Can Structural Reforms Help Europe?*

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Abstract

Ambitious structural reforms that increase competition in product and labor markets are often indicated as the main policy option available to peripheral Europe to regain competitiveness and boost output. We show that, in times when the central bank’s nominal interest rate is at its lower bound, the short-run transmission mechanism of these reforms is contractionary. 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 ongoing 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 hit due to “macroeconomic imbalances” accumulated ever since the introduction of the common currency (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. Relative to Germany, the real exchange rate of peripheral countries appreciated between 7 percent (Italy) and 17 percent (Greece) over the period 2000-2008. Most of these appreciations reflect large increases in

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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).
nontraded good prices, such as housing and other services.\(^3\)

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. Figure 3 presents indexes of economic flexibility in product and labor markets obtained from the World Economic Forum: Peripheral countries score poorly along both dimensions.\(^4\) 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 surprising that structural reforms are the

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\(^3\)See, for instance, Gaulier, and Vicard (2012).

\(^4\)OECD estimates of business markups and regulations burden paint a similar picture. We make explicit use of these estimates in our quantitative exercises.
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 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.5

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 region by nearly 5 percent, and contributes to boost the union-wide level of output as well.6 As output in the service sector

5See, for instance, Bayoumi et al. (2004) and Forni et al. (2010).
6These 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.
expands and its prices fall, the home country experiences a real exchange rate depreciation of about 7 percent. Thus, these figures suggest that ambitious reforms implemented in peripheral EMU countries could greatly reduce the income and competitiveness gap between core and periphery.

Notwithstanding these long-run benefits, we find that the short-run transmission mechanism of these reforms critically depends 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 the nominal interest rate and the currency union experiences a vigorous short-term boom.\(^7\) These effects, however, are completely overturned in crisis times. When the central bank’s nominal interest rate is at the 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).

We next consider two experiments in order to disentangle the transmission of reforms at the ZLB. In the spirit of Eggertsson (2012), we first study the effects of temporarily granting firms and unions with higher monopoly power. Notwithstanding the absence of long-run changes to output (income effect), at the ZLB these temporary reforms are expansionary. 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.\(^8\)

In a second experiment, we follow recent work by Fernandez-Villaverde et al. (2012) and study the effects of announcements to credibly implement structural reforms at some future date. This policy delivers the sizable income effects typically associated with permanent increases in the long-run level of output, but 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

\(^{7}\)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.

\(^{8}\)Eggertsson (2012) argues that New Deal policies of this kind contributed to end the Great Depression.
in the short term.

Our research contributes to a growing literature that studies the implications of the ZLB constraint for the short-run transmission of shocks and policies. Eggertsson (2012) argues that New Deal policies facilitated the recovery form the Great Depression by temporarily granting monopoly power to firms and unions. Our work differ from his in two respects. First, we consider the transmission of (markup) shocks in an open economy environment which features traded and non traded goods, resulting in interesting cross-country spillovers. Second, we focus on shocks that are permanent, emphasizing the horse race between sizable increases in long-run income and short-run deflationary effects. A number of studies have also studied the transmission of fiscal shocks at the ZLB ((see, for example, Erceg and Linde, 2012)), often concluding that fiscal multipliers change greatly when the central bank’s nominal interest rate is at its lower bound. We leave the investigation of structural reforms and fiscal policy to future research.

The rest of the paper is organized 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

\begin{align}
\hat{Y}_t &= E_t \hat{Y}_{t+1} - \sigma^{-1}(i_t - E_t \pi_{t+1} - r_e^t) \\
\pi_t &= \kappa \hat{Y}_t + \beta E_t \pi_{t+1} + \kappa \psi \omega_t
\end{align}

where \(\pi_t\) is inflation, \(\hat{Y}_t\) is output in deviation from its first best level, \(r_e^t\) is an exogenous disturbance, \(\kappa\) is the slope of the Phillips curve (a convolution of structural parameters), \(\sigma\) is the coefficient of relative risk aversion, \(\psi \equiv 1/(\sigma + \nu)\) where \(\nu\) is the inverse Frisch elasticity of labor supply, and \(E_t\) is the expectation operator conditional on all information available at time \(t\). The variable \(\omega_t\) 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

\begin{align}
\hat{Y}_S &= -\psi \omega_S \\
\hat{Y}_L &= -\psi \omega_L
\end{align}

Equations (3) reveals two important insights. First, structural reforms have an unambiguous impact on output, whose magnitude depends on \(\psi\). 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 \((\omega_S, \omega_L)\) 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 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

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

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

Given the policy \((\omega_S, \omega_L)\), 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.\(^9\)

Figure 4 shows the impact of permanent structural reforms (i.e. a reduction in \( \omega_S \) and \( \omega_L \)) 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

\(^9\)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.

As shown in equation (4), however, reforms also have a second effect on short-run output $\dot{Y}_S$ through $\dot{Y}_L$, 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). The question of which effect dominates is ultimately quantitative. For this purpose, in the

\footnote{Eggertsson (2010) calls this effect the “paradox of toil.” His analysis, however, is restricted to temporary reforms, whereas our focus here is on the effects of permanent reforms on the equilibrium.}
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.

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 short-run 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), that belong to a currency union whose population size is normalized to one. A continuum of households of measure \( n \) inhabits country \( H \). Each household derives utility from consumption of tradable and non-tradable goods and disutility from hours worked. Households supply sector-specific differentiated labor inputs. A representative labor agency combines these inputs in sector-specific aggregates, while households set the wage for each input on a staggered basis.

Firms in each country produce traded and a non-traded goods using labor, which is immobile across countries. Production takes place in two stages. In each sector (tradable and non-tradable), a representative retailer combines 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.

In each country, we assume the existence of a full set of transfers that completely insure against the idiosyncratic income risk arising from staggered price and wage setting. Across countries, the only asset traded is a one-period nominal risk-free bond denominated in the common currency. One-period changes in the net foreign asset position define the current account.

The common central bank sets monetary policy for the union targeting zero inflation.

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

A representative wholesale producer in the tradable ($k = H$) and non-tradable ($k = N$) sector combines raw goods according to a technology with constant elasticity of substitution $\theta_k > 1$

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

where $j$ indexes an intermediate goods producer and $\gamma_k = \{\gamma, 1 - \gamma\}$ is the size of the tradable and non-tradable sector, respectively.

The representative retailer in sector $k$ maximizes profits subject to its technological constraint (6)

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

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

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

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

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

### 3.2 Labor Agencies

In each sector, a representative labor agency combines differentiated labor inputs provided by each household $L_{kt}(i)$ into a sector-specific homogenous aggregate according to a technology with constant elasticity of substitution $\phi_k > 1$

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

The representative labor agency in sector $k$ maximizes profits subject to its technological
constraint (10)

\[
\max_{L_{kt}(i)} W_{kt} L_{kt} - \int_0^{\gamma_k n} W_{kt}(i) L_{kt}(i) di,
\]  

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

\[
L_{kt}(i) = \frac{1}{\gamma_k n} \left( \frac{W_{kt}(i)}{W_{kt}} \right)^{-\phi_k} L_{kt}.
\]  

(12)

The zero profit condition implies that the wage index is

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

(13)

### 3.3 Intermediate Goods Producers

A continuum of measure \( \gamma_k \) of intermediate goods producers operate in each sector using the technology

\[
Y_{kt}(j) = Z_{kt} L_{kt}(j),
\]  

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 cost (the Lagrange multiplier on the constraint) equals the nominal wage scaled by the level of productivity

\[
MC_{kt}(j) = MC_{kt} = \frac{W_{kt}}{Z_{kt}}.
\]  

(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) and the production function
(14) to write an aggregate production function as

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

(16)

where equilibrium in the labor market implies

$$L_{kt} = \int_{0}^{\gamma_k} L_{kt}(j) dj$$

and $\Delta_{kt}$ is an index of price dispersion defined as

$$\Delta_{kt} = \frac{1}{\gamma_k} \int_{0}^{\gamma_k} \left[ \frac{P_{kt}(j)}{P_{kt}} \right]^{-\theta_k} dj.$$

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

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

(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 a nominal asset between period $t$ and period $t + s$ (such that $Q_{t,t} = 1$). The time-varying tax $\tau_{kt+s}^p$ is the policy instrument that the government can use to affect the degree of competitiveness in each sector. Ceteris paribus, a lower tax reduces the firms’ effective markup 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 ($\tilde{P}_{kt}(j) = \tilde{P}_{kt}$). After some manipulations, we can write the optimality condition as

$$\frac{\tilde{P}_{kt}}{P_{kt}} = \frac{\theta_k}{\theta_k - 1} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \xi_p^s Q_{t,t+s} MC_{kt+s} Y_{kt+s} \left[ \Pi_{kt+s}^{\theta_k} \right] \right\}$$

$$= \frac{\theta_k}{\theta_k - 1} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \xi_p^s Q_{t,t+s} (1 - \tau_{kt+s}^p) P_{kt+s} Y_{kt+s} \left[ \Pi_{kt+s}^{\theta_k-1} \right] \right\},$$

(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

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

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

$$\Delta_{kt} = \xi_p \Delta_{kt-1} \Pi_{kt}^{\theta_k} + (1 - \xi_p) \left( \frac{1 - \xi_p \Pi_{kt}^{\theta_k-1}}{1 - \theta_k} \right)^{\frac{\theta_k}{\theta_k-1}}. \quad (20)$$

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

$$P_k = \frac{1}{1 - \tau_k^{\theta_k-1}} \frac{\theta_k}{\theta_k-1} MC_k.$$ The government can choose a value of $\tau_k^{\theta_k}$ that fully offsets firms’ monopolistic power—or, more generally, set a desired markup level in the goods market.

### 3.4 Households

In country $H$, a continuum of households of measure $n$ derive utility from consumption and supply differentiated labor inputs while setting wages on a staggered basis (Calvo, 1983). Consumption is a composite of tradable and non-tradable goods with constant elasticity of substitution $\varphi > 0$

$$C_t(i) = \left[ \gamma \frac{1}{\varphi} C_{Tt}(i) \right]^{\frac{\varphi-1}{\varphi}} + (1 - \gamma) \frac{1}{\varphi} C_{Nt}(i)^{\frac{\varphi-1}{\varphi}} \right]^\frac{\varphi}{\varphi-1}, \quad (21)$$

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

$$P_t C_t(i) \equiv \min_{C_{Tt}(i), C_{Nt}(i)} P_{Tt} C_{Tt}(i) + P_{Nt} C_{Nt}(i), \quad (22)$$
subject to (21). The first order condition for this problem yields the demand for the tradable and non-tradable goods

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

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

(23) \hspace{1cm} (24)

The associated price index is

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

(25)

Consumption of tradables includes goods produced in the two countries combined according to a constant elasticity of substitution ($\epsilon > 0$) aggregator

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

(26)

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

$$P_{Ht} = P_{Ht}^*,$$

$$P_{Ft}^* = P_{Ft}.$$  

(27) \hspace{1cm} (28)

The expenditure minimization problem is

$$P_{Tt}C_{Tt}(i) \equiv \min_{C_{Ht}(i), C_{Ft}(i)} P_{Ht}C_{Ht}(i) + P_{Ft}C_{Ft}(i),$$

(29)

subject to (26). The first order conditions for this problem yield the standard demand functions for domestic and foreign traded goods

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

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

(30) \hspace{1cm} (31)
The zero profit condition implies that the price index for traded goods is

\[ P_{t} = \left[ \omega P_{Ht}^{1-\kappa} + (1 - \omega) P_{Ft}^{1-\kappa} \right]^{\frac{1}{1-\kappa}}. \tag{32} \]

While the law of one price holds, home bias in tradable consumption \((\omega > n)\) implies that the price index for tradable goods differs across countries \((P_t \neq P_t^*)\). 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 tradables, the problem of a generic household \(i \in (0, n)\) in country \(H\) is

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

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

\[
P_t C_t(i) + \frac{B_t(i)}{\psi_{Bt}} = (1 + \dot{L}_{t-1}) B_{t-1}(i) + (1 - \tau_{kt}^{w}) W_{kt}(i) L_{kt}(i) + P_t(i) - T_t(i),
\]

where \(B_t\) represents nominal debt, \(P_t\) indicates profits from intermediate goods producers and \(T_t\) represents lump-sum transfers. As for the goods market, the sector-specific time-varying tax \(\tau_{kt}^{w}\) 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 lower tax reduces workers’ monopoly power and increases labor supply. The variable \(\varsigma_t\) is a preference shock that makes agents more or less impatient. For instance, positive preference shocks (an increase in the desire to save) may capture disruptions in financial markets that force the monetary authority to lower the nominal interest rate to zero. Finally, as in Erceg et al. (2006), the intermediation cost \(\psi_{Bt}\) ensures stationarity of the net foreign asset position

\[
\psi_{Bt} \equiv \exp \left[ -\psi_B \left( \frac{nB_t}{P_tY_t} \right) \right],
\]

where \(\psi_B > 0\) and \(P_tY_t\) corresponds to nominal GDP

\[
P_tY_t \equiv P_{Ht}Y_{Ht} + P_{Nt}Y_{Nt}.
\]

16
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.\(^\text{11}\)

The existence of a full set of transfers that completely insure against the idiosyncratic income risk arising from staggered price and wage setting and an appropriate normalization of initial wealth levels implies that all households make the same consumption and savings decisions \((C_t(a) = C_t(b), \forall \{a, b\} \in (0, n))\). Hence, from now on, we will suppress the index \(i\) from consumption variables. The consumption-saving optimality conditions yield

\[
1 = \beta \psi_B t(1 + i_t)\mathbb{E}_t \left[ \frac{S_{t+1}}{S_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+1}} \right]. \tag{37}
\]

From expression (37), we can denote the stochastic discount factor for nominal assets \((Q_{t,t+s})\) as

\[
Q_{t,t+s} = \beta^s \frac{S_{t+s}}{S_t} \left( \frac{C_{t+s}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+s}}. \tag{38}
\]

Each household has a probability of being able to reset the wage at time \(t\) equal to \(\xi_w\). The optimal wage setting problem in case of adjustment for household \(i\) working in sector \(k\) is

\[
\max_{\tilde{W}_{kt}(i)} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta \xi_w)^s \left[ (1 - \tau_{kt+s}^{w}) C_{t+s}^{-\sigma} \frac{\tilde{W}_{kt}(i)}{P_{t+s}} L_{kt+s}(i) - \frac{L_{kt+s}(i)^{1+\nu}}{1+\nu} \right] \right\}, \tag{39}
\]

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

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

\[
\left( \frac{\tilde{W}_{kt}}{W_{kt}} \right)^{1+\phi_k \nu} = \frac{\phi_k \nu}{\phi_k - 1} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta \xi_w)^s \xi_{t+s} (L_{kt+s}/\gamma_k)^{1+\nu} (\Pi_{kt+s}^{w})^{\phi_k (1+\nu)} \right\} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta \xi_w)^s C_{t+s}^{-\sigma} (W_{kt+s}/P_{t+s}) (L_{kt+s}/\gamma_k)^{1+\nu} (\Pi_{kt+s}^{w})^{\phi_k (1+\nu)} \right\}. \tag{40}
\]

where \(\Pi_{kt}^{w} \equiv W_{kt}/W_{kt-1}\) is the wage inflation rate in sector \(k\). The remaining households, who are not able to adjust, on average keep their wages fixed at the previous period’s level. The

\(^{11}\text{We use the intermediation cost only to ensure stationarity of the net foreign asset position. We set the parameter } \psi_B \text{ small enough as to have no discernible effects on the transition dynamics.}\)
wage index (13) for sector $k$ yields a non-linear relation between the optimal relative reset wage and the wage inflation rate

$$\frac{\tilde{W}_{kt}}{W_{kt}} = \left[ 1 - \xi_{w} (\Pi_{kt}^w)^{\phi_k - 1} \right]^{\frac{1}{1-\phi_k}}. \quad (41)$$

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

$$\frac{W_k}{P} = \frac{1}{1 - \tau^w_k} \frac{\phi_k}{\phi_k - 1} \frac{(L_k/\gamma_k n)^\nu}{C^{-\sigma}}. \quad (42)$$

As in the case of prices, the government can choose a tax that fully offsets 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

$$\mathcal{T}_t = \int_0^n \mathcal{T}_t(i)di = \int_0^1 \tau_{kt}^p P_{kt} Y_{kt}(j) dj + \int_0^n \tau_{kt}^w W_{kt} L_{kt}(i) di. \quad (42)$$

Using (36) and its foreign counterpart, we construct a union-wide level of output as a population-weighted geometric average of the levels of output in the two countries

$$Y_t^{MU} \equiv (Y_t)^n (Y_t^*)^n \quad (43)$$

In the same spirit, we define the union-wide price index $P_t^{MU}$ as a population-weighted geometric average of the CPIs in the two countries$^{12}$

$$P_t^{MU} \equiv (P_t)^n (P_t^*)^{1-n} \quad (44)$$

Consequently, the inflation rate in the currency union is

$$\Pi_t^{MU} = (\Pi_t)^n (\Pi_t^*)^{1-n}. \quad (45)$$

$^{12}$This definition is the model-equivalent of the Harmonized Index of Consumer Prices (HICP), the measure of consumer prices published by Eurostat.
We assume that a single central bank sets the nominal interest rate in the entire union 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.

### 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

\begin{align*}
\int_0^n C_{Ht}(i)di + \int_n^1 C^n_{Ht}(i)di &= nC_{Ht} + (1 - n)C^*_Ht = Y_Ht, \tag{46} \\
\int_0^n C_{Ft}(i)di + \int_n^1 C^n_{Ft}(i)di &= nC_{Ft} + (1 - n)C^*_Ft = Y^*_Ft, \tag{47} \\
\int_0^n C_{Nt}(i)di &= nC_{Nt} = Y_{Nt}, \tag{48} \\
\int_n^1 C^*_Nt(i)di &= (1 - n)C^*_Nt = Y^*_Nt. \tag{49}
\end{align*}
Table 1: Product market markup estimates by sector.

<table>
<thead>
<tr>
<th></th>
<th>Periphery ($H$)</th>
<th>Core ($F$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total private firms</td>
<td>1.36</td>
<td>1.25</td>
</tr>
<tr>
<td>Manufacturing ( Tradable)</td>
<td>1.17</td>
<td>1.14</td>
</tr>
<tr>
<td>Services ( Non-Tradable)</td>
<td>1.48</td>
<td>1.33</td>
</tr>
</tbody>
</table>


Integrating the budget constraint across households in country $H$ and using the zero profit conditions for labor agencies and retailers, as well as the government budget constraint and the equilibrium conditions for tradable and non-tradable goods, implies that net foreign assets evolve according to

$$\frac{nB_t}{\psi_{Bt}} = (1 + i_t) nB_{t-1} + P_{Ht}(1 - n)C_{Ht}^* - P_{Ft}nC_{Ft}. \quad (50)$$

Finally, asset market clearing requires

$$nB_t + (1 - n)B_t^* = 0. \quad (51)$$

3.7 Calibration and Solution Strategy

Our main experiments involve changes in the tax rates $\tau_{lt}^w$ and $\tau_{lt}^p$ (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.\(^\text{13}\)

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 the tradable sector in the model and the service sector as a proxy for the non-tradable 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

\(^{13}\)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.
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.

The steady state total markup in sector $k$ is

$$\mu_k \equiv \frac{1}{1 - \tau_k^p \theta_k - 1}.$$  

For the manufacturing sector, we assume symmetry across countries and no policy-induced distortions (i.e. $\tau_H^p = \tau_F^p = 0$). Targeting a steady state net markup of 15%, this strategy allows us to pin down the elasticity of substitution $\theta_H = \theta_F = 7.7$. For the service sector, we assume no policy distortion in the core ($\tau_N^p = 0$). The estimate in Table 1 then implies $\theta_N = 4$. We assume that the elasticity is the same in the periphery ($\theta_N = \theta_N^*$) and attribute the difference in the OECD markup estimates to policy distortions ($\tau_N^p = 0.1$).

Empirical studies point to a similar pattern for wage markups across countries and sectors. Although direct estimates of wage markups are more difficult to obtain, data on wage premia (Jean and Nicoletti, 2002) and evidence on wage bargaining power in Europe (Everaert and Schule, 2006) indicate that wage markups are likely to be higher in peripheral than in core countries because of higher markups in the service sector. Furthermore, the point estimates of these wage premia are not too different from the figures presented in Table 1. Thus, we set the wage elasticities and taxes across sectors and regions equal to the corresponding values for the product market.\(^\text{14}\)

The remaining parameters used in our simulations are relatively standard (Table 2). In our benchmark experiment, the core and the periphery have the same size ($n = 0.5$). The individual discount factor $\beta$ equals 0.99, implying an annualized real interest rate of about 4 percent. The coefficient of relative risk aversion $\sigma$ is equal to 0.5, which is within the range of estimates provided in Hansen and Singleton (1983). The inverse Frisch elasticity $\nu$ is equal to 2, a value commonly used in the New-Keynesian literature (see, for instance, Erceg and Linde, 2012). We calibrate the degree of home bias $\omega = 0.57$ and the size of the tradable sector $\gamma = 0.38$ to match (i) a steady state import share of 15% (corresponding to the average within-eurozone import share for France, Germany, Italy, and Spain) and (ii) a steady state...\(^\text{14}\)Bayoumi et al. (2004) and Forni et al. (2010) follow a similar calibration strategy.
Table 2: Parameter values.

<table>
<thead>
<tr>
<th>Households</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Country size</td>
<td>( n = 0.5 )</td>
</tr>
<tr>
<td>Individual discount factor</td>
<td>( \beta = 0.99 )</td>
</tr>
<tr>
<td>Inverse Frisch elasticity</td>
<td>( \nu = 2 )</td>
</tr>
<tr>
<td>Elasticity of intertemporal substitution</td>
<td>( \sigma^{-1} = 2 )</td>
</tr>
<tr>
<td>Home bias</td>
<td>( \omega = 0.57 )</td>
</tr>
<tr>
<td>Consumption share of tradable goods</td>
<td>( \gamma = 0.38 )</td>
</tr>
<tr>
<td>Elasticity of substitution tradables-nontradables</td>
<td>( \epsilon = 0.5 )</td>
</tr>
<tr>
<td>Elasticity of substitution Home-Foreign tradables</td>
<td>( \varphi = 1.5 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Price and Wage Setting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of not being able to adjust prices</td>
<td>( \xi_p = 0.66 )</td>
</tr>
<tr>
<td>Probability of not being able to adjust wages</td>
<td>( \xi_w = 0.66 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monetary Policy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation target</td>
<td>( \Pi = 1 )</td>
</tr>
<tr>
<td>Effective lower bound on nominal interest rate</td>
<td>( i^{zlb} = 0.0025 )</td>
</tr>
</tbody>
</table>

output share of 38% in manufacturing (from the EU-KLEMS database). We set the elasticity of substitution between traded and nontraded goods (\( \epsilon \)) equal to 0.5, consistent with the estimates for industrialized countries in Mendoza (1991), and the elasticity of substitution between home and foreign traded goods to 1.5, as in Backus et al. (1994). Finally, the probabilities of not being able to reset prices (\( \xi_p \)) and wages (\( \xi_w \)) 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 the 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. 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

\[
1 + i_t = \max \left\{ 1 + i^{zlb}, (1 + i)(\Pi MU)^{\varphi_{\pi}} \right\},
\]

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 \( \varphi_{\pi} \) 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.
4 The Effects of Structural Reforms in Normal Times

We begin our analysis by investigating the consequences of structural reforms in normal times. Specifically, we study the effects of a permanent reduction in the tax component of steady state price and wage markups by one percentage point in the 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, peripheral output sharply expands 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 periphery through higher demand for goods produced in the core, thus stimulating a large, albeit temporary, increase of core output. Overall, output in the monetary union expands nearly 2.5% in the near term and the price level declines a touch, as deflation in the periphery outweighs the modest demand-driven increase of prices in the core (top-right). Crucially, 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 periphery as well as in the core 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 core country (middle-right). International prices in the periphery 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.

In the long-run, the one percentage point reduction in price and wage markups implemented by the periphery increases domestic output by 0.56%. 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 substantially improve, with the real exchange rate in the periphery depreciating by 0.85% in the long run. The
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.
relative price of nontradables drives the depreciation. The terms of trade only accounts for about 20% of the total real exchange rate adjustment.

While the dynamics explicitly take into account the non-linearities of the model, the steady state effects are approximatively log-linear. Therefore, the numbers just reported can be interpreted as elasticities. For example, permanent reduction in markups by 10 percentage points increases output in the monetary union by 5.43%. 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 changes in presence of the ZLB constraint. 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, 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 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.

16See, for instance, Bayoumi et al. (2004) and Forni et al. (2010).
5.1 The Crisis and the ZLB

We study the effects of structural reforms in a monetary union when 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 6 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 10 quarters (bottom-left). The deflationary pressures, combined with the lower bound constraint, implies that the real interest rate remains relatively high (bottom-
Table 3: Impact effects of structural reforms at the ZLB.

<table>
<thead>
<tr>
<th>$\tau^p_N = \tau^w_N$ (in p.p.)</th>
<th>Output</th>
<th>Inflation</th>
<th>Real Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-4.00</td>
<td>-0.93</td>
<td>1.86</td>
</tr>
<tr>
<td>1</td>
<td>-4.13</td>
<td>-1.47</td>
<td>2.22</td>
</tr>
<tr>
<td>5</td>
<td>-4.56</td>
<td>-3.59</td>
<td>3.56</td>
</tr>
<tr>
<td>10</td>
<td>-5.07</td>
<td>-6.25</td>
<td>5.13</td>
</tr>
</tbody>
</table>

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

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 3 summarizes the main finding of our analysis. The last three columns of the table present the impact response of union-wide 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 periphery. Amid contracting output and falling prices due to the crisis, the implementation of reforms in a ZLB environment further reduces aggregate output between 13 basis points (1 percentage point markup reduction) and 1.07 percent (markup reduction of 10 percentage points).

The fall in periphery output primarily explains the union-wide contraction. In the periphery, production falls both in the tradable and nontradable sector. As marginal costs decrease, firms in the nontradable sector cut prices, thus worsening the deflationary pressures associated with the crisis and contributing to increase the real rate. This effect slows down demand even further, with consequences also for the tradable sectors of both countries. Conversely, core aggregate production is roughly unchanged. In that region, the slowdown in tradables is approximately compensated by an increase in the demand for nontradables, driven by a favorable adjustment in relative prices.

The 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

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17The 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.
percentage point generates an increase in output of about 2.5% in normal times (see Figure ?? above), but an output drop of about 15 basis points in a crisis. This change of sign in the output response suggests that the short-run transmission of structural reforms critically depends on the ability of monetary policy to provide stimulus. 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 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 sharper deflationary pressures.

5.2.1 Discussion

Under our baseline calibration (as well as in several robustness checks discussed in the next subsection), permanent reforms at the ZLB do not contribute to support economic activity in the immediate aftermath of a demand-driven crisis. 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 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 periphery 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
Figure 7: 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).

When monetary policy is constrained by the ZLB, temporary reforms entail large output losses in the short-run. At the union level, output drops 7.4% on impact, almost doubling the output costs associated with the crisis. As in the case of permanent reforms, reducing markups increases the deflationary pressures generated by the crisis. However, the temporary nature of

\[\text{ These assumptions, while obviously extreme, make the analysis particularly stark. More realistically, the unwinding may occur with some probability at time of implementation, which would likely lead to a smaller output drop. At the same time, the unwinding may be decoupled from the duration of the crisis—in particular, the reforms could be reversed few quarters after the ZLB stops being binding—which would entail more severe output losses. }\]
the reforms creates much more severe short-run deflationary pressures. 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 for agents to postpone their consumption. Second, households understand 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 the 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.

5.2.2 Robustness

An important parameter governing the short-run response of consumption to changes in the real interest rate is the elasticity of intertemporal substitution ($\sigma^{-1}$). Our calibration for $\sigma$ 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.\footnote{In each experiment, we recalibrate the size of the preference shock to ensure that aggregate output contracts 4% in the crisis episode.} 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 leads to an output drop of 3.40%.

Given the size of the reforms, these gains are quite small if compared to the output drop of 4% absent any change and the 2.5% output increase in normal times, confirming that the presence of the ZLB significantly alters the short-run transmission of reforms. Thus, our findings cast doubts 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.

The effects of reforms during crisis are robust to changes in country size. Our calibration assumes that the currency union consists of two regions of the same size, which represents a good approximation to the relative weight of core and peripheral countries in the EMU.\textsuperscript{20} Our experiments reflect the idea that all peripheral countries are currently being encouraged to implement ambitious reform programs. In practice, however, the implementation of reforms may occur at different times in each country. To check if the size of the country that implements the reforms matters for our results, we run simulations assuming that the periphery country accounts for only 10% of union-wide output.\textsuperscript{21} Perhaps not surprisingly, the main difference relative to the symmetric case is the smaller output decline experienced by the union as whole. However, this difference simply reflects the smaller weight of the periphery in aggregate variables. The additional output contraction in the periphery due to the reforms compared to the crisis scenario remains essentially unaffected.

In our main 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 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 periphery. As in the previous exercise, we continue to calibrate the shock to match a 4% decline in union-

\textsuperscript{20} In the data, Italy and Spain account for, respectively, 17 and 12% of euro-area output, whereas Greece, Ireland, and Portugal each account for about 2% of total output. Thus, peripheral country aggregate account for about 35% of euro-area output.

\textsuperscript{21} In this experiment, we adjust the parameters governing home bias $\omega$ and the share of traded goods $\gamma$ to match the same targets as in the main simulation.
wide output. This crisis is still associated with the nominal interest rate 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.

The main difference in case of an asymmetric shock is the large adjustment in international variables. The periphery runs a large current account surplus and the terms of trade significantly contributes to the depreciation of the real exchange rate. 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.

More importantly, structural reforms that permanently reduce product and labor market markups in the periphery continue to be contractionary in the short run, as more protracted deflation at the ZLB results in higher real interest rates. With an asymmetric crisis, the magnitudes of the additional output losses due to structural reforms are smaller—twenty basis points in case of ten percentage points reduction in markups. Yet, our main conclusion is qualitatively unchanged: Structural reforms are not an effective policy measure to alleviate the short-run consequences of a crisis.

6 Disentangling the Effects of Reforms at the ZLB

The short-run transmission of reforms depends critically on the ability of the central bank to provide monetary policy accommodation. In normal times, the nominal interest rate falls, providing stimulus against deflationary pressures. 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 experiments that shed light on the mechanism behind these findings.

In the first experiment, which we label “New Deal,” we assume that the government sets $\tau_{p,Nt}$ and $\tau_{w,Nt}$ to temporarily increase the monopolistic power of firms and unions. This experiment is in the spirit of Eggertsson (2012), who argues that policies of this kind contributed to end the Great Depression, or can be interpreted as an application of unconventional fiscal policies that provide monetary stimulus at the ZLB as in (Correia et al., 2012). In essence, this policy

---

22Given 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 deval-
aims at generating expectations of price increases in the short run without any implication for the long-run level of output. In our simulations, the government increases distortionary taxes 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

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

where \( \phi > 0 \) is a parameter that controls how aggressively the government increases the taxes in response to the crisis.\(^{23}\)

Our second experiment, 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 when the ZLB stops binding

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

The Delay rule differs from the New Deal rule because the permanent change in the subsidy needs to be consistent with the final steady state. Therefore, the coefficient \( \phi \) is constrained to be equal to \( \tau / i \).

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 an 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 these arguments.

Figure 8 presents the response of the main variables to the New Deal policy (dashed blue lines, 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).\(^{23}\)

\(^{23}\)We calibrate the parameter \( \phi \) in the New Deal policy to minimize deflation on impact. Qualitatively, a constant increase in taxes would achieve the same objective as the state-contingent rule. However, if taxes remain for too long, the nominal interest rate may endogenously spike up even if the crisis is not over yet.
Figure 8: 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).
line) and to the Delay policy (dashed-dotted red line). Notwithstanding the absence of monetary accommodation due to the ZLB, both policies restore the short-run transmission mechanism of reforms operating in normal times: On impact, output in the currency union is well above 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 about 2.5%, much less than the 4% 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 2% on impact and turns positive after about six quarters.

These experiments highlight the main tradeoffs associated with the implementation of reforms at the ZLB. 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 effect of lower real interest rates and has no effect on long-run income. 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 stimulates aggregate demand, thus limiting the short-run output drop due to the crisis and supporting domestic prices.

As for the open-economy variables, the permanent effects associated with the Delay policy 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. The temporary nature of this policy does not bring about 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 periphery relative to the core, where no policy is implemented.
7 Conclusions

Structural reforms can greatly reduce the competitiveness gap between the EMU core and periphery and boost income prospects in the region. However, the timing of such reforms is crucial. If undertaken during a crisis that takes nominal rates to the ZLB, structural reforms can deepen the recession 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 paper contributes to the recent literature on the implications of the ZLB for the transmission of shocks. Several researchers have noted how fiscal policy multipliers are greatly affected by the presence of the ZLB (see, for instance, Christiano et al., 2011; Eggertsson, 2011). The perverse effects of deflationary policies at the ZLB that we find in this paper have also been studied in Eggertsson (2012). We expand on these results by investigating the effects of permanent markup changes at the ZLB in an open economy environment, thus focusing on the domestic and international transmission of shocks.

In addressing the effects of reforms at the ZLB, we have abstracted from important considerations that are likely to shape the policy debate in Europe. First, our analysis features only inputs of production that cannot be accumulated over time. As argued by Fernandez-Villaverde (2013) in his discussion, the presence of physical capital may in principle preserve the standard transmission mechanism of reforms. However, in their simulations, Gavin et al. (2013) find that technology shocks at the ZLB continue to have perverse effects, at least in a closed economy environment. Moreover, if physical capital (or other assets, such as housing) can relax borrowing limits through their collateral value, perverse debt-deflation dynamics at the ZLB are likely to be amplified (see, for instance, Eggertsson and Krugman, 2012). Second, while our analysis has focused on the short-run transmission of reforms, the policy debate in Europe involves non-trivial welfare and political economy considerations (Blanchard and Giavazzi, 2003). The social and political opposition faced by governments in peripheral Europe to adopt relatively small reform packages in times of financial turbulence reveals the difficulties of changing these policies in practice. Our findings emphasize an important macroeconomic tradeoff associated with the absence of sufficient policy stimulus to support reform efforts. Future research efforts could embed the pure macroeconomic forces discussed in this paper in
a political economy environment, with the objective of drawing serious welfare implications.
References


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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:**
  \[
  C_{Ht} = \omega \left( \frac{p_{Ht}}{p_{Tt}} \right)^{-\epsilon} C_{Tt}, \quad C_{Ft} = (1 - \omega) \left( \frac{p_{Ft}}{p_{Tt}} \right)^{-\epsilon} C_{Tt}. \tag{52}
  \]

- **Demand for tradable consumption bundles:**
  \[
  C_{Tt} = \gamma \left( \frac{p_{Tt}}{p_{t}} \right)^{-\varphi} C_{t}, \quad C_{Tt}^{*} = \gamma \left( \frac{p_{Tt}^{*}}{p_{t}^{*}} \right)^{-\varphi} C_{t}^{*}. \tag{54}
  \]

- **Demand for non-tradable goods:**
  \[
  C_{Nt} = (1 - \gamma) \left( \frac{p_{Nt}}{p_{t}} \right)^{-\varphi} C_{t}, \quad C_{Nt}^{*} = (1 - \gamma) \left( \frac{p_{Nt}^{*}}{p_{t}^{*}} \right)^{-\varphi} C_{t}^{*}. \tag{55}
  \]

- **Resource constraint for Home and Foreign tradable goods:**
  \[
  C_{Ht} + C_{Ht}^{*} = Y_{Ht}, \tag{56}
  \]
  \[
  C_{Ft} + C_{Ft}^{*} = Y_{Ft}^{*}. \tag{57}
  \]

- **Resource constraint for non-tradable goods:**
  \[
  C_{Nt} = Y_{Nt}, \tag{58}
  \]
  \[
  C_{Nt}^{*} = Y_{Nt}^{*}. \tag{59}
  \]

- **Real marginal costs** $(mc_{kt} \equiv MC_{kt}/P_{t}^{MU}$; also denote real wages as $w_{kt} \equiv W_{kt}/P_{t}^{MU}$)
  \[
  mc_{Ht} = \frac{w_{Ht}}{Z_{Ht}}, \quad mc_{Nt} = \frac{w_{Nt}}{Z_{Nt}}, \tag{60}
  \]
  \[
  mc_{Ft} = \frac{w_{Ft}^{*}}{Z_{Ft}^{*}}, \quad mc_{Nt}^{*} = \frac{w_{Nt}^{*}}{Z_{Nt}^{*}}. \tag{61}
  \]
• Production functions:

\[ Y_{Ht} \Delta_{Ht} = Z_{Ht} L_{Ht}, \quad Y_{Nt} \Delta_{Nt} = Z_{Nt} L_{Nt}. \] (62)

\[ Y^*_{Ft} \Delta^*_{Ft} = Z^*_{Ft} L^*_{Ft}, \quad Y^*_{Nt} \Delta^*_{Nt} = Z^*_{Nt} L^*_{Nt}. \] (63)

• Evolution of price dispersion:

\[ \Delta_{Ht} = \xi_p \Delta_{Ht-1} \Pi_H^{\theta_H} + (1 - \xi_p) \left( \frac{1 - \xi_p \Pi_H^{-1}}{1 - \xi_p} \right)^{\theta_H} \] (64)

\[ \Delta_{Nt} = \xi_p \Delta_{Nt-1} \Pi_N^{\theta_N} + (1 - \xi_p) \left( \frac{1 - \xi_p \Pi_N^{-1}}{1 - \xi_p} \right)^{\theta_N} \] (65)

\[ \Delta^*_{Ft} = \xi_p \Delta^*_{Ft-1} (\Pi^*_{Ft})^{\theta_F} + (1 - \xi_p) \left[ \frac{1 - \xi_p (\Pi^*_{Ft})^{\theta_F-1}}{1 - \xi_p} \right]^{\theta_F} \] (66)

\[ \Delta^*_{Nt} = \xi_p \Delta^*_{Nt-1} (\Pi^*_{Nt})^{\theta_N} + (1 - \xi_p) \left[ \frac{1 - \xi_p (\Pi^*_{Nt})^{\theta_N-1}}{1 - \xi_p} \right]^{\theta_N} \] (67)

• Price Phillips curves:

\[ \left( \frac{1 - \xi_p \Pi_H^{-1}}{1 - \xi_p} \right)^{1-\theta_H} = \frac{X_{1Ht}}{X_{2Ht}}, \] (68)

where

\[ X_{1Ht} = \frac{\theta_H}{\theta_H - 1} \varsigma_t C^{-\sigma} Y_{Ht} \frac{m_{CHt}}{p_t} + \beta \xi_p \mathbb{E}_t \left( \Pi_H^{\theta_H-1} X_{1Ht+1} \right) \] (69)

and

\[ X_{2Ht} = \varsigma_t (1 + \tau_{Ht}^p) C^{-\sigma} Y_{Ht} \frac{p_{Ht}}{p_t} + \beta \xi_p \mathbb{E}_t \left( \Pi_H^{\theta_H-1} X_{2Ht+1} \right). \] (70)

\[ \left( \frac{1 - \xi_p \Pi_N^{-1}}{1 - \xi_p} \right)^{1-\theta_N} = \frac{X_{1Nt}}{X_{2Nt}}, \] (71)

where

\[ X_{1Nt} = \frac{\theta_N}{\theta_N - 1} \varsigma_t C^{-\sigma} Y_{Nt} \frac{m_{CNt}}{p_t} + \beta \xi_p \mathbb{E}_t \left( \Pi_N^{\theta_N-1} X_{1Nt+1} \right) \] (72)

and

\[ X_{2Nt} = \varsigma_t (1 + \tau_{Nt}^p) C^{-\sigma} Y_{Nt} \frac{p_{Nt}}{p_t} + \beta \xi_p \mathbb{E}_t \left( \Pi_N^{\theta_N-1} X_{2Nt+1} \right). \] (73)
\[
\left[1 - \xi_p (\Pi_{Ft}^{*})^{\theta_F - 1}ight]^{\frac{1}{1 - \theta_F}} = \frac{X_1^*_{Ft}}{X_2^*_{Ft}},
\]

(74)

where
\[
X_1^*_{Ft} = \frac{\theta_F}{\theta_F - 1} \zeta_t (C_t^*)^{-\sigma} Y_t^{*} \frac{mc^*_F}{p_t^*} + \beta \xi_p \mathbb{E}_t \left[ (\Pi_{Ht+1}^{*})^{\theta_F} X_1^*_{Ft+1} \right]
\]

(75)

and
\[
X_2^*_{Ft} = \zeta_t (1 + \tau_{Ft}^{*})(C_t^*)^{-\sigma} Y_t^{*} \frac{p_{Ft}^*}{p_t^*} + \beta \xi_p \mathbb{E}_t \left[ (\Pi_{Ft+1}^{*})^{\theta_F - 1} X_2^*_{Ft+1} \right].
\]

(76)

\[
\left[1 - \xi_p (\Pi_{Nt}^{*})^{\theta_N - 1}\right]^{\frac{1}{1 - \theta_N}} = \frac{X_1^*_{Nt}}{X_2^*_{Nt}},
\]

(77)

where
\[
X_1^*_{Nt} = \frac{\theta_N^{*}}{\theta_N - 1} \zeta_t (C_t^*)^{-\sigma} Y_t^{*} \frac{mc^*_N}{p_t^*} + \beta \xi_p \mathbb{E}_t \left[ (\Pi_{Nt+1}^{*})^{\theta_N} X_1^*_{Nt+1} \right]
\]

(78)

and
\[
X_2^*_{Nt} = \zeta_t (1 + \tau_{Nt}^{*})(C_t^*)^{-\sigma} Y_t^{*} \frac{p_{Nt}^*}{p_t^*} + \beta \xi_p \mathbb{E}_t \left[ (\Pi_{Nt+1}^{*})^{\theta_N - 1} X_2^*_{Nt+1} \right].
\]

(79)

• Wage Phillips curves:
\[
\left[1 - \xi_w (\Pi_{Ht}^{w})^{\phi_H - 1}\right]^{\frac{1 + \phi_H \nu}{1 - \phi_H}} = \frac{D_1^{Ht}}{D_2^{Ht}},
\]

(80)

where
\[
D_1^{Ht} = \frac{\phi_H}{\phi_H - 1} \zeta_t \left( \frac{L_{Ht}}{\gamma} \right)^{1 + \nu} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Ht+1}^{w})^{\phi_H} D_1^{Ht+1} \right]
\]

(81)

and
\[
D_2^{Ht} = \zeta_t (1 + \tau_{Ht}^{w}) C_t^{-\sigma} \frac{W_{Ht}}{p_t} \frac{L_{Ht}}{\gamma} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Ht+1}^{w})^{\phi_H - 1} D_2^{Ht+1} \right].
\]

(82)

\[
\left[1 - \xi_w (\Pi_{Nt}^{w})^{\phi_N - 1}\right]^{\frac{1 + \phi_N \nu}{1 - \phi_N}} = \frac{D_1^{Nt}}{D_2^{Nt}},
\]

(83)

where
\[
D_1^{Nt} = \frac{\phi_N}{\phi_N - 1} \zeta_t \left( \frac{L_{Nt}}{1 - \gamma} \right)^{1 + \nu} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Nt+1}^{w})^{\phi_N} D_1^{Nt+1} \right]
\]

(84)

and
\[
D_2^{Nt} = \zeta_t (1 + \tau_{Nt}^{w}) C_t^{-\sigma} \frac{W_{Nt}}{p_t} \frac{L_{Nt}}{1 - \gamma} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Nt+1}^{w})^{\phi_N - 1} D_2^{Nt+1} \right].
\]

(85)
\[
\left[ \frac{1 - \xi_w (\Pi_{Ft}^{w})^{\phi_F^\nu - 1}}{1 - \xi_w} \right]^{1 + \phi_F^\nu - 1 - \phi_F^\nu} = \frac{D1_{Ft}^*}{D2_{Ft}^*}, \tag{86}
\]

where
\[
D1_{Ft}^* = \frac{\phi_F^*}{\phi_F^* - 1} \kappa_t \left( \frac{L_{Ft}^w}{\gamma} \right)^{1 + \nu} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Ft+1}^{w})^{\phi_{Ft+1}^*} D1_{Ft+1}^* \right] \tag{87}
\]

and
\[
D2_{Ft}^* = \kappa_t (1 + \tau_{Ft}^w) (C_t^*)^{-\sigma} \frac{w_{Ft}^N}{p_t^*} \frac{L_{Ft}^N}{1 - \gamma} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Ft+1}^{w})^{\phi_N^*} D2_{Ft+1}^* \right]. \tag{88}
\]

\[
\left[ \frac{1 - \xi_w (\Pi_{Nt}^{w})^{\phi_N^\nu - 1}}{1 - \xi_w} \right]^{1 + \phi_N^\nu - 1 - \phi_N^\nu} = \frac{D1_{Nt}^*}{D2_{Nt}^*}, \tag{89}
\]

where
\[
D1_{Nt}^* = \frac{\phi_N^*}{\phi_N^* - 1} \kappa_t \left( \frac{L_{Nt}^w}{1 - \gamma} \right)^{1 + \nu} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Nt+1}^{w})^{\phi_N^*} D1_{Nt+1}^* \right] \tag{90}
\]

and
\[
D2_{Nt}^* = \kappa_t (1 + \tau_{Nt}^w) (C_t^*)^{-\sigma} \frac{w_{Nt}^N}{p_t^*} \frac{L_{Nt}^N}{1 - \gamma} + \beta \xi_w \mathbb{E}_t \left[ (\Pi_{Nt+1}^{w})^{\phi_N^*} D2_{Nt+1}^* \right]. \tag{91}
\]

- Price index for tradable consumption bundles:
\[
\begin{align*}
p_{Pt} &= \left[ \omega p_{Ht}^{1-\epsilon} + (1 - \omega) p_{Ft}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}, \\
p_{Pt}^* &= \left[ \omega p_{Ft}^{1-\epsilon} + (1 - \omega) p_{Ht}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \tag{92}
\end{align*}
\]

- Consumer price index:
\[
\begin{align*}
p_t &= \left[ \gamma p_{Pt}^{1-\phi} + (1 - \gamma) p_{Nt}^{1-\phi} \right]^{\frac{1}{1-\phi}}, \\
p_t^* &= \left[ \gamma (p_{Pt}^{1-\phi})^{1-\phi} + (1 - \gamma) (p_{Nt}^{1-\phi})^{1-\phi} \right]^{\frac{1}{1-\phi}}. \tag{93}
\end{align*}
\]

- Euler equations for bonds:
\[
\begin{align*}
1 &= \beta \psi_{Bt} (1 + i_t) \mathbb{E}_t \left[ \frac{s_{t+1}}{s_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+1}} \right], \tag{94}
1 &= \beta (1 + i_t) \mathbb{E}_t \left[ \frac{s_{t+1}}{s_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+1}} \right], \tag{95}
\psi_{Bt} &= \exp \left[ -\psi_B \left( \frac{b_t}{p_{t} Y_t} \right) \right], \tag{96}
\end{align*}
\]

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

45
• Evolution of net foreign assets

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

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

(97) (98)

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:

\[b_t + b_t^* = 0.\]

(99)

• GDP

\[p_tY_t = p_{Ht}Y_{Ht} + p_{Nt}Y_{Nt},\]

\[p_t^*Y_t^* = p_{Ft}^*Y_{Ft}^* + p_{Nt}^*Y_{Nt}^*.\]

(100) (101)

• Union-wide inflation:

\[\Pi_t^{MU} = (\Pi_t)^{0.5}(\Pi_t^*)^{0.5}.\]

(102)

• Union-wide output:

\[Y_t^{MU} \equiv (Y_t)^{0.5}(Y_t^*)^{0.5}.\]

(103)

• Monetary policy rule:

\[1 + i_t = \max \{1 + i^{zlb}, [(1 + i)(\Pi_t^{MU})^{\phi}]\}.\]

(104)

A.1 Additional Variables of Interest

• Terms of trade:

\[TOT_{Ht} = \frac{p_{Ft}}{p_{Ht}}.\]

(105)

• Real exchange rate

\[RER_{Ht} = \frac{p_t^*}{p_t}.\]

(106)
• Net exports (in % of GDP)

\[ NX_t = \frac{p_{Ht}C^*_H - p_{Ft}C_{Ft}}{Y_t}. \]  

(107)

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

\[ RNX_t = \frac{p_{Ht}C^*_H - p_{Ft}C_{Ft}}{Y_t}. \]  

(108)

B Steady State

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

• Demand for Home and Foreign tradable goods:

\[ C_H = \omega \left( \frac{p_H}{p_T} \right)^{-\epsilon} C_T, \quad C_F = (1 - \omega) \left( \frac{p_F}{p_T} \right)^{-\epsilon} C_T. \]  

(109)

\[ C^*_F = \omega \left( \frac{p_F}{p^*_T} \right)^{-\epsilon} C^*_T, \quad C^*_H = (1 - \omega) \left( \frac{p_H}{p^*_T} \right)^{-\epsilon} C^*_T. \]  

(110)

• Demand for tradable consumption bundle:

\[ C_T = \gamma \left( \frac{p_T}{p} \right)^{-\varphi} C, \quad C^*_T = \gamma \left( \frac{p^*_T}{p^*} \right)^{-\varphi} C^*. \]  

(111)

• Demand for non-tradable goods:

\[ C_N = (1 - \gamma) \left( \frac{p_N}{p} \right)^{-\varphi} C, \quad C^*_N = (1 - \gamma) \left( \frac{p^*_N}{p^*} \right)^{-\varphi} C^*. \]  

(112)

• Resource constraint for Home and Foreign tradable goods:

\[ C_H + C^*_H = Y_H, \]  

(113)

\[ C_F + C^*_F = Y^*_F. \]  

(114)

• Resource constraint for non-tradable goods:

\[ C_N = Y_N, \]  

(115)

\[ C^*_N = Y^*_N. \]  

(116)
• Marginal costs

\[
mc_H = \frac{w_H}{Z_H} \quad mc_N = \frac{w_N}{Z_N} \quad (117)
\]

\[
mc_F^* = \frac{w_F^*}{Z_F^*} \quad mc_N^* = \frac{w_N^*}{Z_N^*} \quad (118)
\]

• Production functions:

\[
Y_H = Z_H L_H, \quad Y_N = Z_N L_N \quad (119)
\]

\[
Y_F^* = Z_F^* L_F^*, \quad Y_N^* = Z_N^* L_N^* \quad (120)
\]

• Price setting:

\[
\frac{\theta_H}{\theta_H - 1} mc_H = (1 + \tau_H^p)p_H \quad \frac{\theta_N}{\theta_N - 1} mc_N = (1 + \tau_N^p)p_N \quad (121)
\]

\[
\frac{\theta_F^*}{\theta_F^* - 1} mc_F^* = (1 + \tau_F^p p_F^*) \quad \frac{\theta_N^*}{\theta_N^* - 1} mc_N^* = (1 + \tau_N^p p_N^*) \quad (122)
\]

• Wage setting:

\[
(1 + \tau_H^w)p_H = \frac{\phi_H}{\phi_H - 1} \left( \frac{L_H}{\gamma} \right)^\nu \frac{1}{\sigma^{-\sigma}} \quad (123)
\]

\[
(1 + \tau_N^w)p_N = \frac{\phi_N}{\phi_N - 1} \left( \frac{L_N}{1 - \gamma} \right)^\nu \frac{1}{\sigma^{-\sigma}} \quad (124)
\]

\[
(1 + \tau_F^w)p_F^* = \frac{\phi_F^*}{\phi_F^* - 1} \left( \frac{L_F^*}{\gamma} \right)^\nu \frac{1}{(C^*)^{-\sigma}} \quad (125)
\]

\[
(1 + \tau_N^w)p_N^* = \frac{\phi_N^*}{\phi_N^* - 1} \left( \frac{L_N^*}{1 - \gamma} \right)^\nu \frac{1}{(C^*)^{-\sigma}} \quad (126)
\]

• Price index for tradable consumption bundles:

\[
p_T = [\omega p_H^{1-\epsilon} + (1 - \omega) p_F^{1-\epsilon}]^{\frac{1}{1-\epsilon}}, \quad p_T^* = [\omega p_F^{1-\epsilon} + (1 - \omega) p_H^{1-\epsilon}]^{\frac{1}{1-\epsilon}}. \quad (127)
\]

• Consumer price index:

\[
p = [\gamma p_T^{1-\varphi} + (1 - \gamma) p_N^{1-\varphi}]^{\frac{1}{1-\varphi}}, \quad p^* = [\gamma (p_T^*)^{1-\varphi} + (1 - \gamma) (p_N^*)^{1-\varphi}]^{\frac{1}{1-\varphi}}. \quad (128)
\]
- Euler equations for bonds:

\[ 1 = \beta (1 + i) \quad (129) \]

- Balanced trade:

\[ p_H C^*_H = p_F C_F \quad (130) \]

- Relation between CPIs:

\[ p = \frac{1}{p^*} \quad (131) \]