Unconventional Monetary Policy in a Monetary Union*

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Abstract

I analyze the adoption of unconventional monetary policy measures in a monetary union. To this end, I lay out a two-country monetary union model with balance-sheet constrained financial intermediaries and central bank credit policy. The framework is used to compare the welfare implications of union-wide versus country-specific optimal simple unconventional monetary policy rules. It is shown that – despite the presence of country-specific shocks – country-specific rules are not necessarily associated with higher welfare from the viewpoint of a structurally symmetric union. Instead, to the extent that the central bank reacts to indicators which are highly correlated between countries, union-wide rules can be preferable. When considering structural asymmetries between countries, there is evidence that the introduction of unconventional monetary policy limits incentives to reform financial structures from the viewpoint of a financially less stable country.

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1 Introduction

It is widely known that joining a monetary union inevitably impairs the ability of monetary policy to address country-specific shocks. The common nominal interest rate adjusts proportionally to union-wide circumstances, which might cause either too much or too little stabilization in single countries. Furthermore, given that the nominal exchange rate between member countries is fix, nominal devaluations – which have been occasionally used to prompt productivity in individual countries in the past – are ruled out.

This paper raises the question, whether it is desirable to use unconventional monetary policy to stabilize country-specific shocks in a monetary union. To this end, I lay out a two-country DSGE model with leverage-constrained financial intermediaries. The model features international trade in goods and assets, a common currency and a union-wide nominal interest rate. As in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011), I assume that the common central bank can expand credit to banks ("liquidity facilities") and firms ("corporate sector purchase programs"). Unconventional policy is conducted by following a feedback rule which responds to financial indicators such as the credit spread or credit growth. In particular, I compare the welfare implications of optimal simple rules[1] based upon country-specific indicators to the corresponding outcomes under rules that are based upon union-wide indicators. In the baseline version of my model, I assume that countries are symmetric. However, structural heterogeneity is an important factor when discussing the conduct of unconventional policies in a monetary union. When some countries of a monetary union rely more heavily on central bank credit than others, while costs and risks are born by the union as a whole, incentives to reform financial structures might be misaligned. Therefore, I also consider a modified version of the model in which one country has a more sound financial system than the other. As the order of the approximation needs to be chosen in the light of the research question, the model is solved up to second-order.

A key finding of the analysis is that, under some circumstances, union-wide rules provide higher welfare than their country-specific counterparts despite the presence of country-specific shocks.[2] In particular, whenever the central bank reacts to indicators which are highly correlated between countries, a union-wide rule might be preferable over a country-specific rule. As in Dedola et al. (2013), this finding can be rationalized with the fact that I consider a second-best environment in which policymakers cannot fully eliminate finan-

[1] Optimal simple rules are feedback rules whose reaction coefficients are chosen such that the welfare of an individual household is maximized.

[2] Note that in the symmetric case, union-wide and country-specific welfare are perfectly proportional.

cial frictions or their consequences. Unconventional monetary policy can reduce some of the additional volatility caused by financial frictions,[3] especially, in the economy hit by the shock. However, it can also fuel volatility by "over-stabilizing" the country spared by the shock, especially when the unconventional instrument reacts to union-wide indicators. In general, a reduction in volatility is welfare-improving as it enhances consumption smoothing. On the other hand, in the second-best environment considered here, some degree of volatility interacts with the financial friction to stimulate precautionary behavior, such as precautionary saving and capital accumulation, which also has a positive effect on lifetime utility.[4] In the given setup, the trade-offs between the differing effects of unconventional monetary policy on average volatility and, further, between the differing effects of volatility on union-wide welfare can be tilted towards the positive or the negative depending on how the rule is formulated, i.e., which indicators the central bank reacts to.

When considering financially asymmetric countries – in particular, I consider the case in which one country has implemented a countercyclical capital buffer while the other country features an unregulated financial sector – I find that the introduction of unconventional monetary policy lowers the incentives to reform financial structures in the financially less regulated country.

The unconventional monetary policy measures analyzed in this paper represent instruments which are also part of the ECB's toolbox. Liquidity facilities have been one of the most important instruments of the ECB. Since 2008, liquidity was provided to the banking system elastically and at increasingly long durations through main and longer-term refinancing operations (MROs and LTROs) (Praet, 2017). Before and at the beginning of the financial crisis, Germany was the main user of these instruments (Bruegel, 2017). However, when the most significant three-year LTROs where provided in 2011 and 2012, the composition of country usage changed completely. Since 2011, the periphery's share in the usage of liquidity facilities has increased to more than 70% and has remained at this high level ever since (see figure 1). This implies that liquidity facilities where provided flexibly according to country-specific needs. The picture is quite different when considering the ECB's corporate sector asset purchase program which started in 2016. Direct lending to non-financial firms is

[3]The excess volatility caused by financial friction is a result of what is commonly referred to as "financial accelerator", i.e., the real effects of shocks originating in the real or financial sector are amplified due to the presence of financial frictions.

[4]Lester et al. (2014) and Cho et al. (2015) discuss further model features which can render volatility welfare-improving. Lester et al. (p. 18 2014) show that the "benefits of greater volatility are closely linked to the degree of elasticity in factor supplies." Hence, variable capital utilization and relatively elastic labor supply, which are both features of my model, might also contribute to the positive effects of volatility on welfare.

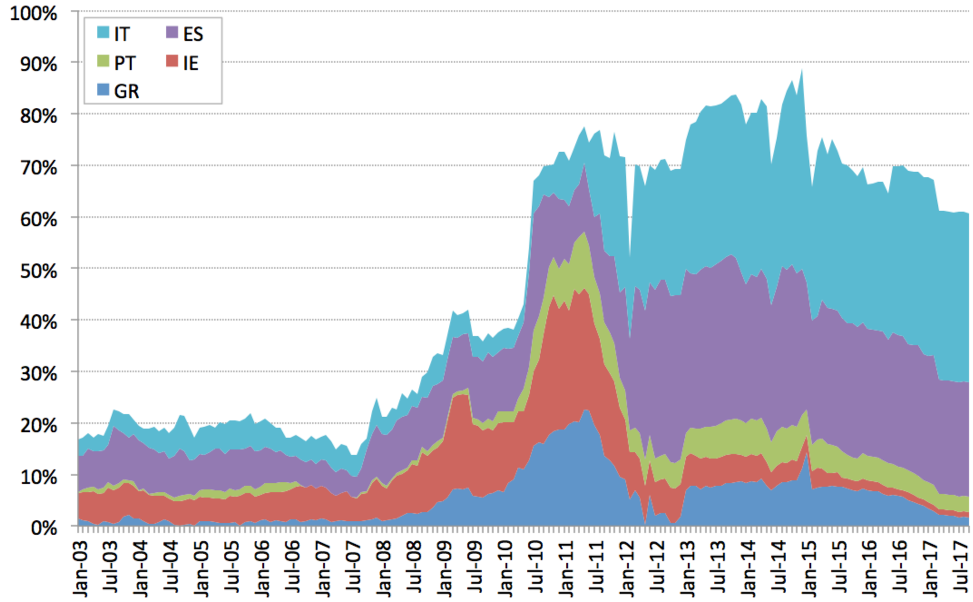

Figure 1: *Periphery's Share in the Usage of the Eurosystem's Main and Longer-Term Refinancing Operations 01/2003 - 09/2017; Bruegel (2017)*

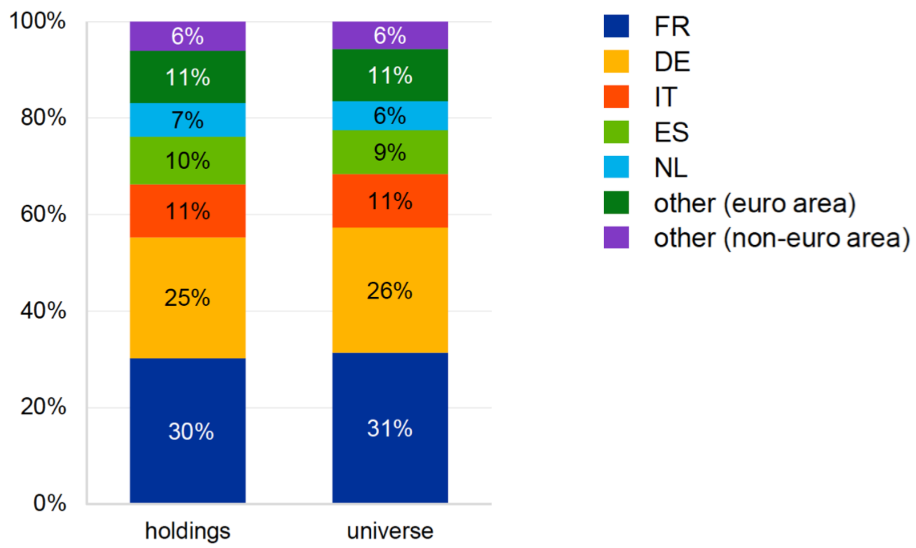

Figure 2: *Country Classification of Corporate Sector Purchase Program (CSPP) Holdings and CSPP-Eligible Bond Universe; ECB (2017)*

distributed between countries in a fixed manner, according to a capital key which reflects the market value of eligible corporate bonds (ECB, 2017). Therefore, as figure 2 shows, mainly firms in the economically largest – and also less troubled – countries have access to central bank credit.

Given the extensive usage of non-standard measures by central banks around the world in recent years, there has been a surge in empirical and theoretical literature trying to analyze the economic effects of different unconventional policy measures. Employing DSGE models featuring a banking sector with financial frictions, Gertler and Karadi (2011), Gertler and Kiyotaki (2011) and Cúrdia and Woodford (2011) have shown that there are substantial gains from expanding central bank credit during crisis. Yet, as the analyses are based on closed economies, they are not well-suited to give advice on how the institutions of a currency union should cope with a financial crisis. Papers which analyze unconventional monetary policy in a two-country setting are usually interested in game theoretical issues associated with two separate monetary authorities interested in their own welfare functions (see, e.g., Dedola et al., 2013; Nuguer, 2016). The focus of my analysis is different. I omit game theoretical issues, for in a monetary union, it is reasonable to assume that a common monetary policy maker adopts a union-wide welfare function. As long as business cycles between member countries are less than perfectly correlated, it is, however, of great interest to analyze union-wide versus country-specific implementation of unconventional monetary policies. To my knowledge, there is only one paper by Tischbirek (2016) which addresses this kind of question, however, focuses on the effects of government debt purchases on fiscal policies. He uses a model which does not feature financial frictions. Further, Auray et al. (2016) use a version of the Gertler and Karadi (2011) model to analyze unconventional monetary policies in the Eurozone. However, they do not distinguish between country-specific and union-wide measures but are rather interested in strategies aimed at different financial market sectors. Schwanebeck (2017) uses the same structurally asymmetric two-country version of the Gertler and Karadi (2011) model as Nuguer (2016) (one country is a net borrower and the other is a net lender) to analyze the effects of unconventional monetary policy on the wholesale interbank market. However, he does not conduct a welfare analysis but focuses on positive policy implications.

To the extent of my knowledge, this paper is the first to analyze whether unconventional monetary policy can and should be used to stabilize country-specific shocks in a monetary union featuring – potentially heterogeneous – financial frictions.

The paper is organized as follows. The next section develops the model. Section 3 provides the calibration. In section 4, I will explain the welfare measure used. In section 5, I present and discuss the results on optimal simple rules in the baseline setup and in the case where one country features a more stable financial system than the other one. The final section concludes and gives an outlook.

2 Model

I assume that the world consists of two countries with symmetric structures which belong to a monetary union, each inhabited by a continuum of agents of equal size. The setup of each country closely resembles the setup of the closed economy modeled in Gertler and Karadi (2011), i.e., besides a banking system the model contains nominal (price stickiness) and real (habit formation, variable capital utilization) rigidities.

Each country features a financial intermediation sector. The role of intermediaries is to transfer funds between households and intermediate goods producers who use the loans to finance investment into physical capital. Intermediaries face an endogenously determined constraint on their leverage ratio, motivated by a simple agency problem which drives a wedge between saving and borrowing rates.

The two countries feature integrated markets for final goods, capital assets and deposits. To allow for these multiple interlinkages, I have to abstract from complete international consumption risk sharing. Allowing the net foreign asset position to be adjusted via two margins - equity and bond trade - might imply two unit roots in a first-order approximation of the model (see, e.g., Schmitt-Grohé and Uribe, 2003)[5]. Hence, I introduce two stationarity-inducing features, an endogenous discount factor, which dates back to Uzawa (1968), and a debt-elastic interest rate yield.

For simplicity only home country equations will be displayed. Foreign variables will be denoted with an asterisk.

2.1 Households

Within each household, there are two member types, workers and bankers. While the worker supplies work to intermediate goods firms and deposits to banks, the banker manages a financial intermediary and transfers retained earnings back to her household when the lifetime of the bank ends. Within the

[5]In the benchmark version of the model, I assume home bias in asset holdings. Under this assumption, integration of asset markets does not imply a unit root. The intuition for this is that assuming home (or foreign) bias has similar effects on the model as assuming some form of portfolio adjustment costs. In section 5, however, I also analyze the case of perfect portfolio diversification. In this special case, the integration of asset markets induces a unit root.

family, there is perfect consumption risk sharing, which allows to maintain the representative agent framework. As in Gertler and Karadi (2011), it is assumed that a fraction $1-f$ of household members are depositors, while a fraction f are bankers. Between periods there is a random turnover between the two groups: with probability θ_b a banker will stay a banker and with probability $1-\theta_b$ she will become a depositor. The relative proportions are kept fixed. New bankers are provided with some start-up funds from their respective households.

The lifetime utility of a representative home worker, who draws utility from consumption, C_t, and disutility from labor, L_t, is given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k} \left(\ln(C_{t+k} - hC_{t+k-1}) - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right),$$

where parameter h determines the degree of habit formation, ϕ is the inverse of the Frisch elasticity of labor supply and χ determines the weight of disutility of labor in the utility function. Variable Θ_t represents the endogenous discount factor of households chosen to ensure stationarity as explained above.

Households save by depositing funds at domestic and foreign intermediaries (see 2.2 for details). Total deposits held between $t-1$ and t, denoted by D_{t-1}, are equivalent to one-period riskless real bonds paying the gross real rate of return R_{t-1}. Furthermore, households provide labor to intermediate goods firms and receive the real wage w_t. Hence, the representative home household's budget constraint in real terms is given by

$$C_t + D_t + T_t = R_{t-1}D_{t-1} + w_t L_t + \Upsilon_t,$$

where Υ_t denotes net profits from the ownership of firms (financial and non-financial) and T_t denotes lump-sum taxes.

Households have equal preferences for home and foreign final goods.[6] Hence, C_t, the CES composite of consumption, is given by

$$C_t = \left(0.5^{\frac{1}{\iota}} C_{H,t}^{\frac{\iota-1}{\iota}} + 0.5^{\frac{1}{\iota}} C_{F,t}^{\frac{\iota-1}{\iota}} \right)^{\frac{\iota}{\iota-1}},$$

with $\iota > 0$ and $C_{H,t}$ and $C_{F,t}$ denoting consumption of home and foreign final goods, respectively. The corresponding consumer price index takes the following form

$$P_t = \left(0.5 P_{H,t}^{1-\iota} + 0.5 P_{F,t}^{1-\iota} \right)^{\frac{1}{1-\iota}}, \tag{1}$$

[6]The main results of this paper are robust to changing this assumption, i.e., the results also hold when household consumption is biased towards home goods. However, the assumption of equal preferences simplifies the interpretation of results because real exchange fluctuations are absent.

where $P_{H,t}$ denotes the price of the home good in the home country and $P_{F,t}$ denotes the price of the foreign good in the home country.

In a currency union, the law of one price always holds, i.e., $P_{H,t} = P^*_{H,t}$ and $P_{F,t} = P^*_{F,t}$. As households preferences are identical in the two countries and no home bias is assumed, the consumption baskets are equal. Hence, Purchasing Power Parity holds and the real exchange rate is constant ($P_t = P^*_t$). The terms of trade are defined as the ratio between the price of exports and the price of imports, $ToT_t \equiv \frac{P_{H,t}}{P_{F,t}}$.

The endogenous discount factor is determined as follows

$$\begin{aligned}\Theta_{t+1} &= \Theta_t \beta(C_{A,t}),\\ \Theta_0 &= 1,\end{aligned}$$

where $C_{A,t}$ is aggregate home consumption. Using aggregate consumption in the endogenous discount factor ensures that the household does not internalize the effect of its consumption decision on the discount factor, which simplifies calculations considerably. As in Schmitt-Grohé and Uribe (2003) and Devereux and Yetman (2010) the following functional form of the endogenous discount factor is assumed

$$\beta(C_{A,t}) = \omega_c (1 + C_{A,t})^{-\eta_c}. \tag{2}$$

Parameter η_c drives the elasticity of the discount factor with respect to consumption. Parameter ω_c captures the steady-state savings propensity. Note that the discount factor decreases in $C_{A,t}$, i.e., whenever a country has relatively higher consumption in the present, it discounts future consumption more heavily and, hence, saves less. The latter implies lower consumption in the future and, therefore, the economy returns to the initial state.

Hence, the household's first-order conditions for the optimal choice of labor and consumption are given by

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t}, \tag{3}$$

and

$$1 = \beta(C_{A,t}) E_t \Lambda_{t,t+1} R_t, \tag{4}$$

with the household's real stochastic discount factor being defined as

$$\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}, \tag{5}$$

where λ_t denotes the marginal utility of consumption given by

$$\lambda_t = (C_t - hC_{t-1})^{-1} - \beta(C_{A,t}) h (E_t C_{t+1} - hC_t)^{-1}. \tag{6}$$

2.2 International Intermediaries

To simplify matters, I implicitly assume that households hold deposits with international savings banks which – according to the needs in the financial system – channel the funds to home and foreign banks via international intermediaries. Total deposits of home households are given by $D_t = D_{H,t} + D_{F,t}$.

Allowing deposits to freely flow between countries, would induce a unit root. Therefore, it is assumed that home deposits can only be channeled to foreign banks by purchasing one-period bonds from international intermediaries. The latter charge a small interest rate premium on the union-wide nominal interest rate. The premium depends on the real net foreign bond position of the respective country. This assumption adds realism to the model and ensures stationarity (see, e.g., Schmitt-Grohé and Uribe, 2003). As in Hjortsoe (2016), I assume

$$i_t = i_t^{CB} \Phi(D_{F,t}), \tag{7}$$

where i_t^{CB} is the nominal interest rate set by the union-wide central bank and i_t is the country rate. It is assumed that the country-specific rate charged by international intermediaries is increasing in the deviation of the external household debt position (real debt is given by $-D_{F,t}$) from its steady state, i.e., $\Phi(\cdot)' < 0$ and $\Phi(0) = 0$. As in Hjortsoe (2016), the following functional form is chosen for the debt-elastic interest rate premium

$$\Phi(D_{F,t}) = (1 - \omega_d D_{F,t}).$$

Parameter ω_d is the yield sensitivity of debt.

Profits of international intermediaries are distributed to households within the current account surplus country. Note that rates of return on home deposits and bonds (equivalent to deposit holdings with foreign banks, $D_{F,t}$) are equalized due to arbitrage.

2.3 Banks

The setup of the banking sector closely follows Gertler and Karadi (2011) except for the modeling of the international dimensions. In the model economy, home financial intermediaries channel funds from households to home and foreign intermediate goods producers, fulfilling the double role of investment as well as commercial banks. In addition to obtaining funds from households, banks also raise funds internally by accumulating retained earnings. The balance sheet of home bank i is given by

$$B_{i,t} = D_{i,t}^B + N_{i,t}, \tag{8}$$

where $N_{i,t}$ denotes intermediary i's net worth. Deposits at bank i, stemming from home and foreign households, are denoted by $D^B_{i,t} = D_{iH,t} + D^*_{iH,t}$. The asset portfolio of bank i, $B_{i,t}$, consists of home as well as foreign assets which are combined according to the following CES aggregator[7]

$$B_{i,t} = \left(\mu_b^{\frac{1}{\iota_b}} (Q_t S_{iH,t})^{\frac{\iota_b - 1}{\iota_b}} + (1-\mu_b)^{\frac{1}{\iota_b}} (Q_t^* S_{iF,t})^{\frac{\iota_b - 1}{\iota_b}} \right)^{\frac{\iota_b}{\iota_b - 1}}. \tag{9}$$

Variable $S_{iH,t}$ ($S_{iF,t}$) denotes the state-contingent claims on future returns of a unit of capital used in intermediate goods production in the home (foreign) economy. The price of the claim is given by Q_t (Q_t^*). Parameter μ_b denotes home bias in portfolio holdings. Accordingly, the return on the portfolio, R_t^A, is determined by the following equation

$$\frac{1}{R_t^A} = \left(\mu_b \left(\frac{1}{R_{k,t}} \right)^{1-\iota_b} + (1-\mu_b) \left(\frac{1}{R_{k,t}^*} \right)^{1-\iota_b} \right)^{\frac{\iota_b}{\iota_b - 1}}, \tag{10}$$

where $R_{k,t}$ ($R^*_{k,t}$) denotes the state-contingent gross real rate of return of the home (foreign) capital asset. The banker chooses the optimal portfolio composition by maximizing expected portfolio returns subject to equation (9).

Intermediary i's net worth evolves according to the following equation

$$N_{i,t} = R_t^A B_{i,t-1} - R_{t-1} D^B_{i,t-1}.$$

Since the banker cannot invest in assets which yield a discounted return smaller than the cost of borrowing, the following inequality has to be satisfied

$$E_t \beta(C_{A,t}) \Lambda_{t,t+1} (R^A_{t+1} - R_t) \geq 0.$$

With perfect capital markets the above relation would hold with equality. In the presence of financial frictions, however, the premium must be positive. It co-varies negatively with output as the intermediary's inability to obtain funds increases during bad states of the economy. As long as the banker earns some positive yield on each unit of money invested, she finds it worthwhile to operate and further accumulate earnings.

[7]Assuming that the portfolio composition is determined by a CES aggregator allows to solve the model without using an endogenous portfolio choice method. The latter are associated with certain drawbacks such as inaccuracies when analyzing structurally asymmetric countries and at higher orders of approximation (cf. Rabitsch et al., 2015). Therefore, the usage of the CES function to determine international portfolios has become more and more popular in recent years (see, e.g., Auray et al., 2016; Poutineau and Vermandel, 2015; Brzoza-Brzezina et al., 2015; Dräger and Proaño, 2018).

It is assumed that each period a fraction 1-θ_b of bankers exit the business with i.i.d. probability and pay out accumulated earnings to their respective households.[8] Therefore, a banker maximizes the terminal value of her net worth given by

$$V_t = \max\ E_t \sum_{k=0}^{\infty} (1-\theta_b)\theta_b^k \Theta_{t+k} \Lambda_{t,t+k+1} N_{i,t+k+1}.$$

To motivate the requirement to build up net worth, the following moral hazard problem is assumed: At the beginning of each period, before the shocks realize and any other transactions take place, the banker can choose to divert the fraction λ_b of available funds back to the household. The cost associated with this fraud is that the depositors recover the remaining fraction $1-\lambda_b$ and force the banker into bankruptcy. Therefore, for households to be willing to deposit funds with the bank, the following incentive constraint must hold

$$V_{i,t} \geq \lambda_b B_{i,t}. \tag{11}$$

To solve the banker's maximization problem define the objective of the bank recursively as

$$V_{i,t} = \max\ E_t \beta(C_{A,t}) \Lambda_{t,t+1} [(1-\theta_b) N_{i,t+1} + \theta_b V_{i,t+1}],$$

and conjecture that the franchise value is linear in assets and net worth

$$V_{i,t} = \nu_{i,t} B_{i,t} + \eta_{i,t} N_{i,t}.$$

The banker's problem consists in choosing the amount of total assets and deposits such that terminal net worth is maximized and the incentive constraint holds. It can be solved using the Lagrange method.

The solutions for the coefficients are given by

$$\nu_t = E_t \Omega_{t,t+1} (R^A_{t+1} - R_t), \text{ and} \tag{12}$$

$$\eta_t = E_t \Omega_{t,t+1} R_t, \tag{13}$$

where

$$\Omega_{t,t+1} = \beta(C_{A,t}) \Lambda_{t,t+1} \left[(1-\theta_b) + \theta_b \left(\eta_{t+1} + \nu_{t+1} \phi_{t+1} \right) \right], \tag{14}$$

which can be interpreted as the stochastic discount factor of the banker. It differs from the household's stochastic discount factor due to the presence of

[8] This arrangement precludes bankers from aggregating so much net worth that the incentive constraint becomes irrelevant for them.

financial frictions. Note that the subscript i was dropped because the coefficients exclusively depend on aggregate variables.

Assuming that the incentive constraint binds,[9] it can be expressed in terms of the coefficients of the value function

$$B_t = \frac{\eta_t}{\lambda_b - \nu_t} N_t = \phi_t N_t, \tag{15}$$

where ϕ_t is the ratio of intermediated assets to net worth, which can be referred to as the leverage ratio. Note that it is determined endogenously in this model.

Finally, the law of motion for aggregate net worth can be derived as

$$N_t = N_{n,t} + N_{e,t}\Xi_{N,t} \tag{16}$$

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1})\phi_{t-1} + R_{t-1} \right] N_{t-1} \tag{17}$$

$$N_{n,t} = \omega_b B_{t-1}, \tag{18}$$

where $N_{e,t}$ denotes existing bankers' net worth, $N_{n,t}$ denotes new bankers' net worth and ω_b is the fraction of assets given to new bankers by households. Variable $\Xi_{N,t}$ denotes an exogenous disturbance to the net worth of existing bankers.

2.4 Intermediate Goods Firms

Intermediate goods firms produce an intermediate good which is sold to final goods producers in the same country at the real price $P_{m,t}$ for use in the production of the final good. The market for intermediate goods is assumed to be perfectly competitive. open The Cobb-Douglas production function of the representative intermediate goods firm is given by

$$Y_{m,t} \quad = \quad A_t(U_t \Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha}, \tag{19}$$

where $Y_{m,t}$ denotes intermediary output, A_t exogenous technology and U_t the utilization rate of capital. Parameter α denotes the output elasticity of capital. Labor L_t is provided by households in the same country only. Capital K_{t-1} was bought from capital goods producers in the same country in the previous period at price Q_{t-1}. To finance capital purchases, the firm issues state-contingent securities to obtain funds from home and foreign intermediaries at the same price. Each period, after being productive, the firm has to pay back capital returns on the securities issued in the previous period. As in Gertler and Karadi

[9] Parameters and steady-state values are chosen such that the incentive constraint binds in the steady state. Holding shocks small enough guarantees that the incentive constraint also binds in a stochastic environment.

(2011), I assume that there exists a shock to the quality of capital, denoted by Ψ_t, to provide a source for exogenous variations in the price of capital. It can be interpreted as the sudden realization that much of the capital installed is of lower quality than previously thought. As the capital stock is equal to the capital claims issued to banks, banks' balance sheets contract in response to a negative capital quality shock. The law of motion for capital is given by

$$K_t = I_t + (1-\delta(U_t))\Psi_t K_{t-1}, \tag{20}$$

where I_t is aggregate investment and $\delta(U_t)$ denotes physical depreciation, where $\delta'(U_t) > 0$ and $\delta''(U_t) > 0$.

The first-order conditions of the intermediate goods producer's profit maximization problem are, therefore, given by[10]

$$R_{k,t+1} = \frac{\alpha \frac{P_{m,t+1} Y_{m,t+1}}{K_t} + (Q_{t+1} - \delta(U_{t+1}))\Psi_{t+1}}{Q_t}, \tag{21}$$

$$w_t = (1-\alpha)\frac{P_{m,t} Y_{m,t}}{L_t}, \tag{22}$$

and

$$\delta'(U_t)\Psi_t K_{t-1} = P_{m,t}\alpha \frac{Y_{m,t}}{U_t}. \tag{23}$$

The firm earns zero profits state-by-state, hence, it simply pays out the ex post return to capital $R_{k,t}$ to the financial intermediary.

2.5 Capital Goods Firms

Competitive capital goods firms produce capital only for the domestic market using national final output as input facing investment adjustment costs (in consumption units). I also follow the approach used by Gertler and Karadi (2011) and assume that adjustment costs are on net investment so that the capital utilization decision is independent of the market price of capital. Their functional form is given by

$$f\left(\frac{I_{n,t} + I}{I_{n,t-1} + I}\right) = \frac{\eta_I}{2}\left(\frac{I_{n,t} + I}{I_{n,t-1} + I} - 1\right)^2, \tag{24}$$

[10] As in Gertler and Karadi (2011), I assume that the replacement price of depreciated capital is unity. Therefore, the value of the capital stock which is left over is given by $(Q_{t+1} - \delta(U_{t+1}))\Psi_{t+1}K_t$.

with $\eta_I > 0$, denoting the inverse elasticity of investment with respect to price of capital, I denoting steady-state investment and net investment being defined as $I_{n,t} \equiv I_t - \delta(U_t)\Psi_t K_{t-1}$. The capital goods producer chooses I_t to maximize lifetime profits given by

$$E_t \sum_{k=0}^{\infty} \Theta_k \Lambda_{t,t+k} \left\{ Q_{t+k} I_{t+k} - \left[1 + f(\cdot)\right] I_{t+k} \right\}.$$

From the first order conditions, the real price of one unit of capital is obtained

$$Q_t = 1 - f(\cdot) + \frac{I_{n,t} + I}{I_{n,t-1} + I} f'(\cdot) - E_t \beta(C_{A,t}) \Lambda_{t,t+1} \left(\frac{I_{n,t+1} + I}{I_{n,t} + I} \right)^2 f'(\cdot). \tag{25}$$

Due to flow investment costs, capital goods firms can earn profits outside the steady state. These profits are distributed lump-sum to the households.

2.6 Final Goods Firms

There is a continuum of mass unity of home final goods firms. Each firm produces a slighly differentiated good. Hence, aggregate home final output, Y_t, can be described by the following CES composite of final good varieties

$$Y_t = \left[\int_0^1 Y_t(f)^{\frac{\epsilon-1}{\epsilon}} df \right]^{\frac{\epsilon}{\epsilon-1}},$$

with $0 < \epsilon$. $Y_t(f)$ denotes output by retailer f. The corresponding home producer price index is given by

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

Given that consumers allocate consumption expenditures optimally between varieties, home final goods firm f faces the following demand by home and foreign consumers[11]

$$Y_t(f) = \left(\frac{P_{H,t}(f)}{P_{H,t}} \right)^{-\epsilon} Y_t,$$

i.e., its share in total home final goods production, Y_t, depends on its relative price.

It is assumed that each final goods firm produces its output, $Y_t(f)$, by costlessly repacking intermediate goods. Real marginal cost is therefore given by

[11] Given that in a currency union the Law of one Price holds, a distinction between home and foreign demand is not necessary.

the intermediate output price $P_{m,t}$. It is further assumed that firms face a positive probability, θ, each period that they a are not able to reset their price (see Calvo, 1983). If not able to reset its price, a firm can partly index its price to the lagged rate of inflation. Hence, the optimal price of a representative home firm, $\tilde{P}_{H,t}$ is given by

$$\tilde{P}_{H,t} \quad = \quad \frac{\epsilon}{\epsilon-1} \frac{E_t \sum_{k=0}^{\infty} \theta^k \Theta_k \lambda_{t+k} \Pi_{H,t,t+k}^{\epsilon} \Pi_{H,t-1,t+k-1}^{-\epsilon\theta_\pi} Y_{t+k} P_{m,t+k}}{E_t \sum_{k=0}^{\infty} \theta^k \Theta_k \lambda_{t+k} \Pi_{H,t,t+k}^{\epsilon-1} \Pi_{H,t-1,t+k-1}^{(1-\epsilon)\theta_\pi} Y_{t+k} p_{H,t+k}} P_{H,t}, \tag{26}$$

where $\Pi_{H,t} \equiv \frac{P_{H,t}}{P_{H,t-1}}$ denotes home producer price inflation between $t-1$ and t, $p_{H,t} \equiv \frac{P_{H,t}}{P_t}$ is the relative price of home goods and θ_π denotes the degree of price indexation. The dynamics of the home price index are given by

$$P_{H,t} = \left(\theta \Pi_{H,t-1}^{\theta_\pi(1-\epsilon)} P_{H,t-1}^{1-\epsilon} + (1-\theta) \tilde{P}_{H,t}^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}. \tag{27}$$

2.7 Interest Rate Policy

Interest rate policy is specified by a standard Taylor rule. It is assumed that the common central bank reacts to variations in the union-wide output gap and the consumer price index (CPI). The union-wide output gap is determined as a weighted average of the country-specific output gaps. Given that Purchasing Power Parity holds, consumer price inflation is the same among both countries, i.e., $\Pi_t = \Pi_t^*$, where $\Pi_t = \frac{P_t}{P_{t-1}}$ denotes consumer price inflation between periods $t-1$ and t. CPI targeting is chosen, because it represents a better description of actual Taylor rules used in central banks following inflation targeting strategies (Devereux et al., 2014, p. 937). The particular Taylor rule of the central bank is given by

$$i_t^{CB} = \left(\beta \Pi_t^{\gamma_\pi} \hat{y}_t^{0.5\gamma_y} \hat{y}_t^{*0.5\gamma_y}\right)^{1-\rho_i} \left(i_{t-1}^{CB}\right)^{\rho_i} \varepsilon_{M,t}, \tag{28}$$

where β is the steady-state discount factor and $\hat{y}_t$ ($\hat{y}_t^*$) denotes the domestic (foreign) output gap, defined as the difference between flexible price output and sticky price output. The output gap is approximated by the inverse of the markup gap.[12] The monetary disturbance is denoted by $\varepsilon_{M,t}$.

The Fisher equation establishes the link between the country-specific nominal and real interest rates, i.e.,

$$i_t = R_t E_t \Pi_{t+1}, \tag{29}$$

where the link between the country-specific nominal rate, i_t, and the union-wide policy rate, i_t^{CB}, is given by equation (7).

[12]In the given setup, the markup is given by $\frac{p_{H,t}}{P_{m,t}}$, where $p_{H,t} \equiv \frac{P_{H,t}}{P_t}$.

Note that I do not assume that conventional monetary policy acts to accommodate unconventional policy. Cahn et al. (2014) model an accommodating interest rate policy and find that, in this case, the effects of unconventional policy are much larger.

2.8 Unconventional Policies

In this paper, I analyze the impact of two kinds of unconventional monetary policy, in particular, liquidity facilities (LF) and corporate sector credit purchases (CCP). Both types of policies are modeled using simple rules.

Liquidity Facilities
In the European Union, since the end of 2008, liquidity facilities are conducted under the fixed rate full allotment tender procedure, i.e., the ECB sets the interest rate and elastically supplies any amount of liquidity financial institutions ask for. The model cannot directly replicate this policy feature as the central bank in the model chooses the quantity of funds by following a feedback rule. However, rule-based liquidity injections capture the endogeneity of the balance sheet expansion to some extent as they imply that the supply of central bank credit reacts elastically to prevailing market conditions (Cahn et al., 2014).

The central bank can lend funds, denoted by M_t, directly to banks at rate $R_{m,t}$. As proposed by Gertler and Kiyotaki (2011), it is assumed that the central bank has superior enforcement possibilities compared to households, hence, only the fraction $\lambda_b(1-\lambda_m)$ with $0 < \lambda_m < 1$ of central bank assets can be diverted.[13] Given these assumptions, a home intermediary's balance sheet takes the following form

$$B_{i,t} = D^B_{i,t} + N_{i,t} + M_{i,t}. \tag{30}$$

The equation for the evolution of intermediary i's net worth needs to be replaced by the following equation

$$N_{i,t} = R^A_t B_{i,t-1} - R_{t-1} D^B_{i,t-1} - R_{m,t-1} M_{i,t-1}.$$

The incentive constraint (formerly defined by equation (11)) is now given by

$$V_{i,t} \geq \lambda_b (B_{i,t} - \lambda_m M_{i,t}). \tag{31}$$

[13] If the fraction of divertable assets would be the same for central bank funds as for household deposits, the extra credit would not expand the supply of liquidity in the banking market but simply supplant it.

Taking into account the modified balance sheet and incentive constraint, the net cost of an extra unit of liquidity facilities is given by

$$\eta_{m,t} = E_t \Omega_{t,t+1}(R_{m,t} - R_t). \tag{32}$$

From the first order conditions of the modified bank's problem, it can be further derived that

$$\eta_{m,t} = \lambda_m \nu_t, \tag{33}$$

which ties down $R_{m,t}$. The law of motion for existing banks' net worth (formerly defined by equation (17)) changes to

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1}) \frac{\phi_{t-1}}{1 - \lambda_m \Phi_{m,t-1}} - (R_{t-1}^m - R_{t-1}) \frac{\phi_{t-1}\Phi_{m,t-1}}{1 - \lambda_m \Phi_{m,t-1}} + R_{t-1} \right] N_{t-1}, \tag{34}$$

where $\Phi_{m,t}$ denotes the fraction of home bank assets intermediated by the central bank, i.e.,

$$M_t = \Phi_{m,t} B_t. \tag{35}$$

As already discussed, I use a rule-based approach to model the provision of liquidity facilities. The fractions of intermediated assets in the home and foreign economy, $\Phi_{m,t}$ and $\Phi^*_{m,t}$, respectively, are determined by simple rules. In particular, I distinguish between union-wide versus country-specific rules and credit spread (rule 1) versus credit growth (rule 2) rules. If a union-wide rule is chosen, the central bank adjusts $\Phi_{m,t} = \Phi^*_{m,t}$ in reaction to union-wide averages, whereas, when a country-specific rule is chosen, it holds that $\Phi_{m,t} \neq \Phi^*_{m,t}$, whenever the economy is not in the deterministic steady state.[14] Note that an increase in the credit spread and a decrease in credit growth indicate a tightening of financial conditions caused by an adverse shock. Hence, the fractions of intermediated assets, $\Phi_{m,t}$ and $\Phi^*_{m,t}$, are either directly proportional to the deviation of the external finance spread[15] from its steady-state value (credit spread rule) or inversely proportional to credit growth (credit growth rule).

[14]I only consider uncorrelated country-specific shocks. If shocks were perfectly correlated between the two economies, it would also hold in the presence of shocks that $\Phi_{m,t} = \Phi^*_{m,t}$.

[15]Note that I use the same definition of the external finance premium as Gertler and Karadi (2011), i.e., the difference between financing costs of firms and the deposit rate. In their model, this spread coincides with the spread relevant for banks. With banking market integration, I could alternatively use $\ln R^A_{t+1} - \ln R_t$, reflecting more closely the conditions in the banking sector. Although I do not expect results to differ much, I plan to include such an analysis into the robustness checks.

Hence, the *union-wide rule* is either given by

$$\Phi_{m,t} = \kappa_m \left[0.5 \left(\ln\left(\frac{R_{k,t}}{R_t}\right) + \ln\left(\frac{R^*_{k,t}}{R^*_t}\right) \right) - \ln\left(\frac{R_k}{R}\right) \right] \tag{36}$$

or

$$\Phi_{m,t} = -\kappa_m \ln \left[\frac{0.5(Q_t K_t + Q^*_t K^*_t)}{0.5(Q_{t-1} K_{t-1} + Q^*_{t-1} K^*_{t-1})} \right]. \tag{37}$$

The *country-specific rules* are either given by

$$\Phi_{m,t} = \kappa_m \left[\ln\left(\frac{R_{k,t}}{R_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{38}$$

$$\Phi^*_{m,t} = \kappa_m \left[\ln\left(\frac{R^*_{k,t}}{R^*_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{39}$$

or

$$\Phi_{m,t} = -\kappa_m \ln \left[\frac{Q_t K_t}{Q_{t-1} K_{t-1}} \right], \tag{40}$$

$$\Phi^*_{m,t} = -\kappa_m \ln \left[\frac{Q^*_t K^*_t}{Q^*_{t-1} K^*_{t-1}} \right]. \tag{41}$$

Corporate Sector Credit Policy

The second type of unconventional monetary policy is the direct provision of non-financial private sector credit by the central bank (see also, e.g., Gertler and Karadi, 2011; Dedola et al., 2013). I assume that the central bank intermediates fraction $\Phi_{f,t}$ of overall funding needs in the home economy, i.e.,

$$F_t = \Phi_{f,t} Q_t K_t, \tag{42}$$

where F_t denotes overall private sector asset purchases by the central bank in the home economy. Hence, the capital market clearing condition, equation (52), which will be provided in the next section, has to account for the fraction of publicly intermediated assets.

As before, I distinguish between union-wide versus country-specific and credit spread (rule 1) versus credit growth (rule 2) rules. And it also holds that whenever the central bank choses a union-wide rule, the same fraction of private sector assets is provided in each country, i.e., $\Phi_{f,t} = \Phi^*_{f,t}$.

Therefore, the *union-wide rule* is either given by

$$\Phi_{f,t} = \kappa_f \left[0.5 \left(\ln\left(\frac{R_{k,t}}{R_t}\right) + \ln\left(\frac{R^*_{k,t}}{R^*_t}\right) \right) - \ln\left(\frac{R_k}{R}\right) \right] \tag{43}$$

or by

$$\Phi_{f,t} = -\kappa_f \ln\left(\frac{0.5(Q_t K_t + Q^*_t K^*_t)}{0.5(Q_{t-1}K_{t-1} + Q^*_{t-1}K^*_{t-1})}\right). \tag{44}$$

The *country-specific rules* are either given by

$$\Phi_{f,t} = \kappa_f \left[\ln\left(\frac{R_{k,t}}{R_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{45}$$

$$\Phi^*_{f,t} = \kappa_f \left[\ln\left(\frac{R^*_{k,t}}{R^*_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{46}$$

or by

$$\Phi_{f,t} = -\kappa_f \ln\left(\frac{Q_t K_t}{Q_{t-1}K_{t-1}}\right), \tag{47}$$

$$\Phi^*_{f,t} = -\kappa_f \ln\left(\frac{Q^*_t K^*_t}{Q^*_{t-1}K^*_{t-1}}\right). \tag{48}$$

Public Intermediation Costs and Government Budget Constraint
I assume that central bank intermediation is costly. These costs could capture efficiency costs but also the risk of credit default whose actual occurrence is ruled out in this kind of model. I follow Gertler et al. (2012) and Dedola et al. (2013) in assuming quadratic intermediation costs. This kind of modeling reflects the more realistic scenario where costs are higher whenever the central bank has a long position in corporate assets or bank credit (Gertler et al., 2012). The cost functions are given by

$$\Gamma_{m,t} = \tau_1(M_t + M^*_t) + \tau_2(M^2_t + M^{*2}_t), \tag{49}$$

$$\Gamma_{f,t} = \tau_1(F_t + F^*_t + \tau_2(F^2_t + F^{*2}_t), \tag{50}$$

where $\Gamma_{m,t}$ and $\Gamma_{f,t}$ denote the total costs of central bank intervention and τ_1 and τ_2 reflect the sensitivity of the costs with respect to the amount of central bank credit provided.

Central bank credit to financial and non-financial firms is financed by the issuance of government debt which is a perfect substitute for household deposits. I assume that in each country the amount of central bank credit is equal to the issuance of government debt. Thereby, the aggregate resource constraint is not affected by unconventional monetary policy. Furthermore, I assume that costs are equally split between the two countries. Hence, the home government flow budget constraint takes the following form

$$0.5(\Gamma_{m,t} + \Gamma_{f,t}) + M_t + F_t = T_t + (R_{m,t-1} - R_{t-1})M_{t-1} + (R_{k,t} - R_{t-1})F_{t-1}. \quad (51)$$

2.9 Market Clearing and Further Equilibrium Conditions

The capital market clearing condition states that in each country, the current value of total installed capital has to be equal to the total value of state-contingent claims on future returns of capital. If the central bank provides corporate sector credit, the fraction of funds intermediated by the central bank, $\Phi_{f,t}$, has to be deducted

$$(1 - \Phi_{f,t})Q_t K_t = Q_t(S_{H,t} + S^*_{H,t}). \quad (52)$$

Home final goods market clearing is given by

$$Y_t = C_{H,t} + C^*_{H,t} + \frac{P_t}{P_{H,t}}\left[I_t + f\left(\frac{I_{n,t} + I}{I_{n,t-1} + I}\right)(I_{n,t} + I)\right]. \quad (53)$$

The home aggregate resource constraint is derived from aggregation of home households' budget constraints, considering profits from the ownership of non-financial firms, profits of international intermediaries, the government flow budget constraint, retained earnings from exiting bankers and the transfer to new bankers

$$\begin{aligned}\frac{P_{H,t}}{P_t} Y_t + Q^*_{t-1} S_{F,t-1} R^*_{k,t} - Q_{t-1} S^*_{H,t-1} R_{k,t} + D_{F,t-1}\frac{i_{t-1}}{\Pi_t} + \Upsilon^{\text{IFI}}_t \\ = C_t + D_{F,t} + \left[I_t + f\left(\frac{I_{n,t} + I}{I_{n,t-1} + I}\right)(I_{n,t} + I)\right] \\ + Q^*_t S_{F,t} - Q_t S^*_{H,t} + 0.5(\Gamma_{m,t} + \Gamma_{f,t}),\end{aligned} \quad (54)$$

where $\Upsilon^{\text{IFI}}_t = -\left(\frac{1}{\Phi(-D_{F,t})} - 1\right)\frac{D_{F,t}}{i^{CB}_t}$ denotes international intermediaries' profits.[16]

[16]As in Hjortsoe (2016), I assume that international intermediaries' profits are redistributed in a lump-sum fashion to households in the current account surplus country.

Bonds are in zero net supply, i.e.,

$$D_{F,t} = -D^*_{H,t},$$

where $D^*_{H,t}$ denotes foreign households' deposits in home banks or, more specifically, foreign international bond holdings invested in home banks.

Last but not least, the relationship between final goods production and intermediate goods production characterizes the equilibrium

$$Y_{m,t} = Y_t \Delta_{p,t}, \tag{55}$$

with $\Delta_{p,t}$ denoting the price dispersion which arises in a model with a two-stage production process with intermediate and final good producers and sticky prices à la Calvo. It can be written in terms of producer price inflation

$$\Delta_{p,t} = \theta \Delta_{p,t-1} \Pi^{\epsilon}_{H,t} \Pi^{-\epsilon\theta_\pi}_{H,t-1} + (1-\theta)\left(\frac{1-\theta \Pi^{\epsilon-1}_{H,t} \Pi^{\theta_\pi(1-\epsilon)}_{H,t-1}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{56}$$

3 Calibration

Table 1 reports the baseline calibration and its sources. The time unit is one quarter.

The values for the habit formation parameter, h, the Frisch elasticity of labor supply, ϕ^{-1}, the steady-state depreciation rate, $\delta(U)$, the elasticity of marginal depreciation with respect to the utilization rate, ζ, the inverse elasticity of net investment to the price of capital, η_I and the Calvo parameter, θ, are taken from Gertler and Karadi (2011). They report to base most of them on estimates from Primiceri et al. (2006).

Parameter η_c in the endogenous discount factor was taken from Devereux and Sutherland (2009). They choose it to be small, to keep the effects of this purely technical feature on the results of the model negligible. The same is true for ω_d, the yield sensitivity to debt, which is calibrated as in Hjortsoe (2016). Given $\eta_c = 0.01$ and the steady-state value of consumption, parameter ω_c was chosen as to guarantee an annual steady-state interest rate of 4%, i.e., a steady-state value of $\beta(C_A)$ of 0.99.

Following Gertler and Karadi (2011), the functional form of the relationship between capital utilization and and the time-varying depreciation rate is given by

$$\delta(U_t) = \delta_u + \frac{b}{1+\zeta} U_t^{1+\zeta}. \tag{57}$$

Parameter	Description	Value	Source
Households			
h	habit formation parameter	0.815	Gertler and Karadi (2011)
χ	utility weight of labor	2.592	
ϕ	inverse of Frisch elast.	0.276	Gertler and Karadi (2011)
η_c	param. from discount factor	0.010	Devereux and Sutherland (2009)
ω_c	param. capturing st.-st. savings propensity	0.996	
ω_d	yield sensitivity to debt	0.010	Hjortsoe (2016)
Capital producing firms			
η_I	inverse elast. of invest. with respect to price of capital	1.728	Gertler and Karadi (2011)
Intermediate goods firms			
α	output elast. of capital	0.330	Gertler and Karadi (2011)
$\delta(U)$	st.-st. depreciation rate	0.025	Gertler and Karadi (2011)
ζ	elast. of marginal depreciation with respect to utilization rate	7.200	Gertler and Karadi (2011)
b	param. from variable capital util.	0.038	
δ_u	param. from variable capital util.	0.020	
Final goods firms			
θ	probability of keeping prices fixed	0.779	Gertler and Karadi (2011)
θ_π	degree of price indexation	0.241	Gertler and Karadi (2011)
ϵ	elast. of subst. between varieties	4.167	Gertler and Karadi (2011)
ι	elast. of subst. between home and foreign goods	4.000	de Walque et al. (2006)
Financial intermediaries			
λ_b	fraction of divertable assets	0.381	Gertler and Karadi (2011)
ω_b	transfer to entering banks	0.002	Gertler and Karadi (2011)
θ_b	quarterly survival rate of banks	0.972	Gertler and Karadi (2011)
ι_b	elasticity of substitution between home and foreign assets	2.020	Poutineau and Vermandel (2015)
μ_b	st.-st. home bias in asset holdings	0.910	Poutineau and Vermandel (2015)
Central bank			
γ_y	feedback coeff. on output gap	0.125	Gertler and Karadi (2011)
γ_π	feedback coeff. on inflation	1.500	Gertler and Karadi (2011)
ρ_i	interest rate smoothing coeff.	0.800	Gertler and Karadi (2011)
λ_m	parameter to determine divertability of CB funds	0.500	
κ_m	feedback coeff. liq. fac. rule	-	
κ_f	feedback coeff. credit policy rule	-	
τ_1	CB intermediation cost parameter	0.000125	Gertler et al. (2012)
τ_2	CB intermediation cost parameter	0.001200	Gertler et al. (2012)
Exogenous processes			
ρ_ψ	persistence of capital quality shock	0.66	Gertler and Karadi (2011)
ρ_A	persistence of technology shock	0.95	Gertler and Karadi (2011)
ρ_N	persistence of net wealth shock	0.66	
$\sigma_\psi, \sigma_N, \sigma_A, \sigma_M$	standard deviation of shocks	0.01	

Table 1: *Parameters*

Parameter b is chosen such that the steady-state capital utilization rate is equal to one. Given b, parameter δ_u is chosen as to guarantee a steady-state depreciation rate of 0.025.

The value chosen for the trade elasticity between home and foreign goods is in line with the values de Walque et al. (2006) estimated for the European Union. Home bias in asset holdings, μ_b, and the elasticity of substitution between home and foreign assets, ι_b, were taken from Poutineau and Vermandel (2015) who estimated them based on Eurozone data. Note that the value of ι_b determines the degree of synchronization between home and foreign asset returns.

The values of the parameters of the banking system, λ_b, θ_b and ω_b are taken from Gertler and Karadi (2011). They choose these values to hit three targets: a steady-state interest rate spread of 100 basis points, a steady-state leverage ratio of four and an average lifetime of a bank of 10 years.

The coefficients of the Taylor rule, γ_y and γ_π, were also taken from Gertler and Karadi (2011). Parameter λ_m was chosen to yield a divertability of government assets of approximately 0.2 $(= \lambda_b(1-\lambda_M))$, which is, admittedly, an arbitrary value. The intermediation cost parameters, τ_1 and τ_2, are taken from Gertler et al. (2012).[17] The feedback coefficients of the unconventional monetary policy rules will be chosen optimally.

The three exogenous variables A_t, Ψ_t and $\Xi_{N,t}$ are assumed to follow AR(1) processes. Persistency and standard deviation of the technology shock are taken from Gertler and Karadi (2011).[18] The persistency of the net wealth shock is set to 0.66 which is equal to the persistency of the capital quality shock. Note that the capital quality shock as well as the net wealth shock directly affect stock variables and, hence, feature a high endogenous persistency. The size of the capital quality shock is set equal to the size of the other shocks.

4 Welfare Measure

Welfare is evaluated by first computing the conditional expected lifetime utility of the representative household under each financial market setting, as proposed by Schmitt-Grohé and Uribe (2004). The advantage of using conditional welfare is that it takes into account the transition to a particular, regime specific,

[17]As there is no information on the cost of central bank credit policy, however, the modeling of these costs directly affects the welfare results, robustness checks were conducted. I found that the main result is not qualitatively affected by choosing considerably higher values of τ_1 and τ_2. The corresponding welfare tables are available on request.

[18]Shock processes are specified in levels. Thereby, it is ensured that positive and negative realizations of shocks affect welfare symmetrically.

stochastic steady state.[19] In the upcoming analyses, all regimes are associated with different stochastic steady states. Welfare is conditioned on the initial state being the deterministic steady state, which is the same in all scenarios. Steady state welfare is given by

$$\overline{W} = \frac{U(\overline{C}, \overline{L})}{1 - \beta(\overline{C})} = \frac{\ln((1-h)\overline{C}) - \chi \frac{\overline{L}^{1+\phi}}{1+\phi}}{1 - \omega_c (1 + \overline{C})^{-\eta_c}}.$$

The conditional expectation of lifetime utility as of time 0 of a particular regime is denoted as

$$W_0 = E_0 \sum_{k=0}^{\infty} \beta(C_{A,t+k}) \left(\ln(C_{t+k} - hC_{t+k-1}) - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right).$$

The benefit or loss of a particular policy regime is calculated as the permanent change in steady-state consumption, necessary to make agents in the non-stochastic steady state as well off as those in the stochastic economy. I define the necessary permanent change in steady-state consumption as g. A positive value of g means that agents in the stochastic setting are better off, whereas a negative value implies that agents in the non-stochastic setting have a higher welfare. The particular value for g is found by solving the following equation:

$$W_0 = \frac{\ln((1+g)(1-h)\overline{C}) - \chi \frac{\overline{L}^{1+\phi}}{1+\phi}}{1 - \omega_c (1 + (1+g)\overline{C})^{-\eta_c}}.$$

Conditional welfare is calculated with Dynare. Following, e.g., Gertler and Karadi (2011), I write welfare recursively as

$$W_t = U(C_t, L_t) + \beta(C_{A,t}) E_t W_{t+1},$$

into the model block and take a second-order approximation of the whole model. From the output I take the uncertainty correction of variable W_t and add it to the deterministic steady state.[20]

For each type of policy – liquidity facilities and credit policy, credit spread and credit growth rule, union-wide and country-specific rule – I search for the optimal rule by searching numerically for the value of κ_m or κ_f which yields the highest conditional welfare. I restrict the values of the reaction coefficients to

[19] I define the stochastic steady state as the point in the state space where agents decide to stay in the absence of shocks, but taking into account the distribution of future shocks (cf. Juillard and Kamenik, 2005).

[20] This procedure is described in the Dynare Forum (see Pfeiffer, 2016).

lay in the interval of $[0, 330]$. Gertler and Karadi (2011) call a rule with $\kappa_f = 100$ "aggressive policy", hence, parameter values which lay even above 100 can be seen as very unrealistic. However, this paper is just a first step towards a deeper analysis of unconventional monetary policy in a monetary union and also a wide arrange of rules is analyzed, therefore, on purpose, the interval was chosen to be very wide as well.

5 Results

In this section, I first present and discuss the welfare implications of the different types of unconventional monetary policy introduced in section 2.8, from the viewpoint of a structurally symmetric union. In oder to better understand what drives these results, I conduct further model analyses, which are presented in subsection 5.2. In particular, I discuss the impulse responses for the home and foreign economy under different unconventional monetary policies and I analyze the sensitivity of my results to varying certain model features which are responsible for the cross-country correlations of the indicator variables. In the last subsection, I turn to a monetary union, in which one country has already implemented a countercyclical capital buffer and analyze whether the introduction of unconventional monetary policy distorts the incentives to introduce the same macroprudential regulation in the other country.

5.1 Optimal Simple Rules in a Symmetric Setup

Table 2 displays the welfare results for the different policy regimes. Column (1) shows the optimal coefficient of the particular liquidity facility or credit policy rule. Column (2) contains the welfare gain of living in a stochastic world under a particular regime compared to staying in the deterministic steady-state forever.[21] It is measured in percent of steady-state consumption. Recall that a positive value of g means that agents in the stochastic setting are better off whereas a negative value implies that agents in the non-stochastic setting have a higher welfare. Finally, column (3) shows the the relative gain of each rule, which is defined as the difference in the g of a particular rule, compared to the g in the case without unconventional policy, i.e., compared to $g = -3.69$.

[21] Recall that the deterministic steady state is the same across all regimes, i.e., in the deterministic steady state no unconventional monetary policy is conducted.

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-3.69	-
Rule 1 - Credit Spread Rule			
LF, country-specific	59	-3.22	0.47
LF, union-wide	73	-3.15	0.53
CCP, country-specific	182	-2.23	1.46
CCP, union-wide	231	-2.09	1.59
Rule 2 - Credit Growth Rule			
LF, country-specific	63	2.50	6.19
LF, union-wide	69	2.28	5.97
CCP, country-specific	132	4.17	7.85
CCP, union-wide	132	3.78	7.46

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 2: *Optimal Simple Rules in a Symmetric Setup*

First, it should be noted, that all unconventional monetary policy rules analyzed here are welfare-improving compared to the case of no unconventional policy (relative gain is always positive). However, this result depends, most importantly, on the presence and calibration of specific shocks in the model, the calibration of λ_m and the assumptions regarding the intervention costs.[22]

Furthermore, it can be seen that in all cases credit policy yields higher welfare than the provision of liquidity facilities. The reason is that in the case of credit policy, the central bank directly provides credit to the corporate sector, while in the case of liquidity facilities, the funds provided by the central bank are channeled through the private financial intermediation sector which is subject to financial frictions.[23] This can also explain, why it is optimal to conduct

[22]As robustness analyses have shown, even for very high intervention cost parameters ($\tau_1 = 0.000625$ and $\tau_2 = 0.0062$) most policies are still welfare-improving. Results of the robustness analyses are available on request.

[23]Rewriting the banking sector's balance sheet in the presence of liquidity facilities as

$$B_t = \phi_t N_t + \lambda_m M_t,$$

it is straightforward to see that of each unit of central bank funds provided, only $\lambda_m < 1$ are credit policy much more aggressively than the provision of liquidity facilities ($\kappa_f > \kappa_m$ for all rules).[24]

A further result is that credit growth rules yield higher welfare than credit spread rules. As the positive g's in the lower part of the table imply, when living in an environment in which the central bank conducts unconventional policies following credit spread rules, households even prefer the stochastic over the deterministic environment.[25] Assumably, the reason for the preferability of credit growth rules over credit spread rules is that credit growth is more closely related to welfare-relevant, i.e., real variables than the credit spread. Moreover, the credit spread should be largely reflected in credit growth while the latter contains additional information about the state of the (real) economy.

The most interesting finding is that whenever the central bank uses a credit spread rule, welfare is higher when the central bank reacts to union-wide averages than when it reacts to country-specific indicators. The opposite holds when the central bank relies on a credit growth rule. In this case, country-specific rules are better suited to address country-specific disturbances. Note that I marked those policies grey which provide higher welfare when comparing country-specific to union-wide rules. In the next section, I will provide some additional analyses in order to find an explanation for this result.

Table 3 reports consumption risk-sharing between the two countries and the stochastic steady-state values of capital (K), bankers' net worth (N), leverage (ϕ) and consumption (C).[26] Again, those lines are marked grey which contain the results for a policy rule which provides higher welfare when comparing country-specific to union-wide rules.

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turned into credit.

[24]If one is interested in a direct welfare comparison between these two types of measures, it might be recommendable to set intervention costs higher for corporate credit policy, given that corporate asset purchases presumably require a higher amount of monitoring activities by the central bank.

[25]As discussed in the introduction to this chapter, in this type of model, a certain degree of volatility can be welfare-improving as it interacts with the financial friction to stimulate precautionary behavior, which, generally, results in a higher stochastic steady state capital stock. The latter permits higher consumption in the stochastic steady state.

[26]The stochastic steady state is computed by simulating the model forward without shocks using the policy functions obtained from a second-order approximation of the model. This procedure is explained in the Dynare Forum (see Pfeiffer, 2018).

	Relative gain (1)	Risk-sharing (2)	K (3)	N (4)	ϕ (5)	C (6)
No UMP	-	0.70	5.609	1.524	3.658	0.7024
Rule 1 - Credit Spread Rule						
LF, country-specific	0.47	0.66	5.646	1.512	3.630	0.7044
LF, union-wide	0.53	0.64	5.653	1.504	3.621	0.7046
CCP, country-specific	1.46	0.67	5.667	1.258	3.709	0.7053
CCP, union-wide	1.59	0.61	5.674	1.170	3.716	0.7055
Rule 2 - Credit Growth Rule						
LF, country-specific	6.19	0.68	5.973	1.297	4.585	0.7129
LF, union-wide	5.97	0.66	5.951	1.308	4.539	0.7126
CCP, country-specific	7.85	0.74	6.077	1.211	4.994	0.7172
CCP, union-wide	7.46	0.64	6.047	1.229	4.907	0.7167

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Relative gain: difference in g to case without unconventional policy. Columns (3)-(6) display the stochastic steady state of the given variable. International riskharing is measured as corr(λ_t, λ_t^*).

Table 3: *Optimal Simple Rules and Stochastic Steady State Implications*

It is interesting to see that the welfare results are not – or only marginally – driven by consumption risk-sharing. Although welfare is lowest in the case without unconventional monetary policy, international risk-sharing ranks second among all regimes. For each rule and policy – quite plausibly – risk-sharing is higher when the policy maker reacts to country-specific indicators, however, as has been pointed out above, welfare is not necessarily higher for country-specific policy. It should further be noted, that welfare is positively related to stochastic steady-state capital (K) and negatively related to stochastic steady-state net worth (N). Taken together, these two findings reflect that unconventional policy is successful in reducing the consequences of the financial friction on the economies. In particular, regarding corporate sector asset purchases, the central bank directly provides credit to the real sector, circumventing the troubled banking sector. This allows for a higher buildup of capital while not requiring a higher buildup of net worth. When supplying liquidity facilities, the central bank provides the private banking sector with assets which can be less easily diverted. Thereby, the tightness of the incentive constraint is reduced, which allows banks to provide the same amount of capital assets with less net wealth. The effects of unconventional policy on the stochastic steady state ratio of capital to net worth are also reflected in the stochastic steady state of the leverage ratio (ϕ). As can be seen in table 3, welfare is positively related to ϕ, except for the case where the central bank provides liquidity facilities adhering to a credit spread rule. A higher capital stock allows for higher production and consumption (C) which can – to some extend – explain the welfare ranking of the policy regimes.

5.2 Understanding the Results

As it is well know, welfare results are – to a large extent – driven by the underlying sources of risk. Therefore, when trying to understand the results, it is advisable to look at the optimal simple rules in environments featuring only one shock at a time. Tables 8 to 11 in the appendix contain the respective coefficients and welfare results. It can be easily seen that the capital quality shock drives the main results. This shock is quite powerful and enters the model in different ways. First, capital quality shocks perfectly resemble technology shocks with respect to their direct impact on output by hitting the production function. Second, they have a direct effect on the capital accumulation process, which brings about additional persistency. Third, they directly hit banks' balance sheets, by changing the value of assets. Due to their large impact on the model, it is not surprising that they have an important effect on the welfare results. When only technology shocks are present, households are mostly indifferent between country-specific and union-wide rules. Furthermore, in such a world, unconventional measures only have a small impact on welfare. These findings are not surprising, as unconventional monetary policy targets the financial sector, which, in the case of technology shocks, only causes "a modest amplification of the decline in output" (Gertler and Karadi, 2011, p. 26). If households were to exist in a world with only net wealth shocks, i.e., purely financial shocks, they would unambiguously prefer rules based upon country-specific indicators. There are sizeable gains from unconventional monetary policy, even with small optimal coefficients. Credit spread rules score higher than credit growth rules, which implies that the credit spread might be a better indicator of the needs of the financial system than credit growth. In a world with only monetary policy shocks, by construction, households are completely indifferent between country-specific and union-wide rules, as these shocks are not country-specific.

As capital quality shocks were found to drive the main result, it seems natural to have a closer look at the economies' direct response to capital quality shocks. Figures 3 and 4 show the impulse responses to an adverse 1% capital quality shock in the home economy. While the blue line portrays the case without central bank credit policy, the red line portrays the case with country-specific credit policy and the black dashed line displays the case with union-wide credit policy. In the setup underlying figure 3 it is assumed that the central bank reacts to the *credit spread* whereas the impulse responses displayed in figure 4 are based on the assumption that the central bank reacts to *credit growth*.

In general, credit policy significantly moderates the contraction in the economy hit by the shock. By taking over some of the lending activities of the troubled banking sector, the central bank succeeds in dampening the rise in the credit spread and the drop in asset prices. This, in turn, dampens the decline in banks' lending activities. In the absence of central bank credit policy, the foreign economy experiences a decline in output which is essentially driven by the deterioration of foreign banks' balance sheets which are exposed to home assets. As explained in Krenz (2016), the home capital quality shock directly hits foreign banks' balance sheets by destroying part of the asset portfolio. Credit policy by the central bank can completely eliminate the adverse effect on foreign output (and other real and financial variables) by effectively combatting the balance sheet recession in the foreign economy.

Recall that in the all-shocks environment as well as in the environment only featuring capital quality shocks, union-wide policies yield higher welfare in the case of credit spread rules (figure 3), whereas country-specific policies yield higher welfare in the case of credit growth rules (figure 4). In order to understand the impulse responses, it is important to remember that when the central banks adheres to a union-wide rule it reacts to union-wide averages and intermediates the same share of funds in both countries. On the other hand, when it follows country-specific rules, the shares of funds provided in each country are chosen based on country-specific needs. Therefore, by construction, in the economy hit by a shock, country-specific policy leads to more stabilization than union-wide policy, while the opposite is true in the economy not hit by the shock.

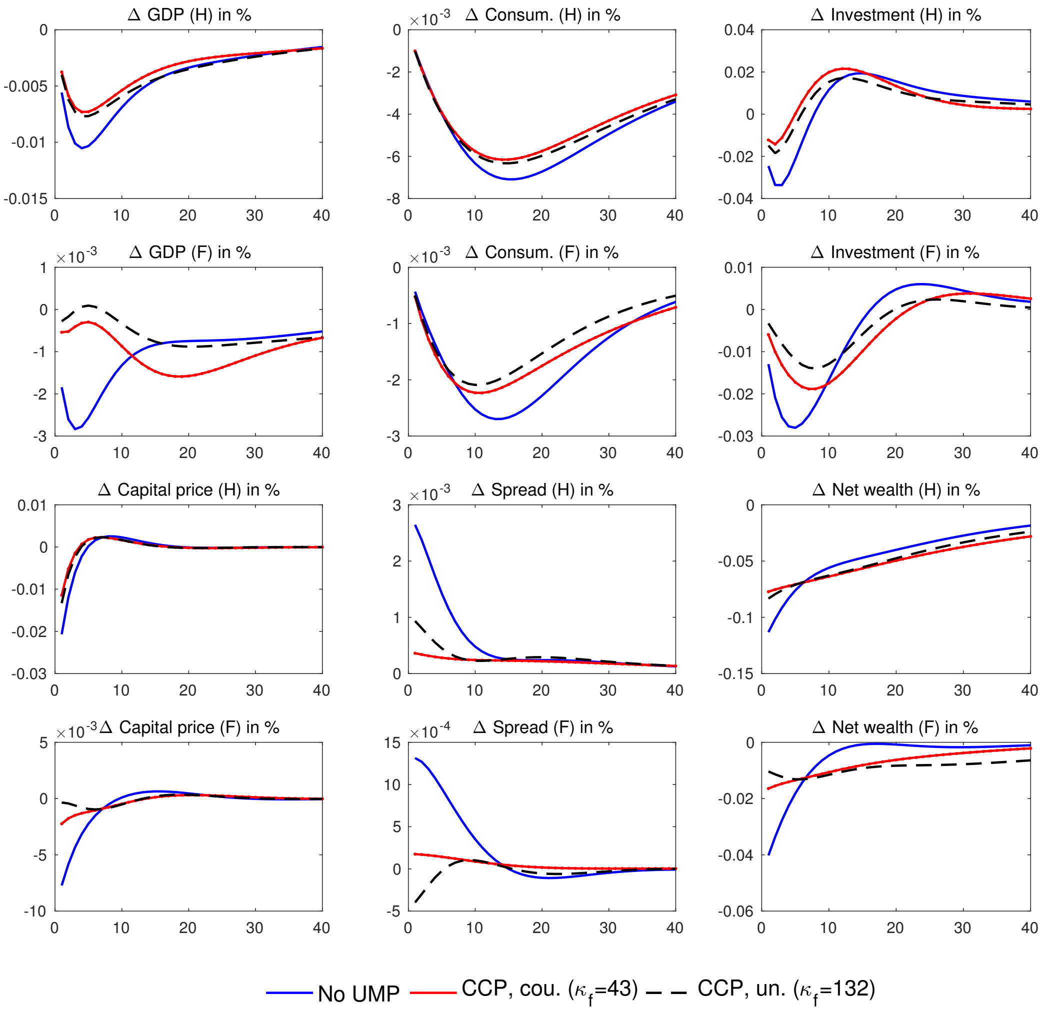

Figure 3: *Impulse Responses to an Adverse 1% Capital Quality Shock under a Credit Spread Rule (Rule 1)*

The figures clearly show that the differences between country-specific and union-wide policies are much smaller for credit spread rules (figure 3) than for credit growth rules (figure 4). This holds even though, in the latter case, the optimal coefficients are much more alike ($\kappa_f = 139$ and $\kappa_f = 135$). When the central bank follows a credit spread rule (figure 3), the stabilization provided to the home economy is very similar, regardless of whether the corporate credit purchases are conducted in a union-wide or a country-specific manner. In the foreign economy, per construction, union-wide policy leads to more stabilization than country-specific policy in both figures. However, for credit growth rules (figure 4) the differences between union-wide and country-specific policy are much more pronounced. In figure 4, we can even observe "overstabilization" for union-wide rules: Foreign investment, net worth and capital prices are pushed into the opposite direction when the monetary authority relies on union-wide as opposed to country-specific indicators.

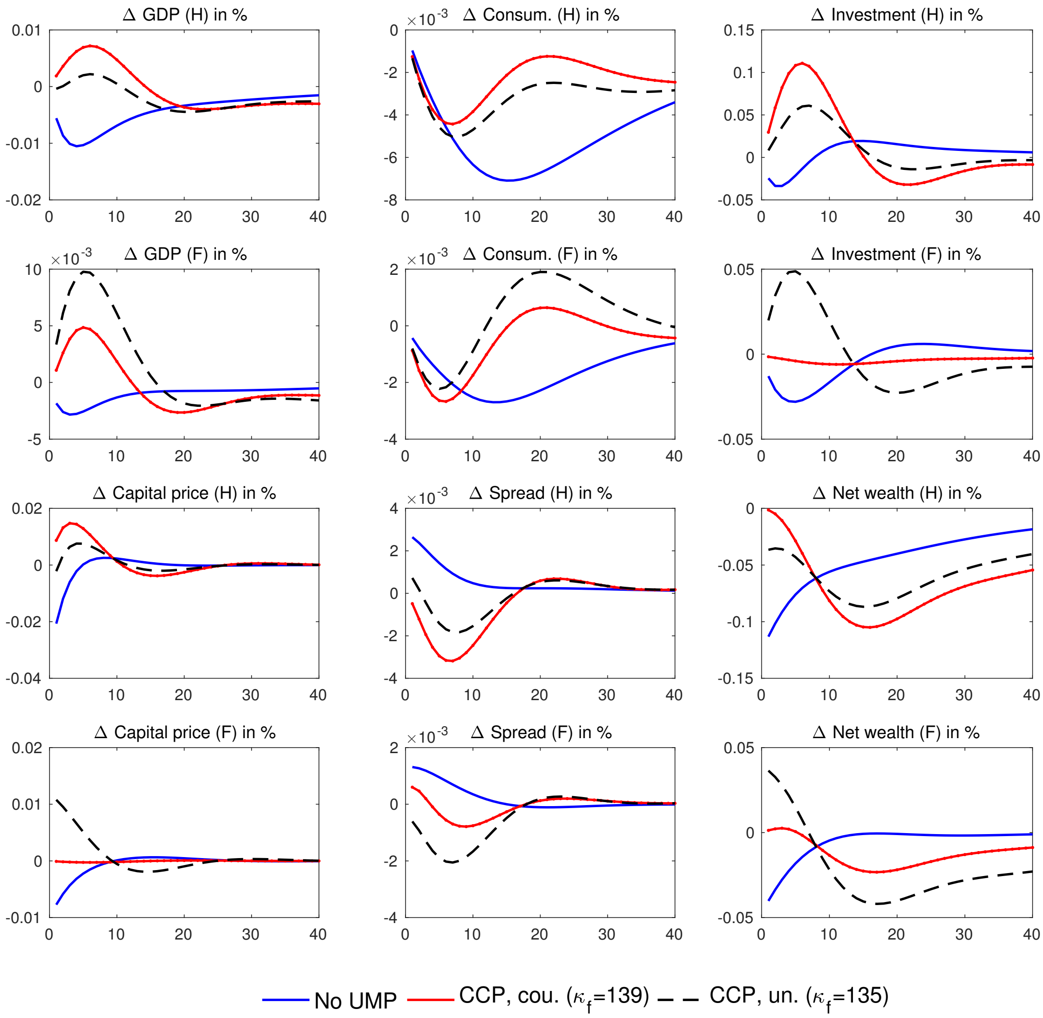

Figure 4: *Impulse Responses to an Adverse 1% Capital Quality Shock under a Credit Growth Rule (Rule 2)*

As the cross-country correlations of the indicators of the unconventional monetary policy rules seem to be an important driver of the findings of the impulse response analyses, it seems worthwhile to conduct robustness checks with respect to some of the determinants of the cross-country correlation of the indicator variables. In particular, I analyze the two extreme cases where banks do not provide credit to foreign firms and, on the other extreme, where banks hold a fully diversified portfolio ($\mu_b = 0.5$). Tables 12 and 13 in the appendix show the optimal coefficients and welfare results for the different rules in the two extreme cases. Table 12 shows that with domestic credit provision, the result that credit policy following a credit spread rule yields higher welfare when reacting to union-wide indicators still holds. In the case of fully diversified banks (see table 13), however, it does not hold any more. Now, union-wide rules yield higher welfare, when the central bank resorts to credit growth as indicator variable. Tables 4 and 5, below, support the view that this is again the result of the underlying cross-country correlations: In the baseline model ($\mu_b = 0.91$) and the model with domestic credit provision, the correlation between home and foreign credit spreads is higher than the correlation between home and foreign credit growth. In the model with fully diversified bank portfolios, the ranking is turned around. This result holds for an environment with all shocks, but is even more pronounced when only taking into account capital quality shocks.

Correlation between	Baseline $\mu_b = 0.91$	Domestic credit	Full diversification $\mu_b = 0.5$
Y, Y^*	0.684	0.608	0.786
λ, λ^*	0.697	0.609	0.845
$\frac{R_k}{R}, \frac{R_k^*}{R^*}$	0.908	0.662	0.871
QK, Q^*K^*	0.686	0.498	0.995

Table 4: *Cross-Country Correlations*

Correlation between	Baseline $\mu_b = 0.91$	Domestic credit	Full diversification $\mu_b = 0.5$
Y, Y^*	0.457	0.608	0.972
λ, λ^*	0.590	0.609	0.981
$\frac{R_k}{R}, \frac{R_k^*}{R^*}$	0.810	0.662	0.228
QK, Q^*K^*	0.384	0.498	0.987

Table 5: *Cross-Country Correlations (Only Capital Quality Shocks)*

Although it is difficult to entirely determine what exactly drives the findings presented in section 5.1, it can be concluded that if the central bank reacts to indicator variables which are highly correlated between countries, it might be welfare-superior to resort to union-wide rules as opposed to country-specific rules. If indicators are highly correlated, union-wide rules provide similar stabilization in the economy hit by the shock while overstabilization in the economy spared by the shock is smaller, rendering union-wide rules preferable over country-specific rules. As explained in the introduction, this can be rationalized with the fact that I consider a second-best environment. When financial frictions cannot be fully eliminated, the effects of unconventional monetary policy on welfare are two-fold. On one hand, reductions in volatility reduce the financial accelerator and please the consumption-smoothing motive of the consumer. On the other hand, reductions in volatility might prevent precautionary behavior, such as precautionary saving and capital accumulation. Therefore, depending on the cross-country correlation of the indicator variables, the overall welfare effects can either be higher for rules providing relatively less stabilization in the economy hit by the shock but relatively more stabilization in the other country (=union-wide rules) or for rules providing relatively more stabilization in the economy hit by the shock but relatively less in the other economy (=country-specific rules).

5.3 Optimal Simple Rules in an Asymmetric Setup

It is very often argued, that unconventional monetary policy can cause free-riding behavior and lower the incentives to reform financial structures. This is especially relevant in a financially heterogeneous monetary union where the risks and costs of unconventional monetary policy are shared among member countries. In this section, I consider the case where country H has a more sound financial system than country F. This is modeled by introducing a macroprudential instrument with similar effects as a countercyclical capital buffer in country H.[27]

Regarding the implementation of the capital requirement, I follow Ghilardi and Peiris (2016) and Levine and Lima (2015) by introducing a countercyclical subsidy on net worth, τ_t^N, which adjusts in proportion to variations in the credit-to-GDP-ratio[28]

$$\ln(1+\tau_t^N) = -\kappa_\tau \ln\left(\frac{B_t/Y_t}{B/Y}\right), \tag{58}$$

where $\kappa_\tau = 0.1$.

[27] The Basel Committee on Banking Supervision (2017) reports considerable cross-country differences in the implementation of the countercyclical capital buffer required by the Basel III framework.

[28] Ghilardi and Peiris (2016) use foreign borrowing as an indicator variable and Levine and Lima (2015) employ a whole set of different indicator variables in the macroprudential rule. However, as it is generally agreed that macroprudential instruments should prevent excessive credit development (see, e.g., Lang and Welz, 2017), the credit-to-GDP-ratio seems to be a natural choice for an indicator variable in a macroprudential rule in the given model.

In general, a subsidy on net worth changes the marginal cost of borrowing from households. If implemented in a countercyclical fashion, the subsidy increases whenever the economy performs below average, reducing lending costs, hence, facilitating lending activities, while it precludes the economy from overheating during economic upswings by increasing the cost of borrowing.

Given the subsidy, intermediary i's net worth evolves according to the following equation

$$N_{i,t} = R_t^A B_{i,t-1} - R_{t-1} D_{i,t-1}^B + \tau_{t-1}^N N_{i,t-1}.$$

Solving the banks' maximization problem in the presence of the subsidy, the marginal cost of deposits (formerly given by equation (13)) changes to

$$\eta_t = E_t \Omega_{t,t+1} (R_t + \tau_t^N). \tag{59}$$

On an aggregate level, only the net worth of existing bankers (formerly given by equation (17), or, in the presence of liquidity facilities, by equation (34)) is affected by the macroprudential subsidy, i.e.,

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1}) \phi_{t-1} + R_{t-1} + \tau_{t-1}^N \right] N_{t-1}. \tag{60}$$

In this asymmetric setup, the optimal policy coefficients of the country-specific unconventional monetary policy rules will obviously differ between countries, i.e., $\kappa_m \neq \kappa_m^*$ and $\kappa_f \neq \kappa_f^*$ in the country-specific rules. Since I assume that unconventional monetary policy is conducted by a single authority, reaction coefficients κ_m and κ_m^*, or κ_f and κ_f^*, respectively, are chosen to jointly maximize union-wide welfare.

Table 6 shows the welfare results for such a heterogeneous monetary union. To facilitate comparisons, column (6) provides the welfare results for the baseline case discussed in section 5.1, in which neither country had implemented any financial regulation. First of all, it should be noted that without unconventional monetary policy, welfare in the financially more regulated country and average union-wide welfare are higher than in the baseline scenario where both countries are symmetric and macroprudential regulations are absent ($g^H, g^{UN} > g$). Welfare in the financially less regulated economy, however, is slightly lower compared to the baseline case ($g^F < g$), which implies a negative externality of the introduction of macroprudential policy in a single country. A possible explanation for this result is that in the stochastic steady state, the financially regulated country (H) resumes some of the financial activities of the other country. Due to home bias in asset holdings this implies a higher capital stock and, hence, higher consumption in country H at the expense of country F. The latter result changes, once unconventional monetary policy is introduced. In combination with any unconventional monetary policy rule considered, country F also profits from the introduction of macroprudential policy in country H.

	Home (regulated fin. sector)		Foreign (non-regulated fin. sector)		Union average	Symm. union (table 2)
	κ_f, κ_m	g^H	κ_f, κ_m	g^F	g^{UN}	g
	(1)	(2)	(3)	(4)	(5)	(6)
No UMP	-	-3.17	-	-3.76	-3.46	-3.69
Rule 1 - Credit Spread Rule						
LF, country-specific	66	-2.45	56	-3.09	-2.77	-3.22
LF, union-wide	69	-2.44	69	-3.06	-2.75	-3.15
CCP, country-specific	330	1.87	185	-1.60	0.13	-2.23
CCP, union-wide	330	2.93	330	-1.75	0.57	-2.09
Rule 2 - Credit Growth Rule						
LF, country-specific	40	0.07	69	2.64	1.35	2.50
LF, union-wide	63	0.20	63	2.04	1.12	2.28
CCP, country-specific	23	1.23	330	3.80	2.51	4.17
CCP, union-wide	46	0.58	46	2.44	1.50	3.78

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption.

Table 6: *Optimal Simple Rules and Welfare Gains with Structurally Heterogeneous Countries*

A further finding is that, once the common central bank adopts a credit growth rule for the conduct of unconventional policies, the macroprudential regulation in country H ceases to be welfare-improving – from the viewpoint of country H and from the viewpoint of the union as a whole ($g^H, g^{UN} < g$). A possible reason for this result is the way the macroprudential rule in country H is specified: As τ_t^N, the macroprudential policy instrument, reacts to a credit measure, its stabilization effects might partly overlap with those of unconventional policies reacting to credit growth. In the following analysis, only the policy combinations which are welfare-improving from the viewpoint of the union will be considered.

The results might imply that unconventional monetary policy aggravates free-riding behavior on the part of a country with a less stable financial sector. To evaluate whether the incentives to reform financial structures are affected by the introduction of unconventional monetary policy measures, country F's welfare gains from unconventional policy provided in column (4) of table 6 have to be compared to its welfare gains in the counterfactual case in which it also adopts a macroprudential policy measure. Note that in this case, the two countries of the union would be perfectly symmetric again.

	g^F, no reform (1)	g^F, reform (2)	Relative gain from reform (2)-(1)
No UMP	-3.76	-3.19	0.57
Rule 1 - Credit Spread Rule			
LF, country-specific	-3.09	-3.06	0.03
LF, union-wide	-3.06	-3.05	0.01
CCP, country-specific	-1.60	-1.51	0.09
CCP, union-wide	-1.75	-1.75	0.00

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption.

Table 7: *Incentives to Reform Financial Structures in the Foreign Economy*

Table 7 shows the welfare gains for country F resulting from different unconventional monetary policy regimes, with and without a reform of the financial sector in country F, respectively, and the difference between the two. As indicated by the positive values in the last column, country F profits from a reform of its own financial sector in the first four regimes considered. However, compared to the case without unconventional monetary policy, incentives to reform are considerably reduced when the central bank provides credit to the banking system or purchases corporate sector assets. For corporate sector credit policy conducted in a union-wide fashion, incentives to reform even cease to exist.

The results of this section imply that the introduction of unconventional monetary policy in a structurally heterogeneous monetary union might reduce the incentives to reform financial structures in individual countries. The analysis constitutes a first approach to modeling and analyzing the interplay between unconventional monetary policy and structural heterogeneity in a monetary union. The results cannot be generalized to the wide range of structural asymmetries found in, e.g., the European Union. I plan on deepening the analysis of unconventional monetary policy in a heterogeneous monetary union.

6 Conclusion

In recent years, the ECB has adopted a wide array of unconventional monetary policy measures. All of them were decided upon on a centralized level, i.e., responding to union-wide conditions. However, while some (several purchase programs) were made available to recipients in Eurozone countries in a fixed manner, according to their respective country's key, others (e.g., liquidity provision) were provided to recipients flexibly according to specific needs and regardless of nationality. Hence, while the former can be seen as measures addressing union-wide circumstances, the latter allow a tailor-made response to country-specific shocks. This paper analyzes the welfare implication of a small sample of unconventional monetary policy measures and, in particular, distinguishes between country-specific and union-wide approaches. Since the subject of cross-country heterogeneity is an important factor when discussing the risks and benefits of unconventional policies in a monetary union, I also consider the case of a structurally asymmetric monetary union.

The results obtained from these analyses provide some important policy implications for a monetary union. First, I show that from a theoretical point of view, it is not in general welfare-improving to use unconventional instruments to address country-specific shocks. In particular, union-wide policy yields higher welfare than country-specific policy, when the central bank reacts upon indicators which are highly correlated between countries. If – for whatever reason – such indicators are not available (measurement problems, high divergence between countries etc.), country-specific policy is preferable of union-wide policies from a welfare point of view. That this might be a relevant problem in the European Union is, e.g., found by Macchiarelli et al. (2017, p. 5) who report that "corporates in countries like Italy and Spain, where the banking system is more under pressure, might benefit less from the CSPP [Corporate Sector Purchase Program; note from the author]". It is difficult to imagine how some of the unconventional monetary policy instruments, such as corporate sector asset purchases, can be provided in a more targeted (i.e., country-specific) way. However, they could, for example, be accompanied by programs which facilitate access to bond markets and support firms in troubled countries or market segments in meeting the eligibility criteria for bond purchase programs.

The analysis of a heterogeneous union showed that unconventional monetary policy – regardless of whether it is conducted in a union-wide or country-specific manner – might lower the incentives to conduct regulatory reforms in single countries. This result supports the case for pushing forward the banking union in order to unify supervision and regulation across countries.

The analysis can be extended in various dimensions. In the given setup, the performance of the different optimal rules should be compared against Ramsey optimal policy. Furthermore, I plan to solve the model under the assumption that the zero-lower bound is binding. This assumption is going to render welfare calculations much more difficult. However, in a first step, it will be interesting to see whether the results of the impulse response and the correlation analyses remain qualitatively the same. An interesting extension to the model, which would, however, go beyond the scope of this paper, is the addition of sovereign bonds to banks' balance sheets and an explicit modeling of government risk. Such a setup would allow the modeling of the so-called "bank-sovereign nexus" and a realistic analysis of a public sector purchase program. Another interesting extension would be to take into account game theoretical issues associated with macroprudential policies being implemented on a national level and unconventional policies being implemented on a union-wide level.

Appendix

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-0.03	-
Rule 1 - Credit Spread Rule			
LF, country-specific	0	-0.03	0
LF, union-wide	0	-0.03	0
CCP, country-specific	43	-0.02	0.02
CCP, union-wide	132	0.03	0.06
Rule 2 - Credit Growth Rule			
LF, country-specific	40	0.92	0.95
LF, union-wide	40	0.67	0.70
CCP, country-specific	139	1.50	1.53
CCP, union-wide	135	1.11	1.14

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 8: *Optimal Simple Rules in a Symmetric Setup (Only Capital Quality Shocks)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-0.16	-
Rule 1 - Credit Spread Rule			
LF, country-specific	330	-0.15	0.02
LF, union-wide	330	-0.15	0.02
CCP, country-specific	330	-0.14	0.02
CCP, union-wide	330	-0.14	0.02
Rule 2 - Credit Growth Rule			
LF, country-specific	23	-0.12	0.04
LF, union-wide	26	-0.12	0.04
CCP, country-specific	139	-0.08	0.09
CCP, union-wide	139	-0.09	0.07

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 9: *Optimal Simple Rules in a Symmetric Setup (Only Technology Shocks)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	0.12	-
Rule 1 - Credit Spread Rule			
LF, country-specific	13	0.21	0.09
LF, union-wide	13	0.18	0.07
CCP, country-specific	7	0.22	0.10
CCP, union-wide	7	0.19	0.07
Rule 2 - Credit Growth Rule			
LF, country-specific	13	0.16	0.04
LF, union-wide	13	0.15	0.03
CCP, country-specific	10	0.17	0.05
CCP, union-wide	7	0.15	0.04

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 10: *Optimal Simple Rules in a Symmetric Setup (Only Net Wealth Shocks)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-3.61	-
Rule 1 - Credit Spread Rule			
LF, country-specific	92	-3.07	0.55
LF, union-wide	92	-3.07	0.55
CCP, country-specific	284	-2.04	1.57
CCP, union-wide	284	-2.04	1.57
Rule 2 - Credit Growth Rule			
LF, country-specific	89	1.66	5.28
LF, union-wide	89	1.66	5.28
CCP, country-specific	139	2.63	6.24
CCP, union-wide	139	2.63	6.24

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 11: *Optimal Simple Rules in a Symmetric Setup (Only Monetary Policy Shocks)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-3.92	-
Rule 1 - Credit Spread Rule			
LF, country-specific	56	-3.44	0.48
LF, union-wide	83	-3.34	0.59
CCP, country-specific	330	-2.19	1.74
CCP, union-wide	304	-2.14	1.78
Rule 2 - Credit Growth Rule			
LF, country-specific	63	2.63	6.55
LF, union-wide	69	2.04	5.97
CCP, country-specific	139	4.60	8.53
CCP, union-wide	135	3.55	7.47

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 12: *Optimal Simple Rules in a Symmetric Setup (Domestic Credit Provision)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-3.75	-
Rule 1 - Credit Spread Rule			
LF, country-specific	56	-3.31	0.44
LF, union-wide	73	-3.23	0.52
CCP, country-specific	218	-1.99	1.76
CCP, union-wide	211	-2.20	1.55
Rule 2 - Credit Growth Rule			
LF, country-specific	53	2.09	5.84
LF, union-wide	69	2.23	5.98
CCP, country-specific	139	3.73	7.48
CCP, union-wide	135	3.75	7.50

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 13: *Optimal Simple Rules in a Symmetric Setup (Fully Diversified Portfolio,)*

	κ_f, κ_m (1)	g (in %) (2)	Relative gain (3)
No UMP	-	-0.10	-
Rule 1 - Credit Spread Rule			
LF, country-specific	0	-0.10	0
LF, union-wide	0	-0.10	0
CCP, country-specific	116	0.14	0.25
CCP, union-wide	76	-0.06	0.04
Rule 2 - Credit Growth Rule			
LF, country-specific	30	0.57	0.68
LF, union-wide	43	0.61	0.71
CCP, country-specific	152	1.06	1.16
CCP, union-wide	149	1.08	1.19

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy.

Table 14: *Optimal Simple Rules in a Symmetric Setup (Fully Diversified Portfolio; Only Capital Quality Shocks)*

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