run gains are consistent with the existent literature (Bayoumi et al., 2004; Forni et al., 2010), although the exact numbers may be sensitive to the introduction of entry and exit in the product market and search and matching frictions in the labor market (Cacciatore and Fiori, 2012; Corsetti et al., 2013).

EMU countries could greatly reduce the income and competitiveness gap between core and periphery.

Notwithstanding these long-run benefits, we find that these reforms may have contractionary effects in the short run, depending on the ability of the central bank to provide policy accommodation. In normal times, reforms increase agents' permanent income and stimulate consumption. Amid falling aggregate prices, the central bank cuts its policy rate and the currency union experiences a vigorous short-term boom.[6] These effects, however, are completely overturned in crisis times. When monetary policy is constrained by the zero lower bound (ZLB), reforms are contractionary, as expectations of prolonged deflation increase the real interest rate and depress consumption. In our simulations, these short-run output losses associated with the ZLB constraint are increasing with the magnitude of the reforms and become particularly large when reforms are not fully credible (and are later undone). Our main finding, therefore, is consistent with a growing literature that studies the constraints imposed by the ZLB on the short-run transmission of shocks and policies (see, for example, Erceg and Linde, 2012; Eggertsson, 2012).

We next study alternative policies that may alleviate the short-term perverse effects of ambitious reforms. In the spirit of Eggertsson (2012), we show that, when the ZLB binds, a policy that temporarily grants firms and unions higher monopoly power would increase output relative to the crisis. The main intuition for this surprising result is that such a policy would create inflationary expectations, thus reducing the real interest rate beyond the direct stimulus provided by monetary policy and providing incentives to households to front-load their consumption.[7] Furthermore, following recent work by Fernandez-Villaverde et al. (2012), we also study the effects of announcements to credibly implement structural reforms at some future date. This alternative policy yields the sizable income effects typically associated with permanent reforms, but at the same time it avoids the short-term costs of prolonged deflation, as reforms are implemented in the future. The net effect is a significant boost in output even in the short term.

[6] Cacciatore et al. (2012) study optimal monetary policy in a monetary union under product and labor market deregulation in a model with endogenous entry and exit and search frictions. As in our "normal times" scenario, the Ramsey plan in that setup also calls for monetary policy accommodation during the transition period.

[7] Eggertsson (2012) argues that New Deal policies of this kind contributed to end the Great Depression.

While structural reforms are at the forefront of the policy debate to address the poor macroeconomic performance of the European periphery, other options have also been recently explored. Given the severe fiscal constraints faced by peripheral countries and the lack of exchange rate flexibility, a recent academic literature (see Adao et al., 2009; Farhi et al., 2012) has focused on the scope for fiscal devaluations, that is, revenue-neutral changes in the composition of taxes that mimic an exchange rate devaluation. However, quantitatively, the potential gains associated with these policies for reasonable changes in tax rates appear to be limited (Lipinska and von Thadden, 2012).

Finally, structural reforms clearly involve important political economy considerations (Blanchard and Giavazzi, 2003). While this aspect is well beyond the scope of our paper, the experiment on the effects of temporary reforms at the ZLB is a simple—albeit admittedly crude—way to capture these more complex dynamics.

The rest of the paper proceeds as follows. Section 2 outlines a simplified closed economy model to illustrate the two offsetting effects that are critical for our evaluation: The perverse effect of structural reforms due to deflationary expectations, and the positive effect due to a permanent increase in future income. Section 3 presents the full model and the calibration. Section 4 discusses the effects of structural reforms in normal times. Section 5 introduces the crisis and re-evaluates the effects of structural reforms in that context. Section 6 studies two alternative policies that avoid the perverse short-run effects of structural reforms. Finally, Section 7 concludes. Appendix A and B report the list of equilibrium and steady state conditions, respectively.

2 An Illustrative Model

To begin our analysis, we take a step back and study the effects of structural reforms in a linearized version of a standard closed economy model with monopolistic competition and sticky prices. The basic New Keynesian structure of this model is also at the heart of the open economy DSGE model that we use in our quantitative experiments. While we study the full non-linear dynamics of our multi-country model, the simple intuition that arises from the linearized closed economy provides insights about the main tradeoffs associated with structural reforms when monetary policy is constrained by the ZLB.

The linearized version of the prototype New-Keynesian model can be summarized by the following two equations

$$\hat{Y}_t = \mathbb{E}_t \hat{Y}_{t+1} - \sigma^{-1}(i_t - \mathbb{E}_t \pi_{t+1} - r_t^e) \quad (1)$$

$$\pi_t = \kappa \hat{Y}_t + \beta \mathbb{E}_t \pi_{t+1} + \kappa \psi \omega_t \quad (2)$$

where π_t is inflation, $\hat{Y}_t$ is output in deviation from its first best level, r_t^e is an exogenous disturbance, κ is the slope of the Phillips curve (a convolution of structural parameters), σ is the coefficient of relative risk aversion, $\psi \equiv 1/(\sigma + \nu)$ where ν is the inverse Frisch elasticity of labor supply, and $\mathbb{E}_t$ is the expectation operator conditional on all information available at time t. The variable ω_t denotes a wedge between output under flexible prices and the first best level of output. In the microfoundation of the model, this wedge could either be driven by the market power of firms (due to monopolistic competition in product markets) or markups in the labor markets. We interpret structural reforms as policies that aim at reducing this wedge by promoting competition in product and labor markets, for instance through lower entry barriers in industries, removal of restrictions on working hours, and privatization of government-owned enterprises with corresponding increase in the number of operating firms in protected sectors.

Consider a regime where $\pi_t = 0$, that is, the central bank manages to target zero inflation at all times. Denote short-run variables by $t = S$ and long-run variables by $t = L$. Then, equation (2) reduces to

$$\hat{Y}_S = -\psi \omega_S \qquad \text{and} \qquad \hat{Y}_L = -\psi \omega_L. \quad (3)$$

Equations (3) reveals two important insights. First, structural reforms matter, and have an unambiguous impact on output, whose magnitude depends on ψ. In particular, a reduction in the wedge increases output. Second, under zero-inflation targeting, equation (1) plays no role in determining short-run output. It is simply a pricing equation that pins down the level of the interest rate i_t consistent with zero inflation.

The dynamics change dramatically when monetary policy is constrained by the ZLB. Consider the following shock, common in the literature on the zero bound due to its analytic simplicity: At time zero, the shock r_t^e takes value $r_S^e < 0$ but then, in each period, it reverts back to steady state with probability $1-\mu$. Once in steady state, the shock stays there forever. We can consider both long- and short-run structural reforms in this framework. In particular, consider reforms such that $\omega = \omega_S$ when the $r_t^e = r_S^e$ and $\omega = \omega_L$ when the shock is back to steady state (i.e. $r_t^e = r_L^e$). Under these assumptions, the model can still be conveniently split into "long run" and "short run" by exploiting the forward-looking nature of the equations. Moreover, as long as $r_S^e < 0$ and the policy (ω_S, ω_L) is sufficiently close to the point around we approximate, the ZLB is binding only in the short run.

This shock dramatically changes the short-run equilibrium. When the ZLB binds and the nominal interest rate is at zero, the economy becomes completely demand-determined and equation (1) becomes relevant for the determination of output. Using our assumptions about the interest rate shock, and taking the solution once the shock is over as given (which we continue to denote by L), we can rewrite equation (1) and equation (2) as

$$\text{AD:} \qquad \hat{Y}_S = \hat{Y}_L + \frac{\sigma^{-1}\mu}{1-\mu}\pi_S + \frac{\sigma^{-1}}{1-\mu}r_S^e \tag{4}$$

$$\text{AS:} \qquad \pi_S = \frac{\kappa}{1-\mu\beta}\hat{Y}_S + \frac{\kappa\psi}{1-\mu\beta}\omega_S \tag{5}$$

Given the policy (ω_S, ω_L), the short-run equilibrium is a pair $(\pi_S, \hat{Y}_S)$ that satisfies these two equations. Graphically, the equilibrium corresponds to the intersection of the AS and the AD "curves," as shown by point A in Figure 4. Note that, when the ZLB binds, the aggregate demand curve becomes upward-sloping, as higher inflation stimulates demand through lower real interest rates.[8]

Figure 4 shows the impact of permanent structural reforms (i.e. a reduction in ω_S and ω_L) on short-run output and inflation. A product or labor market liberalization generates two effects. First, it shifts the AS curve down, as firms can produce more output for any given level of inflation. Perhaps somewhat surprisingly, this effect turns out to be contractionary in the short run. At the ZLB, reforms amplify deflationary pressures, resulting in a higher real interest rate and contracting aggregate demand. Given that the interest rate is stuck at zero, the central bank cannot provide enough monetary stimulus to offset this effect and output

[8]When the ZLB does not bind, the AD curve is horizontal in a zero-inflation targeting regime.

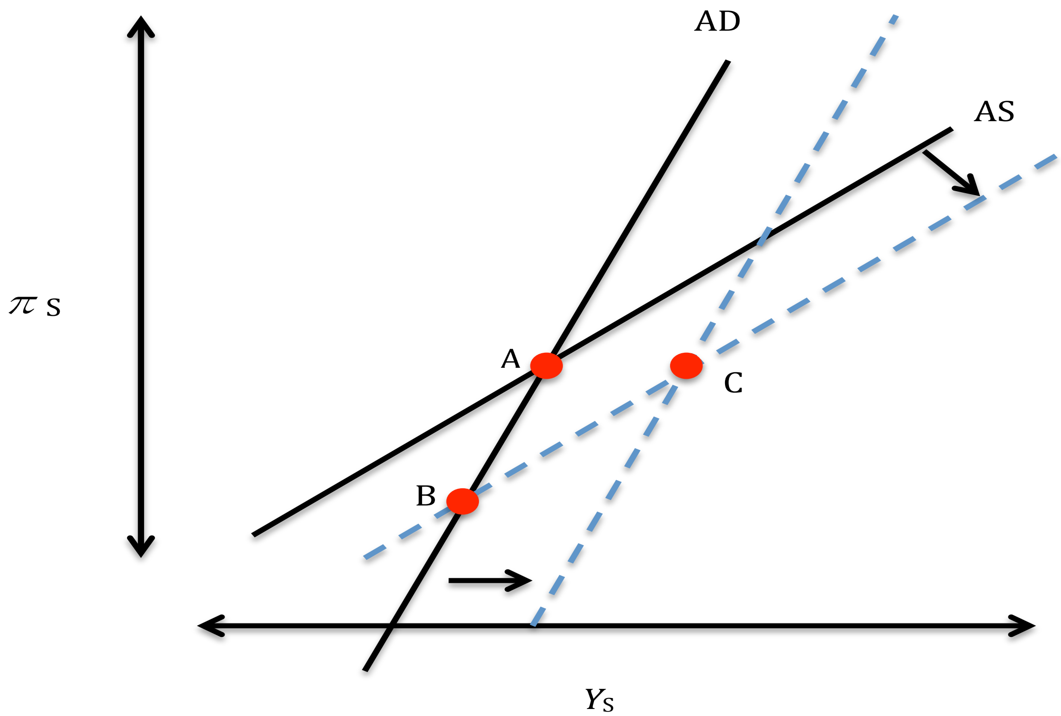

Figure 4: Short-run equilibrium at the ZLB under permanent structural reforms in the illustrative model.

declines.[9]

As shown in equation (4), however, reforms also have a second effect on short-run output $\hat{Y}_S$ through $\hat{Y}_L$, thus shifting the aggregate demand schedule outward (see again Figure 4). The intuition is simple: Structural reforms increase permanent income, boosting output and inflation in the short term. Depending on the relative strength of these two effects, reforms may be contractionary or expansionary in the short run. For instance, if structural reforms do not have much "credibility" (i.e . people expect a policy reversal at some point in the future, such that $\omega_S < 0$ but $\omega_L = 0$), the AS curve shifts down whereas the AD curve does not change, and the reforms are clearly contractionary (point B in Figure 4). In contrast, ambitious reforms that are gradually implemented and become more credible over time are associated with large permanent income effects, shifting the AD curve more than the AS curve (point C in Figure 4).

[9]Eggertsson (2010) calls this effect the "paradox of toil." His analysis, however, is restricted to temporary structural reforms, whereas our focus here is on the effects of permanent reforms on the equilibrium.

The question of which effect dominates is ultimately quantitative. For this purpose, in the next section, we develop and calibrate a two-country model of a monetary union that we then use as a laboratory to evaluate the effects of different structural reforms experiments. Note that the simple model in this section also suggests that the government would do better if it could increase ω_S while at the same time reducing ω_L. In this case, both the short-run effect of the policy (positive ω_S) and its long-run impact (a lower ω_L) are expansionary. We confirm this insight in the quantitative exercise below.

The open-economy monetary-union dimension of the model is important to make our analysis concrete with respect to two key features that are relevant for the debate on the European crisis. First, the evidence in Figure 3 suggests that structural reforms are mostly needed in the periphery, to favor a catch-up in competitiveness with the core. Second, and related, structural reforms may prove helpful in closing the imbalances in external borrowing and relative prices that have received so much attention since the onset of the crisis. Our analysis sheds light on the interaction between the role of structural reforms in correcting these imbalances and monetary policy when the nominal interest rate is constrained by the ZLB.

3 The Full Model

The world economy consists of two countries Home (H) and Foreign (F) of identical size, 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. 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 continuum of households of measure 1 inhabits each country. Each household derives utility from consumption of tradable and non-tradable goods and disutility from hours worked. Households supply sector-specific differentiated labor inputs. Labor agencies combine these inputs in sector-specific aggregates while households set the wage for each input on a staggered basis. Domestic financial markets are complete. Conversely, 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.

3.1 Retailers

Wholesale producers in the tradable ($k = H$) and non-tradable ($k = N$) sector combine raw goods according to a technology with elasticity of substitution $\theta_k > 1$

$$Y_{kt} = \left[\left(\frac{1}{\gamma_k} \right)^{\frac{1}{\theta_k}} \int_0^{\gamma_k} Y_{kt}(j)^{\frac{\theta_k - 1}{\theta_k}} dj \right]^{\frac{\theta_k}{\theta_k - 1}}, \tag{6}$$

where $\gamma_k = \{\gamma, 1 - \gamma\}$ is the size of the tradable and non-tradable sector, respectively.

Wholesale firms operate in perfect competition and maximize profits subject to their technological constraint (6)

$$\max_{Y_{kt}} P_{kt} Y_{kt} - \int_0^{\gamma_k} P_{kt}(j) Y_{kt}(j) dj. \tag{7}$$

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

$$Y_{kt}(j) = \frac{1}{\gamma_k} \left[\frac{P_{kt}(j)}{P_{kt}} \right]^{-\theta_k} Y_{kt}, \tag{8}$$

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

$$P_{kt} = \left[\frac{1}{\gamma_k} \int_0^{\gamma_k} P_{kt}(j)^{1-\theta_k} dj \right]^{\frac{1}{1-\theta_k}}. \tag{9}$$

3.2 Labor Agencies

Competitive labor agencies combine differentiated labor inputs $L_{kt}(i)$ supplied by the households in the economy into a sector-specific homogenous aggregate according to a technology with elasticity of substitution $\phi_k > 1$

$$L_{kt}(j) = \left[\left(\frac{1}{\gamma_k} \right)^{\frac{1}{\phi_k}} \int_0^{\gamma_k} L_{kt}(i)^{\frac{\phi_k - 1}{\phi_k}} di \right]^{\frac{\phi_k}{\phi_k - 1}} \tag{10}$$

Labor agencies operate in perfect competition and maximize their profits subject to (10)

$$\max_{L_{kt}(i)} W_{kt}L_{kt}(j) - \int_0^{\gamma_k} W_{kt}(i)L_{kt}(i)di, \tag{11}$$

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

$$L_{kt}(i) = \frac{1}{\gamma_k}\left(\frac{W_{kt}(i)}{W_{kt}}\right)^{-\phi_k} L_{kt}(j). \tag{12}$$

The zero profit condition implies that the wage index is

$$W_{kt} = \left[\frac{1}{\gamma_k}\int_0^{\gamma} W_{kt}(i)^{1-\phi_k}di\right]^{\frac{1}{1-\phi_k}}. \tag{13}$$

3.3 Intermediate Goods Producers

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

$$Y_{kt}(j) = Z_{kt}L_{kt}(j), \tag{14}$$

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 (14) and the demand for their variety (8).

As customary, we can separate the intermediate goods producers problem in two steps. First, for a 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

$$MC_{kt}(j) = MC_{kt} = \frac{W_{kt}}{Z_{kt}}. \tag{15}$$

This condition also shows that the marginal cost is independent of firm-specific characteristics. However, because of nominal price and wage rigidities, aggregate labor demand in each sector depends on price dispersion. We can use the demand function (8) to write an aggregate production function as

$$Y_{kt}\Delta_{kt} = Z_{kt}L_{kt}, \tag{16}$$

where

$$L_{kt} \equiv \frac{1}{\gamma_k}\int_0^{\gamma_k} L_{kt}(j)dj$$

and

$$\Delta_{kt} \equiv \frac{1}{\gamma_k}\int_0^{\gamma_k} \left[\frac{P_{kt}(j)}{P_{kt}}\right]^{-\theta_k} dj.$$

The second step of the intermediate goods producers' problem is the optimal price setting decision, given the expression for the marginal cost. We assume that firms change their price on a staggered basis. Following Calvo (1983), the probability of not being able to change the price in each period is $\xi_p \in (0,1)$. The optimal price setting problem for a firm j that is able to reset its price at time t is

$$\max_{\widetilde{P}_{kt}(j)} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \xi_p^s Q_{t,t+s} \left[(1+\tau^p_{kt+s})\widetilde{P}_{kt}(j) - MC_{kt+s}\right] Y_{kt+s}(j) \right\} \tag{17}$$

subject to the demand for their variety (8) conditional on no price change between t and $t+s$. Households in each country own a diversified non-traded portfolio of domestic tradable and non-tradable intermediate goods producing firms. Therefore, firms discount future profits using $Q_{t,t+s}$, the individual stochastic discount factor for an asset between period t and period $t+s$ (such that $Q_{t,t} = 1$). The time-varying subsidy τ^p_{kt+s} is the policy instrument that the government can use to affect the degree of competitiveness in each sector. Ceteris paribus, a higher subsidy reduces the firms' monopoly power and increases output. We discuss government policy in more details below.

In equilibrium, all firms that reset their price at time t choose the same strategy ($\widetilde{P}_{kt}(j) = \widetilde{P}_{kt}$). After some manipulations, we can write the optimality condition as

$$\frac{\widetilde{P}_{kt}}{P_{kt}} = \frac{\frac{\theta_k}{\theta_k - 1}\mathbb{E}_t\left\{\sum_{s=0}^{\infty}\xi_p^s Q_{t,t+s} MC_{kt+s} Y_{kt+s}\Pi_{kt+s}^{\theta_k}\right\}}{\mathbb{E}_t\left\{\sum_{s=0}^{\infty}\xi_p^s Q_{t,t+s}(1+\tau^p_{kt+s})P_{kt+s}Y_{kt+s}\Pi_{kt+s}^{\theta_k - 1}\right\}}, \tag{18}$$

where $\Pi_{kt} \equiv P_{kt}/P_{kt-1}$ is the inflation rate in sector k. Firms that are not able to adjust on average keep their price fixed at the previous period's level. The price index (9) for sector k

yields a non-linear relation between the optimal relative reset price and the inflation rate

$$\frac{\widetilde{P}_{kt}}{P_{kt}} = \left(\frac{1 - \xi_p \Pi_{kt}^{\theta_k - 1}}{1 - \xi_p} \right)^{\frac{1}{1-\theta_k}}. \tag{19}$$

Moreover, from the price index (9) and the assumption of staggered price setting, we can also derive the law of motion of the index of price dispersion

$$\Delta_{kt} = \xi_p \Delta_{kt-1} \Pi_{kt}^{\theta_k} + (1 - \xi_p) \left(\frac{1 - \xi_p \Pi_{kt}^{\theta_k - 1}}{1 - \theta_k} \right)^{\frac{\theta_k}{\theta_k - 1}}.$$

In steady state, there is no price dispersion ($\Delta_k = 1$) and the price in sector k is a markup over the marginal cost

$$P_k = \frac{1}{1 + \tau_k^p} \frac{\theta_k}{\theta_k - 1} MC_k.$$

The government can choose a subsidy as to fully offset firms' monopolistic power—or, more generally, set a desired markup level in the goods market.

3.4 Households

In each country, a continuum of measure one of households supply differentiated labor inputs and set wages on a staggered basis (Calvo, 1983). Because of the assumption of complete domestic financial markets (and an appropriate normalization of initial wealth levels), all households take the same consumption and savings decisions.

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

$$C_t = \left[\gamma^{\frac{1}{\varphi}} C_{Tt}^{\frac{\varphi - 1}{\varphi}} + (1 - \gamma)^{\frac{1}{\varphi}} C_{Nt}^{\frac{\varphi - 1}{\varphi}} \right]^{\frac{\varphi}{\varphi - 1}}, \tag{20}$$

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

$$P_t C_t \equiv \min_{C_{Tt}, C_{Nt}} P_{Tt} C_{Tt} + P_{Nt} C_{Nt}, \tag{21}$$

subject to (20). The first order condition for this problem yields the demand for the tradable and non-tradable goods

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t}\right)^{-\varphi} C_t, \tag{22}$$

$$C_{Nt} = (1-\gamma) \left(\frac{P_{Nt}}{P_t}\right)^{-\varphi} C_t. \tag{23}$$

The associated price index is

$$P_t = \left[\gamma P_{Tt}^{1-\varphi} + (1-\gamma) P_{Nt}^{1-\varphi}\right].^{\frac{1}{1-\varphi}} \tag{24}$$

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

$$C_{Tt} = \left[\omega^{\frac{1}{\epsilon}} C_{Ht}^{\frac{\epsilon-1}{\epsilon}} + (1-\omega)^{\frac{1}{\epsilon}} C_{Ft}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{25}$$

where $\omega \in (0.5, 1)$ is the share of Home tradables. We assume that the law of one price holds for internationally traded goods

$$P_{Ht} = P_{Ht}^{*}, \tag{26}$$

$$P_{Ft}^{*} = P_{Ft}. \tag{27}$$

The expenditure minimization problem is

$$P_{Tt} C_{Tt} \equiv \min_{C_{Ht}, C_{Ft}} P_{Ht} C_{Ht} + P_{Ft} C_{Ft}, \tag{28}$$

subject to (25). The first order conditions for this problem yield the standard demand functions for domestic and foreign traded goods

$$C_{Ht} = \omega \left(\frac{P_{Ht}}{P_{Tt}}\right)^{-\epsilon} C_{Tt}, \tag{29}$$

$$C_{Ft} = (1-\omega) \left(\frac{P_{Ft}}{P_{Tt}}\right).^{-\epsilon} C_{Tt} \tag{30}$$

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

$$P_{Tt} = \left[\omega P_{Ht}^{1-\epsilon} + (1-\omega) P_{Ft}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{31}$$

While the the law of one price holds, home bias in tradable consumption ($\omega > 0.5$) implies that the price index for tradable goods differs across countries ($P_{Tt} \neq P^*_{Tt}$). Consumer price indexes (CPI) further differ across countries because of the presence of non-tradable goods. Therefore, purchasing power parity fails ($P_t \neq P^*_t$).

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

$$\max_{C_{t+s}, B_{t+s}, W_{kt+s}(i)} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \varsigma_{t+s} \left[\frac{C_{t+s}^{1-\sigma}}{1-\sigma} - \frac{L_{kt+s}(i)^{1+\nu}}{1+\nu} \right] \right\}, \tag{32}$$

subject to the demand for labor input (12) and the budget constraint

$$P_t C_t + \frac{B_t}{\psi_{Bt}} = (1 + i_{t-1}) B_{t-1} + (1 + \tau^w_{kt}) W_{kt}(i) L_{kt}(i) + \mathcal{P}_t - \mathcal{T}_t, \tag{33}$$

where B_t represents nominal debt, $\mathcal{P}_t$ indicates profits from intermediate goods producers and $\mathcal{T}_t$ represents lump-sum taxes. As for the goods market, the sector-specific time-varying subsidy τ^w_{kt} is the policy instrument that the government can use to affect the degree of competitiveness in the labor market of each sector. Ceteris paribus, a higher subsidy reduces workers' monopoly power and increases labor supply. 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. Finally, as in Erceg et al. (2006), the intermediation cost ψ_{Bt} ensures stationarity of the net foreign asset position

$$\psi_{Bt} \equiv \exp \left[-\psi_B \left(\frac{B_t}{P_t Y_t} \right) \right], \tag{34}$$

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

$$P_t Y_t \equiv P_{Ht} Y_{Ht} + P_{Nt} Y_{Nt}. \tag{35}$$

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.[10]

[10]We use the intermediation cost only to ensure stationarity of the net foreign asset position. We set the

The consumption-saving optimality conditions yield

$$1 = \beta \psi_{Bt}(1+i_t)\mathbb{E}_t\left[\frac{\varsigma_{t+1}}{\varsigma_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\right]. \tag{36}$$

From expression (36), the stochastic discount factor for nominal assets is

$$Q_{t,t+s} = \beta^s \frac{\varsigma_{t+s}}{\varsigma_t}\left(\frac{C_{t+s}}{C_t}\right)^{-\sigma}\frac{1}{\Pi_{t+s}}. \tag{37}$$

Finally, for each household, the probability of being able to reset the wage at time t is ξ_w. The optimal wage setting problem in case of adjustment for household i working in sector k is

$$\max_{\widetilde{W}_{kt}(i)} \mathbb{E}_t\left\{\sum_{s=0}^{\infty}(\beta\xi_w)^s\left[(1+\tau^w_{kt+s})C^{-\sigma}_{t+s}\frac{\widetilde{W}_{kt}(i)}{P_{t+s}}L_{kt+s}(i) - \frac{L_{kt+s}(i)^{1+\nu}}{1+\nu}\right]\right\}, \tag{38}$$

subject to the demand for the specific labor variety (12) conditional on no wage change between t and $t+s$.

In equilibrium, all workers who reset their wage at time t choose the same strategy ($\widetilde{W}_{kt}(i) = \widetilde{W}_{kt}$). After some manipulations, we can rewrite the first order condition for optimal wage setting as

$$\left(\frac{\widetilde{W}_{kt}}{W_{kt}}\right)^{1+\phi_k\nu} = \frac{\frac{\phi_k}{\phi_k-1}\mathbb{E}_t\left\{\sum_{s=0}^{\infty}(\beta\xi_w)^s\varsigma_{t+s}\left(L_{kt+s}/\gamma_k\right)^{1+\nu}\left(\Pi^w_{kt+s}\right)^{\phi_k(1+\nu)}\right\}}{\mathbb{E}_t\left\{\sum_{s=0}^{\infty}(\beta\xi_w)^s\varsigma_{t+s}(1+\tau^w_{kt+s})C^{-\sigma}_{t+s}(W_{kt+s}/P_{t+s})(L_{kt+s}/\gamma_k)(\Pi^w_{kt+s})^{\phi_k-1}\right\}}, \tag{39}$$

where $\Pi^w_{kt} \equiv W_{kt}/W_{kt-1}$ is the wage inflation rate in sector k. Workers who are not able to adjust on average keep their wage fixed at the previous period's level. The wage index (13) for sector k yields a non-linear relation between the optimal relative reset wage and the wage inflation rate

$$\frac{\widetilde{W}_{kt}}{W_{kt}} = \left[\frac{1-\xi_w(\Pi^w_{kt})^{\phi_k-1}}{1-\xi_w}\right]^{\frac{1}{1-\phi_k}}. \tag{40}$$

In steady state, the real wage in sector k is a markup over the marginal rate of transformation between labor and consumption

$$\frac{W_k}{P} = \frac{1}{1+\tau^w_k}\frac{\phi_k}{\phi_k-1}\frac{(L_k/\gamma_k)^{\nu}}{C^{-\sigma}}.$$

parameter ψ_B small enough as to have no discernible effects on the transition dynamics.

As for prices, the government can choose a subsidy as to fully offset workers' monopolistic power—or, more generally, set a desired markup level in the labor market.

3.5 Fiscal and Monetary Policy

We assume that the government in each country finances goods and labor market subsidies levying lump-sum taxes

$$\mathcal{T}_t = \int_0^1 \tau_{kt}^p P_{kt} Y_{kt}(j) dj + \int_0^1 \tau_{kt}^w W_{kt} L_{kt}(i) di. \tag{41}$$

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[11]

$$P_t^{MU} \equiv (P_t)^{0.5} (P_t^*)^{0.5} \tag{42}$$

The inflation rate of the union-wide price index (42) is[12]

$$\Pi_t^{MU} = (\Pi_t)^{0.5} (\Pi_t^*)^{0.5}. \tag{43}$$

We assume that a single central bank conducts monetary policy for the entire union, setting the nominal interest rate to implement a strict inflation target

$$\Pi_t^{MU} = \bar{\Pi}.$$

However, we take explicitly into account the possibility that the nominal interest rate cannot fall below some lower bound

$$i_t \geq i^{zlb}$$

In the aftermath of shocks that take the economy to the lower bound, the central bank keeps the nominal interest rate at i^{zlb} until inflation reaches its target again. Our results would be unchanged if we were to specify an interest rate rule that responds to inflation, the output gap and/or the natural rate of interest.

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

[12] In the same spirit, using (35) and its foreign counterpart, we construct a union-wide level of output as $Y_t^{MU} \equiv (Y_t)^{0.5} (Y_t^*)^{0.5}$ that later we report in our simulations.

3.6 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, the markets for final non-tradable goods and for labor inputs in each sector clear at the country level, and the markets for tradable goods and financial assets clear at the union level. Because of nominal rigidities, intermediate goods producers and workers who cannot adjust their contracts stand ready to supply goods and labor inputs at the price and wage prevailing in the previous period. Appendix A reports a detailed list of equilibrium conditions. Here we note that goods market clearing in the tradable and non-tradable sectors satisfies

$$C_{Ht} + C_{Ht}^* = Y_{Ht}, \tag{44}$$

$$C_{Ft} + C_{Ft}^* = Y_{Ft}^*, \tag{45}$$

$$C_{Nt} = Y_{Nt}, \tag{46}$$

$$C_{Nt}^* = Y_{Nt}^*. \tag{47}$$

Net foreign assets evolve according to

$$\frac{B_t}{\psi_{Bt}} = (1 + i_t)\, B_{t-1} + P_{Ht} C_{Ht}^* - P_{Ft} C_{Ft}. \tag{48}$$

Finally, asset market clearing requires

$$B_t + B_t^* = 0. \tag{49}$$

3.7 Calibration and Solution Strategy

Our main experiments involve changes in the subsidies τ_t^w and τ_t^p (structural reforms) that affect, permanently or temporarily, the degree labor and product market competitiveness (i.e. the markups). We run deterministic non-linear simulations that allow us to quantify the steady state effects and trace the dynamic evolution of the endogenous variables in response to the policy experiment.[13]

[13] We perform our simulations using Dynare, which relies on a Newton-Rapson algorithm to compute non-linear transitions between an initial point and the final steady state.

Table 1: Product market markup estimates and implied price elasticities by sector.

	Markup Estimates		Implied Price Elasticity	
	Periphery (H)	Core (F)	Periphery (H)	Core (F)
Total private firms	1.36	1.25	3.8	5.0
Manufacturing (Tradable)	1.17	1.14	7.7	7.7
Services (Non-Tradable)	1.48	1.33	3.0	4.0

Note: Source: OECD (2005). Periphery: Italy and Spain. Core: France and Germany.

The calibration of the markups is central for our quantitative results. We set the initial levels of price markups in the home and foreign country following the estimates produced by the OECD (2005) for peripheral and core EMU (Table 1). 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. The OECD estimates for price markups show two interesting patterns. First, markups in the periphery are higher than in the core, consistent with the evidence provided in Figure 3. Second, this difference is largely accounted for by higher markups in the service sector of the periphery, whereas markups in the manufacturing sector are similar across regions. These data support the view that peripheral European countries could greatly benefit from the implementation of liberalization measures in the product market.

Using the model, we map these estimates into values for the elasticity of substitution according to the steady state formula

$$markup = \frac{\theta_k}{\theta_k - 1}.$$

We impose symmetry between countries in the manufacturing sector and set the initial values of θ_k, the price elasticity in the two sectors, to reproduce the OECD markup estimates.

Unfortunately, estimates for wage markups in the labor market are more difficult to obtain. Using sectoral wage data, Bayoumi et al. (2004) estimate that wage markups are higher in peripheral countries than in core countries (and U.S.) because of higher markups in the service sector. Since their point estimates are in line with the figures presented in Table 1, we set wage elasticities across sectors and regions equal to the corresponding price elasticities.[14]

Table 2 presents the values of the remaining parameters used in our simulations, which are

[14] Forni et al. (2010) follow a similar approach.

Table 2: Parameter values.

Households			
Home bias	ω	=	0.65
Consumption share of tradable goods	γ	=	0.45
Elasticity of substitution tradables-nontradables	ϵ	=	0.5
Elasticity of substitution Home-Foreign tradables	φ	=	1.5
Individual discount factor	β	=	0.99
Elasticity of intertemporal substitution	σ^{-1}	=	2
Inverse Frisch elasticity	ν	=	2
Price and Wage Setting			
Probability of not being able to adjust prices	ξ_p	=	0.66
Probability of not being able to adjust wages	ξ_w	=	0.66
Monetary Policy			
Inflation target	$\bar{\Pi}$	=	1
Effective lower bound on nominal interest rate	i^{zlb}	=	0.0025

relatively standard. Following Stockman and Tesar (1995), we set the degree of home bias ω equal to 0.65 and the steady state share of tradable goods in total consumption γ is 0.45. These parameters imply that the import share in steady state is around 15 percent, corresponding to the average within-eurozone import share for France, Germany, Italy, and Spain. The elasticity of substitution between traded and nontraded goods (ϵ) is 0.5, consistent with the estimates for industrialized countries provided in Mendoza (1991). 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. The coefficient of relative risk aversion σ is equal to 0.5, which is within the range of estimates provided in Hansen and Singleton (1983), and the inverse Frisch elasticity ν is equal to 2, a value commonly used in the New-Keynesian literature (see, for instance, Erceg and Linde, 2012). Finally, the probabilities of not being able to reset prices $\left(\xi_p\right)$ and wages (ξ_w) in any given quarter equal 0.66, implying an average frequency of price and wages changes of 3 quarters. We assume that the ECB targets zero inflation and we consider an effective lower bound of the short term interest rate of 1%, consistent with evidence that the ECB has been resistant to lower nominal rates below that threshold throughout the crisis.[15]

[15]The exact level of either the inflation target or the bound on the interest rate is not central for our results.

4 The Effects of Structural Reforms in Normal Times

We begin our analysis by investigating the effects of structural reforms in the benchmark economy. Specifically, we study the effects of a permanent reduction in price and wage markups by one percentage point in the home (periphery) nontradable sector. Figure 5 presents the dynamics of the main economic variables following the implementation of these reforms.

In response to lower markups in the nontradable sector, home output expands sharply on impact and subsequently decreases before converging to a higher long-run steady state (top-left). Significant trade linkages between the two regions of the monetary union propagate this expansion in the home country through higher demand for goods produced in the foreign country, thus stimulating a large, albeit temporary, increase of foreign output. Thus, output in the monetary union expands nearly 2.5 percent in the near term and the price level declines a touch, as deflation in the home country outweighs the modest demand-driven increase of prices in the foreign country (top-right). The common central bank accommodates the effects of structural reforms by lowering policy rates (bottom-left).

As for developments across sectors, lower markups in the nontradable sector generate a sizable short-term increase of nontradable and tradable output in the home as well as in the foreign country (middle-left). Lower markups also induce a decline of nontradable prices but an increase in the price of traded goods as well as of prices indices in the foreign country (middle-right). International prices in the home country depreciate, but most of the variation in the real exchange rate is accounted for by changes in the relative price of nontradables, whereas changes in the terms of trade are comparatively small (bottom-right). The current account (also bottom-right panel) responds little to structural reforms, as permanent changes in the income of the home country reduce the incentive to smooth consumption through the trade balance.

What we need is that a lower bound for the policy rate exists, thus preventing the monetary authority from providing additional stimulus. To implement the zero-inflation targeting in the simulations, we assume the policy reaction function

$$1 + i_t = \max\left\{1 + i^{zlb}, (1+i)(\Pi_t^{MU})^{\varphi_\pi}\right\},$$

where $\varphi_\pi > 1$ is the feedback coefficient on inflation and $i^{zlb} \geq 0$ is the effective lower bound for the interest rate. A high enough value for φ_π approximates a zero-inflation targeting regime well. We set $\varphi_\pi = 10$, although higher values would make no difference. Lower values can still approximate a zero-inflation targeting in the model if we were to assume that the ECB also responds to the output gap and/or the natural rate of interest.

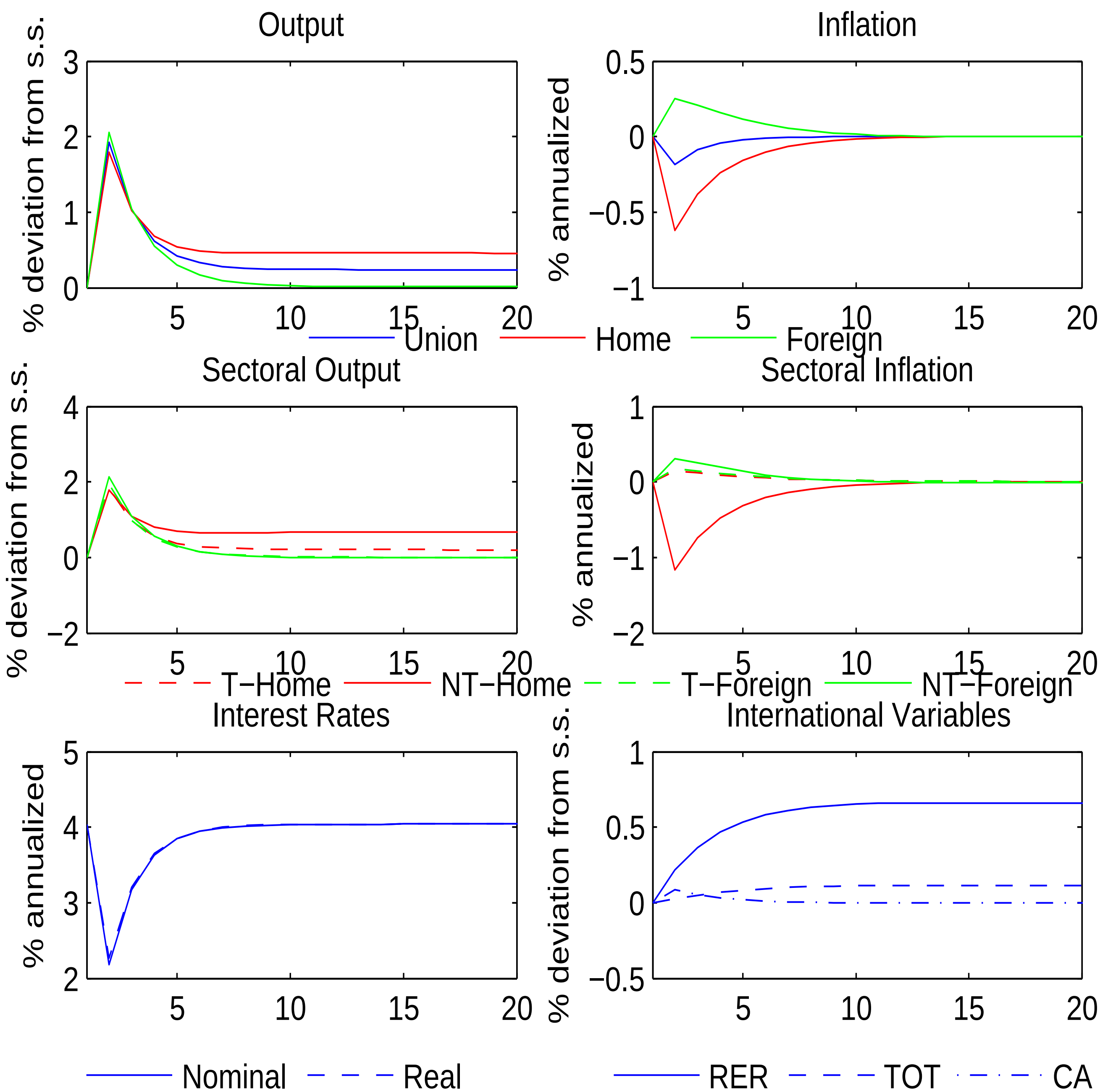

Figure 5: Response of output (top-left), inflation (top-right), sectoral output (middle-left), sectoral inflation (middle-right), interest rates (bottom-left) and international variables (bottom-right) to a permanent increase in labor and product market subsidies by one percentage point.

Table 3: Long-Run Effects of Structural Reforms on Home Country Variables

Output	Terms of Trade	Real Exchange Rate
0.45	0.13	0.67

Note: Response (in %) to a permanent reduction in price and wage markups of home nontradable sector by one percentage point.

Table 3 summarizes the long-run effects of structural reforms on the level of output and relative prices in the Home country. Over the course of 5 years, a reduction in both price and wage markups by one percentage point increases output by 0.45%. This gain reflects the permanent expansion of production in the nontradable sector. Notwithstanding the modest size of the reforms considered, measures of competitiveness typically observed by policymakers improve substantially, with the real exchange rate in the home country depreciating by nearly 0.7% in the long run.

While the dynamics explicitly take into account the non-linearities of the model, the steady state effects are approximatively log-linear. Therefore, the numbers in Table 3 can be interpreted as elasticities. For example, permanent reduction in markups by 10 percentage points increases output in the monetary union by 4.35%. This finding is consistent with other studies in the literature and support the policy prescription that higher competition in product and labor markets can significantly boost the growth prospects of countries in peripheral Europe.[16]

5 The Effects of Structural Reforms in a Crisis

In this section, we investigate how the short-run transmission mechanism of structural reforms is affected by the presence of the ZLB. The motivation for this analysis is twofold. First, a legacy of the 2008-09 global financial crisis is that policy rates have been at the ZLB in many countries for some time. This development has prompted a large debate on the role of alternative policies at the ZLB, the impact of the ZLB on the recovery, and the ability of monetary policy to deal with unexpected adverse events (such as the European debt crisis). Second, a growing literature finds that the effects of shocks in the presence of the ZLB can be qualitatively and quantitatively very different than in normal circumstances. For instance,

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

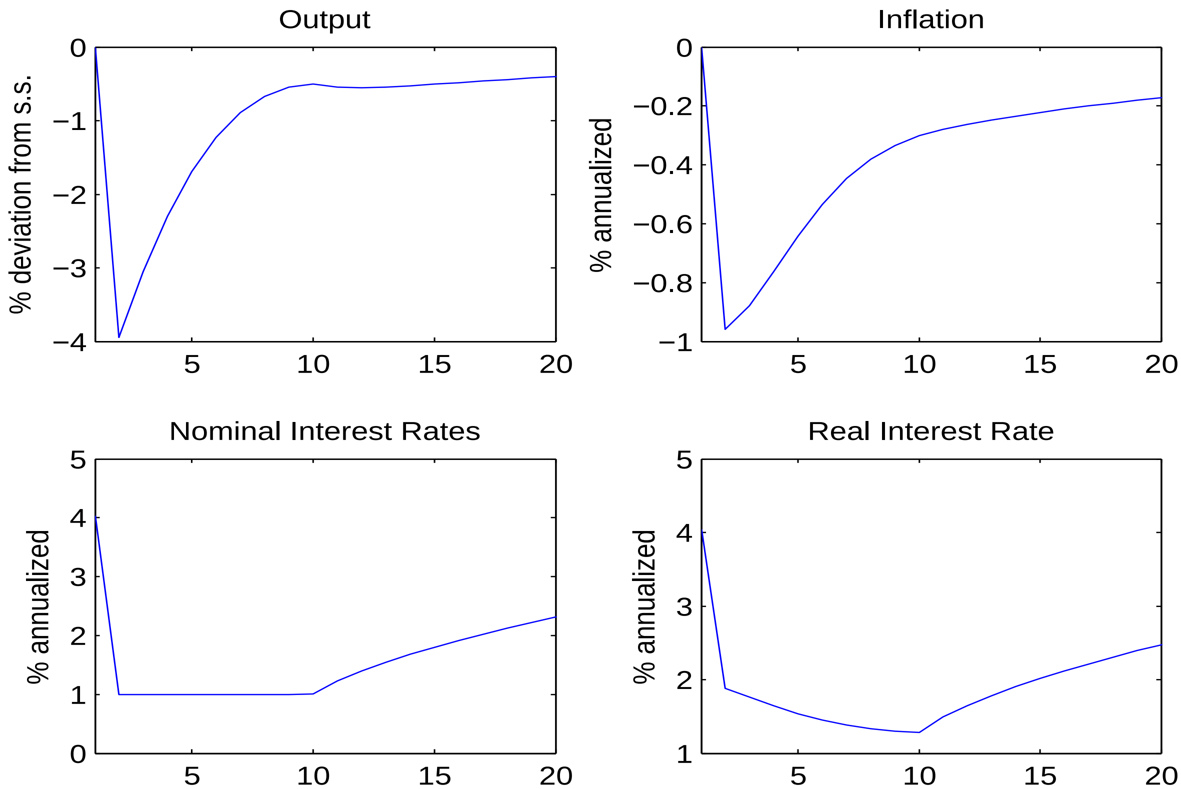

Figure 6: Response of output (top-left), inflation (top-right), nominal interest rates (bottom-left) and real interest rate (bottom-right) to the crisis.

Erceg and Linde (2012) find that tax-based fiscal consolidations may have lower output losses in the short run than expenditure-based fiscal consolidations, thus overturning findings previously established in the literature (see, for instance, Alesina and Ardagna, 2010). Our analysis is closer in spirit to Eggertsson (2012), who finds that policies that a temporary increase in the monopoly power of firms and union helped the U.S. recovery during the Great Depression by relaxing the ZLB constraint on monetary policy. This result is in contrast with the conventional wisdom that these policies increased the persistence of the recession (see, for instance, Cole and Ohanian, 2004). The main contribution of this paper is to go beyond the investigation of temporary reforms and illustrate the tradeoffs between short-run costs and long-run gains of permanent changes in markups during a crisis.

Table 4: Impact effects of structural reforms at the ZLB.

$\tau_N^p = \tau_N^w$ (in p.p.)	**Output**	**Inflation**	**Real Rate**
0	-3.95	-0.95	1.88
1	-4.07	-1.40	2.18
5	-4.51	-3.12	3.30
10	-5.03	-5.22	4.62

Note: Response (in %) to a permanent reduction in price and wage markups in the home nontradable sector.

5.1 The Crisis and the ZLB

We study the the effects of structural reforms in a monetary union in a situation where the common central bank cannot further lower the nominal interest rate. Following the recent literature (Eggertsson and Woodford, 2003, for example), we assume that an aggregate preference shock takes the monetary union to the ZLB. Figure 7 displays the impact of the crisis. We calibrate the size of the shock so that we can reproduce the peak-to-trough decline of euro-area output of about 4% following the collapse of Lehman Brothers in September 2008 (top-left). Interestingly, under our baseline calibration, prices drop nearly 1% (top-right) in line with the data. The central bank immediately cuts the nominal interest rate to its effective lower bound of 1% and keeps this accommodative stance for about 10 quarters (bottom-left). The deflationary pressures, combined with the lower bound constraint, implies that the real interest rate remains relatively high (bottom-right).[17] In this environment, we next study the response of the economy to structural reforms considered in Section 4.

5.2 Effects of Structural Reforms at the ZLB

Table 4 summarizes the main finding of our analysis. The last three columns of the table present the impact response of aggregate output (second column), prices (third column), and the real interest rate (fourth column) to a permanent reduction in labor and product market markups of different sizes (first column) in the nontradable sector of the home country. Amid contracting output and falling prices due to the crisis, the implementation of reforms in a ZLB environment further reduces output between 12 basis points (1 percentage point markup

[17] The real interest rate is high relative to a counterfactual world in which the nominal interest rate could go below its lower bound, and possibly into negative territory.

reduction) and 1.08 percent (markup reduction of 10 percentage points). These losses are quite persistent, as it takes almost a full year for output to return to the crisis level that would have prevailed in the absence of reforms.[18]

These short-run perverse effects of reforms are quantitatively even more remarkable when compared to the standard effects of reforms in normal times. A markup reduction by one percentage point generates a nearly 2% increase in output in the benchmark model (see Figure **??** above), but an output drop in a crisis times. Thus, we conclude that the short-run transmission of structural reforms critically depends on the ability of monetary policy to provide stimulus.

These findings suggest that, when the ZLB constrains monetary policy, the income and substitution effects of reforms may work in opposite directions. On the one hand, agents anticipate that income will be permanently higher, resulting in strong wealth effects and higher consumption. On the other hand, these policies stimulate production and competitiveness through lower domestic prices (column 3) that result in rising real interest rates. While in normal times the central bank accommodates deflation by reducing the policy rate, at the ZLB higher real rates depress consumption and output. Not surprisingly, then, a more ambitious reform effort is associated with a deeper output contraction as it produces a sharper deflationary spiral.

An important parameter governing the short-run response of consumption to changes in the real interest rate is the elasticity of intertemporal substitution (σ^{-1}). Our calibration for σ is on the lower side of the spectrum commonly used in macroeconomics (Hall, 1988), although several contributions in the literature (Hansen and Singleton, 1983; Summers, 1984; Attanasio and Weber, 1989; Rotemberg and Woodford, 1997; Gruber, 2006) provide evidence that the elasticity of intertemporal substitution may be well above one. Given the disagreement on the appropriate value for the elasticity of intertemporal substitution in the literature, we repeat our simulations with $\sigma = 1$ and 2.[19] A smaller elasticity of intertemporal substitution implies a smaller negative output effect of permanent reforms on impact. In this case, larger reforms lead to smaller output losses. Yet, a permanent reduction in labor and product markups by 10 percentage points with an elasticity of intertemporal substitution equal to 0.5 ($\sigma = 2$) still

[18] After one year, output remains more than 2 percentage points below its pre-crisis level.

[19] In each experiment, we recalibrate the size of the preference shock to ensure that aggregate output contracts 4% in the crisis episode.

Table 5: Impact effects of structural reforms at the ZLB under an asymmetric shock.

$\tau_N^p = \tau_N^w$ (in p.p.)	**Output**		**Inflation**		**Real Rate**	
	Symm	Asymm	Symm	Asymm	Symm	Asymm
0	-3.95	-3.95	-0.95	-2.10	1.88	2.86
1	-4.07	-3.99	-1.40	-2.54	2.18	3.13
5	-4.51	-4.19	-3.12	-4.28	3.30	4.21
10	-5.03	-4.41	-5.22	-6.40	4.62	5.46

Note: Response (in %) to a permanent reduction in price and wage markups in the home nontradable sector.

leads to an output drop of 3.53%. These gains are quite small if compared to the output drop of 3.95% absent any reform and the nearly 2% output increase in normal times, confirming that the presence of the ZLB significantly alters the short-run transmission of reforms. Thus, our findings cast doubt on the emphasis put in policy and academic environment on ambitious reforms as a way to boost the growth prospects of vulnerable euro-area countries.

5.3 Asymmetric Shocks

In our previous experiment, we considered the crisis as a shock that hits symmetrically both countries in the currency union. However, the recovery from the global financial crisis in core and peripheral European countries reveals a great deal of asymmetry between the two regions, perhaps reflecting the "macroeconomic imbalances" accumulated in the early 2000s.

Motivated by this observation, we next investigate the robustness of our main findings to a crisis shock that is not symmetric. We consider a scenario where the shock only hits the home country. As in the previous exercise, we continue to calibrate the shock to match a 4% decline in union-wide output. This crisis is still associated with monetary policy rates stuck at the ZLB for about three years. We then study the effects of structural reforms implemented in the periphery in the context of this crisis.

Table 5 compares the impact response of output, inflation, and the real interest rate in our baseline crisis scenario (first column of each section) and in our asymmetric crisis scenario (second column of each section) to structural reforms of 1, 5, and 10 percentage points. Our main conclusion is unchanged: Reforms continue to be contractionary in the short run, as more protracted deflation at the ZLB results in higher real interest rates. The magnitude of

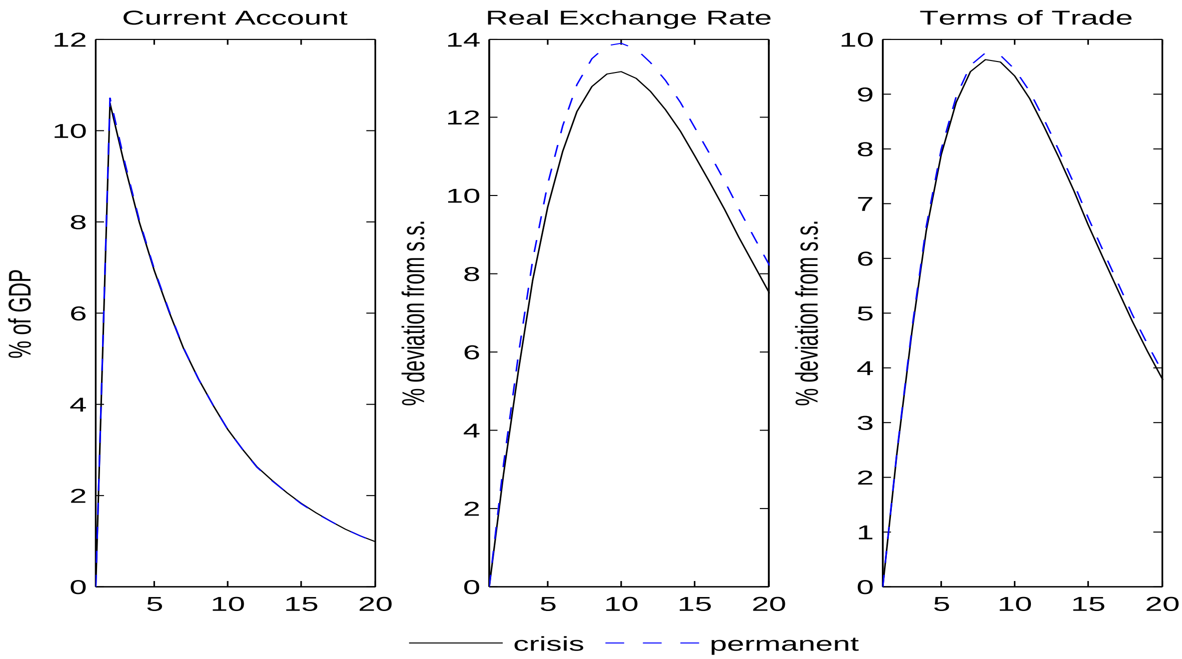

Figure 7: Response of current account (left), real exchange rate (middle) and terms of trade (right) in a crisis (continuous black line) and with permanent reforms of 1 percentage point (dashed blue line).

the output losses appears only a touch lower across experiments.

One notable difference in this case, compared to a crisis generated by a symmetric shock, is the large adjustment in international variables. The home country runs a large current account surplus and international prices depreciate sharply. However, these movements largely reflect the asymmetric nature of the shock, whereas the reforms continue to have effects on these variables comparable to our baseline scenario.

5.4 Discussion

Under our baseline calibration, as well as in several robustness checks, permanent reforms at the ZLB induce short-run output losses. Even in normal times, the short-run gains of structural reforms are substantially lower, and some times negligible, compared to the long run. In practice, other impediments, such as social unrest, political economy considerations, reallocation of factors across sectors, uncertainty about the implementation and gains of reforms, may actually exacerbate the short-term costs and limit the long-term benefits. The Greek and Spanish strikes over the recent austerity measures, as well as the pledge of some parties

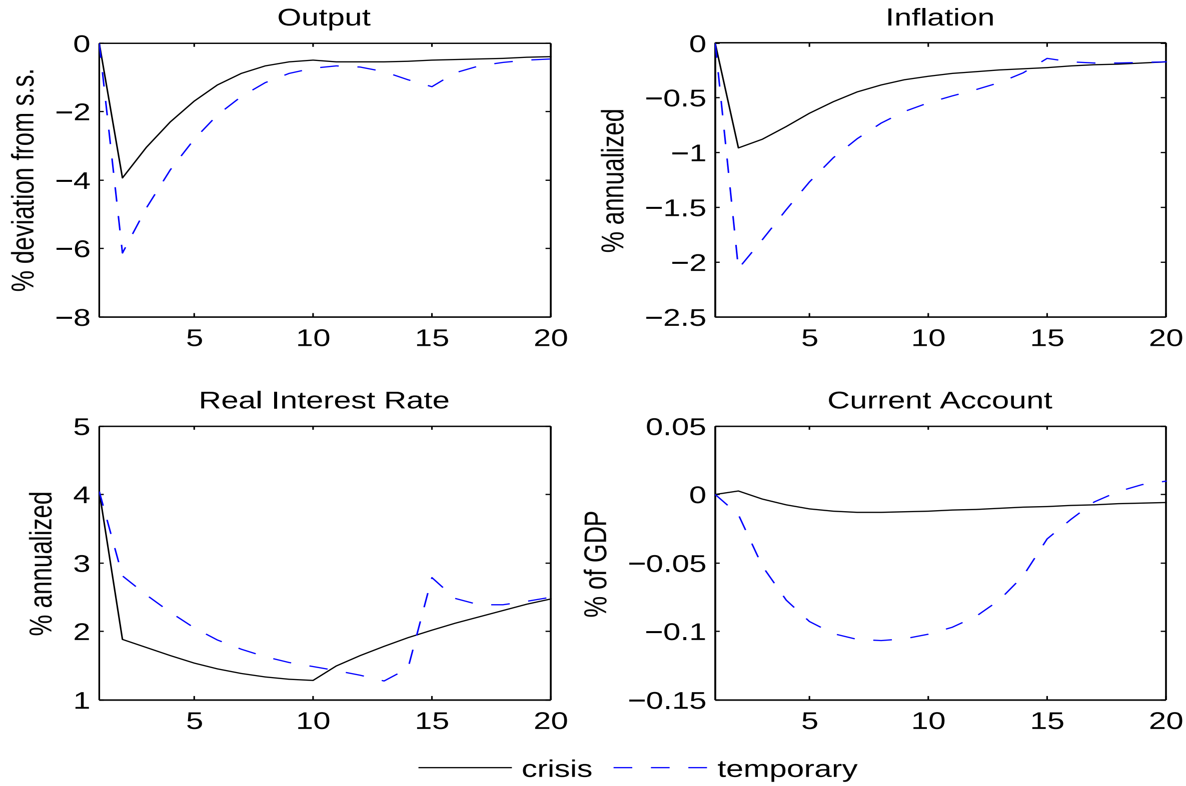

Figure 8: Response of output (top-left), inflation (top-right), real interest rate (bottom-left) and the current account (bottom-right) to the crisis without reforms (continuous black line) and with a temporary increase in labor and product market subsidies by one percentage point (dashed blue line).

to undo the labor market reforms undertaken by the previous government during the recent Italian elections, are two clear examples of these issues.

We model these complex socio-political dynamics by considering an experiment in which the reforms are perceived as (and in fact turn out to be) temporary. Governments in the home country implement labor and product market reforms as the crisis hits. However, the short-run costs in terms of deflation and the absence of output gains lead to social unrest and imply that the reforms are eventually undone. We make the simplifying assumptions that this outcome is perfectly anticipated at the time of implementation and the reforms are unwound when the ZLB stops binding.[20]

[20]These assumptions, while obviously extreme, make the analysis particularly stark. More realistically, the unwinding may occur with some probability at time of implementation, which would likely lead to a smaller output drop. At the same time, the unwinding may be decoupled from the duration of the crisis—in particular, the reforms could be reversed before the ZLB stops being bindings—which would entail more severe output losses.

Figure 8 compares the response of output (top-left panel), inflation (top-right panel), the real interest rate (bottom-left panel) and the current account (bottom-right panel) to the crisis without reforms (continuous black line) against the case of a temporary reduction in labor and product market markups by one percentage point (dashed blue line).

When monetary policy is constrained by the ZLB, temporary reforms entail large output losses in the short-run. At the union level, output drops 6% on impact, deepening the output costs associated with the crisis by more than 50%. As in the case of permanent reforms, reducing markups increases the deflationary pressures generated by the crisis. However, the temporary nature of the reforms creates a much steeper short-run deflationary spiral. This result reflects two mechanisms. First, as in the case of permanent reforms, lower prices increase the short-term real interest rate. However, temporary reforms are associated with much smaller wealth effects as long-run output is unchanged, thus providing stronger incentives to agents to postpone consumption. Second, forward-looking agents anticipate that the eventual unwinding of reforms (i.e. higher markups) when the crisis has almost completely vanished will have inflationary consequences, triggering a sharp increase in the nominal and real interest rate. Anticipating this future tightening, aggregate demand contracts immediately, contributing to a deeper crisis. This effect adds to the initial deflationary pressures and creates a perverse feedback loop, as the real interest rate further increases. Moreover, the economy suffers a policy-induced double-dip recession when the ZLB stops binding. The absence of long-run wealth effects together with higher short-run output losses imply that, differently from the case of permanent reforms, the home country borrows from abroad and runs a current account deficit.

In sum, our experiments suggest that when monetary policy is at the ZLB, ambitious and credible structural reforms may have undesirable short-run effects. In addition, when political economy factors such as electoral outcomes and social unrest undermine the credibility of the reforms and cast doubts on their long-lasting impact, these perverse effects are likely to be magnified. The next section explores two alternative reform policies that directly deal with the negative short-run consequences of structural reforms.

6 Alternative Reform Policies at the ZLB

Short-run deflation is the unpleasant feature of structural reforms. In normal times, monetary policy can accommodate deflationary pressures by cutting nominal interest rates. However, in a severe crisis, whereby the central bank runs into the ZLB constraint, the deflationary pressures associated with structural reforms lead to higher real rates and further depress economic activity. In this section, we consider two alternative reform policies that address these concerns.

In the first policy, which we label "New Deal," we assume the government sets the subsidies τ^p_{Nt} and τ^w_{Nt} to actually increase monopolistic power in the short run (as in Eggertsson, 2012). In particular, we design this policy to be state-contingent. The subsidy remains negative (i.e. the government levies a tax on firms and workers) as long as the "shadow" nominal interest rate (i.e. the nominal interest rate absent the ZLB constraint) stays in negative territory

$$\tau^p_t = \tau^w_t = \tau^{nd}_t = \min\left\{0, \phi_\tau\left[(1+i)\left(\Pi^{MU}_t\right)^{\varphi_\pi} - 1\right]\right\},$$

where $\phi_\tau > 0$ is a parameter that controls how aggressively the government increases the taxes in response to the crisis.[21] Qualitatively, a constant tax would achieve a similar objective. However, if the tax is too high, the nominal interest rate may endogenously react, partly undoing the gains from less deflation and leading to temporary spikes in the nominal interest rate during the crisis.

Whereas our "New Deal" policy can be interpreted as a policy prescription to directly address the negative effects of deflation at the ZLB, our second policy, which we label "Delay", aims at retaining the long-run benefits of structural reforms without imposing the short-run costs in terms of deflation. When the crisis hits, the government (credibly) announces that it will implement structural reforms once the crisis is over, or, more precisely in our case, when the ZLB stops being binding

$$\tau^p_t = \tau^w_t = \tau^d_t = \max\left\{0, \tau\left[(1+i)\left(\Pi^{MU}_t\right)^{\varphi_\pi} - 1\right]/i\right\}.$$

The "Delay" rule differs from the "New Deal" rule because the permanent change in the subsidy

[21] We calibrate the parameter ϕ_τ in the "New Deal" policy to minimize deflation on impact.

needs to be consistent with the final steady state. Therefore, the coefficient ϕ_τ is constrained to be equal to τ/i.[22]

The idea that news about future supply increases may stimulate subdued aggregate demand in an economy facing a liquidity trap is not new. In their discussion about the Japanese ZLB experience of the late 1990s, Krugman (1998) argues that expected drop in productivity due to population aging contributed to the persistence of the ZLB, while Rogoff (1998) suggests that future productivity gains ought to be the solution to the ZLB constraint. More recently, Fernandez-Villaverde et al. (2012) formalize this argument in a two-period New-Keynesian model. Our "Delay" policy can be interpreted as a state-contingent application of this same prescription.

Figure 9 presents the response of the main variables to the "New Deal" policy (dashed blue line) and to the "Delay" policy (dashed-dotted red line). Both policies result in short-run output gains relative to the crisis scenario (and, as a consequence, the permanent reform scenario discussed in Section 5.2). Under the "New Deal" policy, the initial drop in output is 3.20%, much less than the 3.95% contraction experienced in the absence of announced reforms. Under the "Delay" policy, which is calibrated to a long-run reduction in markups of 10 percentage points, the output gains are even larger, as output drops only 1.66% on impact.

Although both these policies improve output prospects relative to the crisis (and our baseline policy experiment of permanent reforms), different economic mechanisms are at work. The "New Deal" policy attempts to offset the deflationary effects of the crisis by creating inflation through higher, albeit temporary, monopoly power. Thus, this policy operates mainly through the substitution effects of lower real interest rates. In the case of the "Delay" policy, the expectation that reforms will be permanent, though implemented in the future, generates a large wealth effect that stimulate aggregate demand, thus limiting the short-run output drop due to the crisis and supporting domestic prices. Notwithstanding similar effects on inflation and the real interest rate, the wealth effects associated with "Delay" policy appear to be more supportive of output in the short-run.

As for the open-economy variables, the permanent effects associated with the "Delay" policy

[22]We could additionally combine the two rules in a third alternative that counteracts the deflationary pressures stemming from the crisis through short run taxes as in the "New Deal rule," while at the same time taking full advantage of the long-run gains associated with the "Delay" rule.

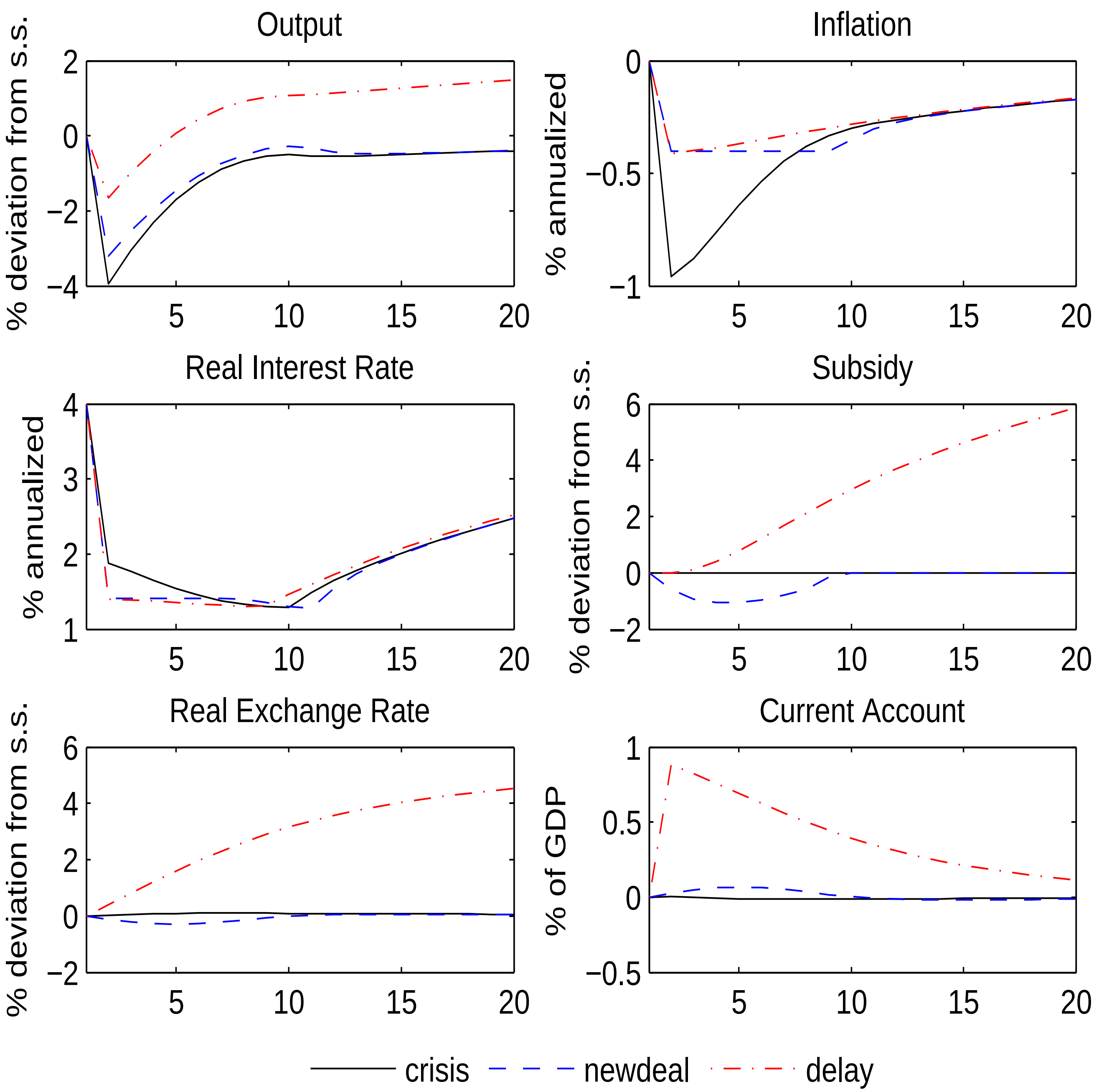

Figure 9: Response of output (top-left), inflation (top-right), real interest rate (middle-left), subsidy (middle-right), real exchange rate (bottom-left) and current account (bottom-right) in the crisis without reforms (continuous black line), under the "new deal" rule (dashed blue line) and under the "delay" rule (dashed-dotted red line).

result in a gradual depreciation of the real exchange rate and a current account surplus. These patterns are consistent with the effects of these reforms in normal times. Taken together, these effects suggest that permanent structural reforms may indeed lead to a substantial improvement of external imbalances in the vulnerable European countries.

The "New Deal" policy, in contrast, has very little impact on international variables. As a temporary policy, it is not designed to bring any realignment in international prices or permanent gain in competitiveness. In the short-run, the real exchange rate modestly appreciates and the current account turns slightly positive. These responses reflect higher output and prices in the home country relative to the foreign country, where no policy is implemented.

In sum, our experiments show that temporarily granting monopoly power to firms and unions ("New Deal") or committing to implementing reforms in the future ("Delay") are associated with higher short-run output than aggressively passing reforms in crisis times. Admittedly, our findings neglect political economy considerations that may reduce the benefits these strategies. For instance, amidts a fiscal crisis, financial markets may look for signals of "good policies" to gauge public debt sustainable. In addition, the social and political opposition faced by governments in peripheral Europe to adopt small reform package in times of financial turbulence reveals how difficult it is to change these policies in practise. That said, we think that our findings emphasize an important macroeconomic tradeoff associated with the absence of sufficient policy stimulus to support reform efforts. In this respect, some of these political economy considerations could be importantly affected by the output costs of reforms in the short run.

7 Conclusions

Structural reforms can partly close the gap in competitiveness between the EMU core and periphery that has led to the development of large macroeconomic imbalances before the recent crisis. However, the timing of implementation of such reforms is crucial. If undertaken during a crisis, structural reforms can deepen the recession by up to one percentage point, by worsening deflation and increasing real rates. This effect becomes even stronger if exogenous factors force policymakers to unwind the reforms, due to their short-run costs.

Our results have important implications for the design of structural reforms as a tool to rebalance Europe. We have studied two policies that avoid the perverse short-run effects of structural reforms in a crisis. The first policy actually calls for an increase in markups for as long as the nominal interest rate is at its lower bound. The second policy requires the government to commit to implement structural reforms once the ZLB stops being binding. Both policies have short-run inflationary consequences, which counterbalance the deflationary pressures associated with the crisis, and provide stimulus by allowing the real interest rate to drop below what monetary policy can achieve. In addition, the second policy retains the positive wealth effect of permanent reforms. Conceivably, the two policies could be combined to obtain the maximum impact.

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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:

$$C_{Ht} = \omega \left(\frac{p_{Ht}}{p_{Tt}}\right)^{-\epsilon} C_{Tt}, \qquad C_{Ft} = (1-\omega)\left(\frac{p_{Ft}}{p_{Tt}}\right)^{-\epsilon} C_{Tt}. \tag{50}$$

$$C_{Ft}^* = \omega \left(\frac{p_{Ft}}{p_{Tt}^*}\right)^{-\epsilon} C_{Tt}^*, \qquad C_{Ht}^* = (1-\omega)\left(\frac{p_{Ht}}{p_{Tt}^*}\right)^{-\epsilon} C_{Tt}^*. \tag{51}$$

- Demand for tradable consumption bundles:

$$C_{Tt} = \gamma \left(\frac{p_{Tt}}{p_t}\right)^{-\varphi} C_t, \qquad C_{Tt}^* = \gamma \left(\frac{p_{Tt}^*}{p_t^*}\right)^{-\varphi} C_t^*. \tag{52}$$

- Demand for non-tradable goods:

$$C_{Nt} = (1-\gamma) \left(\frac{p_{Nt}}{p_t}\right)^{-\varphi} C_t, \qquad C_{Nt}^* = (1-\gamma) \left(\frac{p_{Nt}^*}{p_t^*}\right)^{-\varphi} C_t^*. \tag{53}$$

- Resource constraint for Home and Foreign tradable goods:

$$C_{Ht} + C_{Ht}^* = Y_{Ht}, \tag{54}$$

$$C_{Ft} + C_{Ft}^* = Y_{Ft}^*. \tag{55}$$

- Resource constraint for non-tradable goods:

$$C_{Nt} = Y_{Nt}, \tag{56}$$

$$C_{Nt}^* = Y_{Nt}^*. \tag{57}$$

- Real marginal costs ($mc_{kt} \equiv MC_{kt}/P_t^{MU}$; also denote real wages as $w_{kt} \equiv W_{kt}/P_t^{MU}$)

$$mc_{Ht} = \frac{w_{Ht}}{Z_{Ht}}, \qquad mc_{Nt} = \frac{w_{Nt}}{Z_{Nt}}. \tag{58}$$

$$mc_{Ft}^* = \frac{w_{Ft}^*}{Z_{Ft}^*}, \qquad mc_{Nt}^* = \frac{w_{Nt}^*}{Z_{Nt}^*}. \tag{59}$$

- Production functions:

$$Y_{Ht}\Delta_{Ht} = Z_{Ht}L_{Ht}, \qquad Y_{Nt}\Delta_{Nt} = Z_{Nt}L_{Nt}. \tag{60}$$

$$Y^*_{Ft}\Delta^*_{Ft} = Z^*_{Ft}L^*_{Ft}, \qquad Y^*_{Nt}\Delta^*_{Nt} = Z^*_{Nt}L^*_{Nt}. \tag{61}$$

- Evolution of price dispersion:

$$\Delta_{Ht} = \xi_p \Delta_{Ht-1}\Pi_{Ht}^{\theta_H} + (1-\xi_p)\left(\frac{1-\xi_p\Pi_{Ht}^{\theta_H-1}}{1-\xi_p}\right)^{\frac{\theta_H}{\theta_H-1}} \tag{62}$$

$$\Delta_{Nt} = \xi_p \Delta_{Nt-1}\Pi_{Nt}^{\theta_N} + (1-\xi_p)\left(\frac{1-\xi_p\Pi_{Nt}^{\theta_N-1}}{1-\xi_p}\right)^{\frac{\theta_N}{\theta_N-1}} \tag{63}$$

$$\Delta^*_{Ft} = \xi_p \Delta^*_{Ft-1}(\Pi^*_{Ft})^{\theta^*_F} + (1-\xi_p)\left[\frac{1-\xi_p(\Pi^*_{Ft})^{\theta^*_F-1}}{1-\xi_p}\right]^{\frac{\theta^*_F}{\theta^*_F-1}} \tag{64}$$

$$\Delta^*_{Nt} = \xi_p \Delta^*_{Nt-1}(\Pi^*_{Nt})^{\theta^*_N} + (1-\xi_p)\left[\frac{1-\xi_p(\Pi^*_{Nt})^{\theta^*_N-1}}{1-\xi_p}\right]^{\frac{\theta^*_N}{\theta^*_N-1}} \tag{65}$$

- Price Phillips curves:

$$\left(\frac{1-\xi_p\Pi_{Ht}^{\theta_H-1}}{1-\xi_p}\right)^{\frac{1}{1-\theta_H}} = \frac{X1_{Ht}}{X2_{Ht}}, \tag{66}$$

where

$$X1_{Ht} = \frac{\theta_H}{\theta_H-1}\varsigma_t C_t^{-\sigma}Y_{Ht}\frac{mc_{Ht}}{p_t} + \beta\xi_p\mathbb{E}_t\left(\Pi_{Ht+1}^{\theta_H}X1_{Ht+1}\right) \tag{67}$$

and

$$X2_{Ht} = \varsigma_t(1+\tau^p_{Ht})C_t^{-\sigma}Y_{Ht}\frac{p_{Ht}}{p_t} + \beta\xi_p\mathbb{E}_t\left(\Pi_{Ht+1}^{\theta_H-1}X2_{Ht+1}\right). \tag{68}$$

$$\left(\frac{1-\xi_p\Pi_{Nt}^{\theta_N-1}}{1-\xi_p}\right)^{\frac{1}{1-\theta_N}} = \frac{X1_{Nt}}{X2_{Nt}}, \tag{69}$$

where

$$X1_{Nt} = \frac{\theta_N}{\theta_N-1}\varsigma_t C_t^{-\sigma}Y_{Nt}\frac{mc_{Nt}}{p_t} + \beta\xi_p\mathbb{E}_t\left(\Pi_{Nt+1}^{\theta_N}X1_{Nt+1}\right) \tag{70}$$

and

$$X2_{Nt} = \varsigma_t(1+\tau^p_{Nt})C_t^{-\sigma}Y_{Nt}\frac{p_{Nt}}{p_t} + \beta\xi_p\mathbb{E}_t\left(\Pi_{Nt+1}^{\theta_N-1}X2_{Nt+1}\right). \tag{71}$$

$$\left[\frac{1-\xi_p(\Pi^*_{Ft})^{\theta^*_F-1}}{1-\xi_p}\right]^{\frac{1}{1-\theta^*_F}} = \frac{X1^*_{Ft}}{X2^*_{Ft}}, \tag{72}$$

where

$$X1^*_{Ft} = \frac{\theta^*_F}{\theta^*_F-1}\varsigma^*_t(C^*_t)^{-\sigma}Y^*_{Ft}\frac{mc^*_{Ft}}{p^*_t} + \beta\xi_p\mathbb{E}_t\left[(\Pi^*_{Ht+1})^{\theta^*_F}X1^*_{Ft+1}\right] \tag{73}$$

and

$$X2^*_{Ft} = \varsigma^*_t(1+\tau^{p*}_{Ft})(C^*_t)^{-\sigma}Y^*_{Ft}\frac{p^*_{Ft}}{p^*_t} + \beta\xi_p\mathbb{E}_t\left[(\Pi^*_{Ft+1})^{\theta^*_F-1}X2^*_{Ft+1}\right]. \tag{74}$$

$$\left[\frac{1-\xi_p(\Pi^*_{Nt})^{\theta^*_N-1}}{1-\xi_p}\right]^{\frac{1}{1-\theta^*_N}} = \frac{X1^*_{Nt}}{X2^*_{Nt}}, \tag{75}$$

where

$$X1^*_{Nt} = \frac{\theta^*_N}{\theta^*_N-1}\varsigma^*_t(C^*_t)^{-\sigma}Y^*_{Nt}\frac{mc^*_{Nt}}{p^*_t} + \beta\xi_p\mathbb{E}_t\left[(\Pi^*_{Nt+1})^{\theta^*_N}X1^*_{Nt+1}\right) \tag{76}$$

and

$$X2^*_{Nt} = \varsigma^*_t(1+\tau^{p*}_{Nt})(C^*_t)^{-\sigma}Y^*_{Nt}\frac{p^*_{Nt}}{p^*_t} + \beta\xi_p\mathbb{E}_t\left[(\Pi^*_{Nt+1})^{\theta^*_N-1}X2^*_{Nt+1}\right). \tag{77}$$

- Wage Phillips curves:

$$\left[\frac{1-\xi_w(\Pi^w_{Ht})^{\phi_H-1}}{1-\xi_w}\right]^{\frac{1+\phi_H\nu}{1-\phi_H}} = \frac{D1_{Ht}}{D2_{Ht}}, \tag{78}$$

where

$$D1_{Ht} = \frac{\phi_H}{\phi_H-1}\varsigma_t\left(\frac{L_{Ht}}{\gamma}\right)^{1+\nu} + \beta\xi_w\mathbb{E}_t\left[(\Pi^w_{Ht+1})^{\phi_H}D1_{Ht+1}\right] \tag{79}$$

and

$$D2_{Ht} = \varsigma_t(1+\tau^w_{Ht})C_t^{-\sigma}\frac{w_{Ht}}{p_t}\frac{L_{Ht}}{\gamma} + \beta\xi_w\mathbb{E}_t\left[(\Pi^w_{Ht+1})^{\phi_H-1}D2_{Ht+1}\right). \tag{80}$$

$$\left[\frac{1-\xi_w(\Pi^w_{Nt})^{\phi_N-1}}{1-\xi_w}\right]^{\frac{1+\phi_N\nu}{1-\phi_N}} = \frac{D1_{Nt}}{D2_{Nt}}, \tag{81}$$

where

$$D1_{Nt} = \frac{\phi_N}{\phi_N-1}\varsigma_t\left(\frac{L_{Nt}}{1-\gamma}\right)^{1+\nu} + \beta\xi_w\mathbb{E}_t\left[(\Pi^w_{Nt+1})^{\phi_N}D1_{Nt+1}\right] \tag{82}$$

and

$$D2_{Nt} = \varsigma_t(1+\tau^w_{Nt})C_t^{-\sigma}\frac{w_{Nt}}{p_t}\frac{L_{Nt}}{1-\gamma} + \beta\xi_w\mathbb{E}_t\left[(\Pi^w_{Nt+1})^{\phi_N-1}D2_{Nt+1}\right). \tag{83}$$

$$\left[\frac{1-\xi_w(\Pi^{*w}_{Ft})^{\phi^*_F-1}}{1-\xi_w}\right]^{\frac{1+\phi^*_F\nu}{1-\phi^*_F}} = \frac{D1^*_{Ft}}{D2^*_{Ft}}, \tag{84}$$

where

$$D1^*_{Ft} = \frac{\phi^*_F}{\phi^*_F-1}\varsigma^*_t\left(\frac{L^*_{Ft}}{\gamma}\right)^{1+\nu} + \beta\xi_w\mathbb{E}_t\left[(\Pi^{*w}_{Ft+1})^{\phi^*_F}D1^*_{Ft+1}\right] \tag{85}$$

and

$$D2^*_{Ft} = \varsigma^*_t(1+\tau^{*w}_{Ft})(C^*_t)^{-\sigma}\frac{w^*_{Ft}}{p^*_t}\frac{L^*_{Ft}}{\gamma} + \beta\xi_w\mathbb{E}_t\left[(\Pi^{*w}_{Ft+1})^{\phi^*_F-1}D2^*_{Ft+1}\right). \tag{86}$$

$$\left[\frac{1-\xi_w(\Pi^{*w}_{Nt})^{\phi^*_N-1}}{1-\xi_w}\right]^{\frac{1+\phi^*_N\nu}{1-\phi^*_N}} = \frac{D1^*_{Nt}}{D2^*_{Nt}}, \tag{87}$$

where

$$D1^*_{Nt} = \frac{\phi^*_N}{\phi^*_N-1}\varsigma^*_t\left(\frac{L^*_{Nt}}{1-\gamma}\right)^{1+\nu} + \beta\xi_w\mathbb{E}_t\left[(\Pi^{*w}_{Nt+1})^{\phi^*_N}D1^*_{Nt+1}\right] \tag{88}$$

and

$$D2^*_{Nt} = \varsigma^*_t(1+\tau^{*w}_{Nt})(C^*_t)^{-\sigma}\frac{w^*_{Nt}}{p^*_t}\frac{L^*_{Nt}}{1-\gamma} + \beta\xi_w\mathbb{E}_t\left[(\Pi^{*w}_{Nt+1})^{\phi^*_N-1}D2^*_{Nt+1}\right). \tag{89}$$

- Price index for tradable consumption bundles:

$$p_{Tt} = \left[\omega p_{Ht}^{1-\epsilon} + (1-\omega)p_{Ft}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \qquad p^*_{Tt} = \left[\omega p_{Ft}^{1-\epsilon} + (1-\omega)p_{Ht}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{90}$$

- Consumer price index:

$$p_t = \left[\gamma p_{Tt}^{1-\varphi} + (1-\gamma)p_{Nt}^{1-\varphi}\right]^{\frac{1}{1-\varphi}}, \qquad p^*_t = \left[\gamma (p^*_{Tt})^{1-\varphi} + (1-\gamma)(p^*_{Nt})^{1-\varphi}\right]^{\frac{1}{1-\varphi}}. \tag{91}$$

- Euler equations for bonds:

$$1 = \beta\psi_{Bt}(1+i_t)\mathbb{E}_t\left[\frac{\varsigma_{t+1}}{\varsigma_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\right], \tag{92}$$

$$1 = \beta(1+i_t)\mathbb{E}_t\left[\frac{\varsigma^*_{t+1}}{\varsigma^*_t}\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{1}{\Pi^*_{t+1}}\right], \tag{93}$$

$$\psi_{Bt} = \exp\left[-\psi_B\left(\frac{b_t}{p_tY_t}\right)\right], \tag{94}$$

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

- Evolution of net foreign assets

$$\frac{b_t}{\psi_{Bt}} = \left(\frac{1+i_t}{\Pi_t^{MU}}\right) b_{t-1} + p_{Ht}C_{Ht}^* - p_{Ft}C_{Ft}, \tag{95}$$

$$b_t^* = \left(\frac{1+i_t}{\Pi_t^{MU}}\right) b_{t-1}^* + p_{Ft}C_{Ft} - p_{Ht}C_{Ht}^* + \left(\frac{1}{\psi_{Bt}} - 1\right) b_t, \tag{96}$$

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:

$$b_t + b_t^* = 0. \tag{97}$$

- GDP

$$p_t Y_t = p_{Ht}Y_{Ht} + p_{Nt}Y_{Nt}, \tag{98}$$

$$p_t^* Y_t^* = p_{Ft}^* Y_{Ft}^* + p_{Nt}^* Y_{Nt}^*. \tag{99}$$

- Union-wide inflation:

$$\Pi_t^{MU} = (\Pi_t)^{0.5}(\Pi_t^*)^{0.5}. \tag{100}$$

- Union-wide output:

$$Y_t^{MU} \equiv (Y_t)^{0.5}(Y_t^*)^{0.5}. \tag{101}$$

- Monetary policy rule:

$$1 + i_t = \max\left\{1 + i^{zlb}, \left[(1+i)\left(\Pi_t^{MU}\right)^{\varphi_\pi}\right]\right\}. \tag{102}$$

A.1 Additional Variables of Interest

- Terms of trade:

$$TOT_{Ht} = \frac{p_{Ft}}{p_{Ht}}. \tag{103}$$

- Real exchange rate

$$RER_{Ht} = \frac{p_t^*}{p_t}. \tag{104}$$

- Net exports (in % of GDP)

$$NX_t = \frac{p_{Ht}C^*_{Ht} - p_{Ft}C_{Ft}}{Y_t}. \tag{105}$$

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

$$RNX_t = \frac{p_H C^*_{Ht} - p_F C_{Ft}}{Y_t}. \tag{106}$$

B Steady State

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

- Demand for Home and Foreign tradable goods:

$$C_H = \omega \left(\frac{p_H}{p_T}\right)^{-\epsilon} C_T, \qquad C_F = (1-\omega)\left(\frac{p_F}{p_T}\right)^{-\epsilon} C_T. \tag{107}$$

$$C^*_F = \omega \left(\frac{p_F}{p^*_T}\right)^{-\epsilon} C^*_T, \qquad C^*_H = (1-\omega)\left(\frac{p_H}{p^*_T}\right)^{-\epsilon} C^*_T. \tag{108}$$

- Demand for tradable consumption bundle:

$$C_T = \gamma \left(\frac{p_T}{p}\right)^{-\varphi} C \qquad C^*_T = \gamma \left(\frac{p^*_T}{p^*}\right)^{-\varphi} C^*. \tag{109}$$

- Demand for non-tradable goods:

$$C_N = (1-\gamma)\left(\frac{p_N}{p}\right)^{-\varphi} C, \qquad C^*_N = (1-\gamma)\left(\frac{p^*_N}{p^*}\right)^{-\varphi} C^*. \tag{110}$$

- Resource constraint for Home and Foreign tradable goods:

$$C_H + C^*_H = Y_H, \tag{111}$$

$$C_F + C^*_F = Y^*_F. \tag{112}$$

- Resource constraint for non-tradable goods:

$$C_N = Y_N, \tag{113}$$

$$C^*_N = Y^*_N. \tag{114}$$

- Marginal costs

$$mc_H = \frac{w_H}{Z_H} \qquad mc_N = \frac{w_N}{Z_N} \tag{115}$$

$$mc_F^* = \frac{w_F^*}{Z_F^*} \qquad mc_N^* = \frac{w_N^*}{Z_N^*} \tag{116}$$

- Production functions:

$$Y_H = Z_H L_H, \qquad Y_N = Z_N L_N. \tag{117}$$

$$Y_F^* = Z_F^* L_F^*, \qquad Y_N^* = Z_N^* L_N^*. \tag{118}$$

- Price setting:

$$\frac{\theta_H}{\theta_H - 1} mc_H = (1 + \tau_H^p) p_H \qquad \frac{\theta_N}{\theta_N - 1} mc_N = (1 + \tau_N^p) p_N \tag{119}$$

$$\frac{\theta_F^*}{\theta_F^* - 1} mc_F^* = (1 + \tau_F^{*p}) p_F^* \qquad \frac{\theta_N^*}{\theta_N^* - 1} mc_N^* = (1 + \tau_N^{p*}) p_N^* \tag{120}$$

- Wage setting:

$$(1 + \tau_H^w) \frac{w_H}{p} = \frac{\phi_H}{\phi_H - 1} \left(\frac{L_H}{\gamma} \right)^{\nu} \frac{1}{C^{-\sigma}} \tag{121}$$

$$(1 + \tau_N^w) \frac{w_N}{p} = \frac{\phi_N}{\phi_N - 1} \left(\frac{L_N}{1 - \gamma} \right)^{\nu} \frac{1}{C^{-\sigma}} \tag{122}$$

$$(1 + \tau_F^{*w}) \frac{w_F^*}{p^*} = \frac{\phi_F^*}{\phi_F^* - 1} \left(\frac{L_F^*}{\gamma} \right)^{\nu} \frac{1}{(C^*)^{-\sigma}} \tag{123}$$

$$(1 + \tau_N^{w*}) \frac{w_N^*}{p^*} = \frac{\phi_N^*}{\phi_N^* - 1} \left(\frac{L_N^*}{1 - \gamma} \right)^{\nu} \frac{1}{(C^*)^{-\sigma}} \tag{124}$$

- Price index for tradable consumption bundles:

$$p_T = \left[\omega p_H^{1-\epsilon} + (1 - \omega) p_F^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}, \qquad p_T^* = \left[\omega p_F^{1-\epsilon} + (1 - \omega) p_H^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \tag{125}$$

- Consumer price index:

$$p = \left[\gamma p_T^{1-\varphi} + (1 - \gamma) p_N^{1-\varphi} \right]^{\frac{1}{1-\varphi}}, \qquad p^* = \left[\gamma (p_T^*)^{1-\varphi} + (1 - \gamma) (p_N^*)^{1-\varphi} \right]^{\frac{1}{1-\varphi}}. \tag{126}$$

- Euler equations for bonds:

$$1 = \beta(1+i) \tag{127}$$

- Balanced trade:

$$p_H C_H^* = p_F C_F \tag{128}$$

- Relation between CPIs:

$$p = \frac{1}{p^*} \tag{129}$$