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Benjamin Schwanebeck

Unconventional Monetary Policy in a Financially Heterogeneous Monetary union

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Benjamin Schwanebeck[b]

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Abstract

The cross-country interbank market in the euro area was a crucial transmission channel of financial stress. By using a two-country DSGE model of a financially heterogeneous monetary union where banks in one country lend funds to their foreign counterparts, I examine its role as shock amplifier and the implications for unconventional policy interventions

Using the international interbank market to pool and insure against shocks is not neutral, the resulting spillovers rather act as shock multipliers on union output. Country-specific unconventional policies of direct lending to firms seem to be the most effective interventions in terms of union and relative output stabilization. The higher the size of the interbank market, the more effective are these policies in terms of union stabilization. The effectiveness of interventions in the interbank market seems to be very sensitive to the type of shock and the interbank market size. Hence, the central bank should rather shy away from this policy as it is only useful under specific circumstances.

JEL-Classification: E32, E44, E58, F45

Keywords: financial intermediation; financial frictions; interbank market; monetary union; unconventional policy;

1   Introduction

After its creation, the euro area had experienced massive financial flows from the core to the periphery countries whereby these flows were mainly channeled through the cross-country interbank market. Due to the greater monetary integration with the elimination of currency risks and the harmonization of regulations, banks in countries in the core of the euro area, mainly France, Germany, and the Netherlands, had strongly increased lending to the periphery, i.e. Greece, Ireland, Italy, Portugal, Spain (Hale and Obstfeld, 2016). This had led to a situation in which the higher degree of synchronization within the euro area was driven by financial synchronization instead of business cycle synchronization (Ahmed et al., 2017). While cross-country interbank funds might contribute to a smooth functioning of the monetary union, the financial crisis strikingly revealed the vulnerability of this system. Stress in the periphery could easily spill over to the core and due to their large asset position, systemically important core banks got into trouble which had led to an increased financial fragility (see, e.g., Gros and Alcidi, 2015 and Hale and Obstfeld, 2016).

As conventional monetary policy reached its limits, the ECB started to implement several unconventional measures with a focus on avoiding liquidity shortages in the interbank market. The aim was to stabilize the malfunctioning interbank market by mainly providing (unlimited) liquidity to the banking sector (such as the FRFA-program).[1] Compared to other major central banks such as the Fed which reacted promptly after the collapse in 2008/2009 by conducting quantitative easing, this approach was rather moderate as the financial stress started much later in the euro area. However, with the implementation of the asset purchase programme in 2015 and especially the most recent corporate sector purchase programme in June 2016, the ECB joined other central banks by using credit easing to improve the financing condition of stressed peripheral countries (Andrade et al., 2016 and Szczerbowicz, 2015).

In this paper, I use a two-country DSGE model with banks that interact internationally in addition to managing the financial intermediation in their respective country, to examine the role of the international interbank market in the transmission of shocks and its role for unconventional policy interventions. The model closely follows Nuguer (2016) that builds on the closed-country frameworks of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). Within each country, financial intermediaries combine own net worth and domestic households' deposits in order provide loans to the domestic production sector. However, a costly enforcement problem between depositors and bankers leads to a credit intermediation that is limited by banks' net worth. Since the financial sectors are heterogeneous across the monetary union in the sense that

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[1] These measures range from long-term and short-term sovereign bond purchases, covered bond purchase programs, long-term refinancing operations, to liquidity provisons (Szczerbowicz, 2015).

financial intermediaries in the core country accumulate more net worth than banks in the periphery country, an international interbank market emerges where core banks lend funds to their periphery counterparts. While this market is used for asset and liability diversification, shocks that lead to a deterioration of banks' net worth can now be propagated via the conventional trade channel and via the cross-country interbank market.

Since conventional monetary policy is no option in a zero-lower-bound environment and fiscal policy[2] has its budgetary limits, I abstract from this policy interventions. I rather focus on unconventional monetary policy as a large part of the literature agrees that this policy is effective in stabilizing the financial turmoil and stimulating the economic activity[3] and some even call for unconventional measures as an additional tool besides interest rate policies in normal times (e.g. Ellison and Tischbirek, 2014). In the present paper, two different unconventional measures are implemented as stabilization tools: increasing the amount of available funds in the international interbank market or direct lending to firms (direct asset purchases). With these measures, I try to capture some of the programs that the ECB has introduced. Depending on the kind of shock, I distinguish between cases where the central bank uses direct lending only in the country that is hit by the shock, intervenes in both countries, intervenes in the interbank market, or combines both unconventional policies.

This paper is related to three strands of the literature. There is a plenty of research with a focus on financial heterogeneity in a monetary union. However, while these studies mainly examines macroprudential policy or how the financial structures affect the effectiveness of monetary policy, there is no role for channeling funds through a cross-country interbank market. As the effectiveness and transmission of unconventional policy is the focus of this study, I abstract from macroprudential policy and refer the reader to, among others, Quint and Rabanal (2014) and Palek and Schwanebeck (2015). By analyzing a two-country model of a monetary union with asymmetric national banking sectors, Badarau and Levieuge (2011) show that a symmetric shock causes cyclical divergences inside the union which worsen due to a common monetary policy. The transmission of shocks is increasing in the degree of heterogeneity. Lama and Rabanal (2014) build a two-country model with banking sectors à la Gertler and Karadi (2011) and study the welfare gains from forming a currency union out of two heterogeneous countries. While there are standard trade linkages, "financial linkages" are only introduced in the sense that there is either a common or a national authority that conducts conventional and unconventional monetary policy. In times of financial

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[2] For the optimal mix of monetary and fiscal policy in a monetary union with country-specific financial frictions, see Palek and Schwanebeck (2017).

[3] For empirical evidence, see e.g. Joyce et al. (2012), and for a focus on the euro area, see Andrade et al. (2016) and Szczerbowicz (2015).

stress, a common policy is welfare reducing.

Another strand of the literature focuses on the international transmission of shocks by global banks. Cross-country financial linkages are introduced by allowing banks to collect deposits and lend funds to firms either in one or both countries. Again, there is no interbank market. By using such a framework, Kollmann et al. (2011) analyze the (important) role of global banks in the international transmission of shocks and show how this could be affected by bank capital requirements. In a similar vein, Dedola et al. (2013) build a two-country model in which banks collect deposits at home and abroad and make loans to firms in both countries. As both countries are perfectly symmetric and produce only one homogeneous good, trade linkages play no role and due to the banking structure, the propagation and output correlation across both countries are shock-specific. Unconventional policy in form of direct asset purchases serves as stabilization tool and due to a free-riding problem, coordinated national unconventional policies are welfare improving.

In contrast, Nuguer (2016) studies a two-country DSGE model with cross-border banking where a small open economy with a large banking sector (e.g. Switzerland) is linked to a big economy with a relatively small banking sector (e.g. the US). Global banks in the first country can lend to intermediaries in the other country, whereby the latter uses the interbank market as insurance against shocks. The main aim is to study the international transmission of a capital-quality shock to the big economy and the effects of implementing different unconventional policy measures. While unconventional policy interventions could be effective stabilization tools, there are negative cross-country spillovers and coordination leads to a policy response in only the big country. This is in sharp contrast to Dedola et al. (2013) and to the policies during the financial crisis (see also Kollmann, 2016).

There are few papers that analyze the implications of an interbank market within a monetary union. Gerali et al. (2010) use a single-country framework with two banking sectors where an interbank market emerges as one sector collects deposits while the other provide credits to firms and households. Banks in both sectors operate under imperfect competition. This type of financial intermediation leads to an increased propagation of shocks and mitigates the effects of monetary policy. A two-country version of a monetary union with interbank markets is studied by Lakdawala et al. (2017). There are national interbank markets à la Gertler and Kiyotaki (2010) and the authors analyze the effects of unconventional policy that raises banks' liquidity but lowers the value of banks' collaterals if the policy is financed via issuing government debt. This could lead to international spillovers although there is no cross-country interbank market. Poutineau and Vermandel (2015) provide empirical evidence that cross-country financial flows within the euro area were mainly channeled through interbank lending. Direct cross-border lending to firms is quite small and direct cross-border lending to household

(and also collecting deposits abroad) is rather irrelevant. Building on this, they develop a model of a financially heterogeneous two-country monetary union with cross-border lending to firms and banks. There are two types of banks in each country: illiquid banks that rely on funds from liquid banks and make loans to entrepreneurs while liquid banks have access to central bank funding and provide loans to firms and illiquid banks. The resulting cross-border interbank market leads to a financial synchronization and amplifies the transmission of country-specific shocks, especially for financial shocks. In their empirical analysis, Ahmed et al. (2017) obtain similar results. However, Poutineau and Vermandel (2015) do not analyze different policy interventions, not to mention unconventional policy.

Indeed, to the best of my knowledge, there is no study that focuses on the implication of a cross-country interbank market for the transmission of shocks and the effects of unconventional monetary policy in a currency union. The aim of this paper is to fill this gap. The closest paper to my framework is Nuguer (2016). The assumed frictionless global interbank market and financial synchronization do rather match the aforementioned empirical evidence for the euro area. Hence, I use a currency-union version of the model in which trade linkages play a greater role. As pointed out by Poutineau and Vermandel (2015), there seems to be no integration in the markets for deposits and firm credits. Thus, cross-border financial flows are assumed to be channeled through the interbank market. Nuguer (2016) lacks a clear-cut analysis of the importance of the interbank market size and the dominating forces of the transmission channels since it is not perfectly clear whether the propagation of the shock and policies are solely driven by the banking structure or other asymmetries (e.g. country size and home bias). In contrast, I focus on financial heterogeneity and analyze the effects of union-wide and idiosyncratic shocks and unconventional policy responses. Furthermore, I introduce a shock to the survival probability of banks that leads to a banking crisis. In a second step, I vary the size of the interbank market and analyze the implications for the transmission of shocks and the effectiveness of unconventional policy interventions.

I can draw four major results. First, although the interbank market is used to pool shocks and thereby lowers cross-country gaps, banks do not internalize the negative side effects of the portfolio rebalancing which results in a decline in firm credits and thus output. This results in stronger fluctuations in union output. Hence, using the international interbank market in order to pool and insure against shocks is not neutral. The resulting spillovers act as shock multipliers on union output. Second, regardless of the shock, the volatility of union output and the gap between the countries is increasing in the size of the interbank market. Third, a policy of direct asset purchases which is only active in the country that is hit by a shock seems to be the most effective intervention in terms of output stabilization at the union and national level, closely followed by a policy where the central bank is restricted to have shock-independent

interventions of direct lending in both countries. The higher the size of the interbank market, the more effective are these policies in terms of union stabilization. Fourth, the effectiveness of interventions in the interbank market seems to be very sensitive to the type of shock and the interbank market size. Hence, the central bank should rather shy away from this policy.

The rest of the paper is organized as follows. In the next section, I outline the model in detail with the main focus on the financial intermediaries and the interaction between core banks and their periphery counterparts and I explain the implementation of the different unconventional policy measures. In Section 3, I analyze the dynamics of shocks to the capital quality and to banks' survival probability that hit either one or both countries. The stabilization effects of unconventional monetary policy interventions are studied as well. Section 4 highlights the role of the international interbank market in propagating the shocks and affecting the effectiveness of unconventional policy. Section 5 concludes.

2 The Model

The two-country model of a currency union I propose closely follows Nuguer (2016) and builds on the closed-country frameworks of Gertler and Karadi (2011) and Gertler et al. (2016). The total population is normalized to one, the population on the segment $[0, \gamma)$ belongs to the core, while the population on $[\gamma, 1]$ belongs to the periphery. In line with the aforementioned empirical observations, financial intermediaries in both countries combine own net worth and domestic households' deposits to make loans to the domestic production sector. A costly enforcement problem between depositors and bankers limits the amount of available credit. For the sake of simplicity, I abstract from nominal rigidities such as sticky prices and wages and rather focus on financial heterogeneity. Banking sectors are assumed to be asymmetric across the monetary union in the sense that financial intermediaries in the core country accumulate more net worth than banks in the periphery country. As a result, an international interbank market emerges where core banks lend funds to their periphery counterparts. This market is then used for asset and liability diversification, however, shocks that lead to a deterioration of banks' net worth can now be propagated via the conventional trade channel and via the cross-country interbank market. As unconventional monetary policy can be targeted to specific markets, the central bank can either intervene in the international interbank market and/or in the national markets for firm credits. In the following, I present the core country. Periphery variables are denoted by an asterisk. Unless otherwise stated, both countries are assumed to be symmetrical.

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2.1 Households

There exists a continuum of representative infinitely-lived households in each country. Households consume bundles of domestic and foreign goods given by the index C_t, supply labor L_t and save in form of depositing funds D_t at domestic banks (others than they own) and lending funds $D_{g,t}$ to the government. As in Gertler and Karadi (2011), the following modelling structure allows for maintaining the representative agent framework while preventing bankers from accumulating enough net worth to independently fund all their investments. Every household consists of two types of members, workers and bankers, who return their earnings back to their household under the assumption of perfect consumption insurance among the household members. Workers supply labor to goods producers and each banker manages one financial intermediary. Every period, banks are shut down with i.i.d. probability $1 - \sigma_t$ and bankers who exit the industry become workers while a corresponding fraction of workers become bankers. Upon exit, bankers transfer their retained earnings back to their respective family, whereas new bankers receive startup funds from their respective households.

Similar to Aoki and Sudo (2012), there may be a country-specific exogenous shock ϵ_t^σ to the survival probability $\sigma_t = \sigma \epsilon_t^\sigma$. However, I will call this shock ($\epsilon_t^\sigma < 0$) a banking crisis instead of net worth shock, since it leads to a shut down of the banking sector with adverse effects on the real economy that are different from a pure net worth shock as in Gertler and Karadi (2011).

Following Gilchrist and Zakrajšek (2011), households' preferences are given by

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(Z_\tau, Z_{\tau-1}) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\frac{1}{1-\rho} (Z_\tau - h Z_{\tau-1})^{1-\rho} \right], \tag{1}$$

with

$$Z_t = C_t - \frac{\chi}{1+\varphi} L_t^{1+\varphi},$$

where E_t is the expectation operator conditional on information that is available at t and Z_t denotes the habit index. The discount factor is given by β, ρ is the inverse of the elasticity of intertemporal substitution, h is the habit parameter, φ is the inverse Frisch elasticity, and χ is the utility weight on labor. As in Greenwood, Hercowitz, and Huffman (GHH, 1988), this preference structure leads to a quasi-linear combination of C_t and L_t which in turn eliminates the wealth effect on the labor supply decision. Furthermore, it allows for habit formation that does not affect the no-wealth-effect-on-labor-supply outcome. GHH preferences help to solve the "international correlation puzzle" in standard international real business cycle models, i.e. to obtain business cycle synchronization in form of a positive cross-country comovement between labor and investment and a "more realistic" cross-country consumption correlation (see, among

others, Dmitriev and Roberts, 2012).[4] Since the model does not include nominal rigidities, GHH preferences and habit formation are also a simple way to ensure reasonable variations in labor (Gertler et al., 2012).

The representative household maximizes (1) subject to the budget constraint

$$C_t + D_t + D_{g,t} = W_t L_t + R_{t-1} (D_{t-1} + D_{g,t-1}) + \Pi_t - T_t, \tag{2}$$

where W_t is the real wage rate, Π_t is the profit from ownership of both capital producers and banks net of startup funds provided to new bankers, and T_t denotes lump-sum taxes. Both deposits and government debt are non-contingent one-period real riskless assets that pay the gross real return R_t from t to $t+1$.

The maximization problem leads to the standard first-order conditions for labor supply and consumption/savings

$$
\begin{align}
W_t &= \chi L_t^{\varphi} \tag{3}\\
E_t \Lambda_{t,t+1} R_{t+1} &= 1 \tag{4}
\end{align}
$$

with the marginal utility of wealth defined as

$$U_{C_t} = (Z_t - hZ_{t-1})^{-\rho} - \beta h E_t (Z_{t+1} - hZ_t)^{-\rho}$$

and the households stochastic discount factor written as

$$\Lambda_{t,\tau} = \beta^{\tau - t} \frac{U_{C_\tau}}{U_{C_t}}.$$

The consumption index is defined as

$$C_t \equiv \left[\frac{(C_{H,t})^{\gamma} (C_{F,t})^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \right], \tag{5}$$

where $C_{H,t}$ is the consumption of homemade goods while $C_{F,t}$ is the consumption of foreign-made goods.[5] Let $P_{H,t}$ ($P_{F,t}$) be the producer price index in country H (F) and

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[4]See also Kollmann (2017) for an extensive discussion on this issue.

[5]Recent research justifies the implied assumption that the so-called "macro" Armington elasticity, i.e. the elasticity of substitution between the two bundles of goods, is restricted to unity. By using a nested CES preference structure, Feenstra et al. (2014) show that there may be differences between the "micro" Armington elasticity, i.e. the elasticity between foreign varieties, and the "macro" Armington elasticity. For the U.S., the estimated macro elasticity is not significantly different from unity which is in sharp contrast to the macro elasticity of about 6 in Imbs and Méjean (2015). However, the latter only use imports instead of matching the data with domestic production which leads to an aggregate

taking prices as given, cost minimization leads to the standard demand functions

$$C_{H,t} = \gamma \left(\frac{P_{H,t}}{P_t}\right)^{-1} C_t \tag{6}$$

$$C_{F,t} = (1-\gamma) \left(\frac{P_{F,t}}{P_t}\right)^{-1} C_t. \tag{7}$$

The corresponding consumer price index is given by

$$P_t \equiv (P_{H,t})^{\gamma} (P_{F,t})^{1-\gamma}. \tag{8}$$

Prices are set in the origin country. However, there are no trade barriers, so the law of one price holds for each good. Assuming that preferences are identical in both countries of the monetary union leads to the purchasing power parity condition:

$$P_t = P_t^*. \tag{9}$$

For the subsequent analysis, it is useful to express price changes as deviations in the terms of trade that are defined as the relative price of foreign-made goods in terms of homemade goods, i.e. $ToT_t \equiv P_{F,t}/P_{H,t}$.

2.2   Goods producers

Competitive goods firms employ the constant-returns-to-scale Cobb-Douglas production function given by

$$Y_t = K_t^{\alpha} L_t^{1-\alpha} \tag{10}$$

using the input factors capital K_t and labor L_t to produce output Y_t that is sold at the price $P_{H,t}$.

Profit maximization leads to the standard first-order condition for labor input:

$$W_t = \frac{P_{H,t}}{P_t}(1-\alpha)\frac{Y_t}{L_t}. \tag{11}$$

Capital for production in the subsequent period $t+1$ needs to be purchased from capital producers at the end of period t. Denote S_t as this capital stock "in process" at the end of t for $t+1$. Then, S_t is given by the sum of current investment I_t and existing undepreciated capital $(1-\delta)K_t$:

$$S_t = I_t + (1-\delta)K_t. \tag{12}$$

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elasticity that is still a micro elasticity as it is just a weighted average of sectoral elasticities.

At the beginning of the next period and after the realization of a country-specific capital quality shock ψ_{t+1}, capital in process is transformed into capital for production purposes according to

$$K_{t+1} = \psi_{t+1} S_t. \tag{13}$$

Following Gertler et al. (2012), the capital quality shock reflects an exogenous source of variation in the effective value of capital and thus leads to exogenous asset price variations, which can cause devaluations of banks' balance sheets resulting in a financial crisis.[6]

In order to obtain loans to finance the acquisition of capital, intermediate firms issue perfectly state-contingent claims to financial intermediaries. These claims equal the amount of acquired capital and are priced with Q_t, reflecting the real price of a unit of capital. The funding process between domestic firms and domestic financial intermediaries is assumed to be frictionless. The latter are able to perfectly monitor their debtors as well as to enforce repayment of all funds and the former can commit to pay all future gross profits to the creditor bank. As a consequence, intermediate firms solely rely on domestic banks to finance their capital acquisition.

Perfect competition leads to a price of Q_t for new capital goods and goods producers make zero profits state by state. Thus, banks obtain the following gross ex post return to a unit of capital from $t-1$ to t:

$$R_{k,t} = \psi_t \frac{\frac{P_{H,t}}{P_t} \alpha \frac{Y_t}{K_t} + (1-\delta)Q_t}{Q_{t-1}}. \tag{14}$$

2.3   Capital producers

Competitive capital producers produce new capital goods and sell the capital to goods producers at the price Q_t. Production of capital goods utilizes domestic output as input and is subject to investment adjustment costs following the functional form

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{15}$$

satisfying $f(1) = f'(1) = 0$ and $f''(1) > 0$. By choosing investment I_t, capital producers maximize their profits according to the objective function

$$\max E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \frac{P_{H,t}}{P_t}\left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}. \tag{16}$$

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[6]The reader will find a micro-foundation of this shock in the supplementary material of Gertler et al. (2012).

Profit maximization leads to the first-order condition for the marginal cost of investment

$$Q_t = \frac{P_{H,t}}{P_t}\left[1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}}f'\left(\frac{I_t}{I_{t-1}}\right)\right] - E_t\Lambda_{t,t+1}\frac{P_{H,t+1}}{P_{t+1}}\left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right) \quad (17)$$

which equals the price Q_t of a capital good. Since capital producers are owned by households, they return all profits back to their household.

2.4 Financial intermediaries

Within each country, financial intermediaries channel funds from savers (households) to investors (goods producer). In order to provide loans, banks combine own net worth, which is accumulated from retained earnings, and deposits obtained from domestic households. However, following Nuguer (2016), I allow for cross-country interbank funding by assuming an asymmetric banking system where financial intermediaries in the core accumulate more net worth than periphery banks due to different survival rates and different agency frictions in the sense of Gertler et al. (2016). As a result, an international wholesale market emerges where core banks act solely as lenders and periphery banks appear solely as borrowers.

2.4.1 Core banks

As noted above, an individual core bank starts period t with net worth n_t and raises deposits d_t from core households to provide loans s_t priced at Q_t to core goods producer and funds b_t to periphery banks. Accordingly, the balance sheet is given by

$$Q_t s_t + b_t = d_t + n_t. \quad (18)$$

At the beginning of period t and before obtaining new deposits and making new loans, financial intermediaries have to return interest payments on deposits out of earnings on assets that they receive at the end of $t-1$. Thus, net worth n_t evolves as the difference between earnings on non-financial loans s_{t-1} from $t-1$ to t and funds to periphery banks b_{t-1} from $t-1$ to t at the interbank lending rate $R_{b,t}$ net of payments on deposits d_{t-1}:

$$\begin{aligned}
n_t &= R_{k,t}Q_{t-1}s_{t-1} + R_{b,t}b_{t-1} - R_{t-1}d_{t-1} \\
n_t &= [R_{k,t} - R_{t-1} - (R_{k,t} - R_{b,t})x_{t-1}](Q_{t-1}s_{t-1} + b_{t-1}) + R_{t-1}n_{t-1}, \quad (19)
\end{aligned}$$

where $x_t = b_t/(Q_t s_t + b_t)$ is the ratio of interbank loans to all assets. I follow Gertler and Kiyotaki (2010) by assuming a non-contingent interbank interest rate.

As long as $R_{k,t}$ and $R_{b,t}$ are higher than the cost of borrowing, positive spreads let the core bankers provide loans indefinitely by raising new deposits until they are shut down and become workers. Given the probability of being shut down, $1 - \sigma_t$, the core banker maximizes the expected present value of future dividends given by the (end of t) value function

$$V_t = E_t \left[\sum_{\tau=t+1}^{\infty} (1 - \sigma_{\tau-1}) \sigma_{\tau-1}^{\tau-t-1} \Lambda_{t,\tau} n_\tau \right], \qquad (20)$$

rewritten as the Bellman equation:

$$V_t = E_t \Lambda_{t,t+1} \left[(1 - \sigma_t) n_{t+1} + \sigma_t V_{t+1} \right], \qquad (21)$$

where the households' stochastic discount factor is used since retail bankers are members of the same.

Following Gertler and Karadi (2011), a simple agency problem limits the banker's ability to obtain funds: after raising deposits but still in period t, the banker may transfer the fraction θ of assets back to the respective household. If the banker defaults, the other households shut this bank down and reclaim the remaining fraction $1 - \theta$. It follows that households are only willing to deposit additional funds, if the incentive to remain in business, the franchise value V_t, exceeds the gain from diverting funds. However, in line with Gertler et al. (2016), the ability to divert assets depends on the uses of the funds. More precisely, core bankers are able to divert the fraction θ of non-financial loans and the fraction $\theta\omega$ of interbank loans. Accordingly, the incentive constraint is given by

$$V_t \geq \theta Q_t s_t + \theta\omega b_t. \qquad (22)$$

If $\omega > 1$, loans to foreign banks are easier to divert compared to non-financial loans. Thus, a shift from lending to firms towards lending in the wholesale market tightens the incentive constraint and makes interbank loans less attractive. However, following Gertler et al. (2016), the analysis is restricted to the more realistic case of $0 < \omega < 1$, i.e. it is easier to divert non-financial loans compared to interbank loans. This is motivated by the assumption that loans granted within the interbank market are easier to monitor and to evaluate for third parties (i.e. households) compared to loans from banks to non-financial firms. Due to financial integration (e.g. within the euro area) and financial innovations, mutual interbank lending largely destroys the idiosyncratic features inherent in such loans thereby making them a safer asset and more pledgeable. It follows that the attractiveness and thus the size of the interbank market depends on ω. As ω declines, core banks find it the more difficult to divert interbank loans leading

to a higher incentive to use these loans in order to relax the incentive constraint.

The optimization problem of the core banker is to maximize (21) by choosing s_t and b_t subject to (19) and (22). This problem boils down to maximize the following conjecture of (21) subject to (22):

$$V_t = \mu_{s,t} Q_t s_t + \mu_{b,t} b_t + \nu_t n_t, \tag{23}$$

where $\mu_{s,t}$ is the excess return of non-financial loans over deposits, $\mu_{b,t}$ is the excess return of interbank loans over deposits while ν_t is the marginal value of net worth. The first-order conditions lead to

$$\mu_{s,t} = \frac{1}{\omega} \mu_{b,t}. \tag{24}$$

This relation states that for the core banker to be indifferent between providing loans to firms or foreign banks, the excess return of non-financial loans has to be equal to the excess return of interbank loans times the increased willingness of households to supply deposits due to the relaxation of the incentive constraint.

Combining (22)-(24) yields an expression for the leverage ratio ϕ_t:

$$\phi_t = \frac{Q_t s_t + b_t}{n_t} = \frac{\nu_t}{\left(\theta - \mu_{s,t}\right)\left[1 + (\omega - 1)x_t\right]}. \tag{25}$$

By combining (22)-(25), I obtain the following value function:

$$
\begin{aligned}
V_t &= E_t \Omega_{t+1}\left[(R_{k,t+1} - R_t) Q_t s_t + (R_{b,t+1} - R_t) b_t + R_t n_t\right] \\
V_t &= E_t \Omega_{t+1}\left[(R_{k,t+1} - R_t - (R_{k,t+1} - R_{b,t+1})x_t)\phi_t + R_t\right] n_t,
\end{aligned}
\tag{26}
$$

where

$$\Omega_{t+1} = \Lambda_{t,t+1}\left[1 - \sigma_t + \sigma_t(\nu_{t+1} + \mu_{s,t+1}\phi_{t+1}\left[1 + (\omega - 1)x_{t+1}\right])\right]$$

is the stochastic discount factor of core bankers which differs from the one of households due to the binding (financial) agency friction.

Comparing the initial conjecture (23) with (26) yields

$$\mu_{s,t} = E_t \Omega_{t+1}(R_{k,t+1} - R_t) \tag{27a}$$

$$\mu_{b,t} = E_t \Omega_{t+1}(R_{b,t+1} - R_t) \tag{27b}$$

$$\nu_t = E_t \Omega_{t+1} R_t. \tag{27c}$$

According to (27a)-(27c) and the leverage ratio (25), the binding incentive constraint limits the amount of loans that a core banker can provide to his net worth. It can be seen that the leverage ratio is increasing in $\mu_{s,t}$, ν_t, and x_t if $\omega < 1$, while it is decreasing

in θ and ω. Since a higher excess return on non-financial loans leads to a higher franchise value of the bank, increasing the incentive to continue to operate, households are more willing to deposit funds. The same holds true for ν_t, while the opposite holds for θ and ω: the higher the ability to divert funds, the lower the willingness to supply deposits. For $\omega < 1$, a higher share of interbank loans x_t relaxes the incentive constraint and thus leads to an increase in the (accepted) leverage ratio.

Finally, total net worth in the core country is the sum of net worth of surviving bankers which evolves according to (19) and net worth of entering bankers. The latter receive startup funds in the amount of $\xi[R_{k,t}Q_{t-1}S_{t-1} + R_{b,t}B_{t-1}]/(1 - \sigma_t)$ from their respective household. Thus, aggregate net worth N_t evolves according to

$$
\begin{aligned}
N_t &= \sigma_t \left[(R_{k,t} - R_{t-1} - (R_{k,t} - R_{b,t})\, x_{t-1})\, \phi_{t-1} + R_{t-1} \right] N_{t-1} \\
&\quad + \xi \left(R_{k,t} - (R_{k,t} - R_{b,t})\, x_{t-1} \right) \phi_{t-1} N_{t-1}.
\end{aligned}
\tag{28}
$$

2.4.2 Periphery banks

Periphery banks face a similar problem as core banks except for the fact that they are borrowers in the interbank market. Thus, an individual periphery bank starts period t with net worth n_t^*, raises deposits d_t^* from periphery households and obtains funds b_t^* from core banks in order to provide loans s_t^* priced at Q_t^* to periphery goods producer. The balance sheet identity reads

$$
Q_t^* s_t^* = d_t^* + n_t^* + b_t^*.
\tag{29}
$$

Net worth n_t^* evolves as the difference between earnings on non-financial loans s_{t-1}^* net of interest payments on deposits d_{t-1}^* at the riskless rate R_{t-1}^* and interbank loans b_{t-1}^* at the interbank borrowing rate $R_{b,t}$:

$$
\begin{aligned}
n_t^* &= R_{k,t}^* Q_{t-1}^* s_{t-1}^* - R_{b,t} b_{t-1}^* - R_{t-1}^* d_{t-1}^* \\
n_t^* &= \left[R_{k,t}^* - R_{t-1}^* - (R_{b,t} - R_{t-1}^*) x_{t-1}^* \right] Q_{t-1}^* s_{t-1}^* + R_{t-1}^* n_{t-1}^*,
\end{aligned}
\tag{30}
$$

where $x_t^* = b_t^*/Q_t^* s_t^*$ is the ratio of interbank loans to assets.

Given a positive spread on non-financial loans, the periphery banker will provide loans indefinitely by raising new deposits and borrowing additional funds from core banks until being shut down. Given the probability of exiting the industry, $1 - \sigma_t^*$, the banker maximizes the expected present value of net worth given by the

$$
V_t^* = E_t \left[\sum_{\tau=t+1}^{\infty} (1 - \sigma_{\tau-1}^*) \left(\sigma_{\tau-1}^* \right)^{\tau-t-1} \Lambda_{t,\tau}^* n_\tau^* \right],
\tag{31}
$$

rewritten as the Bellman equation:

$$V_t^* = E_t \Lambda_{t,t+1}^* \left[(1 - \sigma_t^*) n_{t+1}^* + \sigma_t^* V_{t+1}^* \right], \tag{32}$$

with $\Lambda_{t,t+1}^*$ as the stochastic discount factor of periphery households.

Financial intermediaries in the periphery country face an agency problem that is similar to the one of the core country: after raising deposits but still in period t, the banker may transfer the fraction θ_t^* of assets back to the respective household, defaults, and the other households shut this bank down and reclaim the remaining fraction $1 - \theta^*$. Thus, households will only deposit additional funds, if the incentive to remain in business exceeds the gain from diverting funds. Furthermore, as in Gertler et al. (2016), the ability to divert assets depends on the sources of the funds. In particular, periphery bankers are able to divert the fraction θ^* of non-financial loans financed by net worth and deposits while they can divert the fraction $\theta^* \omega^*$ of non-financial loans financed by interbank loans. Accordingly, the incentive constraint is given by

$$V_t^* \geq \theta^* \left(Q_t^* s_t^* - b_t^* \right) + \theta^* \omega^* b_t^*. \tag{33}$$

Similar to core banks, if $\omega^* > 1$, non-financial loans financed by interbank funds are easier to divert compared to the other sources of funds. Thus, obtaining more funds at the wholesale market tightens the incentive constraint and makes interbank loans less attractive. However, I again restrict the analysis to the scenario of $0 < \omega^* < 1$ as in Gertler et al. (2016). Core banks that lend in the interbank market are better able to monitor and evaluate the quality of periphery banks. Then, it is more difficult to divert non-financial loans that are financed by interbank funds. As the pledgeability of interbank funds rises when ω^* decreases, borrowing from core banks grows in attractiveness and periphery banks want to increase interbank borrowing in order to relax their incentive constraint. It follows that the size of the interbank market also depends on ω^*.

Now, the optimization problem of the periphery banker is to maximize (32) by choosing s_t^* and b_t^* subject to (30) and (33). This problem boils down to maximize the following guess of (32) subject to (33):

$$V_t^* = \mu_{s,t}^* Q_t^* s_t^* - \mu_{b,t}^* b_t^* + \nu_t^* n_t^*, \tag{34}$$

where the coefficients $\mu_{s,t}^*$, $\mu_{b,t}^*$, ν_t^* are defined similar to the ones of the core bankers. The first-order conditions lead to

$$\mu_{s,t}^* = \frac{1}{(1 - \omega^*)} \mu_{b,t}^*, \tag{35}$$

stating that the excess return of non-financial loans has to be equal to the excess cost of interbank funds over deposits times the gain from the relaxation of the incentive constraint which manifests in an increased willingness of households to supply deposits.

Combining (33)-(35) yields an expression for the leverage ratio ϕ_t^*:

$$\phi_t^* = \frac{Q_t^* s_t^*}{n_t^*} = \frac{\nu_t^*}{\left(\theta_t^* - \mu_{s,t}^*\right)\left[1 + (\omega^* - 1)\, x_t^*\right]}. \tag{36}$$

Now, combining (22)-(25) to obtain:

$$
\begin{aligned}
V_t^* &= E_t \Omega_{t+1}^* \left[\left(R_{k,t+1}^* - R_t^*\right) Q_t^* s_t^* - (R_{b,t+1} - R_t^*) b_t^* + R_t^* n_t^*\right] \\
V_t^* &= E_t \Omega_{t+1}^* \left[\left(R_{k,t+1}^* - R_t^* - (R_{b,t+1} - R_t^*) x_t^*\right) \phi_t^* + R_t^*\right] n_t^*,
\end{aligned} \tag{37}
$$

where

$$\Omega_{t+1}^* = \Lambda_{t,t+1}^* \left[1 - \sigma_t^* + \sigma_t^*(\nu_{t+1}^* + \mu_{s,t+1}^* \phi_{t+1}^* \left[1 + (\omega^* - 1)\, x_{t+1}^*\right])\right]$$

is the stochastic discount factor of periphery bankers which differs from the one of households due to the binding agency friction.

Comparing the initial guess (34) with (37) yields

$$\mu_{s,t}^* = E_t \Omega_{t+1}^* (R_{k,t+1}^* - R_t^*) \tag{38a}$$

$$\mu_{b,t}^* = E_t \Omega_{t+1}^* (R_{b,t+1} - R_t^*) \tag{38b}$$

$$\nu_t^* = E_t \Omega_{t+1}^* R_t^*. \tag{38c}$$

The binding incentive constraint limits the amount of loans that a periphery banker can provide to his net worth. Analogous to core banks, the leverage ratio ϕ_t^* is increasing in $\mu_{s,t}^*$, ν_t^*, and x_t^* if $\omega^* < 1$, whereas it is decreasing in θ^* and ω^*.

Aggregate net worth in the periphery country evolves according to

$$
\begin{aligned}
N_t^* &= \sigma_t^* \left[\left(R_{k,t}^* - R_{t-1}^* - (R_{b,t} - R_{t-1}^*) x_{t-1}^*\right) \phi_{t-1}^* + R_{t-1}^*\right] N_{t-1}^* \\
&\quad + \xi^* R_{k,t}^* \phi_{t-1}^* N_{t-1}^*,
\end{aligned} \tag{39}
$$

where entering bankers receive startup funds $\xi^* R_{k,t}^* Q_{t-1}^* S_{t-1}^* / (1 - \sigma_t^*)$.

2.5 Central bank policies

The central bank is endowed with two different unconventional tools in order to stabilize financial markets and mitigate the negative consequences of the shocks. The implementation of these measures follows Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Gertler et al. (2012), Dedola et al. (2013), and Nuguer (2016) and are

motivated by (some of) the measures that the ECB has implemented. The first one is the intervention in the (international) wholesale market by purchasing interbank loans (B-Policy). The central bank engages in this funding market between core and periphery banks by increasing the amount of available funds by providing $B_{g,t} = \zeta_{B,t}^* Q_t^* S_t^*$ to the funding needs B_t^* of periphery banks following the feedback rule given by

$$\zeta_{B,t}^* = \kappa_B^*[E_t(R_{k,t+1}^* - R_t^*) - (R_k^* - R^*)]. \tag{40}$$

This rule states that the central bank responds to movements in the spread between the return on non-financial loans and the risk-free rate, $E_t(R_{k,t+1}^* - R_t^*)$, and its steady-state value $R_k^* - R^*$, whereas κ_B^* is the feedback parameter for this policy. The aim of this kind of intervention is to stabilize the drop in credit flows between intermediaries.

Building on the recent attempts of the ECB to conduct unconventional policy by purchasing corporate sector bonds, the second policy option is to directly intervene in the market for non-financial loans (S-Policy). In order to stabilize the asset price and credit spreads and thus output, the central bank intermediates the fraction $\zeta_{S,t}$ ($\zeta_{S,t}^*$) of overall non-financial loans in the core (periphery) country. Thereby, the feedback rules take the form

$$\begin{aligned} \zeta_{S,t} &= \kappa_S[E_t(R_{k,t+1} - R_t) - (R_k - R)] \\ \zeta_{S,t}^* &= \kappa_S^*[E_t(R_{k,t+1}^* - R_t^*) - (R_k^* - R^*)], \end{aligned} \tag{41}$$

where κ_S and κ_S^* are the feedback parameter while the central bank intervenes if the spreads between the return on non-financial loans and the risk-free rate differ from their steady-state values.

As will become clear later on, I focus on union-wide and country-specific shocks in order to have a clear-cut analysis of the international transmission of the shocks and the unconventional policies. Therefore, I will distinguish, if needed, between cases where the central bank is only active in the country that is hit by the shock, intervenes in both countries by following analogous rules (41), or combines S-Policy and B-Policy. With the shock-independent intervention in both countries, I try to capture some specific conditions for subprograms of the ECB's asset purchase programme, where the purchases must be allocated according to the ECB's capital key (see Andrade et al., 2016).

As the central bank is not balance sheet constrained, it would be optimal for the central bank to always intervene in credit markets. Instead, I follow Gertler et al. (2012)

and Dedola et al. (2013) and assume an increasing cost function of intermediation:[7]

$$\Gamma_t = \tau_1 \zeta_{S,t} Q_t S_t + \tau_2 \left(\zeta_{S,t} Q_t S_t \right)^2 \tag{42}$$

$$\Gamma_t^* = \tau_1 \left(\zeta_{B,t}^* Q_t^* S_t^* + \zeta_{S,t}^* Q_t^* S_t^* \right) + \tau_2 \left(\zeta_{B,t}^* Q_t^* S_t^* \right)^2 + \tau_2 \left(\zeta_{S,t}^* Q_t^* S_t^* \right)^2. \tag{43}$$

These resource costs reflect the fact that unconventional policy interventions are subject to high administrative effort due to limited information about favorable investment projects and a less efficient monitoring technology (see e.g. Gertler and Karadi, 2011). It follows that, during normal times, these costs prevent the central bank from inefficient engagement in private financial markets. However, in a crisis situation where credit spreads rise sharply above their steady-state values, the gain from conducting unconventional measures and mitigating the drop in overall credit and thus output exceeds the resource costs and the central bank makes use of these tools.

The expenditures of the intervention policies and associated resource costs are financed by issuing one-period riskless government bonds to households in the respective country and by lump-sum taxes. For the sake of simplicity, when the central bank conducts unconventional policy in one country, this particular country has to bear the costs, i.e. resource costs are not shared.[8]

2.6 Equilibrium

In order to close the model all markets in both countries must clear. Goods market clearing in both countries requires

$$Y_t = C_{H,t} + \frac{1-\gamma}{\gamma} C_{H,t}^* + \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] I_t + \Gamma_t \tag{44a}$$

$$Y_t^* = C_{F,t}^* + \frac{\gamma}{1-\gamma} C_{F,t} + \left[1 + f\left(\frac{I_t^*}{I_{t-1}^*} \right) \right] I_t^* + \Gamma_t^*. \tag{44b}$$

The wholesale interbank market is in equilibrium when the following equation holds:

$$B_t^* = \frac{\gamma}{1-\gamma} B_t + B_{g,t}, \tag{45}$$

implying that, at the union level, interbank loans are in zero net supply.

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[7]A convex function is used as a proxy for capturing different aspects of a higher central bank intermediation such as e.g. higher management and exit costs and potential risks of default of these intermediated assets.

[8]However, τ_1 and τ_2 are calibrated so that resource costs have only negligible effects and do not change the dynamics of the model.

Finally, imposing market clearing for labor, deposits, and non-financial loans, core country's net foreign asset position can be derived from households' budget constraint. As long as there is an active interbank market, it evolves according to the following law of motion

$$B_t = R_{b,t}B_{t-1} + \frac{1-\gamma}{\gamma}\frac{P_{H,t}}{P_t}C^*_{H,t} - \frac{P_{F,t}}{P_t}C_{F,t}. \tag{46}$$

3 Crisis experiments and unconventional policy interventions

3.1 Calibration

Table 1 summarizes the parametrization of the model. The time interval is one quarter. I follow Brzoza-Brzezina et al. (2015), Galí and Monacelli (2016) and Kolasa and Lombardo (2014) and use euro-area standard parameters for households, goods producer and capital producers. All of these parameters are assumed to be equal in both countries and both countries are assumed to be equal-sized, i.e. $\gamma = 0.5$. The value of 2.585 for the relative utility weight of labor ensures $L = L^* = 1/3$.

As a financially heterogenous monetary union is the focus of the present analysis, the banking sector parameters are set in order to have different leverage ratios and an international interbank market. In the sense of Nuguer (2016), the survival rates of core and periphery banks are set equal to 0.975 and 0.972 respectively, implying an average horizon of 10 and 9 years. The other parameters are set to match the following steady state ratios. Between years 1999 and 2012, Poutineau and Vermandel (2015) find an average share of interbank loans in all assets of core banks of $x = 20\%$ while periphery banks have a share of $x^* = 25\%$.[9] As in Lama and Rabanal (2014), I set the credit spreads to 100 basis points p.a. in both countries. This ensures identical steady states of real-term variables such as, e.g. output, capital, investment, labor, and real prices. Lama and Rabanal (2014) also find a leverage ratio of 4 for the euro area which I use for the core country. For the periphery, I rather choose a slightly higher leverage ratio of 4.8 which is similar to Badarau and Levieuge (2011). The interbank interest rate is assumed to be symmetrical between R_k and R which requires $\omega = \omega^* = 0.5$. In order to match the mentioned targets, θ and θ^* are set to 0.429 and 0.377 while $\xi = \xi^* = 0.0016$.[10]

The capital quality shocks and the shocks to the survival probability of banks follow AR(1) processes with an autoregressive factor of 0.66 and the disturbance is a 5%

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[9]Hale and Obstfeld (2016) report similar values for core countries.

[10]Since periphery banks have a lower survival probability, θ^* must be lower than θ in order to allow for a higher leverage ratio in the periphery.

Households			
β, β^*	0.99		Discount factor
ρ, ρ^*	2		Inverse of intertemporal elasticity of substitution
h, h^*	0.564		Habit parameter
χ, χ^*	17.6		Relative utility weight of labor
φ, φ^*	2		Inverse of Frisch elasticity of labor supply
Goods producers			
α, α^*	0.33		Capital share in production
δ, δ^*	0.025		Depreciation rate
Capital producers			
η, η^*	5.169		Elasticity of investment
Financial intermediaries			
σ, σ^*	0.975,0.972		Survival probability
θ, θ^*	0.429,0.377		Divertable fraction of assets
ω, ω^*	0.5		Relative divertibility of interbank loans
ξ, ξ^*	0.0016		Proportional startup transfer to new bankers
Union-wide parameters			
γ	0.5		Core country size
τ_1, τ_2	0.000125,0.0012		Cost of central bank intermediation

Table 1: Parametrization

decline. This is a common value for the capital quality shock in the literature and for comparability, I use the same shock process for the survival probability. Both shocks can hit the whole union, i.e. aggregate shocks in both countries, or they are country-specific, i.e. idiosyncratic shocks. In latter case, I focus on shocks in the periphery country.

Regarding unconventional policy, I follow Gertler et al. (2012) and set the resource costs of central bank intermediation to $\tau_1 = 0.000125$ and $\tau_2 = 0.0012$. In line with, for instance, Gertler and Karadi (2011) and Gertler et al. (2012), the parameter for the rule on direct asset purchases is set to 100, which describes an "aggressive" credit policy. When an aggregate shock hits the union, I set $\kappa_S = \kappa_S^* = 100$, whereas in the case of an idiosyncratic shock that hits the periphery only, κ_S^* is set to 100. The parameters for the other intervention policies are set in such a way that the total amount of central bank intervention relative to union output is equal on impact. This guarantees comparability among policies.

In order to highlight the role of the interbank market, I focus on a monetary union that is only financially heterogenous. When the international interbank market is shut down, i.e. no-interbank case, I modify the calibration of the financial sector ($\theta = 0.411$,

$\theta^* = 0.36$, $\xi = 0.0014$, $\xi^* = 0.0013$) in order to have identical leverage ratios and credit spreads in the steady state of both scenarios.[11] Obviously (see (25)), core banks' net worth is lower in the no-interbank ($B = 0$) scenario.

3.2 Capital quality shocks

Although this crisis experiment is widely analyzed in the literature (see, e.g., Gertler and Karadi, 2011; or for a two-country setting: Dedola et al., 2012; Nuguer, 2016), it is not clear how the transmission of union-wide and country-specific shocks solely depends on cross-country interbank linkages and is not driven by other asymmetries.

3.2.1 Aggregate capital quality shock

Figure 1 and 2 show the impulse responses to a union-wide 5 percent decline in the quality of capital (ψ_t and ψ_t^*) for an active and inactive (cross-country) interbank market. In order to analyze the pure dynamics of the financial linkages, unconventional monetary policy is turned off. As the disturbances due to the interbank market are relatively small, Figure 2 serves as additional clarification by displaying union variables as the weighted average of national variables, $X_t^U = \gamma X_t + (1 - \gamma)X_t^*$, and relative variables as the gap between national variables, $X_t^U = X_t - X_t^*$.

Starting with the no-interbank scenario, it can be seen that the periphery suffers more from the aggregate shock due to the higher leveraged banking sector. As the capital quality suddenly shrinks, the initial effect of a reduction in the effective quantity of capital and thus production is the same for both countries. However, the subsequent effects depend on the leverage ratios: lower asset values deteriorate banks' net worth which let them start a fire sale of assets in order to meet the leverage constraint. As a result, the price of capital (Q_t as well as Q_t^*) shrinks even further which leads to widened credit spreads and falls in investment, capital and output. At first, the recession is more severe in the periphery since banks are more financially constrained. However, periphery banks are able to rebuild net worth at a faster pace (see relative net worth) resulting in a quicker recovery (see relative variables). Although a positive output differential initially emerges, the core experiences a deterioration of its terms of trade which improve in the aftermath according to the recovery paths. This is a result of the strong increase in relative investment (not shown) due to the sharp contraction in periphery investment. Hence, relative demand would be higher than relative production and in order to clear the goods markets, demand has to switch from core to periphery.

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[11]Due to this, all of the real-term variables have the identical steady state except for consumption and deposits.

Allowing for an international interbank market has (nearly) no effect on the union level but changes the picture at the national (relative) level. While the first-round effect is the same for both countries, the balance sheet effect is now even worse for periphery banks although banks in both countries use the interbank market for asset/liability diversification and to pool country-specific shocks. When core banks start the fire sale, they now have two assets to cut down. Due to the different effects on the incentive constraint, core banks reduce lending to non-financial firms more than interbank lending. Hence, they effectively increase the share of interbank loans (x_t, not shown) which relaxes the incentive constraint more than in the no-interbank scenario. This portfolio switching effect ultimately mitigates the net worth contraction, the fire sale, the increase in the credit spread and thus the downturn in the core.

However, for foreign banks, this reaction amplifies the negative effects on their balance sheets. Due to the lower asset value and the additional increase in the spread on interbank borrowing (the spread comoves with the credit spreads due to asset market integration), the initial deterioration of periphery banks' net worth is larger (see (30)), making the incentive constraint more binding. Since core banks cut down interbank lending, periphery banks cannot replace net worth by interbank loans in order to relax their leverage constraint. As a result, the deleveraging process is stronger which leads to a deeper recession.

Overall, the core country benefits from the international interbank market while it amplifies the downturn in the periphery (see Figure 2). This leads to larger gaps between the countries in favor of the core.[12] At the union level, the differences are negligible.

Let the focus now turn on unconventional policy interventions. Figure 3 displays the impulse responses whereby union variables are shown as differences from the no-policy scenario in percentage terms, e.g. the S-Policy leads to a union output that is 0.2 percentage points (at its peak) higher compared to the case of no policy interventions. I distinguish three interventions: direct purchases of non-financial loans in both countries (S-Policy), interbank market intervention (B-Policy), and a combination of both policies (S&B-Policy).[13]

The main effect of direct lending to firms is the stabilization of asset prices and credit spreads which mitigates the downturn in investment, capital and therefore production. However, this comes at the cost of a crowding out of private financial intermediation (see also Kirchner and Schwanebeck, 2017) and lower consumption as households pay the cost of the intervention. On impact, the central bank is responsible for roughly

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[12]Even the fall in consumption is lower in percentage terms. However, as the core steady-state level is higher in the interbank scenario, the initial decline in absolute terms is larger than abroad.

[13]The parameters for the policy interventions are set as follows: $\kappa_S = \kappa_S^* = 100$, $\kappa_B^* = 101.56$, $\kappa_S = \kappa_S^* = \kappa_B^* = 41.9$.

11% and 15% of the credit intermediation in the core and periphery where the tapering process is very slow. Although the stabilization of assets prices leads to a less severe drop in net worth, the lower private intermediation and the lower credit spreads make it harder for banks to re-capitalize which results in prolonged lower levels of net worth (see union net worth) compared to the no-policy case. In addition, this process leads to a larger cut in interbank funding. As the foreign country is more financially constrained, the policy is more active here resulting in lower relative (cross-country) gaps.

Providing funds to periphery banks in the interbank market leads to a stabilization of the foreign economy that is comparable to a policy of direct lending in that country, but slightly less effective. The effects on the core country are almost negligible so that union and relative variables are mainly driven by the periphery country. Due to the additional funds, the fire sale in this country is less severe which leads to a more stable credit intermediation which moderates the downturn. The central bank massively intervenes by (initially) providing funds in the amount of 25% of firm credits. Again, the tapering process is relatively slow which results in a prolonged rebuilding of net worth. For the core country, this policy has two opposed effects: a positive trade effect due to the moderation of the downturn in periphery (see also terms of trade) and a negative interbank market effect. The latter is a result of the policy intervention that stabilizes the spread $E_t(R_{b,t+1} - R_t)$ which makes interbank lending less attractive. On impact, core banks' net worth is slightly higher but due to the lower spread they now cut down interbank lending and also non-financial loans more than without the policy. This effect is quite small but nevertheless it outweighs the trade effect. In sum, this policy intervention slightly harms the core[14] while the periphery benefits from the stabilization effects.

Since the B-Policy leads to negative spillovers to the core, a combination of both policies (S&B-Policy) is less effective than direct lending. However, as the combined simple rules lead to a stronger engagement in the financially more constrained country, the relative gaps are more stabilized.

3.2.2 Idiosyncratic capital quality shock

Suppose now that only the periphery country is hit by a shock that lowers the quality of capital (ψ_t^*) by 5 percent. Figure 4 shows the impulse responses for an active and inactive interbank market. For the periphery, the order of events is as stated above: lower asset values induce a deleveraging process that leads to an increase in credit spreads and declines in investment and output. In the no-interbank case, the core is only affected by the trade channel. Although demand switches to this country (terms

---

[14] By comparing union and relative variables it can be seen that the change in relative variables (improvement of periphery variables, e.g. output) is stronger than the change in union variables.

of trade improvement) due to the sharp downturn in periphery production, overall demand declines even more which leads to a mild recession in the core economy. This is associated with a decline in assets prices, a deleveraging process and an increase in the credit spread. Not surprisingly, periphery suffers more from the shock. However, by comparing union and relative variables, it can be seen that the maximum decline in core output is about 1.1% and thus not negligible.

As in Nuguer (2016), the international interbank market is used by periphery banks to pool this country-specific shock. During the fire sale, they (initially) lower interbank borrowing but to a lesser extent than lending to non-financial firms which effectively increases x_t^* and relaxes the incentive constraint more than in the no-interbank scenario. This reaction is similar to the core banks' portfolio switching when an aggregate shock hits the union. In sum, the fire sale and thus the downturn in the periphery are slightly moderated. In contrast to the aggregate shock, the interbank market now harms the core country. While the negative trade effect remains, the downturn abroad and the reaction of periphery banks lead to an increase in the spread $R_{k,t} - R_{b,t}$ (not shown) which lowers core banks' net worth on impact. This negative spillover makes the incentive constraint more binding and amplifies the resulting deleveraging process. Core banks try to switch to interbank lending in order to relax the incentive constraint (by lowering lending to non-financial firms more than interbank lending), but this cannot compensate the former effect.[15] Hence, investment, capital and output are lower compared to the no-interbank scenario. In the aftermath of the shock, switching to interbank lending leads to an strong increase in B_t, benefitting the foreign country. Nevertheless, periphery still suffers more from the shock. Though the relative variables show that there is a partial pooling of the shock, the negative effects on the core country prevail which leads to a marginally stronger union-wide recession (see union variables).

Again, unconventional monetary policy serves as stabilization tool. Figure 5 shows the impulse responses whereby all variables are now stated as differences from the no-policy scenario (cf. Figure 4 and 5) for reasons of clarity and comprehensibility. Here, I distinguish three interventions: direct purchases of non-financial loans in periphery (S*-Policy), direct purchases in both countries (S&S*-Policy), and interbank lending (B-Policy).[16]

A policy of direct lending in the country that is hit by the shock seems to be the most effective intervention in terms of stabilizing union and relative output. Due to the stabilization of asset prices and credit spreads the downturn in the periphery is less severe. Again, there is a crowding out of private intermediation. While the central

---

[15]In the case of an aggregate shock, this switching effect overcompensates the initial negative effect of an increase in the spread $R_{k,t} - R_{b,t}$.

[16]The parameters for the policy interventions are set as follows: $\kappa_S^* = 100$, $\kappa_S = \kappa_S^* = 48.49$, $\kappa_B^* = 28.55$.

bank provides roughly 11% of non-financial loans (on impact) which tapers off very slowly over time, the lower credit spread leads to a prolonged rebuilding of periphery banks' net worth. Since this process leads to a larger cut in interbank funding, the incentive constraint of core banks is more binding, resulting in a slightly larger fire sale and downturn in the core country (cf. relative and union variables). Thus, this intervention harms the core by increasing the negative spillover via the interbank market. This finding is in sharp contrast to Nuguer (2016) and stems from the assumption of non-contingent interbank funds where a lower level of interbank borrowing is fully transmitted to the lending country, implying a tighter leverage constraint. If interbank funds were state-contingent claims, the price of these claims would adjust according to the shock and unconventional policy would stabilize this price which would then lead to less constrained core banks. Therefore, the policy spillovers depend on the nature of interbank funds, i.e. whether they are state-contingent claims as in Nuguer (2016) or debt-like non-contingent claims that promise a fixed return as in Gertler and Kiyotaki (2010).[17] For an interbank wholesale market within a monetary union as the U.S. or the euro area, the latter case seems to be more plausible given the short-term nature of interbank funds.

When the central bank intervenes in both countries (S&S*-Policy), the stabilization level is lower. Although the downturn in core and periphery is moderated, this intervention is less effective since the country that needs more support gets only one fifth of the funds of the S*-Policy.

Similar to the aggregate shock, the interbank market intervention (B-Policy) stabilizes the periphery comparable to the S*-Policy case but at a distinctly lower level. Again, this policy intervention slightly harms the core since the stabilization of the spread $E_t(R_{b,t+1} - R_t)$ induces a stronger cut down in interbank lending and lending to firms. Hence, a combination of interbank market interventions and direct lending would be less effective compared to the S*-Policy or the S&S*-Policy.

3.3   Banking crisis

Let the focus now turn to shocks that reduce the survival probability of banks which results in a banking crisis. As with capital quality shocks, I emphasize the transmission channels of the shocks and the effects of unconventional monetary policy interventions. The former section has shown, that there are spillovers due to trade and portfolio switching. Before I proceed, the reader should be aware of the relevance of the trade channel.

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[17]See also Meeks et al. (2017) for a discussion on how the interbank transmission of shocks within the Gertler-Karadi-Kiyotaki type of DSGE models with financial intermediation depends on this issue.

In the no-interbank case ($B_t = 0$) and under the assumptions of a Cobb-Douglas type of consumption index, the law of one price, symmetry (which results in purchasing power parity), it follows that $C_t = C_t^*$ which results in a large trade spillover due to terms of trade movements that ensure perfect risk sharing (see, among others, Corsetti et al., 2008 and Sutherland, 2005). Allowing for an international interbank market relaxes this outcome ($C_t \neq C_t^*$) but the aforementioned assumptions still imply significant trade effects. This is in sharp contrast to Nuguer (2016) who analyzes a global interbank market and assumes high degrees of home bias and that the home country is a small open economy with a large banking sector. Indeed, trade linkages and spillovers from home to foreign play no role with corresponding implications for unconventional monetary policy and the relevance of a cross-country interbank market. In the present analysis of a monetary union, however, abstracting from these assumptions seems to be more plausible.

3.3.1 Aggregate shock to the survival probability of banks

Again, I start with analyzing a union-wide 5 percent decline in the survival probability of banks for an active and inactive interbank market. Figure 6 and 7 show the impulse responses.

In both cases, it can be seen that the core suffers more from this aggregate shock. On impact, the shock lowers the aggregate level of net worth in both financial systems (see (28) and (39)) and the franchise values V_t and V_t^* (see (20) and (31)). This tightens the incentive constraints, but even more so in the core since $\theta > \theta^*$ and financial intermediaries in that country experience a larger drop in σ_t in absolute terms ($\sigma > \sigma^*$). As a result, banks in both countries start a deleveraging process which results in a drop in asset prices and lower levels of investment and capital. Meanwhile, households cut down their deposit holdings and receive retained earnings from exiting bankers which leads to increasing levels of consumption in the early stages. As this initially leads to an increase in the real interest rate according to the Euler equation (see (4)), there is even a decline in the credit spreads at first, making it harder for banks to re-capitalize. Although consumption increases, the fall in investment is larger which leads to a downturn in both countries As output deteriorates, households' income also declines and hence consumption reaches a peak and drops in the aftermath. As the deleveraging process is more severe in the core, investment contracts more than in the periphery (not shown). Hence, relative demand would be lower than relative production and in order to clear the goods markets, demand has to switch from periphery to core, i.e. core experiences an improvement of its terms of trade.

With an international interbank market, core and periphery banks rebalance their portfolios in order to relax their incentive constraint which results in an increase in

$R_{b,t}$. However, the resulting cut down in lending to firms and thus economic downturn outweighs the relaxing effect which leads to a stronger deleveraging (see union variables). Furthermore, the increase in the spread on interbank borrowing harms periphery banks (see N_t^*), leading to a deeper recession (see relative variables).[18] Overall, both countries suffer from the interbank market as the banks do not internalize the negative effects of their portfolio rebalancing.

Turning to unconventional monetary policy, I focus on two interventions: direct purchases of non-financial loans in both countries (S-Policy) and an interbank market intervention (B-Policy).[19] As will become clear later on, a combination of both policies will make no sense from a union perspective. Figure 8 displays the impulse responses whereby union variables are shown as differences from the no-policy case.

Direct lending to firms seems to be very effective in stabilizing both economies as this policy mitigates the negative effects of banks' portfolio rebalancing and stabilizes their balance sheets. The drop in union output is halved (cf. Figure 7 and 8) and since the core country suffers more from the shock, the policy is more active here which results in lower relative gaps. Nevertheless, the crowding out of private financial intermediation leads to prolonged lower levels of net worth (see union and relative net worth) and an extremely slow tapering process. Even after 10 years, the central bank intermediates nearly the same amount of non-financial loans as at the beginning of the intervention.

Again, the interbank market intervention (B-Policy) stabilizes the periphery country while it harms the core by stabilizing the spread on interbank lending (cf. union and relative variables). This leads to a stronger deleveraging process in the core. Since this policy leads to a stabilization of only one country and is less effective in doing so compared to the S-Policy, the relative gaps become wider. From a union perspective, this policy is rather pointless for stabilization purposes. Hence, a combination of interbank interventions and direct lending makes no sense.

3.3.2 Idiosyncratic shock to the survival probability of banks

Suppose now that there is a 5 percent decline in the survival probability of periphery banks. Figure 9 shows the impulse responses for an active and inactive interbank market. As with the aggregate shock, the periphery banking system is shut down with a corresponding deleveraging process and recession. As the core country is only affected by the trade channel in the no-interbank scenario, the initial consumption increase in periphery (due to the cut down in deposits and the payment of retained earnings from exiting bankers) leads to a boom in core. By comparing union and relative

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[18]Note that relative net worth declines more in absolute terms since core banks' net worth is higher in the interbank scenario.

[19]The parameters for the policy interventions are set as follows: $\kappa_S = \kappa_S^* = 100$, $\kappa_B^* = 163.5$.

variables, it can be seen that this positive trade spillover increases net worth, asset prices, investment, capital, and production in the core country. Since core experiences a boom while periphery suffers from the downturn, core's terms of trade deteriorate.

Again, the interbank market is used by periphery banks to pool this idiosyncratic shock which leads to a negative spillover to the core while the downturn in periphery is moderated (see relative variables). However, the positive trade effect prevails, leading to a (mitigated) boom in the core country. As periphery banks switch to interbank borrowing, they can effectively relax their incentive constraint which results in a slightly moderated deleveraging process and economic downturn. On impact, there is an increase in the spread $R_{k,t} - R_{b,t}$ (not shown) which marginally lowers core banks' net worth. But since the positive trade effect prevails, core banks still expand their balance sheets. However, they also switch to interbank lending which mitigates the increase in investment, capital, and production. In sum, rebalancing banks' portfolios is beneficial for the periphery while it harms the core. Though the relative variables show that there is a partial pooling of the shock, the negative effects on the core country prevail which leads to a stronger union-wide downturn (see union variables).

Next, I allow for three different types of unconventional policy: direct purchases of non-financial loans in periphery (S*-Policy), direct purchases in both countries (S&S*-Policy), and interbank lending (B-Policy).[20] The impulse responses are shown in Figure 10 whereby all variables are stated as differences from the no-policy scenario (cf. Figure 9 and 10).

Similar to the aggregate shock, direct lending to periphery firms (S*-Policy) seems to be very effective in stabilizing both economies as this policy mitigates the negative effects of the portfolio rebalancing and stabilizes the financial intermediation in the periphery. For instance, the gaps in union and relative output are halved. As this policy also lowers the increase in consumption, the positive trade spillover (which dominates spillovers via B_t) is smaller. Core experiences only a minor boom. Thus, this intervention harms the core country. Furthermore, periphery banks witness a crowding out effect which again results in prolonged lower levels of net worth (see union and relative net worth). While the central bank provides roughly 3% of loans to periphery firms on impact and 5.5% later on, the tapering process is extremely slow. After 10 years, the central bank still provides roughly 2.5% of non-financial loans.

Intervening in both countries (S&S*-Policy) leads to virtually the same stabilization effects and the same outcome since the central bank is almost only active in the periphery country (see $\zeta_{S,t}$ and $\zeta_{S,t}^*$). This is a result of the mild boom in the core country with only a marginal deviation in the credit spread. Hence, unconventional policy is almost inactive here (providing roughly 0.08% of non-financial loans on impact).

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[20]The parameters for the policy interventions are set as follows: $\kappa_S^* = 100$, $\kappa_S = \kappa_S^* = 95.45$, $\kappa_B^* = 72.35$.

The interbank market intervention (B-Policy) leads to a stabilization of the periphery economy that is comparable to the S*-Policy case but at a distinctly lower level. It also harms the core due to the lower trade effect. As this policy is less effective in stabilizing union and relative variables compared to the S*-Policy or the S&S*-Policy, a combination of interbank market interventions and direct lending would make no sense.

4   Implications of an international interbank market

The former section has shown that an international interbank market amplifies the shocks and can lead to higher volatilities at the union level. Although this channel is used to pool shocks and thereby lowers the relative (cross-country) gaps (e.g. output), banks do not internalize the negative side effects from portfolio switching (decline in loans to firm, investment, output) which leads to lower levels of union investment, capital, output and so forth. On the contrary, in the case of an aggregate capital quality shock, the interbank market channel has virtually no effect on the union level whereas it increases the relative gaps.

As regards unconventional monetary policy, a policy of direct asset purchases which is only active in the country that is hit by a shock seems to be the most effective intervention in terms of stabilizing union and relative output. In the case of idiosyncratic shocks, a simple rule of direct lending in both countries (irrespectively of the shock) yields similar (but slightly less effective) stabilization outcomes. Hence, irrespectively of the kind of shock, simply having active rules of direct lending in both countries seems to be appropriate. From a union perspective, interventions in the interbank market show less efficiency as they benefit only the borrowing institutions while harming the lenders. The usefulness of this policy seems to be sensitive to the kind of shock. Only in the case of an aggregate capital quality shock, a combination of direct lending and interbank interventions could lead to significant stabilization effects that are comparable to a pure S-Policy in both countries.

However these observations hold for the benchmark calibration ($x = 20\%$). Next, I consider variations in the size of the international interbank market. To highlight the role of the interbank market, I modify the size of this market but adjust the calibration of the model in a similar manner as above (see section "Calibration") in order to have the same steady-state leverage ratios.[21] Table 2 shows standard deviations of union and relative output in relation to the standard deviations in the no-interbank scenario.[22] For

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[21] Also, most of the other variables (e.g. output, capital, investment, labor, prices) have the identical steady state. There are only changes in consumption, deposits, core banks' net worth and obviously B_t and $R_{b,t}$.

[22] A further increase in the size of the interbank market leads to a situation where periphery banks

x	5%	10%	15%	20%	25%	30%	35%	40%	45%
x^*	5%	11%	18%	25%	33%	43%	54%	67%	82%
Aggregate capital quality shock									
Y^U	0.999	1.000	1.000	1.001	1.002	1.004	1.007	1.011	1.016
Y^R	0.327	0.811	1.683	2.777	4.099	5.702	7.665	10.10	13.17
Idiosyncratic capital quality shock									
Y^U	1.004	1.007	1.010	1.014	1.019	1.026	1.033	1.043	1.056
Y^R	0.812	0.843	0.863	0.881	0.899	0.920	0.945	0.975	1.012
Aggregate shock to the survival probability of banks									
Y^U	1.034	1.073	1.116	1.165	1.222	1.287	1.362	1.452	1.559
Y^R	0.349	0.520	0.591	0.639	0.679	0.679	0.750	0.783	0.817
Idiosyncratic shock to the survival probability of banks									
Y^U	1.055	1.095	1.139	1.187	1.242	1.306	1.383	1.474	1.588
Y^R	0.357	0.561	0.666	0.751	0.833	0.920	1.016	1.127	1.258

Table 2: Standard deviations of union and relative output relative to the standard deviations in the no-interbank market scenario

instance, the value 0.327 for relative output in the case where 5% of core banks' assets are interbank loans and an aggregate capital quality shock hits the union means that the interbank market leads to a standard deviation that is 67% lower compared to the no-interbank scenario. In this case, the interbank market stabilizes the cross-country output gap.

For each type of shock, the volatility of union and relative output is increasing in the size of the interbank market. As regards relative output, the shock pooling stabilizes this gap for moderate, empirical relevant (see, e.g., Poutineau and Vermandel, 2015) sizes of the interbank market except for the aggregate capital quality shock. Here, the volatility reduction results only for small sector sizes. However, closing the cross-country output gap comes at the cost of a more volatile union output. Except for $x = 5\%$ in the case of an aggregate capital quality shock, the spillovers due to the pooling activities of the financial intermediaries via the cross-country interbank market always lead to stronger fluctuations in union output. Hence, using the international interbank market in order to pool and insure against shocks is not neutral. The resulting spillovers act as shock multipliers on union output.

In the exceptional case of $x = 5\%$ and to a lesser extend also for $x = 10\%$ in the case of an aggregate capital quality shock, the pooling of the shock stabilizes union and relative output compared to the no-interbank scenario. In these cases, the interbank

fully rely on core bank funding and lend funds to firms and households.

	x = 5%			x = 20%			x = 40%		
	S-Pol	B-Pol	S&B	S-Pol	B-Pol	S&B	S-Pol	B-Pol	S&B
Aggregate capital quality shock									
Y^U	1.005	0.997	1.008	0.999	1.002	1.007	0.975	0.993	0.992
Y^R	1.434	7.002	0.640	0.767	1.506	0.700	0.450	0.821	0.543
Aggregate shock to the survival probability of banks									
Y^U	0.852	0.882	0.855	0.836	0.900	0.846	0.789	0.882	0.800
Y^R	0.463	2.838	0.769	0.529	2.827	0.830	0.746	3.290	1.083
	S*-Pol	S&S*	B-Pol	S*-Pol	S&S*	B-Pol	S*-Pol	S&S*	B-Pol
Idiosyncratic capital quality shock									
Y^U	1.002	1.014	1.009	0.994	1.010	1.009	0.961	0.987	0.999
Y^R	0.989	0.999	1.001	0.956	0.979	0.999	0.882	0.920	0.981
Idiosyncratic shock to the survival probability of banks									
Y^U	0.881	0.889	0.865	0.865	0.867	0.879	0.785	0.783	0.861
Y^R	0.648	0.662	0.680	0.643	0.654	0.730	0.588	0.595	0.744

Table 3: Standard deviations of union and relative output relative to the standard deviations in the no-policy scenario

market act as insurance system. Otherwise, this market is rather a shock amplifier and there seems to be a need for stabilization policy.

Unconventional monetary policy could accomplish this purpose. Table 3 shows standard deviations of union and relative output under the unconventional policies that are described in the former section in relation to the standard deviations when there is no policy intervention. For instance, the value 1.005 for union output in the case of $x = 5\%$ and an aggregate capital quality shock hits the monetary union shows that direct lending in both countries increases the volatility of output by 0.5%. To guarantee comparability among the policies in the different sector-size cases, I use the on-impact value of central bank intervention expenditures relative to union output of the benchmark calibration ($x = 20\%$) and set the parameters of the unconventional policy rules in the other scenarios ($x = 5\%$, $x = 40\%$) accordingly to hit the same on-impact value of expenditures to union output.

Several comments are in order. At first, I focus on direct asset purchases. The higher the size of the interbank market, the more effective is the policy of direct lending (S-Policy, S*-Policy as well as S&S*Policy) in terms of union stabilization. This is also true for the stabilization of relative output except for an aggregate shock to the survival probability of banks. Here, increasing the interbank market size makes the policy more effective in stabilizing union output at the cost of a more volatile relative output. Except

for $x = 5\%$ in the case of an aggregate capital quality shock, direct lending to firms (in one or both countries) leads to a stabilization of at least one of the variables Y^U or Y^R. Furthermore, in the case of idiosyncratic shocks, a simple rule of direct lending in both countries stabilizes Y^U and Y^R similar to the S*-Policy, but to a lesser extent.

The effectiveness of interventions in the interbank market seems to be very sensitive to the type of shock and the interbank market size. Only in the case of an idiosyncratic shock to the survival probability of periphery banks, this policy leads to a stabilization of Y^U and Y^R, irrespectively of the interbank market size. Otherwise, the size has ambiguous effects on the effectiveness of the B-Policy. For instance, in the case of idiosyncratic capital quality shock, increasing the size makes this policy more effective. While for the other shocks the effectiveness of stabilizing Y^U drops by increasing the size from 5 to 20 percent, it rises again when raising the size even further.

Overall, direct lending (in one or both countries) seems to outperform the B-Policy except for stabilizing Y^U in the case of an aggregate capital quality shock and an idiosyncratic shock to the survival probability of banks for $x = 5\%$. However, in these cases, the volatility of relative output is significant lower compared to the B-Policy. The interbank market intervention seems to be only appropriate within a combination with direct lending in both countries in the case of an aggregate capital quality shock for $x = 5\%$ (and to some extent also for $x = 20\%$). Otherwise, the central bank should rather shy away from the B-Policy.

In sum, a policy of direct asset purchases which is only active in the country that is hit by a shock seems to be the most appropriate intervention in terms of union and relative output stabilization closely followed by a policy where the central bank is restricted to have shock-independent rules for direct lending in both countries.

5 Conclusions

In this paper, I use a simple two-country model of a monetary union with financial intermediation and an international interbank market that is a result of the heterogeneity of the banking sectors across the monetary union. While this market is used for asset and liability diversification, it is also a channel for the transmission of shocks. The central bank is endowed with two different unconventional measures as stabilization tools: increasing the amount of available funds in the international interbank market or direct lending to firms. Depending on the kind of shock, I distinguish between cases where the central bank uses direct lending only in the country that is hit by the shock, intervenes in both countries, intervenes in the interbank market, or combines the unconventional policies. This setup allows to examine the role of the international interbank market in the transmission of shocks and its role for unconventional policy interventions.

I can draw four major results. First, although the interbank market is used to pool shocks and thereby lowers cross-country gaps, banks do not internalize the negative side effects of their portfolio rebalancing which results in a decline in firm credits and thus output. This results in stronger fluctuations in union output. Hence, using the international interbank market in order to pool and insure against shocks is not neutral. The resulting spillovers act as shock multipliers on union output. Second, regardless of the shock, the volatility of union and relative output is increasing in the size of the interbank market. Third, a policy of direct lending which is only active in the country that is hit by a shock seems to be the most effective intervention in terms of union and relative output stabilization, closely followed by a policy where the central bank is restricted to have shock-independent rules of direct lending in both countries. The higher the size of the interbank market, the more effective are these policies in terms of union stabilization. In terms of relative output stabilization, the implications of the interbank market for direct asset purchases are shock-specific. Fourth, the effectiveness of interventions in the interbank market seems to be very sensitive to the type of shock and the interbank market size. Hence, the central bank should rather shy away from this policy as this measure is only useful under specific circumstances.

The analysis could be extended in several directions. Implementing price and wage stickiness would alter the transmission mechanism and could lead to more effective unconventional measures and a meaningful role for conventional monetary policy (Kollmann, 2016). Thus, the optimal mix of both unconventional and conventional monetary policy would be a fruitful extension. Another interesting issue for future research is the implementation of macroprudential policy (see, e.g., Palek and Schwanebeck, 2015) and the analysis of the resulting interdependencies with the cross-country interbank market.

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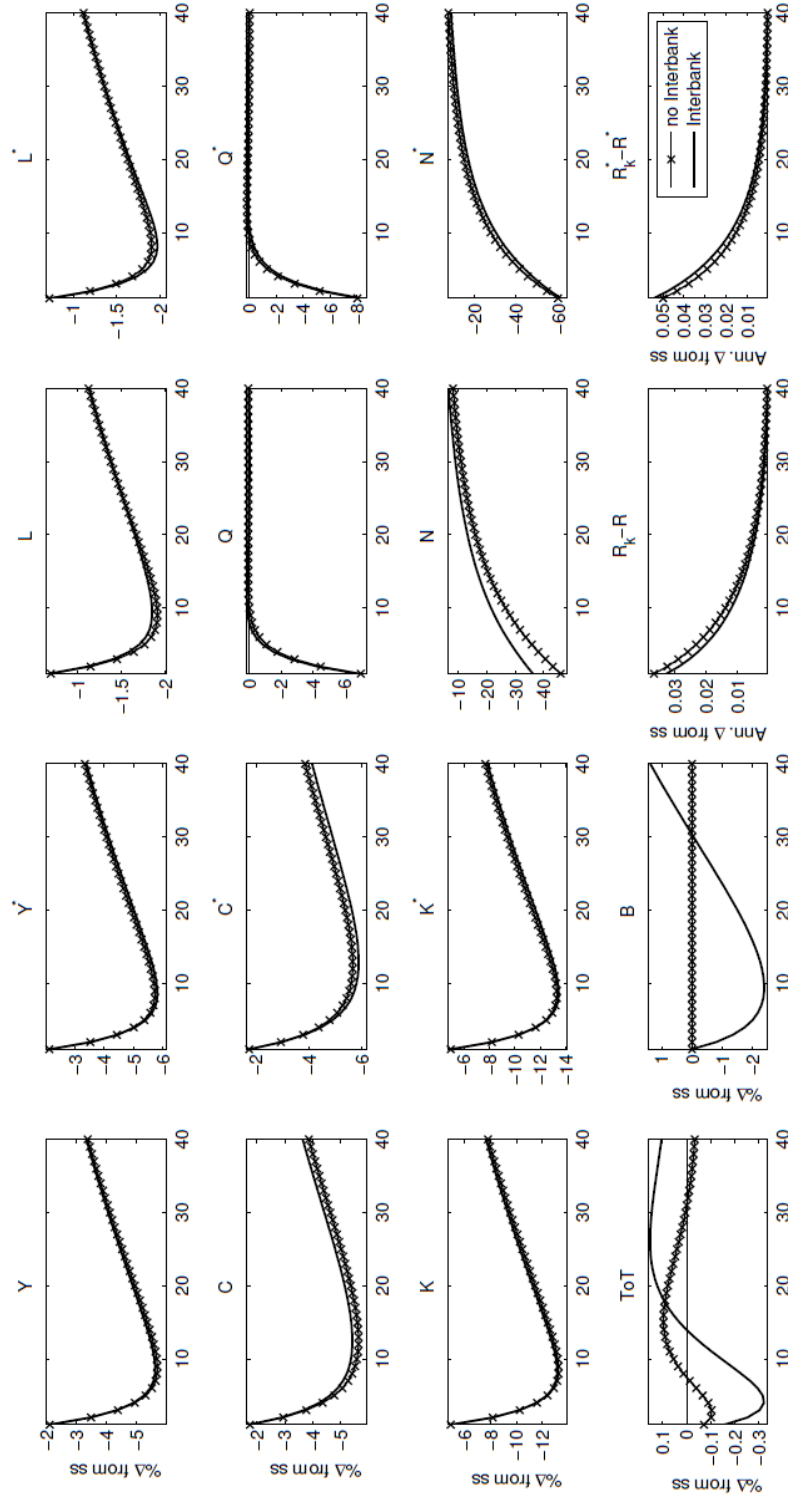
Appendix: Figures

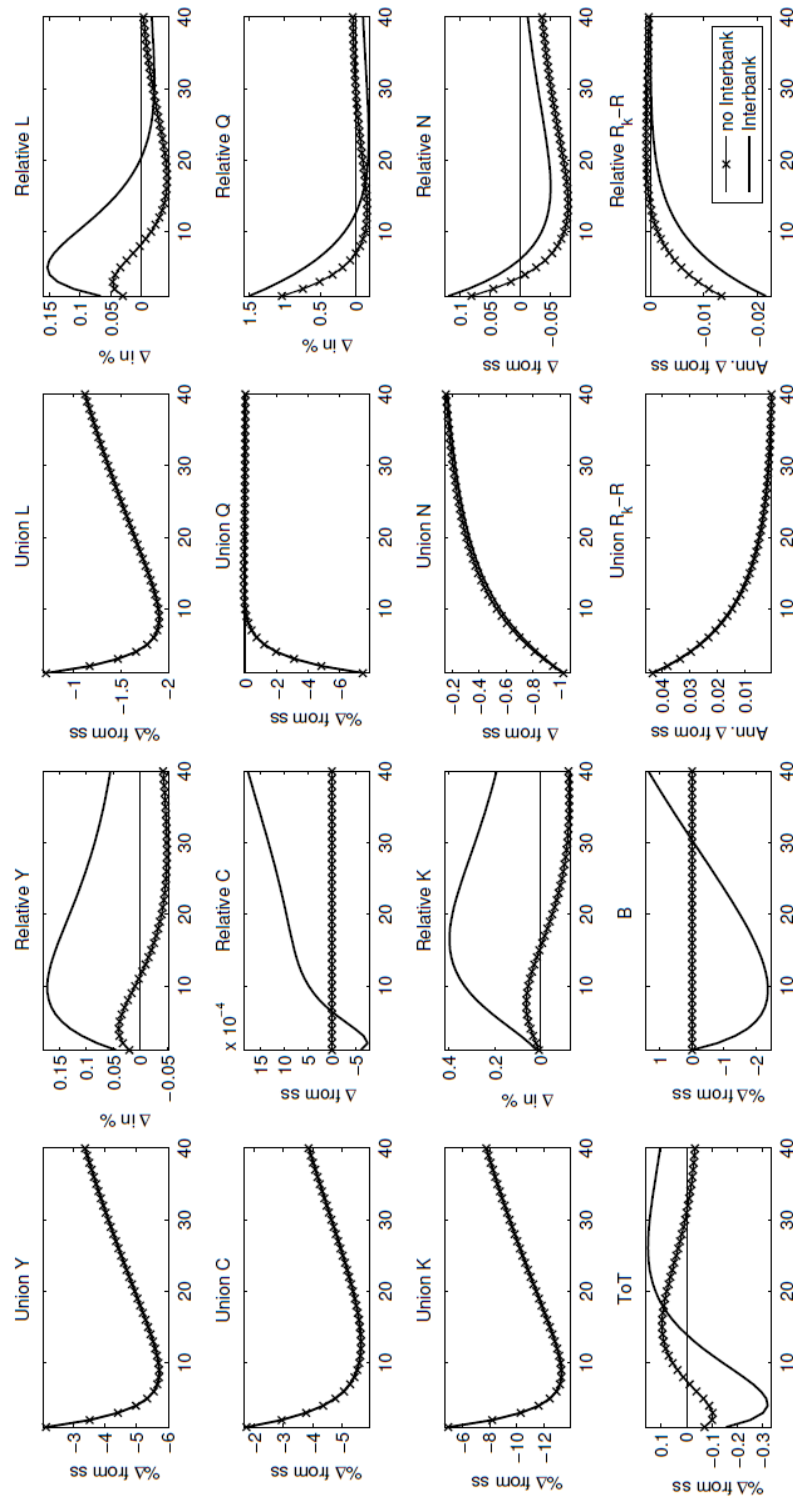Figure 1: Impulse responses to an aggregate capital quality shock

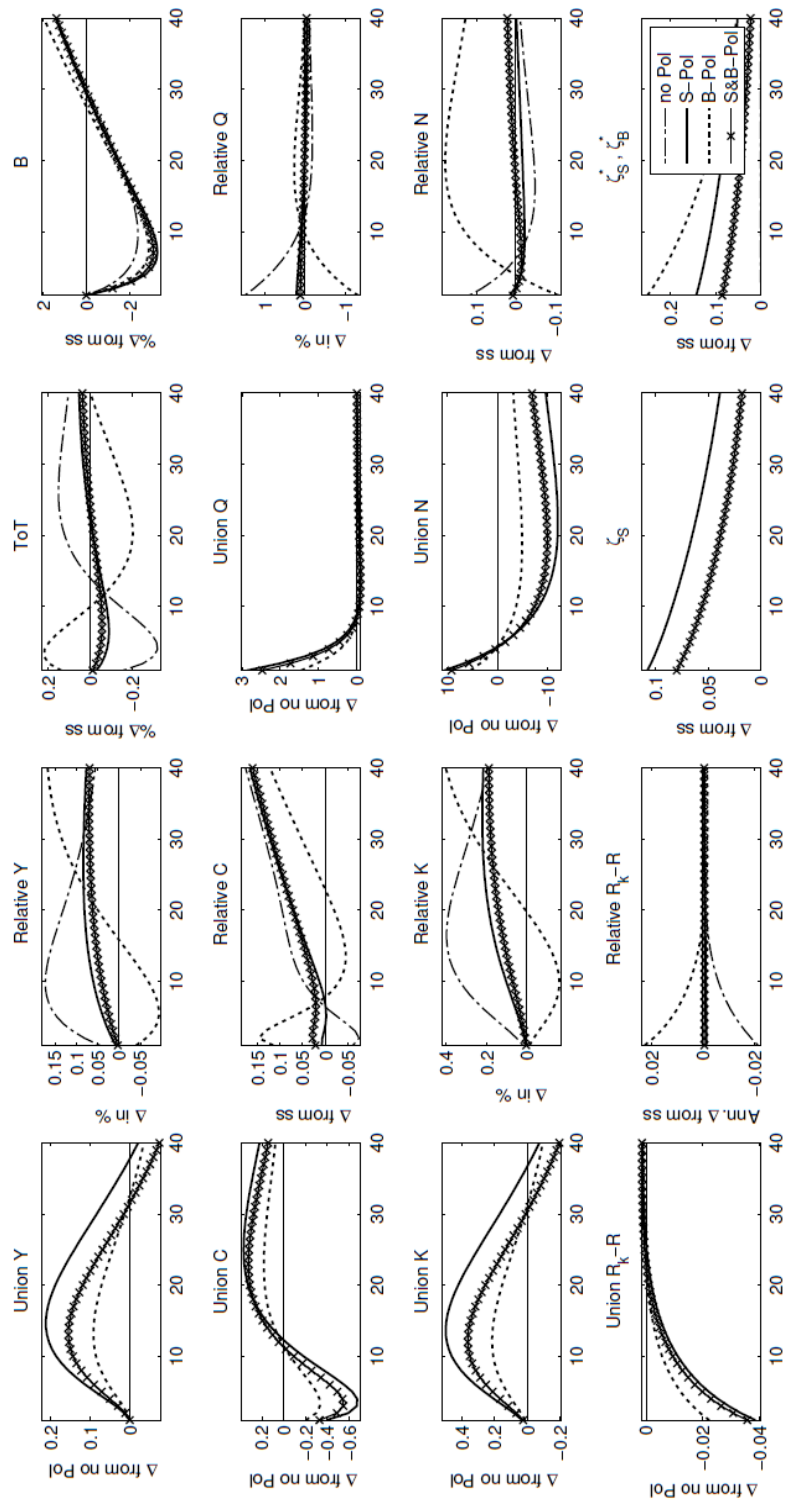Figure 2: Impulse responses to an aggregate capital quality shock (con't)

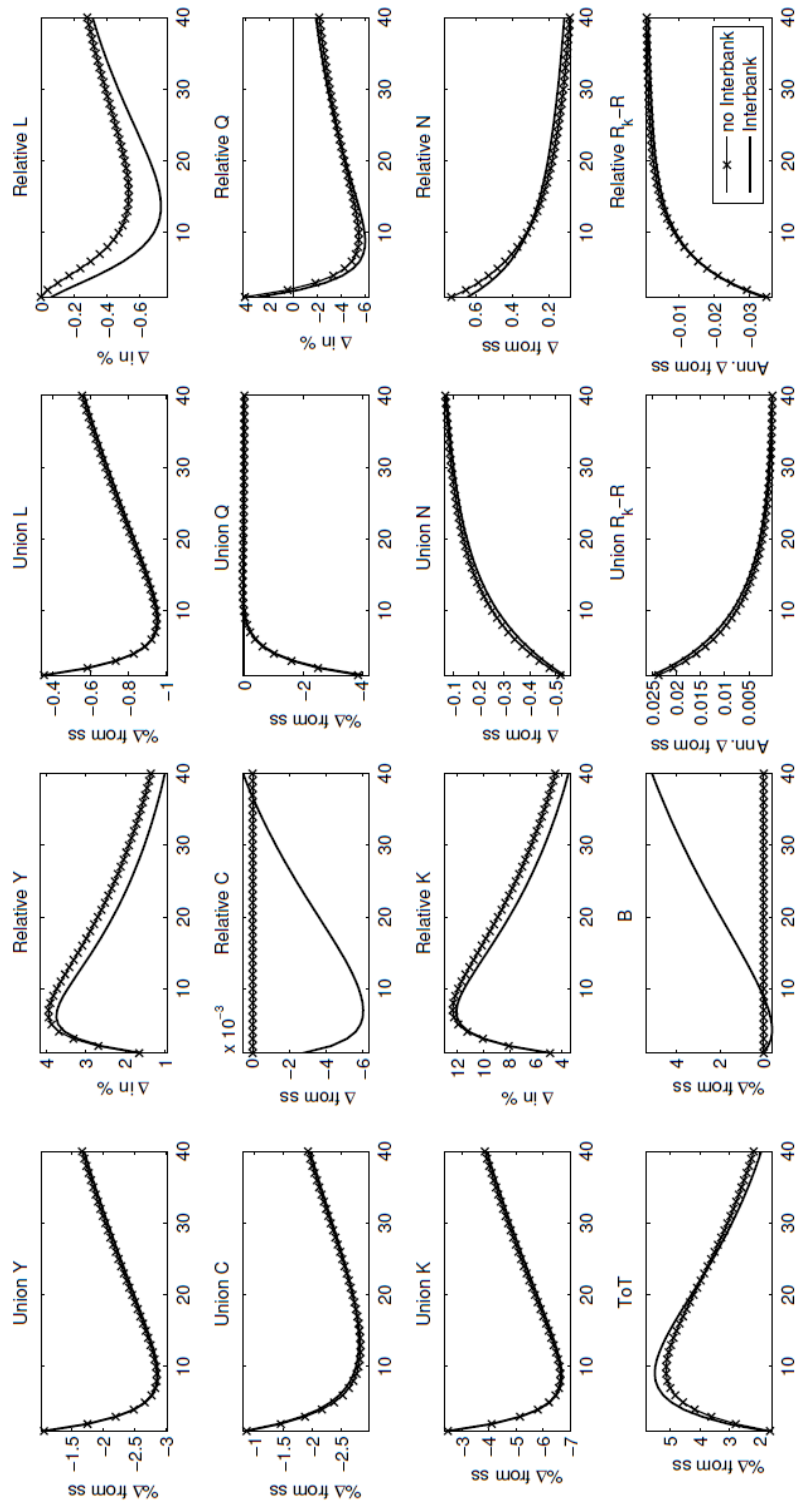Figure 3: Impulse responses to an aggregate capital quality shock with policy interventions

Figure 4: Impulse responses to a periphery capital quality shock
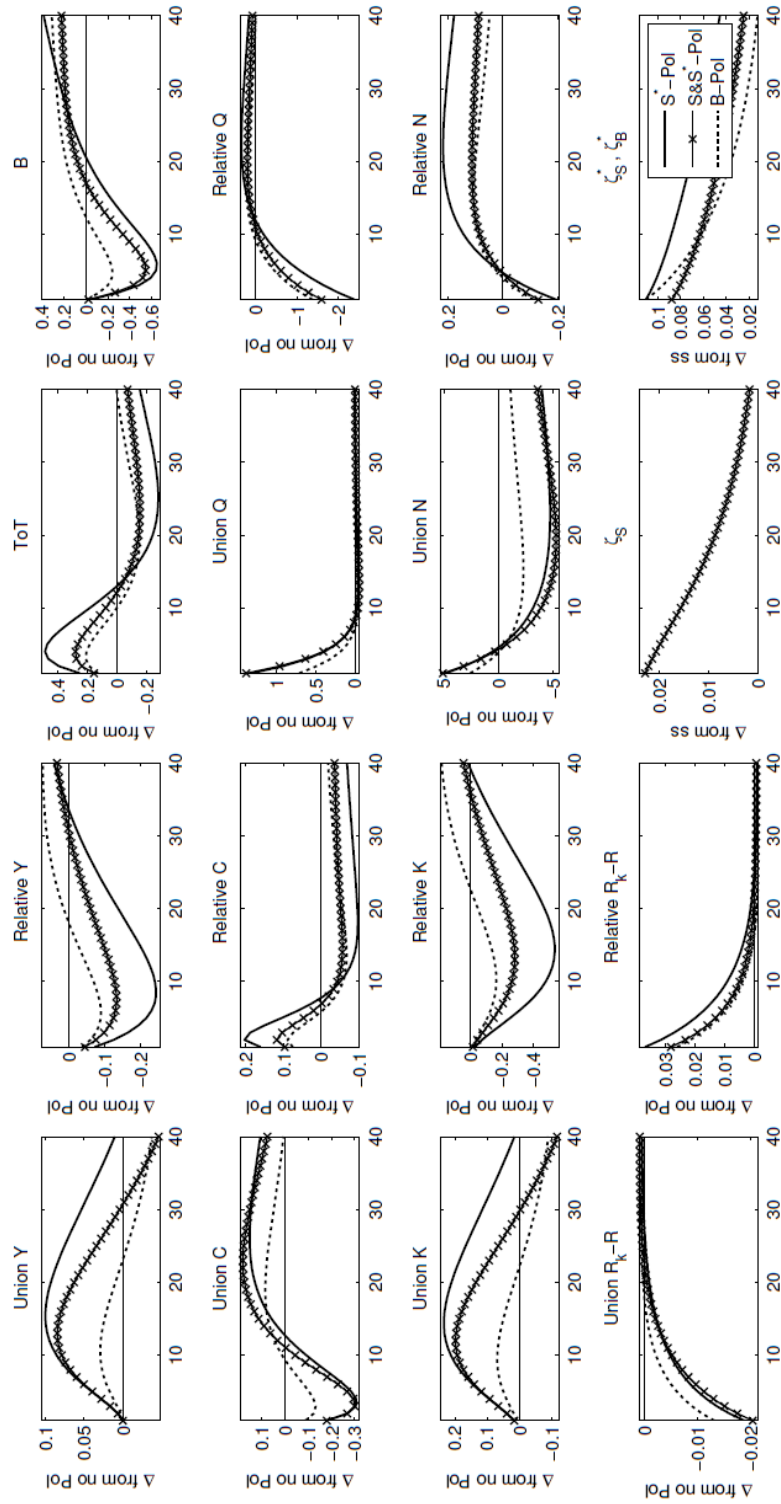
Figure 5: Impulse responses to a periphery capital quality shock with policy interventions
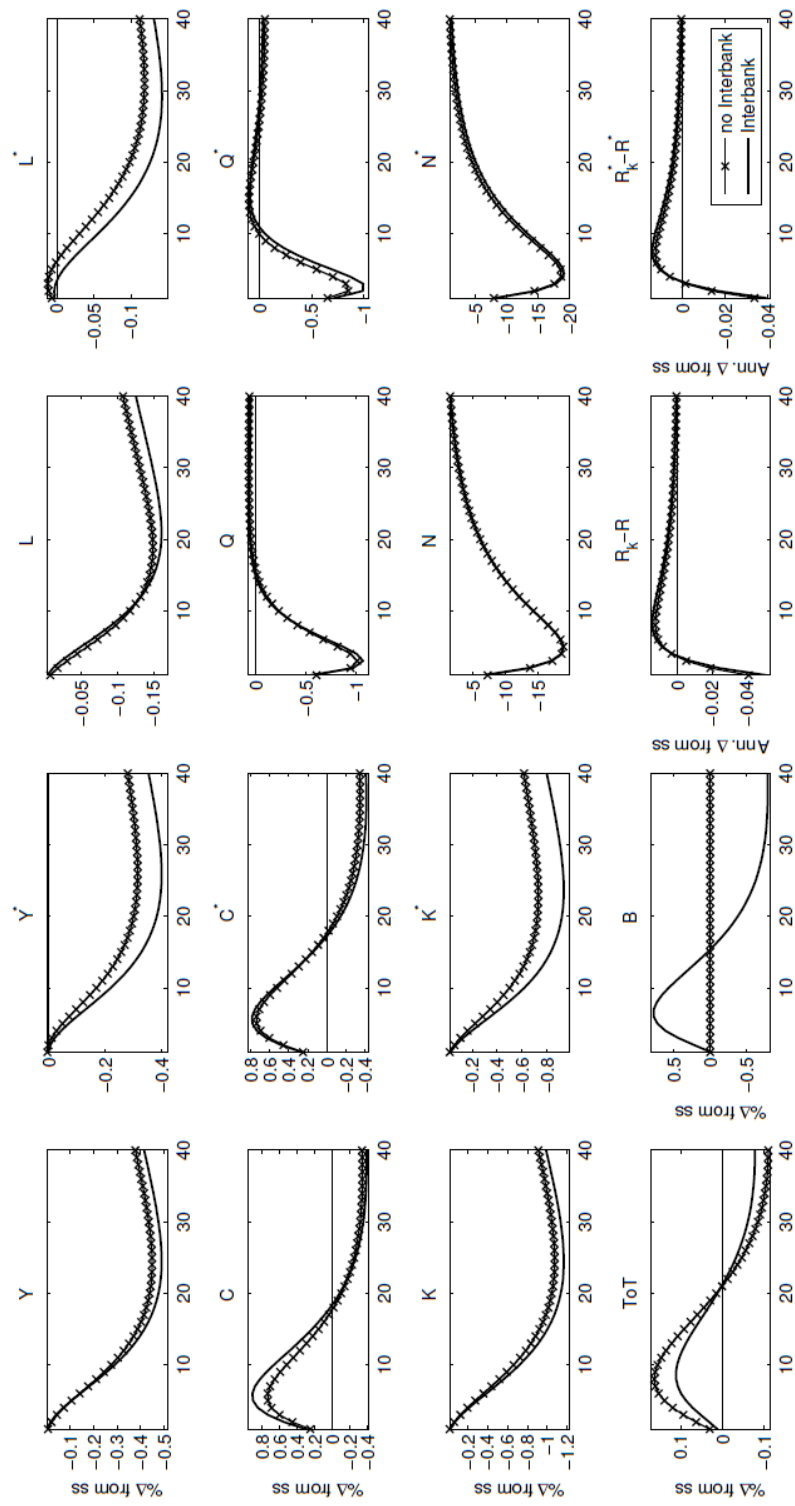
Figure 6: Impulse responses to an aggregate shock to banks' survival probability
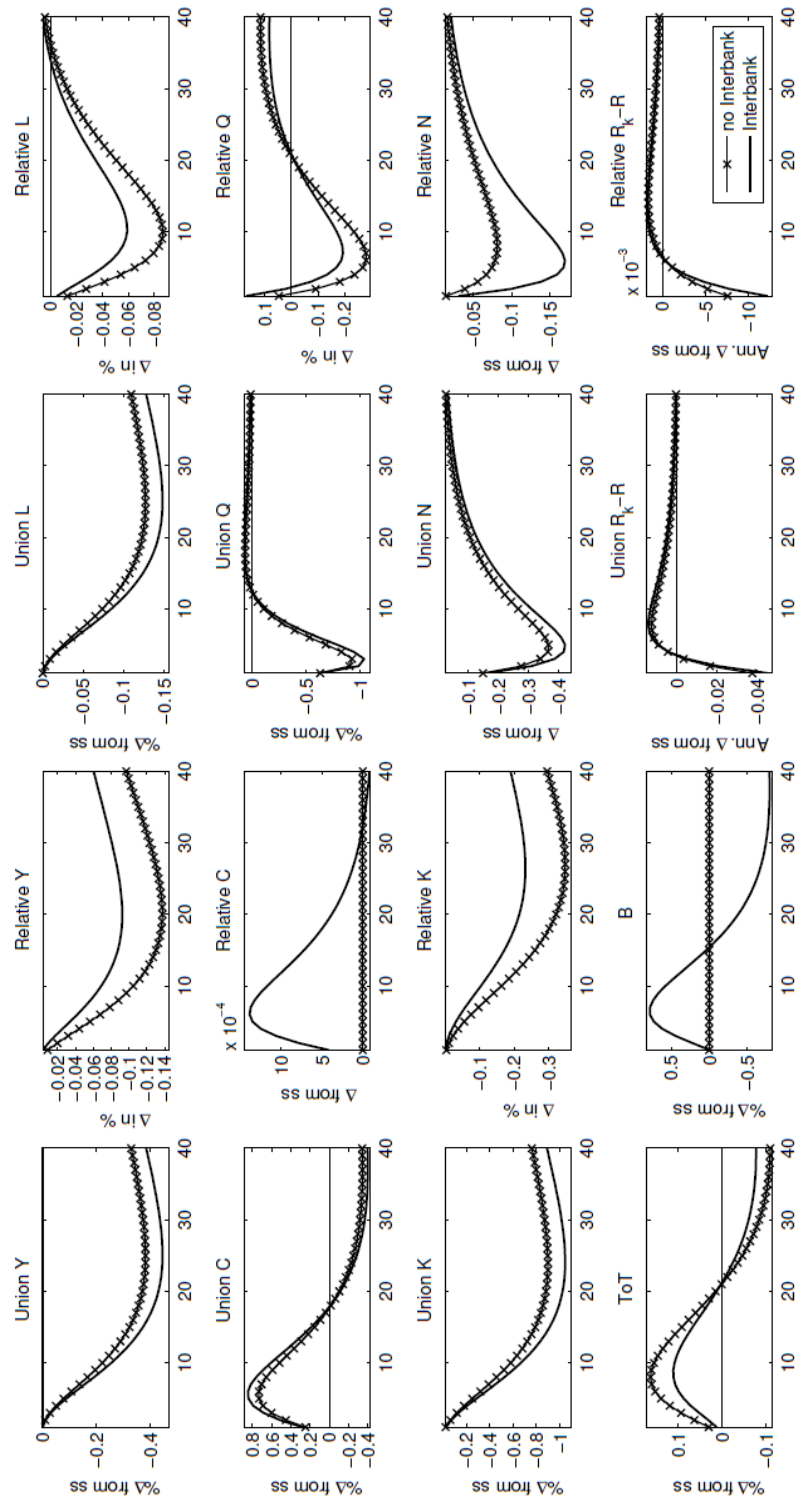
Figure 7: Impulse responses to an aggregate shock to banks' survival probability (con't)
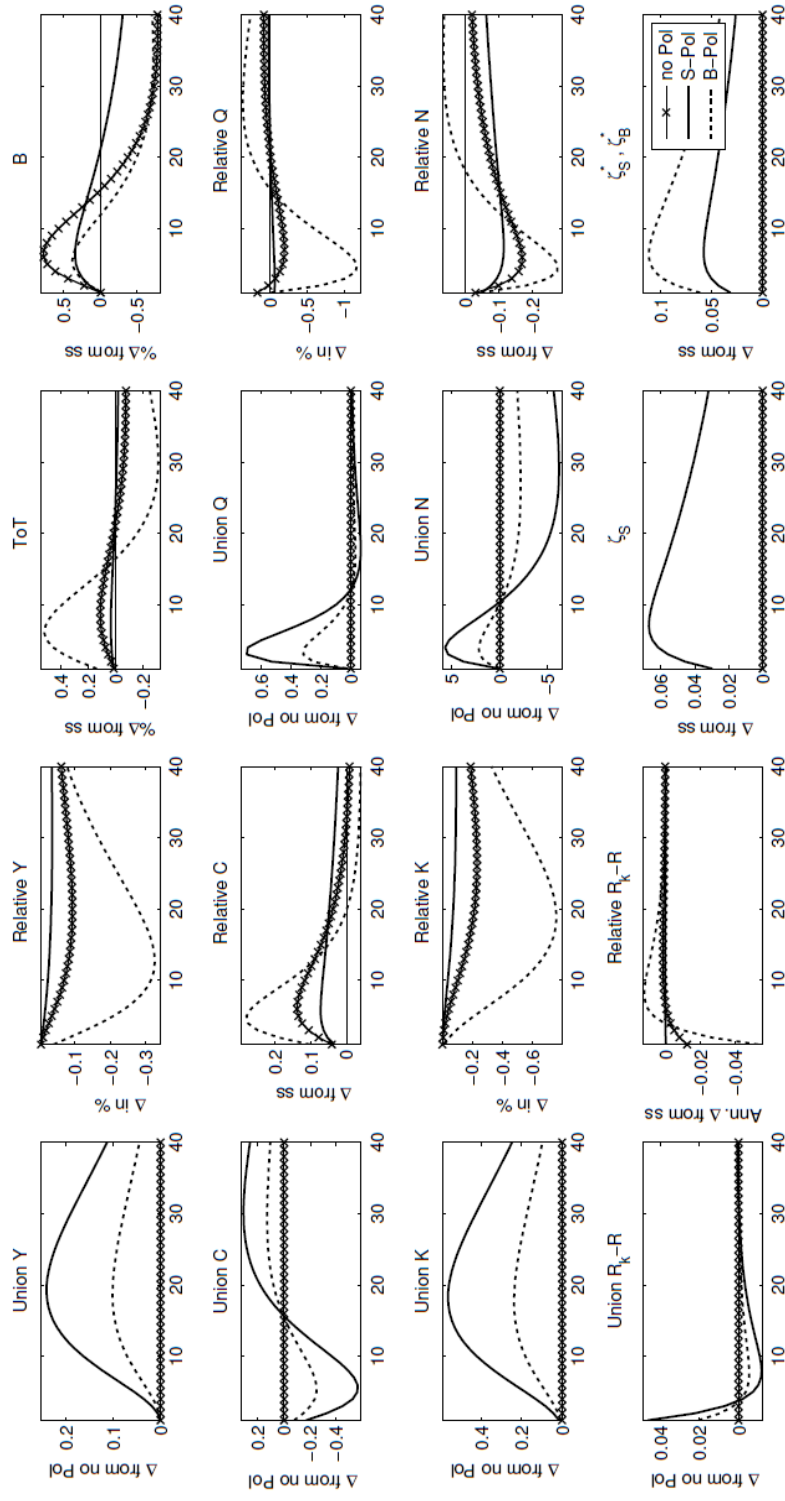
Figure 8: Impulse responses to an aggregate shock to banks' survival probability with policy interventions
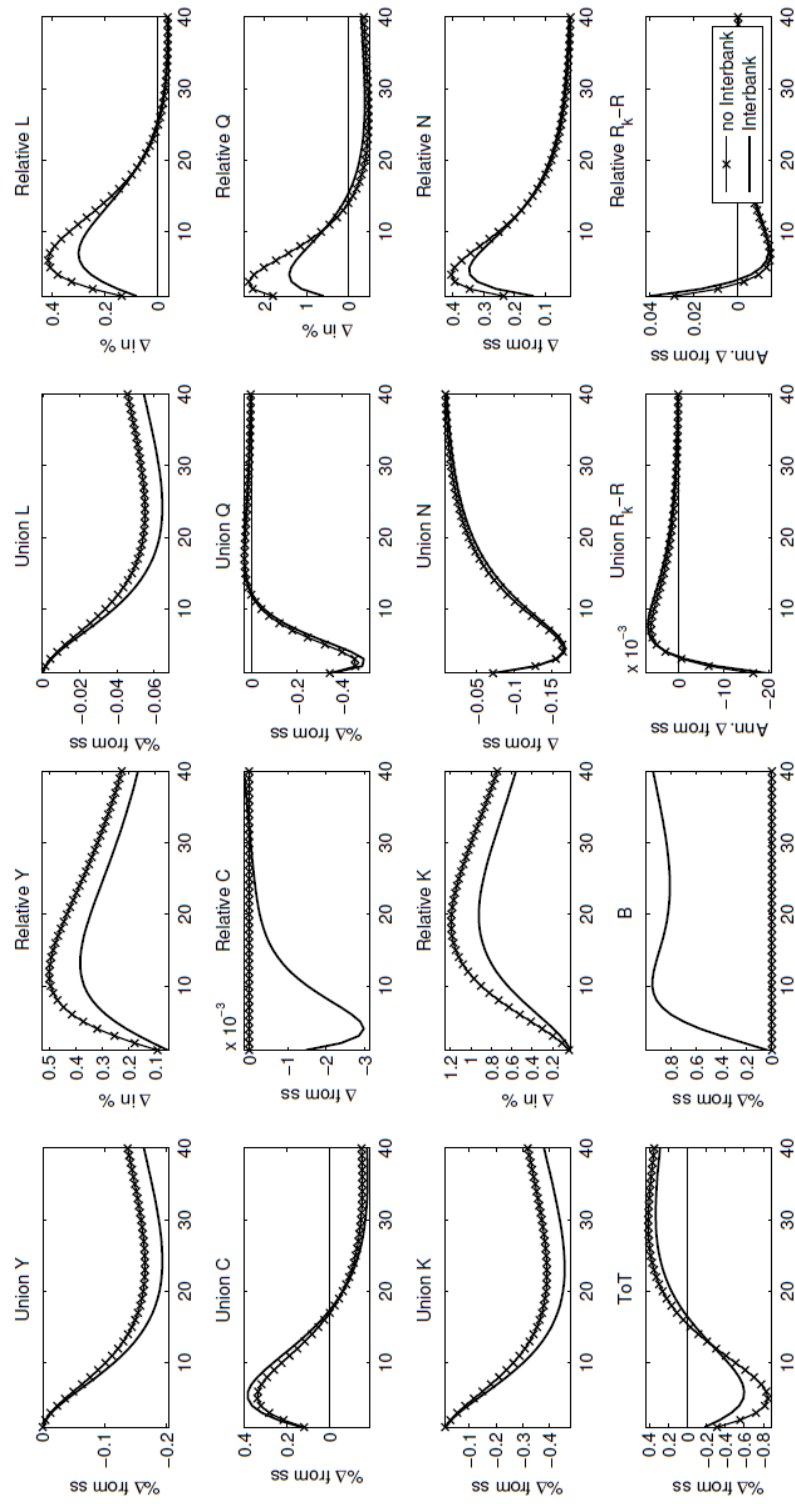
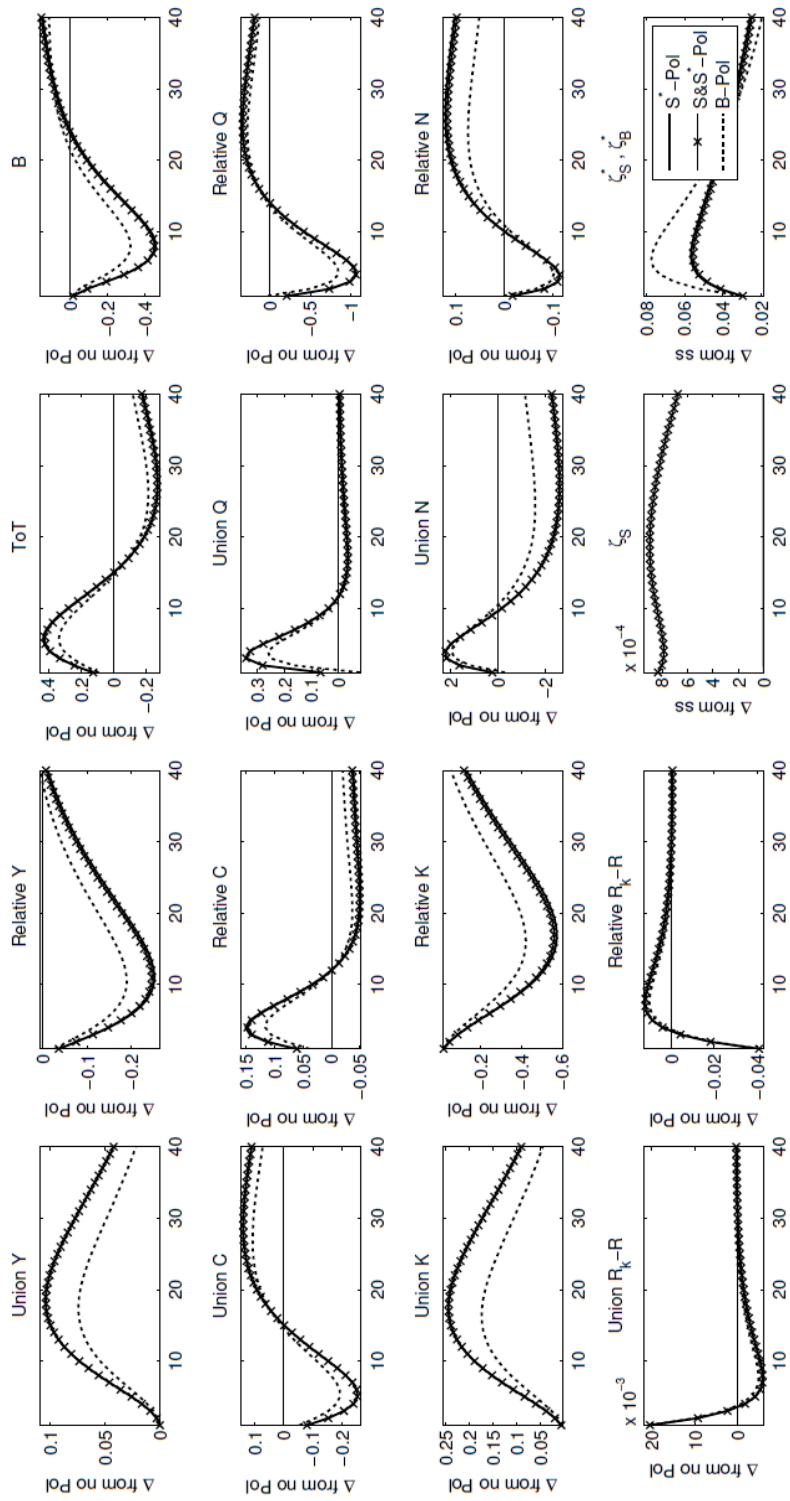Figure 9: Impulse responses to a shock to periphery banks' survival probability

Figure 10: Impulse responses to a shock to periphery banks' survival probability with policy interventions