Structural Reforms, Financial Acceleration, and Unconventional Monetary Policy

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Abstract

I study how structural reforms in the periphery of the European Monetary Union affect economic activity during a financial crisis. The main contribution of the paper is that it considers three key characteristics of the recent financial crisis that are potentially relevant for policy analysis: First, the crisis was triggered in the financial sector; second, there were spillovers from the financial to the real sector due to credit rationing; third, governments actively intervened in the credit market during the crisis. I construct a dynamic general equilibrium model with financial frictions to address these issues. The model allows insights into how asset prices, credit spreads, and credit intermediation respond to reforms. I show that permanent structural reforms have positive effects on aggregate output in both the long and the short run. They affect the capital market positively and stimulate credit intermediation. Moreover, structural reforms are not in conflict with credit market interventions.

Keywords: Structural reforms; financial accelerator; financial crisis; monetary union; zero lower bound; unconventional monetary policy

JEL: E44; E52; F45; G01
1 Introduction and Motivation

Do structural labor and product market reforms in peripheral Europe depress output in the short run when a financial crisis hits the economy? This paper addresses the question by considering three essential characteristics of the recent crisis: First, the crisis was triggered in the financial markets; second, there were spillovers from the financial sector to the real economy; third, monetary policy measures were unconventional. My results favor permanent reforms. The wealth effect associated with reforms enhances credit intermediation and mitigates the contraction of economic activity.

When Lehman Brothers collapsed in 2008, the global financial system began to struggle. Interbank lending froze, resulting in a slow-down of the real economy worldwide. A sovereign debt crisis followed in the European Monetary Union. Politicians and economists alike have since been debating about the appropriate policies to adopt. One suggestion is to reduce macroeconomic imbalances within member states. Indeed, differences in the ability to compete have been documented (see e.g. Dieppe et al., 2012). There is, however, dissent on the effectiveness of structural policies in a crisis scenario, particularly when interest rates are close to zero.

The main argument in favor of structural reforms is that they initiate a wealth effect. Shifts in the long-run aggregate supply are associated with increases in expected future income that immediately stimulate demand and lead to output growth (see e.g. Fernández-Villaverde et al. (2014)). In the context of a monetary union, reforms in less competitive member states can lead to real devaluations relative to the rest of the union. In addition to wealth effects, there are changes in terms of trade, encouraging households to substitute in favor of the reforming countries (see e.g. Farhi et al., 2014).

However, reforms might have negative implications for output growth in the short run. In a recent paper, Eggertsson et al. (2014) show that if the nominal interest rate is at a lower bound, deflationary pressures resulting from reforms can cause the real interest rate to appreciate. The higher real interest rate induces households to reduce current consumption in favor of future consumption, leading to a further contraction of economic activity in the short run.

In special situations such as a crisis, standard transmission channels of specific policy initiatives may be distorted. Therefore, the crisis scenario
itself was often considered in the analysis of reforms. However, the fact that the recent crisis was financial in its nature has frequently been ignored. In the following, I address three issues that are potentially relevant for policy analysis.

First, the crisis originated in the financial sector of the economy. After a long period of growth, asset prices in the housing and mortgage market in the United States suddenly began to decline by the end of 2006. In turn, falling asset prices deteriorated the balance sheets of some major financial institutions, including Bear Stearns, Fannie Mae, Freddie Mac, and Lehman Brothers. Ultimately, an asymmetric information problem appeared in the interbank market: The fact that any borrower in the market was potentially linked to a struggling financial institution induced a vicious circle that drastically slowed down interbank lending. Many existing models used to study reforms omit these dynamics. Instead, they focus on the outcomes of the crisis, such as a contraction of output, deflation, and the fact that interest rates are close to the zero lower bound. For example, a standard procedure to initiate a crisis in a model is to induce a shock to the preference structure of households which leads to a reduction in consumption demand. It is, however, questionable if preference shocks are appropriate for modeling debt related crisis (see e.g. Eggertsson and Krugman, 2012).

Second, there is a fundamental link between the financial and the real sector. The fact that interbank lending slows down is by itself not alarming. However, in the recent crisis, the distortions in the financial sector swapped over to the real economy. Financial intermediaries restricted lending to firms in the real sector drastically. The depletion of credit supply became apparent in substantially increasing credit spreads. The increased costs of borrowing in turn affected the profits of firms and thus their asset prices. Ultimately, the drop in real sector asset prices fed back to the financial sector, further eroding financial intermediaries’ ability to carry out their main function. Such an amplification is known as financial acceleration. Although there is seminal research on the interaction between the financial and the real sector1, showing that worsening conditions in the process of credit intermediation have substantial consequences for the real sector, much of the literature on structural reforms

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ignores the financial sector.

Third, governments intervened in the credit markets during the financial crisis. Large scale asset purchasing programs were initiated in the United States and Europe with the purpose of restoring the functioning of the financial markets. Thus, governments stepped in as *lenders of last resort* to relax the credit constraints which hampered the flow of funds from capital suppliers to goods producing firms. The previous literature on reforms rarely takes this behavior into account. Instead, monetary policy is assumed to rely on the nominal interest rate in order to react to crisis. Therefore, the constraint imposed on the monetary authority by the zero lower bound on interest rate was of primary interest in many studies.

The main contribution of this paper consists in addressing these issues when studying the effects of structural reforms in a crisis scenario. The model I construct builds on the standard monetary New-Keynesian dynamic equilibrium framework (see e.g. Smets and Wouters, 2003, 2007; Christiano et al., 2005). The core element of the model is the financial sector which channels capital from households to firms. Credit constraints arise endogenously from a moral hazard problem following Gertler and Karadi (2011). Financial intermediaries’ leverage is therefore an important state variable in the model. Eventually, shocks are accelerated in the capital markets. The model incorporates asset prices and credit spreads. The dynamical behavior of these variables in response to structural reforms provides insights into how these policies influence credit intermediation. Prices and wages are sticky and hence money plays a role in the model. I consider different types of monetary policy rules. These include Taylor rules in which a constraint on the lower level of the nominal interest rate is imposed, as well as unconventional monetary policy rules as in Gertler and Karadi (2011). Specific characteristics of the European Monetary Union are modeled following Eggertsson et al. (2014). Reforms are modeled as reductions in taxes on wages and retail prices, which increase competition in the labor and product markets, respectively.

I deviate from the previous literature in various aspects. In contrast to Fernández-Villaverde et al. (2014), Eggertsson et al. (2014), and Cacciatore et al. (2016), I consider investment in physical capital. In contrast to Eggertsson et al. (2014), Gerali et al. (2015a,b), Vogel (2016), Gomes (2014), and Anderson et al. (2014), I do not model the crisis as originat-
ing from a shock to demand. Instead, the starting point of my analysis is a shock in the financial market that leads to a credit crunch. The major distinction from Andrés et al. (2017), who also consider financial frictions, is the modeling of leverage and credit market frictions. In contrast to Anderson et al. (2014), who intend to capture unconventional monetary policy by relaxing the zero lower bound constraint, I explicitly account for direct interventions in the credit market while keeping the interest rate constraint.

My analysis reveals that the financial sector plays an important role in the way structural reforms affect the economy. The following scenario illustrates the main mechanisms: Financial intermediaries borrow funds at fixed interest from households. They invest these funds and their own equity in the capital stock. Hence, they hold a leveraged position. A moral hazard problem imposes a constraint on leverage. Assume that a financial market shock lets asset prices drop sharply. As a result, the net worth of financial intermediaries falls and balance sheets of banks deteriorate. Bankers’ debt-to-equity ratios increase substantially, tightening the credit constraint and letting credit spreads increase accordingly. Households respond by reducing the amount of funds supplied to bankers. Consequently, the supply of credit to goods producing firms declines, and so does production. In sum, the initial disturbance is accelerated in the financial market and ultimately the real sector is driven into a recession. In this setting reforms aimed at reducing the cost of labor or the monopoly power of firms are effective in reducing the multiplicative effects in the credit intermediation process. Expectations of higher future income and production volume are immediately reflected in the financial market. Asset prices increase and credit spreads adjust. Balance sheets in the financial sector recover and debt-to-equity ratios decrease. The moral hazard constraint is relaxed. Households’ capital supply increases, facilitating production and mitigating the recession. The wealth effect works, no matter whether the central bank is facing a lower bound on interest rates or not. Moreover, unconventional policy measures that stimulate credit intermediation are not in conflict with structural reforms. Thus, my model suggests that reforms are an appropriate measure to combat economic contraction in a financial crisis.

The structure of this paper is as follows. Section 2 introduces a monetary union model with financial frictions. Section 3 discusses how the model responds to a financial shock and how structural reforms affect
credit intermediation and economic activity. The final section draws conclusions.

2 A Monetary Union Model with Capital Market Frictions

I construct a model with two countries that share a common currency managed by a central bank. Households consume tradable and non-tradable goods, save by purchasing bonds, and supply labor. Perfectly competitive firms producing intermediate goods in the non-tradable sector use labor as input, whereas the tradable sector uses labor and capital in its production. Labor is mobile across sectors but immobile across countries. Monopolistically competitive retailers buy intermediate goods and sell them to consumers. Prices and wages are nominally rigid. In each country, there is a financial sector that borrows funds from domestic households and lends to domestic firms. The financial sector is balance sheet constrained leading to financial acceleration when the capital market is disturbed. Countries differ with respect to their international competitive position due to taxes, which represent an inefficiency in the product and labor markets. Structural reforms are modeled as permanent changes in these taxes.

I keep the model description to a minimum while preserving completeness. The framework builds on the work of Eggertsson et al. (2014) who study structural reforms in a monetary union without financial sector. The capital market framework is that of Gertler and Karadi (2011). More detailed descriptions including some derivations can be attained in these papers.

Most of the model equations refer to the home country which is considered the periphery of the monetary union. If not stated otherwise, similar equations hold for the core of the union. A * denotes a foreign variable. I provide an appendix with the full set of model equations.

2.1 Households

Households maximize their expected lifetime utility. They decide on consumption and saving and set wages on a staggered basis. The opti-
mization problem of each individual \((j)\) is given by

\[
\max_{C_{j,t+s}, B_{j,t+s}, W_{j,t+s}, E_{t}} \ E_{t} \left[ \sum_{s=0}^{\infty} \beta^{s} \left( \frac{(C_{j,t+s} - hC_{j,t+s-1})^{1-\sigma}}{1 - \sigma} - \frac{L_{1+\nu}^{1+\nu}}{1 + \nu} \right) \right],
\]

subject to labor demand and the sequence of the budget constraints

\[
P_{t}C_{j,t} + \frac{B_{j,t}}{\psi_{B,t}} = (1 + \psi_{t-1})B_{j,t-1} + (1 - \tau_{w})W_{j,t}L_{j,t} + T_{j,t}.
\]

\(L_t\) denotes the amount of labor supplied, \(W_t\) denotes the nominal wage and \(C_t\) is a consumption bundle. \(\beta\) is the subjective time preference factor, \(h\) is a habit parameter, and \(\nu\) is the inverse Frisch elasticity of labor supply. \(\sigma\) is the inverse of the elasticity of intertemporal substitution. \(P_t\) denotes the price level, \(T_t\) is a placeholder for all net transfers of firm profits and taxes to households, \(i_t\) is the nominal interest rate and \(B_t\) represents the total amount of nominal bonds. \(\tau_w\) is a tax on wage income and is used by governments as a policy instrument. \(E_t[\cdot]\) denotes the mathematical expectation of a variable conditional on information available at time \(t\). \(\psi_{B,t}\) is a time varying intermediation cost, which is introduced to ensure stationarity of the net foreign asset position. It decreases in the nominal debt-to-output ratio:

\[
\psi_{B,t} = \exp \left[ - \psi_{B} \frac{B_t}{P_t Y_t} \right],
\]

with \(\psi_B > 0\). Thus, if domestic households have a large amount of debt relative to output, the intermediation cost will be large, and consequently households will have less incentive to assume more debt. If domestic households are net lenders to the foreign country, they will earn a slightly lower return on bond holdings. Thus, there is neither an incentive to increase lending nor to increase borrowing to the foreign country indefinitely.\(^2\)

\(C_{j,t}\) represents a consumption bundle that consists of tradable \((T)\) and non-tradables \((N)\) goods:

\[
C_{j,t} = \left( \gamma_{H}^{\nu} C_{T,j,t}^{\nu} + (1 - \gamma_{H})^{\nu} C_{N,j,t}^{\nu} \right)^{\frac{1}{\nu}}.
\]

\(^2\)The transaction cost will be small so that its effects on the model dynamics are negligible. The cost is only paid by home households, while foreign households receive the corresponding fee (see Erceg et al., 2006; Eggertsson et al., 2014).
The parameter $\gamma_H$ reflects households’ preferred share of tradable goods in total consumption, and $\varphi$ is the elasticity of substitution between tradable and non-tradable goods. A standard assumption is that $0 < \varphi < 1$, which implies that tradable and non-tradable goods are complements. Households minimize their consumption expenditures:

$$\min_{C_{Tj,t},C_{Nj,t}} P_{T,t}C_{Tj,t} + P_{N,t}C_{Nj,t},$$

(5)

where $P_T$ and $P_N$ are the price indices of tradable and non-tradable composites, respectively. Optimality implies the following demand functions:

$$C_{Tj,t} = \gamma_H \left( \frac{P_{T,t}}{P_t} \right)^{-\varphi} C_{j,t},$$

(6)

$$C_{Nj,t} = (1 - \gamma_H) \left( \frac{P_{N,t}}{P_t} \right)^{-\varphi} C_{j,t}.$$  

(7)

Thus, consumption of tradable and non-tradable goods depends on the preference for tradables, the degree of substitutability between the goods, and how the respective prices relate to the overall price level. The price index is given by

$$P_t = \left( \gamma_H P_{T,t}^{1-\varphi} + (1 - \gamma_H) P_{N,t}^{1-\varphi} \right)^{\frac{1}{1-\varphi}}.$$  

(8)

The consumption bundle of tradable goods comprises goods produced at home ($H$) and in the foreign ($F$) country. The consumption composites are, respectively

$$C_{Tj,t} = \left( \frac{1}{\rho} C_{Hj,t} \right)^{\frac{1-\rho}{\rho}} + \left( 1 - \frac{1}{\rho} \right) C_{Fj,t}$$

(9)

and

$$C_{Tj,t}^* = \left( \frac{1}{\rho} C_{Fj,t} \right)^{\frac{1-\rho}{\rho}} + \left( 1 - \frac{1}{\rho} \right) C_{Hj,t}$$

(10)

where $\omega_H$ and $\omega_F$ are the shares of domestically produced tradable goods, and $\rho$ is the elasticity of substitution between tradable goods produced at home and in the foreign country. If $\rho > 1$, domestic and foreign tradable products will be substitutes. The law of one price holds for tradable goods. Hence, the price of a tradable that is both produced and consumed at home ($P_H$) is equal to the price of that same good consumed
in the foreign country \((P^*_H)\). The domestic households optimize their consumption expenditures as follows:

\[
\min_{C_{H,j,t}, C_{F,j,t}} P_{H,j,t} C_{H,j,t} + P_{F,j,t} C_{F,j,t}.
\]

The home country’s demand for tradable goods produced domestically and in the foreign country are, respectively,

\[
C_{H,t} = \omega_H \left( \frac{P_{H,t}}{P_T} \right)^{-\rho} C_{T,t},
\]

and

\[
C_{F,t} = (1 - \omega_H) \left( \frac{P_{F,t}}{P_T} \right)^{-\rho} C_{T,t}.
\]

The price index of tradable goods is

\[
P_{T,t} = \left( \omega_H P_{H,t}^{1-\rho} + (1 - \omega_H) P_{F,t}^{1-\rho} \right)^{1/1-\rho}.
\]

Thus, consumption of domestic and foreign tradable goods depends on the preference for home tradables, the degree of substitutability between the goods, and how the respective prices relate to the price level of tradable goods.

The optimal consumption-saving conditions are standard:

\[
1 = \beta \psi_B t (1 + i_t) E_t \left[ \Lambda_{t,t+1} \Pi_{t+1}^{-1} \right],
\]

where the intertemporal marginal rate of substitution, \(\Lambda_{t,t+1}\), is

\[
\Lambda_{t,t+1} = \frac{\varphi_{t+1}}{\varphi_t},
\]

and the partial derivative of the utility function with respect to consumption, \(\varphi_t\), is

\[
\varphi_t = (C_t - hC_{t-1})^{-\sigma} - \beta h (C_{t+1} - hC_t)^{-\sigma}.
\]

To assign a price or value to a stream of future payoffs it is useful to define a nominal stochastic discount factor, \(M\):

\[
M_{t,t+s} = \beta^s \Lambda_{t,t+s} \Pi_{t+s}^{-1}.
\]

\(\Pi_t\) denotes gross inflation.
In addition to the consumption-saving decision, households decide on wages that they require in return for supplying differentiated labor. There are representative labor agencies which buy labor from households and combine these inputs to form aggregate labor supply. Labor agencies are perfectly competitive and their technology is

\[ L_t = \left( \int_0^1 L_{j,t}^{-1} \frac{\epsilon_w}{\epsilon_w} \, dj \right)^{-\frac{\epsilon_w}{\epsilon_w-1}}, \]  

where \( \epsilon_w \) is the elasticity of substitution of labor with respect to wages. Labor agencies sell the labor aggregate to good producing firms at the aggregate wage level \( W_t \). Their optimization problem consists of maximizing profits by choosing the amount of labor they hire from each household, that is

\[ \max_{L_{j,t}} W_t L_t - \int_0^1 W_{j,t} L_{j,t} \, dj. \]  

Agencies’ profit maximization leads to labor demand functions

\[ L_{j,t} = \left( \frac{W_{j,t}}{W_t} \right)^{-\epsilon_w} L_t \]  

with corresponding wage index

\[ W_t = \left( \int_0^1 W_{j,t}^{-1-\epsilon_w} \, dj \right)^{\frac{1}{1-\epsilon_w}}. \]  

Hence, the labor that the representative agency demands from a household depends on how this household’s wage relates to the overall wage level. Moreover, the elasticity of substitution, \( \epsilon_w \), determines how labor demand reacts to changes in wages. Households are more powerful in setting wages if \( \epsilon_w \) is low.

Wage rigidity is modeled following Calvo (1983). This framework assumes that not every household is able to adjust its wage in every period. To implement the idea technically, it is assumed that households are not able to adjust wages with probability \( \xi \) in each period. The optimization problem of the household can be written as

\[ \max_{W_{j,t}} E_t \left[ \sum_{s=0}^{\infty} (\beta \xi)^s \left( 1 - \tau_w \right) \frac{\tilde{W}_{j,t}}{F_{t+s}} L_{j,t+s} q_{t+s} - \frac{L_{j,t+s}^{1+\nu}}{1+\nu} \right], \]  

(23)
where the choice variable $\tilde{W}_{j,t}$ is the reset wage. Optimization is subject to labor demand, given in Equation (21). The optimality condition for this problem is:

\[
\left( \frac{1 - \xi \Pi_{w,t}^{w-1}}{1 - \xi} \right)^{1+\epsilon_w \nu} \frac{X^A_{w,t}}{X^B_{w,t}} = \left( \frac{\epsilon_w}{\epsilon_w - 1} \right)^{1+\epsilon_w \nu} \frac{X^A_{w,t}}{X^B_{w,t}},
\]

(24)

where

\[
X^A_{w,t} = L_t^{1+\nu} + \xi \beta E_t \left[ \Pi_{w,t+1}^{w} X^A_{w,t+1} \right]
\]

and

\[
X^B_{w,t} = (1 - \tau_w) \frac{W_t}{P_t} L_t Q_t + \xi \beta E_t \left[ \Pi_{w,t+1}^{w-1} X^B_{w,t+1} \right].
\]

(26)

$\Pi_{w,t}$ denotes gross wage inflation.

### 2.2 Intermediate Goods Firms

Intermediate good firms are perfectly competitive. The non-tradable sector uses labor as the sole input. The aggregate production function is

\[
\hat{Y}_{N,t} = L_{N,t}^{1-\alpha}.
\]

(27)

In contrast, the tradable goods sector uses capital, $K_{t-1}$, and labor as inputs. The production function is

\[
\hat{Y}_{T,t} = (U_t Q_t K_{t-1})^{\alpha} L_{T,t}^{1-\alpha},
\]

(28)

where $U_t$ denotes capital utilization and $Q_t$ determines capital quality. The price of replacing one unit of depreciated capital is $P_{H,t}$. Firms take prices as given and maximize profits by choosing the utilization rate and labor, considering the level of wages, the cost of depreciation, and the capital stock. The optimality conditions are

\[
\alpha \hat{P}_{T,t} \hat{Y}_{T,t} = P_{H,t} \delta'(U_t) U_t Q_t K_{t-1}
\]

(29)

and

\[
(1 - \alpha) \hat{P}_{q,t} \hat{Y}_{q,t} = L_{q,t} W_t,
\]

(30)

where $q \in (T, N)$. The depreciation function $\delta(\cdot)$ is

\[
\delta(U_t) = \delta_A + \frac{\delta_B}{1 + \zeta} U_t^{1+\zeta},
\]

(31)
where $\zeta$ is the elasticity of marginal depreciation with respect to capital utilization and $\delta_A, \delta_B, \zeta > 0$. The parameters $\delta_A$ and $\delta_B$ will be calibrated so that, in the steady state, capital utilization is 100 percent and depreciation is 2.5 percent quarterly. If the entrepreneur chooses to increase capital utilization, it will imply a higher rate of depreciation.

The logarithm of $Q_t$ follows an autoregressive process of order one:

$$
\log(Q_t) = \phi \log(Q_{t-1}) + \varepsilon_t, \tag{32}
$$

where $\phi$ determines autocorrelation and $\varepsilon_t$ is an exogenous shock. I assume that capital quality is identical in both countries and that financial shocks appear simultaneously:

$$
Q_t = Q_t^*; \varepsilon_t = \varepsilon_t^*. \tag{33}
$$

The impact of a financial shock on production will, however, depend on each country’s capital intensity.

### 2.3 Retail Firms

Monopolistically competitive retailers in sectors $q \in (T, N)$ buy intermediate goods at price $\hat{P}_{q,t}$, repackage the goods, and finally sell the finished goods to consumers at their individual price $P_{q,t}$. The final output amount is a constant elasticity of substitution aggregate:

$$
Y_{q,t} = \left( \int_0^1 Y_{qf,t}^{\frac{\epsilon_q - 1}{\epsilon_q}} df \right)^{\frac{1}{1 - \epsilon_q}}. \tag{34}
$$

$\epsilon_q$ are the elasticities of substitution in the tradable and non-tradable sectors, respectively. $Y_{qf,t}$ denotes retailer $f$’s output. Profit maximization leads to the following demand functions:

$$
Y_{qf,t} = \left( \frac{P_{qf,t}}{P_{q,t}} \right)^{-\epsilon_q} Y_{q,t}. \tag{35}
$$

The respective price indicies are

$$
P_{q,t} = \left( \int_0^1 P_{qf,t}^{1-\epsilon_q} df \right)^{\frac{1}{1 - \epsilon_q}}. \tag{36}
$$

Retailers set optimal individual prices $P_{qf,t}$ subject to the prices $\hat{P}_{q,t}$ they pay to intermediate goods firms. Nominal rigidities are introduced
following Calvo (1983). In analogy to wage setting framework, it is assumed that retailers are not able to adjust their price with probability $\xi$ in every period. A firm that can reset at time $t$ will set a new price $\tilde{P}_{q,t}$ to maximize profits subject to its individual demand, that is

$$
\max_{\tilde{P}_{q,t}} E_t \left[ \sum_{s=0}^{\infty} \xi^s M_{t,t+s}(1 - \tau_P)(\tilde{P}_{q,t} - \tilde{P}_{q,t+s})Y_{q,t,t+s} \right].
$$

A retailer’s profit in any period depends on its margin over the price of intermediate goods firms, its individual demand, and the tax rate $\tau_P$. This tax rate will subsequently represent the policy instrument with respect to the product market reform. The resulting optimality conditions are:

$$
\left( \frac{1 - \xi \Pi_{q,t}^{-1}}{1 - \xi} \right)^{1/\epsilon_q} = \frac{\epsilon_q}{\epsilon_q - 1} \frac{X_{q,t}^A}{X_{q,t}^B},
$$

where

$$
X_{q,t}^A = Y_{q,t} \tilde{P}_{q,t} q_t + \xi \beta E_t [\Pi_{q,t+1}^{-1} X_{q,t+1}^A],
$$

and

$$
X_{q,t}^B = (1 - \tau_q)Y_{q,t} P_{q,t} q_t + \xi \beta E_t [\Pi_{q,t+1}^{-1} X_{q,t+1}^B].
$$

Finally, the output of intermediate goods firms must be equal to retailers’ output multiplied by price dispersion.

$$
Y_{q,t} D_{q,t} = \tilde{Y}_{q,t},
$$

where the indices of price dispersion are

$$
D_{q,t} = (1 - \xi) \left( \frac{1 - \xi \Pi_{q,t}^{-1}}{1 - \xi} \right)^{\epsilon_q/(\epsilon_q - 1)} + \xi \Pi_{q,t} D_{q,t-1}.
$$

All retail profits are transferred to households.

### 2.4 Capital Producing Firms

After the production of intermediate goods is finalized, capital-producing firms buy all of the capital stock, rebuild depreciated capital, build new capital, and finally sell the capital back to firms producing intermediate goods. Investment adjustment is costly. The costs, however, only apply for building new capital. As noted earlier, the cost of one unit of depreciated capital is $P_{H,t}$. Thus, depreciated capital is rebuilt form domestic
tradable goods. The cost of creating a new unit of capital stock is $P_{S,t}$, which is equal to the price of a unit of capital in the market. The optimization problem of capital-producing firms is to maximize discounted profits:

$$\max_{I_{t+s}} E_t \left[ \sum_{s=0}^{\infty} M_{t,t+s} \left( (P_{S,t+s} - P_{H,t+s})\hat{I}_{t+s} - f\left( \frac{\Delta I_{t+s}}{\Delta I_{t+s-1}} \right) (\Delta I_{t+s}) \right) \right] .$$

(43)

where net investment $\hat{I}$ is given by

$$\hat{I}_t = I_t - \delta(U_t)Q_tK_{t-1}. \quad (44)$$

$\Delta I_{t+s}$ is the sum of net and steady state investment:

$$\Delta I_{t+s} = \hat{I}_{t+s} + I_{ss}. \quad (45)$$

The adjustment cost function is

$$f(\cdot) = \eta/2(\Delta I_{t+s}/\Delta I_{t+s-1})^2. \quad (46)$$

In equilibrium optimal net investment is identical in all firms and the stock price $P_{S,t}$ relates to net investment as follows:

$$P_{S,t} = P_{H,t} + f(\cdot) + \frac{\Delta I_{t,t}}{\Delta I_{t,t-1}} f'(\cdot) - E_t \left[ M_{t,t+1} \left( \frac{\Delta I_{t+1}}{\Delta I_{t,t-1}} \right)^2 f'(\cdot) \right] . \quad (47)$$

The profits earned by capital-producing firms outside the steady state are transferred to households.

### 2.5 Financial Intermediaries

A fraction of each household comprises bankers while the remaining fraction is made up of workers. In each period, the probability that a banker stays a banker is $\theta$. Otherwise, the banker becomes a worker. However, the ratio of bankers to workers is constant, which means that exiting bankers are randomly replaced by workers. Retiring bankers return their accumulated net worth to their households. Bankers manage financial intermediaries whose purpose is to borrow funds from households by issuing nominal one-period bonds $B^B_{j,t}$ and simultaneously provide capital to intermediate producers by buying the stock of capital at price $P_{S,t}$.
To do so, the financial intermediary must, however, have an equity stake $N_{j,t}$ in the business. Each bank’s balance sheet is thus

$$P_{S,t}S_{j,t} = B_{j,t}^P + N_{j,t}, \quad (48)$$

where $S_{j,t}$ denotes the share of total capital a banker owns.

Financial intermediaries have to pay nominal interest $i_t$ on deposits. Their investment in the capital stock yields the uncertain nominal return $\hat{i}_{t+1}$ that is given by

$$\hat{i}_{t+1} = \frac{\alpha \hat{P}_{T,t+1}Y_{T,t+1} - \delta (U_{t+1})Q_{t+1}K_t}{P_{S,t}K_t} + \frac{P_{S,t+1}}{P_{S,t}} - 1. \quad (49)$$

Bankers’ objective is to maximize their expected terminal wealth $V_{j,t}$, that is

$$\max_{S_{j,t}} E_t \left[ \sum_{s=0}^{\infty} (1 - \theta) \theta^s M_{t,s+1}N_{j,t+s+1} \right]. \quad (50)$$

To prevent infinite capital expansion by financial intermediaries a constraint is introduced. In particular, bankers can cheat by diverting some fraction $\lambda$ of the funds provided to them and make a payment to their own household. These funds can not be recovered by lenders. However, the banker will not be able to continue business after cheating. The result of this moral hazard problem is that households are only willing to provide funds to financial intermediaries as long as the banker’s net worth is greater than or equal to the value of the fraction of assets that can be diverted. That is,

$$V_{j,t} \geq \lambda P_{S,t}S_{j,t}. \quad (51)$$

In equilibrium the constraint binds and the amount of assets the financial sector can acquire depends on the sector’s leverage $\Phi_t$ as follows:

$$P_{S,t}S_t = \Phi_t N_t. \quad (52)$$

The ratio of intermediated assets to bankers’ equity is

$$\Phi_t = \frac{\Gamma^A_t}{\lambda - \Gamma^B_t} \quad (53)$$

with

$$\Gamma^A_t = E_t \left[ M_{t,t+1} \left[ (1 - \theta)(\hat{i}_{t+1} - \hat{i}_{t+1}) + \theta \frac{\Phi_{t+1}}{\Phi_t} ((\hat{i}_{t+1} - \hat{i}_{t+1})\Phi_t + (1 + \hat{i}_{t+1})) \Gamma^A_{t+1} \right] \right]. \quad (54)$$
and
\[ \Gamma_t^B = E_t[(1 - \theta) + \theta M_{t,t+1}(\hat{i}_{t+1} - i_{t+1})\Phi_t + (1 + i_{t+1})\Gamma_{t+1}^B]. \] (55)

Exiting bankers transfer their net worth to the households they belong to. Workers that randomly become new bankers receive a fraction \( \chi/(1 - \theta) \) of the assets managed by existing bankers. As a result, the evolution of aggregate financial sector net worth is given by
\[ N_t = \theta((\hat{i}_{t+1} - i_{t+1})\Phi_{t-1} + (1 + i_{t+1}))N_{t-1} + \chi P_{S,t}S_{t-1}. \] (56)

Details on the derivation of the above conditions are provided in Gertler and Karadi (2011).

2.6 Government

The central bank follows a zero-inflation target for the monetary union. Union-wide price index and inflation are
\[ P_{MU,t} = \sqrt{P_t \sqrt{P^*_t}} \] (57) and
\[ \Pi_{MU,t} = \sqrt{\Pi_t \sqrt{\Pi^*_t}}, \] (58)
respectively. This implies that the periphery and core of the monetary union are of equal size. To achieve zero inflation, the monetary authority sets the nominal interest rate according to
\[ i_t = (1 + \bar{i})(\Pi_{MU,t} - 1), \] (59)
where \( \bar{i} \) is the steady state nominal interest rate and \( \kappa \) determines the strength of reaction to deviations from the inflation target. In case there is a lower bound on the nominal interest rate, the rule changes to
\[ i_t = \max[i_{lb}, (1 + \bar{i})(\Pi_{MU,t}^\kappa - 1)], \] (60)
where \( i_{lb} \) denotes the lower interest rate bound.
2.7 Aggregation

The resource constraints in this economy are:

\[ Y_{T,t} = C_{H,t} + C_{H,t}^* + I_t + \frac{\eta}{2} \left( \frac{\Delta I_t}{\Delta I_{t-1}} - 1 \right)^2 (\Delta I_t), \]  

\[ Y_{T,t}^* = C_{F,t} + C_{F,t}^* + I_t^* + \frac{\eta}{2} \left( \frac{\Delta I_t^*}{\Delta I_{t-1}^*} - 1 \right)^2 (\Delta I_t^*), \]  

\[ Y_{N,t} = C_{N,t}, \]  

\[ Y_{N,t}^* = C_{N,t}^*. \]  

Bond market clearing conditions are

\[ \frac{B_X}{\psi B_t} = (1 + i_{t-1}) B_{X,t-1} + P_{H,t} C_{H,t}^* - P_{F,t} C_{F,t}, \]  

\[ B_t^X + B_t^{X^*} = 0, \]  

where \( B_X \) denotes a bond that finances net trade. The total bond amount is

\[ B_t = B_t^X + B_t^B. \]  

Total labor in each country is the sum of tradable and non-tradable labor:

\[ L_t = L_{T,t} + L_{N,t}. \]  

Each unit of capital corresponds to one share issued by firms producing intermediate goods:

\[ K_t = S_t. \]  

2.8 Calibration

The discount rate \( \beta \) is 0.995, implying an annual steady state real interest rate of 2 percent. The habit parameter is 0.65 as in Christiano et al. (2005). The inverse Frisch elasticity \( \nu \) is 1.5, as suggested by Chetty et al. (2011). The intertemporal elasticity of substitution is 0.492, as suggested by Havranek et al. (2015). The elasticities of substitution in the tradable and non-tradable sectors, \( \epsilon_T \) and \( \epsilon_N \), are 7.7 and 4, respectively. Eggertsson et al. (2014) calibrate these values as they imply steady state price markups of 15 percent in the core countries' tradable sector and
33 percent in the non-tradable sector consistent with the estimates of Hoj et al. (2007). The wage elasticity of substitution $\epsilon_w$ equals that of the tradable sector. The tax rates $\tau_N$ and $\tau_w$ in the periphery are initially 10 percent, leading to markups of 48 percent in the non-tradable sector and 28 percent in periphery wages. Three. Tax rates are zero in the core. The probabilities $\xi$ that prices and wages cannot be reset are 0.66. The elasticity of substitution between home and foreign tradable goods $\rho$ is 1.5, and the elasticity of substitution between tradable and non-tradable goods $\varphi$ is 0.5. That is, foreign and domestic tradable goods are substitutes, whereas tradable and non-tradable goods are complements. The intermediation cost $\psi$ is 0.001 as in Erceg et al. (2006).

The parameters of firms producing intermediate goods, capital-producing firms, and financial intermediaries are calibrated following Gertler and Karadi (2011). Four. The capital share $\alpha$ is 0.33. Parameters of the depreciation function are chosen to match a steady state annual depreciation of 10 percent and a steady state utilization rate of capital of 100 percent ($\delta_A = 0.021$ and $\delta_B = 0.033$). The elasticity of marginal depreciation with respect to capital utilization is 7.2. The elasticity of the price of capital with respect to net investment $\eta$ is 1.728.

The survival rate of bankers $\theta$ is 0.975, implying an expected lifetime of a banker of 40 years. $\lambda$ and $\chi$ are 0.4125 and 0.0026, respectively. These values imply a steady state private leverage ratio of 4 and an average annual credit spread of 100 basis points. The Taylor rule inflation coefficient $\kappa$ is 2.

I set the remaining parameters to match consumption demand shares in the steady state of 67 percent in the core and 48 percent in the periphery, as documented by Lombardo and Ravenna (2012). Five. Home bias $\omega$ is 0.7 in both regions. The preference shares of tradable goods in the core $\gamma_F$ and in the periphery $\gamma_H$ are 0.57 and 0.31, respectively. These parameters imply a union-wide steady state import share of 15 percent, with 9 percent in the core and 21 percent in the periphery. Table 1 in the appendix summarizes all parameters.

The calibrated model is also reasonable with respect to some other

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3Markups have been shown to be higher in periphery countries (e.g. Dieppe et al. (2012)). However, there is substantial variation in wage markups across industries (Jean and Nicoletti, 2015).

4Some of these values are based on estimates of Primiceri et al. (2006).

5Average values of Austria, Belgium, France, Germany, and the Netherlands for the core and of Greece, Italy, Portugal, and Spain for the periphery.
relative quantities. Real wages are 43 percent higher in the core. Total labor is about 4 percent lower in the periphery due to higher wage markups. The shares of labor in the tradable sector are 74 and 49 percent in the core and periphery, respectively. The capital intensity in the core is twice as high as in the periphery.

3 Model Analysis

I run several deterministic simulations to study how the model responds to exogenous shocks and structural policies over time. Special emphasis is placed on the impact of the zero lower bound, the similarities between structural reforms and credit market interventions, and how peripheral reforms affect the monetary union as a whole.

3.1 Crisis Scenario

To demonstrate the behavior of the model in a crisis scenario, the impulse responses to a financial shock that hits both countries are plotted in Figure 1. I consider a 5 percent shock to capital quality $Q_t$ with an autocorrelation coefficient $\phi$ of 0.66.

The dynamics are similar to those shown in Gertler and Karadi (2011). There is an immediate drop in asset prices and required returns increase accordingly. Balance sheets of financial intermediaries deteriorate and leverage ratios significantly increase. There is a lack of credit and the economy enters a period of recession, which is characterized by unemployment and a decline in investment and consumption. The recession is long-lasting. The economy has not fully recovered after 10 years. Output contraction is accompanied by deflation, which is mainly driven by the periphery and, in particular, by the non-tradable sector. Union-wide inflation drops to -1.3 percent when the shock occurs. The central bank cuts the nominal interest rate substantially to combat deflation. The price level in the core increases relative to that of the periphery, which is reflected in the real exchange rate.

The shock depresses union-wide output by about 4.4 percent after one year. Output contraction in the core is more severe than in the periphery because production in the core is much more capital intensive.

6I use Dynare (see Adjemian et al., 2011) to run all the simulations.
Figure 1: Crisis Scenario

Note: Responses to a capital quality shock of five percentage points in the monetary union (black line), the core (green line), and the periphery (blue line). Inflation rates, interest rates and spreads are annualized percentages. All other numbers are percentage deviations from the steady state. Time in quarters.
This pattern seems to be at odds with reality as countries in the periphery have been hit at least as hard as countries in the core. Although it is straightforward to recalibrate the shocks to get closer to the data, I choose not to do so for the following reasons: First, it does not alter the main point with respect to structural reforms I want to make here. Second, having a symmetric shock makes regional comparison easier. Third, this scenario does not yet reflect a lower bound on the nominal interest rate. The presence of a lower bound makes the recession worse, particularly in the periphery. Finally, this scenario does not consider unconventional monetary measures of the central bank. There is reason to believe that some of the excessive output contractions in the core relative to the periphery were smoothed out by the European Central Bank, as will be shown subsequently.

3.2 Structural Reforms in a Financial Crisis

Next, I assume that structural reforms are initiated in the periphery’s labor and product markets. The policy instruments $\tau_N$ and $\tau_w$ are each permanently reduced by 5 percentage points. Figure 2 plots the responses to such reforms for selected variables.

The policy’s intention is to reduce markups on wages and non-tradable goods. Consequently, prices fall and deflation worsens by about 1.5 percentage points annually. In response, the central bank decreases the nominal interest rate to less than -3 percent annually, which is far below the zero lower bound.

The contraction of output in the monetary union is considerably lower when reforms are initiated, with a peak deviation of only 2.4 percent compared to 4.4 percent without reforms. Although reforms are only initiated in the periphery, both regions benefit in the short run. This is because the steady state output in the periphery increases by about 1.6 percent. Hence, there is a wealth effect associated with such measures. The present value of future income goes up and consumption is adjusted accordingly. In contrast, saving is not attractive due to negative interest rates. The capital market also mirrors positive future outlooks. Asset prices rise by about 5.7 and 5.5 percentage points relative to the crisis scenario in the core and periphery, respectively, whereas credit spreads decrease by 3.3 percentage points. Higher asset prices imply lower bank leverage and improved liquidity. The flow of credit finally encourages
Figure 2: Structural Reforms in a Crisis

Note: Responses to a capital quality shock of five percentage points (black line) and a capital quality shock of five percentage points, followed by a permanent reduction in policy rates in the product and labor markets of five percentage points (red line). Inflation rates, interest rates and spreads are annualized percentages. All other numbers are percentage deviations from the steady state. Time in quarters.
investment and production.

3.3 Effect of Lower Interest Rate Bounds

The presence of a lower interest rate bound can seriously limit the central bank’s ability to combat deflation with standard measures. To study the effects of a lower bound, I run a simulation where the annual interest rate cannot fall below 1 percent. Figure 3 summarizes the results.

The response functions reveal that the lower bound has the following implications for the dynamics of the model. First, output contraction in both regions is more severe. For example, in the scenario without reforms the maximum deviation from the steady state is 4.5 percent in the periphery and 6.1 percent in the core, compared to 3.7 and 5.1 percent in a scenario without a lower bound. The relative impact of the bound is slightly higher in the periphery than in the core. Second, reforms are an adequate measure to stimulate the economy, even if the nominal interest rate is bounded. The impact of reforms on output is qualitatively identical to that in the scenario without lower bound. In other words, short-run output recovery is superior in both regions when reforms are initiated. However, the quantitative short-run effects are smaller when the central bank is constrained. For example, the average improvement in union-wide output in the first four quarters due to reforms is 1.7 percentage points in the case without bound and 1.6 percent in the case with bound.

This result is in contrast to Eggertsson et al. (2014), who study structural reforms in a similar model without capital and financial intermediation. In their model, output contracts further in the short run when permanent reforms are initiated. The reason is that expected deflation increases the real interest rate drastically when the nominal interest rate hits the lower bound. As a result, households have an incentive to save and postpone consumption to the future. Since their model does not include capital, this real interest rate effect cannot be offset by investment.

In the model I have presented, the real interest rate is not dominating. The initial shock raises real interest rates by 2.6 percentage points in the periphery and 2.1 percentage points in the core. The reform causes a sizable deflation in the periphery that raises the real rate by an additional 4.7 percentage points to 9.3 percent. Hence, although the real interest rate in the periphery increases to more than four times its steady
Figure 3: Structural Reforms at the Zero Lower Bound

Note: Responses to a capital quality shock of five percentage points (black line) and a capital quality shock of five percentage points, followed by a permanent reduction in policy rates in the product and labor markets of five percentage points (red line). Inflation rates, interest rates and spreads are annualized percentages. All other numbers are percentage deviations from the steady state. Time in quarters.
state value, there is still a substantial improvement in output following a reform.

The quantitatively small effect of the reform, compared to the case without a lower bound, on the nominal interest rate is attributable to the impact the bound has on credit spreads. In response to the reforms, these decrease by 3.2 percentage points in both the core and the periphery, which is slightly less than in the case with no lower bound. Nevertheless, there is a reduction in spreads when reforms are initiated.

3.4 Credit Policy and Structural Reforms

In the aftermath of the financial crisis, the European Central Bank and other central banks implemented large-scale asset purchasing programs in order to encourage credit intermediation and stimulate the economy. In this section I compare structural reforms to credit intervention policies.

Gertler and Karadi (2011) study the implications of such unconventional monetary policy measures in a dynamic equilibrium framework. The main idea is that, on the one hand, the government is less efficient than private financial intermediaries in intermediating credit, but on the other hand, it has an advantage because it is not balance sheet constrained. Therefore, the government can choose to intervene in any of the following ways. It can issue government debt directly to households and use these funds to supply credit to firms producing goods. Alternatively, it could issue securities to banks, which, in turn, finance their security purchases by issuing bonds to households. Either way, the implications are identical. The fact that there is an unconstrained debtor stimulates credit flow.

Formally, the government intends to lower credit spreads by varying the amount of credit it supplies to the economy. Its feedback rule is

$$\Psi_{c,t} = v E_t [(i_{t+1} - i_t) - (\bar{i} - \bar{i})],$$

where $\Psi_{c,t}$ is the share of publicly intermediated assets, $\bar{i} - \bar{i}$ is the steady state credit spread, and $v \geq 0$ determines the strength of reaction to credit spreads. Thus, if the credit spread increases and credit constraints tighten in response to a financial shock, the government increases the share of publicly intermediated assets in order to relax the constraints and strengthen credit intermediation. Gertler and Karadi (2011) show that the private leverage ratio $\Phi_t$ is related to the overall leverage ratio
\( \Phi_{c,t} \) as follows:

\[
\Phi_{t} = \Phi_{c,t}(1 - \Psi_{c,t}).
\]  

(71)

Hence, if the share of publicly intermediated assets increases, the leverage ratio of private financial intermediaries decreases.

Figure 4 shows the responses to a financial shock if the government follows a credit policy rule as defined above.\(^7\) When the financial shock hits the economy, the government intervenes to reduce credit spreads. The issuance of debt leads to improving balance sheets in the financial sector because government-backed securities are considered safe. As leverage decreases, investment picks up and the recession is considerably mitigated.

In contrast to structural reforms, credit policy does not change the steady state output. Nevertheless, the effectiveness of both policies relies on the same mechanism: the resolution of deficiencies in the process of credit intermediation. While credit policy approaches the financial market directly, structural reform policies indirectly facilitate lending through positive wealth effects. Hence, structural reforms have similar qualitative implications for the process of financial intermediation as a direct intervention in the credit market. Both policies lead to a reduction in credit spreads, rising asset prices, and lower leverage ratios.

Moreover, the two policies are not in conflict with each other. If structural reforms are implemented in addition to a government intervention, there will be an additional reduction in credit spreads. With respect to inflation, the policies have opposite effects. While reforms make deflation worse in a financial crisis, credit policy leads to rising prices. Hence, credit policy offsets some of the negative effects that reforms have on prices and reduces the time that the central bank is constrained by the lower interest rate bound. The reform experiments with and without credit policy (Figures 3 and 4, respectively) reveal that credit policy reduces deflation by more than one percentage point. Moreover, the time when interest rate is at the lower bound is shortened from five to three quarters.

The structure of the credit policy experiment implies that there are government interventions in both countries of the monetary union. Here, I have assumed that the interventions in both countries follow the same rule. The quantitative implications, however, are not identical in both

\(^7\)I follow the baseline calibration of Gertler and Karadi (2011) in which \( v \) is 10. This parametrization illustrates a moderate intervention strategy.
Figure 4: Credit Policy

Note: Responses to a capital quality shock of five percentage points (black line), a capital quality shock of five percentage points followed by credit policy (green line), and a capital quality shock of five percentage points followed by credit policy and a permanent reduction in policy rates in the product and labor markets of five percentage points (red line). Inflation rates, interest rates and spreads are annualized percentages. All other numbers are percentage deviations from the steady state. Time in quarters.
countries due to different magnitudes of capital intensity. Specifically, the core country, which is more capital intensive, would issue more debt because the effects of a financial shock are more severe. In a monetary union, it may therefore be relevant whether the government intervention strategy is executed by the government independently or by the common central bank. If each government acts independently, the liabilities associated with the intervention policy accrue in each government’s balance sheet and are consequently only borne by national households. If the same credit policy were initiated by the central bank, the liabilities would accrue in a common balance sheet. However, the assets and liabilities of a monetary union’s central bank are typically not distributed among the member states based on capital intensity. In the European Monetary Union, the shares are distributed according to population and output. Thus, the distribution of liabilities when the central bank intervenes does not necessarily match the distribution liabilities in case of independent government interventions.

4 Concluding Remarks

This article contributes to the literature by taking the financial sector into account in the evaluation of structural reforms. My main finding is that reforms work. They work in the short- and in the long-run and in the presence of a lower bound on interest rates. Permanent reforms generate wealth. Asset prices and required returns adjust accordingly. The credit market becomes more liquid. Credit intermediation enhances and eventually the real sector benefits. Insofar, reforms have similar implications for financial intermediation than direct credit market interventions by the government. Moreover, the policies are not in conflict with each other.
References


A Equilibrium Conditions

Euler Equations:

\[ 1 = \beta \psi_{Bt}(1 + i_t)E_t[\Lambda_{t,t+1}] \] (72)

\[ 1 = \beta(1 + i_t)E_t[\Lambda^*_{t,t+1}] \] (73)

\[ \Lambda_{t,t+1} = \frac{q_{t+1}}{q_t} = \frac{(C_{t+1} - hC_t)^{-\sigma} - \beta h(C_{t+2} - hC_{t+1})^{-\sigma}}{(C_t - hC_{t-1})^{-\sigma} - \beta h(C_{t+1} - hC_t)^{-\sigma}} \] (74)

\[ \Lambda^*_{t,t+1} = \frac{q^*_{t+1}}{q^*_t} = \frac{(C^*_{t+1} - hC^*_t)^{-\sigma} - \beta h(C^*_{t+2} - hC^*_{t+1})^{-\sigma}}{(C^*_t - hC^*_{t-1})^{-\sigma} - \beta h(C^*_{t+1} - hC^*_t)^{-\sigma}} \] (75)

\[ \psi_{Bt} = \exp \left[ - \psi_B \frac{B_t}{P_t Y_t} \right] \] (76)

Consumption Demand:

\[ C_{T,t} = \gamma_H \left( \frac{P_{T,t}}{P_t} \right)^{-\varphi} C_t \] (77)

\[ C^*_{T,t} = \gamma_F \left( \frac{P^*_{T,t}}{P^*_t} \right)^{-\varphi} C^*_t \] (78)

\[ C_{N,t} = (1 - \gamma_H) \left( \frac{P_{N,t}}{P_t} \right)^{-\varphi} C_t \] (79)

\[ C^*_{N,t} = (1 - \gamma_F) \left( \frac{P^*_{N,t}}{P^*_t} \right)^{-\varphi} C^*_t \] (80)

\[ C_{H,t} = \omega_H \left( \frac{P_{H,t}}{P_{T,t}} \right)^{-\rho} C_{T,t} \] (81)

\[ C_{F,t} = (1 - \omega_H) \left( \frac{P_{F,t}}{P_{T,t}} \right)^{-\rho} C_{T,t} \] (82)

\[ C^*_{F,t} = \omega_F \left( \frac{P^*_{F,t}}{P^*_{T,t}} \right)^{-\rho} C^*_{T,t} \] (83)

\[ C^*_{H,t} = (1 - \omega_F) \left( \frac{P_{H,t}}{P^*_{T,t}} \right)^{-\rho} C^*_{T,t} \] (84)
Price Indicies:

\[
P_t = \left( \gamma H P_{1,t}^{1 - \varphi} + (1 - \gamma H) P_{N,t}^{1 - \varphi} \right) \frac{1}{\varphi} \tag{85}
\]

\[
P_t^* = \left( \gamma F P_{T,t}^{1 - \varphi} + (1 - \gamma F) P_{N,t}^{1 - \varphi} \right) \frac{1}{\varphi} \tag{86}
\]

\[
P_{T,t} = \left( \omega H P_{1,t}^{1 - \rho} + (1 - \omega H) P_{F,t}^{1 - \rho} \right) \frac{1}{\rho} \tag{87}
\]

\[
P_{T,t}^* = \left( \omega F P_{F,t}^{1 - \rho} + (1 - \omega F) P_{H,t}^{1 - \rho} \right) \frac{1}{\rho} \tag{88}
\]

Price Setting:

\[
\left( \frac{1 - \xi \Pi_{T,t}^T - 1}{1 - \xi} \right) \frac{1}{\xi - \tau} = \left( \frac{\epsilon_T}{\epsilon_T - 1} \right) \frac{X_{T,t}^A}{X_{T,t}^B} \tag{89}
\]

\[
\left( \frac{1 - \xi \Pi_{N,t}^N - 1}{1 - \xi} \right) \frac{1}{\xi - \tau} = \left( \frac{\epsilon_N}{\epsilon_N - 1} \right) \frac{X_{N,t}^A}{X_{N,t}^B} \tag{90}
\]

\[
\left( \frac{1 - \xi \Pi_{T,t}^* - 1}{1 - \xi} \right) \frac{1}{\xi - \tau} = \left( \frac{\epsilon_T}{\epsilon_T - 1} \right) \frac{X_{T,t}^A^*}{X_{T,t}^B^*} \tag{91}
\]

\[
\left( \frac{1 - \xi \Pi_{N,t}^N - 1}{1 - \xi} \right) \frac{1}{\xi - \tau} = \left( \frac{\epsilon_N}{\epsilon_N - 1} \right) \frac{X_{N,t}^A^*}{X_{N,t}^B^*} \tag{92}
\]

\[
X_{T,t}^A = Y_{T,t} \hat{P}_{T,t} \theta_t + \xi \beta E_t \left[ \Pi_{T,t+1}^T X_{T,t+1}^A \right] \tag{93}
\]

\[
X_{T,t}^B = (1 - \tau_T) Y_{T,t} P_{T,t} \theta_t + \xi \beta E_t \left[ \Pi_{T,t+1}^{T-1} X_{T,t+1}^B \right] \tag{94}
\]

\[
X_{N,t}^A = Y_{N,t} \hat{P}_{N,t} \theta_t + \xi \beta E_t \left[ \Pi_{N,t+1}^N X_{N,t+1}^A \right] \tag{95}
\]

\[
X_{N,t}^B = (1 - \tau_N) Y_{N,t} P_{N,t} \theta_t + \xi \beta E_t \left[ \Pi_{N,t+1}^{N-1} X_{N,t+1}^B \right] \tag{96}
\]

\[
X_{T,t}^{A*} = Y_{T,t}^* \hat{P}_{T,t}^* \theta_t^* + \xi \beta E_t \left[ \Pi_{T,t+1}^{T*} X_{T,t+1}^{A*} \right] \tag{97}
\]

\[
X_{T,t}^{B*} = Y_{T,t}^* P_{T,t}^* \theta_t^* + \xi \beta E_t \left[ \Pi_{T,t+1}^{T*-1} X_{T,t+1}^{B*} \right] \tag{98}
\]

\[
X_{N,t}^{A*} = Y_{N,t}^* \hat{P}_{N,t}^* \theta_t^* + \xi \beta E_t \left[ \Pi_{N,t+1}^{N*} X_{N,t+1}^{A*} \right] \tag{99}
\]

\[
X_{N,t}^{B*} = Y_{N,t}^* P_{N,t}^* \theta_t^* + \xi \beta E_t \left[ \Pi_{N,t+1}^{N*-1} X_{N,t+1}^{B*} \right] \tag{100}
\]
Price Dispersion:

\[ D_{T,t} = (1 - \xi) \left( \frac{1 - \xi \Pi_{T,t}^{-1}}{1 - \xi} \right)^{\frac{T}{T-1}} + \xi \Pi_{T,t}^{T} D_{T,t-1} \]  \hspace{1cm} (101)

\[ D_{N,t} = (1 - \xi) \left( \frac{1 - \xi \Pi_{N,t}^{-1}}{1 - \xi} \right)^{\frac{N}{N-1}} + \xi \Pi_{N,t}^{N} D_{N,t-1} \]  \hspace{1cm} (102)

\[ D_{T,t}^* = (1 - \xi) \left( \frac{1 - \xi \Pi_{T,t}^{T*}^{-1}}{1 - \xi} \right)^{\frac{T}{T-1}} + \xi \Pi_{T,t}^{T*} D_{T,t-1} \]  \hspace{1cm} (103)

\[ D_{N,t}^* = (1 - \xi) \left( \frac{1 - \xi \Pi_{N,t}^{N*}^{-1}}{1 - \xi} \right)^{\frac{N}{N-1}} + \xi \Pi_{N,t}^{N*} D_{N,t-1} \]  \hspace{1cm} (104)

Wage Setting:

\[ \left( \frac{1 - \xi \Pi_{w,t}^{-1}}{1 - \xi} \right)^{\frac{1+\nu}{1+\nu} + \frac{1}{1+\nu}} = \left( \frac{\epsilon_{w}}{\epsilon_{w} - 1} \right) \frac{X_{w,t}^A}{X_{w,t}^B} \]  \hspace{1cm} (105)

\[ \left( \frac{1 - \xi \Pi_{w,t}^{w*}^{-1}}{1 - \xi} \right)^{\frac{1+\nu}{1+\nu} + \frac{1}{1+\nu}} = \left( \frac{\epsilon_{w}}{\epsilon_{w} - 1} \right) \frac{X_{w,t}^{A*}}{X_{w,t}^{B*}} \]  \hspace{1cm} (106)

\[ X_{w,t}^A = L_t^{1+\nu} + \xi \beta E_t [\Pi_{w,t+1}^{w} X_{w,t+1}^A] \]  \hspace{1cm} (107)

\[ X_{w,t}^B = (1 - \tau_w) \frac{W_t}{P_t} L_t \theta_t + \xi \beta E_t [\Pi_{w,t+1}^{w} X_{w,t+1}^B] \]  \hspace{1cm} (108)

\[ X_{w,t}^{A*} = L_t^{1+\nu} + \xi \beta E_t [\Pi_{w,t+1}^{w*} X_{w,t+1}^{A*}] \]  \hspace{1cm} (109)

\[ X_{w,t}^{B*} = \frac{W_t}{P_t} L_t^* \theta_t^* + \xi \beta E_t [\Pi_{w,t+1}^{w*} X_{w,t+1}^{B*}] \]  \hspace{1cm} (110)
Production Functions:

\[ Y_{N,t}D_{N,t} = L_{N,t}^{1-\alpha} \quad (111) \]
\[ Y^*_{N,t}D^*_{N,t} = L_{N,t}^{1-\alpha} \quad (112) \]

\[ Y_{T,t}D_{T,t} = (U_tQ_tK_{t-1})^a L_{T,t}^{1-\alpha} \quad (113) \]
\[ Y^*_{T,t}D^*_{T,t} = (U^*_tQ_tK^*_t)^a L_{T,t}^{1-\alpha} \quad (114) \]

\[ \log(Q_t) = \phi \log(Q_{t-1}) + \varepsilon_t, \quad (115) \]

Optimal Capital Utilization:

\[ \alpha \hat{P}_{T,t}Y_{T,t}D_{T,t} = P_{H,t}\delta'(U_t)U_tQ_tK_{t-1} \quad (116) \]
\[ \alpha \hat{P}^*_{T,t}Y^*_{T,t}D^*_{T,t} = P^*_{F,t}\delta'(U^*_t)U^*_tQ_tK^*_{t-1} \quad (117) \]

\[ \delta(U_t) = \delta_A + \frac{\delta_B}{1 + \zeta} U_t^{1+\zeta} \quad (118) \]
\[ \delta(U^*_t) = \delta_A + \frac{\delta_B}{1 + \zeta} U^*_t^{1+\zeta} \quad (119) \]

Optimal Labor:

\[ (1 - \alpha) \hat{P}_{T,t}Y_{T,t}D_{T,t} = L_{T,t}W_t \quad (120) \]
\[ (1 - \alpha) \hat{P}^*_{T,t}Y^*_{T,t}D^*_{T,t} = L^*_{T,t}W^*_t \quad (121) \]
\[ (1 - \alpha) \hat{P}_{N,t}Y_{N,t}D_{N,t} = L_{N,t}W_t \quad (122) \]
\[ (1 - \alpha) \hat{P}^*_{N,t}Y^*_{N,t}D^*_{N,t} = L^*_{N,t}W^*_t \quad (123) \]

\[ L_t = L_{T,t} + L_{N,t} \quad (124) \]
\[ L^*_t = L^*_{T,t} + L^*_{N,t} \quad (125) \]
Investment:

\[ \hat{I}_t = I_t - \delta(U_t)Q_tK_{t-1} \]
\[ \hat{I}_t^* = I_t^* - \delta(U_t^*)Q_tK_{t-1}^* \]

\[ \Delta_{I,t+s} = \hat{I}_{t+s} + \bar{I} \]
\[ \Delta_{I,t+s}^* = \hat{I}_{t+s}^* + \bar{I}^* \]

Asset Prices:

\[ P_{S,t} = P_{H,t} + f(\cdot) + \frac{\Delta_{I,t}}{\Delta_{I,t-1}} f'(\cdot) - E_t \left[ M_{t,t+1} \left( \frac{\Delta_{I,t+1}}{\Delta_{I,t}} \right)^2 f'(\cdot) \right] \]
\[ P_{S,t}^* = P_{H,t}^* + f(\cdot) + \frac{\Delta_{I,t}^*}{\Delta_{I,t-1}^*} f'(\cdot) - E_t \left[ M_{t,t+1} \left( \frac{\Delta_{I,t+1}^*}{\Delta_{I,t}^*} \right)^2 f'(\cdot) \right] \]

\[ f(\cdot) = \frac{\eta}{2} \left( \frac{\Delta_{I,t+s}}{\Delta_{I,t+s-1}} - 1 \right)^2 \]
\[ f(\cdot^*) = \frac{\eta}{2} \left( \frac{\Delta_{I,t+s}^*}{\Delta_{I,t+s-1}^*} - 1 \right)^2 \]

Capital Returns:

\[ \hat{r}_t = \alpha \frac{\tilde{P}_{T,t}Y_{T,t} - \delta(U_t)Q_tK_{t-1}}{P_{S,t-1}K_{t-1}} + \frac{P_{S,t}}{P_{S,t-1}} - 1 \]
\[ \hat{r}_t^* = \alpha \frac{\tilde{P}_{T,t}^*Y_{T,t}^* - \delta(U_t^*)Q_t^*K_{t-1}^*}{P_{S,t-1}K_{t-1}^*} + \frac{P_{S,t}}{P_{S,t-1}} - 1 \]

Financial Sector:

\[ P_{S,t}S_t = \Phi_tN_t \]
\[ P_{S,t}^*S_t^* = \Phi_t^*N_t^* \]
\[
\Phi_t = \frac{\Gamma_t^A}{\lambda - \Gamma_t^B} \\
\Phi_t^* = \frac{\Gamma_t^{A*}}{\lambda - \Gamma_t^{B*}} \\
\]

\[
\Gamma_t^A = E_t \left[ M_{t,t+1} \left[ (1 - \theta) \left( \hat{i}_{t+1} - i_t \right) + \theta \frac{\Phi_{t+1}^*}{\Phi_t^*} \left( \hat{i}_{t+1}^* - i_t \right) \Phi_t + (1 + i_t) \Gamma_{t+1}^A \right] \right] \\
\Gamma_t^{A*} = E_t \left[ M_{t,t+1}^* \left[ (1 - \theta) \left( \hat{i}_{t+1}^* - i_t \right) + \theta \frac{\Phi_{t+1}^*}{\Phi_t^*} \left( \hat{i}_{t+1}^* - i_t \right) \Phi_t^* + (1 + i_t) \Gamma_{t+1}^{A*} \right] \right] \\
\]

\[
\Gamma_t^B = E_t \left[ (1 - \theta) + \theta M_{t,t+1} \left( \hat{i}_{t+1} - i_t \right) \Phi_t + (1 + i_t) \Gamma_{t+1}^B \right] \\
\Gamma_t^{B*} = E_t \left[ (1 - \theta) + \theta M_{t,t+1}^* \left( \hat{i}_{t+1}^* - i_t \right) \Phi_t^* + (1 + i_t) \Gamma_{t+1}^{B*} \right] \\
\]

\[
N_t = \theta \left( \hat{i}_t - i_{t-1} \right) \Phi_{t-1} + (1 + i_{t-1}) N_{t-1} + \chi P_{S,t} S_{t-1} \\
N_t^* = \theta \left( \hat{i}_t^* - i_{t-1} \right) \Phi_{t-1}^* + (1 + i_{t-1}) N_{t-1}^* + \chi P_{S,t}^* S_{t-1}^* \\
\]

\[
K_t = S_t \\
K_t^* = S_t^* \\
\]

**Taylor Rule:**

\[
i_t = (1 + \bar{i}) \Pi_{M,U,t}^\kappa - 1 \\
\Pi_{M,U,t} = \sqrt{\Pi_t} \sqrt{\Pi_t^*} \\
\]

**Resource Constraints:**

\[
Y_{T,t} = C_{H,t} + C_{H,t}^* + I_t + \frac{\eta}{2} \left( \frac{\Delta_{I,t}}{\Delta_{I,t-1}} - 1 \right)^2 (\Delta_{I,t}) \\
Y_{T,t}^* = C_{H,t}^* + C_{H,t} + I_t^* + \frac{\eta}{2} \left( \frac{\Delta_{I,t}^*}{\Delta_{I,t-1}^*} - 1 \right)^2 (\Delta_{I,t}^*) \\
\]
\[ Y_{N,t} = C_{N,t} \quad (152) \]
\[ Y^*_{N,t} = C^*_{N,t} \quad (153) \]

**Bond Market:**

\[ \frac{B_t^X}{\psi_{B,t}} = (1 + i_{t-1})B_{t-1}^X + P_{H,t}C_{H,t}^* - P_{F,t}C_{F,t} \quad (154) \]

\[ B_t^X + B_t^{X*} = 0 \quad (155) \]

\[ B_t = B_t^X + B_t^B \quad (156) \]

\[ B_t^* = B_t^{X*} + B_t^{B*} \quad (157) \]
## B Calibration

### Table 1: Parameters

<table>
<thead>
<tr>
<th><strong>Households</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
<td>$\beta$</td>
</tr>
<tr>
<td>Habit parameter</td>
<td>$h$</td>
</tr>
<tr>
<td>Inverse Frisch elasticity of labor supply</td>
<td>$\nu$</td>
</tr>
<tr>
<td>Elasticity of intertemporal substitution</td>
<td>$\sigma^{-1}$</td>
</tr>
<tr>
<td>Preference share of tradable goods in core countries</td>
<td>$\gamma_H$</td>
</tr>
<tr>
<td>Preference share of tradable goods in periphery countries</td>
<td>$\gamma_F$</td>
</tr>
<tr>
<td>Home bias in core countries</td>
<td>$\omega_H$</td>
</tr>
<tr>
<td>Home bias in periphery countries</td>
<td>$\omega_F$</td>
</tr>
<tr>
<td>Elasticity of substitution between tradable and non-tradable goods</td>
<td>$\varphi$</td>
</tr>
<tr>
<td>Elasticity of substitution between home and foreign tradable goods</td>
<td>$\rho$</td>
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<tr>
<td>Probability of not being able to reset wages and prices</td>
<td>$\xi$</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Retailers</strong></th>
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<tbody>
<tr>
<td>Elasticity of substitution in the tradable goods sector</td>
<td>$\epsilon_T$</td>
</tr>
<tr>
<td>Elasticity of substitution in the non-tradable goods sector</td>
<td>$\epsilon_N$</td>
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<table>
<thead>
<tr>
<th><strong>Labor agencies</strong></th>
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</thead>
<tbody>
<tr>
<td>Wage elasticity of substitution</td>
<td>$\epsilon_w$</td>
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<thead>
<tr>
<th><strong>Intermediate goods firms</strong></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Effective capital share</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>Steady state depreciation</td>
<td>$\delta$</td>
</tr>
<tr>
<td>Elasticity of marginal depreciation w.r.t capital utilization</td>
<td>$\zeta$</td>
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</table>

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<thead>
<tr>
<th><strong>Capital-producing firms</strong></th>
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<tbody>
<tr>
<td>Elasticity of the price of capital w.r.t net investment</td>
<td>$\eta$</td>
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<thead>
<tr>
<th><strong>Financial intermediaries</strong></th>
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<tbody>
<tr>
<td>Fraction of capital that can be diverted</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>Proportional transfer of households to entering bankers</td>
<td>$\chi$</td>
</tr>
<tr>
<td>Survival rate of bankers</td>
<td>$\theta$</td>
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<th><strong>Government</strong></th>
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<tbody>
<tr>
<td>Inflation coefficient of Taylor rule</td>
<td>$\kappa$</td>
</tr>
<tr>
<td>Lower bound on nominal interest rate</td>
<td>$i_{lb}$</td>
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