Joint Discussion Paper
Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 24-2020

Philipp Kirchner and Benjamin Schwanebeck

Shadow Banking and the Design of Macroprudential Policy in a Monetary Union

Coordination: Bernd Hayo • Philipps-University Marburg
School of Business and Economics • Universitätsstraße 24, D-35032 Marburg
Tel: +49-6421-2823091, Fax: +49-6421-2823088, e-mail: hayo@wiwi.uni-marburg.de

Shadow banking and the design of macroprudential policy in a monetary union*

Philipp Kirchner[†] and Benjamin Schwanebeck[‡]

May 19, 2020

Abstract

This paper studies the interaction of international shadow banking with monetary and macroprudential policy in a two-country currency union DSGE model. We find evidence that cross-country financial integration through the shadow banking system is a source of financial contagion in response to idiosyncratic real and financial shocks due to harmonization of financial spheres. The resulting high degree of business cycle synchronization across countries, especially for financial variables, makes union-wide policy tools more effective. Nevertheless, optimal monetary policy at the union-level is too blunt an instrument to adequately stabilize business cycle downturns and needs to be accompanied by macroprudential regulation. Our welfare analysis reveals that the gains from the availability of country-specific prudential tools vanish with the degree of financial integration as union-wide macroprudential regulation is able to effectively reduce losses among the union members.

JEL-Classification: E32, E44, E58, F45

Keywords: financial frictions; shadow banking; currency union; financial integration; macroprudential policy

*Acknowledgements: We thank Jochen Michaelis and Hans-Joerg Schmerer for valuable commments.

[†]Department of Economics, University of Kassel, Nora-Platiel-Str. 4, D-34127 Kassel, Germany, Tel.: + 49 561-804-3085, E-mail: p.kirchner@uni-kassel.de.

[‡]Department of Economics, University of Hagen, Universitaetsstraße 47, D-58097 Hagen, Germany, Tel.: + 49 2331-987-4526, E-mail: benjamin.schwanebeck@fernuni-hagen.de.

1 Introduction

An unprecedented feature of the Global Financial Crisis (GFC) was the international synchronization of core macroeconomic real and financial variables. As lately pointed out by Perri and Quadrini (2018) or Imbs (2010), the decade before the GFC and the periods thereafter showed exceptionally high comovements in financial and business cycles along major industrialized countries. Among others, two distinctive features fostered these developments. On the one hand, the last decades showed a trend of financial globalization through cross-border banking activities, leading to an integration of financial systems (Claessens 2017). While this accounts for the bulk of advanced economies, it has especially been the case for Europe and the euro area. Prior to the GFC, EU and euro area located banks accounted for 57% of global cross-border banking flows (Emter et al. 2019). Intra-euro area cross-border banking flows likewise increased in importance. Amounting to €700 billion in 1999, they tripled until 2008 to reach roughly €2100 billion (Poutineau and Vermandel 2015). On the other hand, shadow banking gained in importance as a provider of credit. As it combined high leverage and excessive credit growth with missing regulatory requirements, shadow banking appeared as a significant vulnerability and risk to financial stability. In Europe, its amount increased from EUR 9 trillion in 2003 to EUR 31 trillion in 2017, reflecting roughly 40% of total euro area financial assets (Kirchner 2020). As regards the banking exposure towards EU and euro area shadow banking entities, Abad et al. (2017) show that one third of EU-banking exposure is towards shadow banking entities within EU member countries (largely within the euro area). In the wake of the GFC, these developments have been responded to with international regulatory reforms that resulted in macroprudential regulations aimed at the resilience and stability of financial systems (the BASEL III-accords). However, given tightly regulated banking sectors on the one hand, and largely unregulated shadow banking sectors on the other, a gap in financial stability policy emerges that may induce cross-sector substitution effects (Abad et al. 2017). This is especially important in the context of a monetary union within which financial linkages in combination with a single market and a common currency promote economic and financial integration and thereby a synchronization of real and financial variables. What arises as a natural question in this context then is to what extent country-specific (i.e. at the level of national authorities) or superordinate macroprudential measures (i.e. at the level of the ESRB and ECB) are able to mitigate the transmission and impact of shocks and how they interact with monetary policy.

In this paper, we address these considerations and develop a monetary DSGE-model to document the optimal design of macroprudential measures in the context of a monetary union within which shadow banking exists alongside retail banking. Our core model builds on the stylized two-country model with financial frictions of Dedola et al.

(2013) that we adjust to a two-country monetary union setup with nominal frictions and shadow banking. In this setup, retail banks collect deposits and bank equity from households and use these funds to make loans to domestic goods producers and domestic shadow banks (we loosely think of this as interbank credit). Shadow banks, however, are not able to collect deposits or equity from households and are dependent on funds from their sponsoring retail banks. They use interbank credit and retained earnings to make loans to both domestic and foreign intermediate goods producers. Accordingly, our benchmark scenario features financial integration realized through cross-border activities of shadow banks. As a result of this cross-border financial integration, the main financial variables are perfectly aligned internationally. A supranational central bank targets inflation through the union-wide nominal interest rate and macroprudential supervision follows the common BASEL III-Accords. We roughly capture these objectives through a capital buffer based on the outside equity ratio of retail banks. The policy rule reacts countercyclically to changes in credit spreads from its steady-state level as a sign for financial distress. More precisely, when a shock forces a deep recession with accompanied downturns in macroeconomic and financial variables, credit spreads tend to widen and hence put additional pressure on economic activity. In such a case, macroprudential policy reacts by allowing retail banks to operate at a higher leverage ratio through holding less equity capital against their outstanding assets. As this allows retail banks to operate their business with lower levels of capital, it moderates the process of deleveraging and motivates credit origination.

In this setup, we analyze the design of monetary and macroprudential policy when real (technology) and financial (net worth) shocks hit the monetary union. A financial shock unfolds equivalent destructive impacts in both countries while a real shock hits with varyingly strong impacts. The impact on the productive sectors depends on the nature of the shock (real vs. financial and union-wide vs. idiosyncratic shocks) while financial variables co-move as a result of integration in the financial sphere. Using regulatory policies in the setup of a monetary union then implies considerations on the country-specific vs. union-wide arrangement of such policies as internationally integrated financial markets might require common prudential standards (Cecchetti and Tucker 2016). We address these aspects and consider country-specific and union-wide macroprudential regulation and their optimal design to stabilize household welfare.

Our analysis allows the following results. In the case of shocks to the real sphere, we find that the existence of shadow banking intensifies the financial accelerator effects. Shadow banks, highly leveraged and dependent on retail banking funds, appear to be an additional source of instability and thus operate as a shock amplifier. However, during financial shocks, shadow banking under financial autarky rather operates as shock absorber as it can partly compensate the losses incurred by retail banks.

In terms of the optimal design of macroprudential policy, we find that regulation situated at the country-level is only beneficial under financial autarky or absent shadow banking. A sufficiently large stabilization of the relevant household welfare measure is only achieved once macroprudential regulation acts union-wide hence coordinated. Such a supranational macroprudential regulation that symmetrically intervenes in both countries of the union is able to effectively counteract the negative consequences of the observed shocks. While the gains are larger for financial shocks than for real shocks, they are even facilitated through the forces of financial integration. This result seems plausible as macroprudential regulation as based on BASEL III is primarily designed to address system-wide risk in the banking sector and hence financial stability (see e.g. BIS 2010). A policy designed to counteract the build-up of bank exposure is thus highly effective given shocks emanating from this very sector. Furthermore, the follow-up effect of union-wide macroprudential regulation is a more stringent setting of the policy rate through monetary policy. Since financial stability is cared for by the macroprudential regulator, monetary policy is now able to react more aggressively to its primary objective inflation. Moreover, our welfare analysis shows that under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. In such a case, neither financial integration nor macroprudential policy can compensate the additional losses. As the shadow banking sector in our model (and in general) is unregulated and highly leveraged, it constitutes a vulnerability to the stability of the financial system. A macroprudential regulator equipped with an entity-based regulation approach as in our case thus only indirectly affects the vulnerabilities originating from this sector.

To the best of our knowledge, this is the first paper that analyses the cross-border transmission of shocks and the effectiveness of macroprudential policy in a two-country monetary union model with shadow banking.

The paper is structured as follows: we review related literature in Section 2. In Section 3, we introduce the basic model and our monetary and macroprudential policies. Section 4 provides the dynamics of the model. We start with the calibration and then turn towards the international transmission of shocks and the corresponding analyses. We then discuss the implications of macroprudential policy at the country and union level, and analyze the welfare implications given the optimal design. Section 5 concludes.

2 Related Literature

Our analysis is related to several strands of literature. As we use a monetary DSGE setup with financial intermediaries, our analysis is related to the early wave of models that accounts for banks as intermediaries of financial capital between savers (households) and investors (firms). A seminal paper in this direction is Gertler and Karadi (2011). The authors implement retail banks into an otherwise standard monetary DSGE setup along the lines of Smets and Wouters (2003, 2007) and Christiano et al. (2005). Financial frictions arise as a moral hazard problem between banks and households and restrain banks in their ability to receive unlimited funding from households. In this setup, the authors study the impact of a capital quality shock and the ability of unconventional monetary policy measures (credit market interventions by the central bank) to stabilize the business cycle. The model by Gertler and Kiyotaki (2011) resembles the former except for they implement liquidity risk (in the sense of Kiyotaki and Moore 2012) and abstract from nominal rigidities. Given this setup, the authors analyze unconventional credit policies conducted by the central bank. In Gerali et al. (2010), the banking sector is modeled in monopolistic competition as opposed to perfect competition in Gertler and Karadi or Gertler and Kiyotaki. The authors use the setup to study the impact of real and financial shocks (e.g. bank capital loss) on the business cycle.

Whereas the former papers consider closed-economy models, our model is a two-country setup with international financial flows within a currency union. Accordingly, we join the ranks of the strand of literature that deploys open economy models to study cross-country banking activities and financial flows and the international transmission of shocks. For example, Dedola et al. (2013) use a two-country model with symmetric countries and financial intermediation in the sense of Gertler and Karadi (2011). The financial market is integrated internationally in that households can make deposits in home and foreign banks, and banks can lend internationally to firms. Given this setup, they study the international transmission of financial and real shocks and implement different unconventional credit policies in cooperative and noncooperative settings. Opposed to this, Nuguer (2016) develops a two-country model with an international interbank market where banks can lend to each other on an international scale. As this transmits shocks from one country to another, the setup is used to study the international transmission of shocks through bank balance sheets and the model response to different credit policy measures. While these papers consider two independent countries, we use the setup of a currency union. We are thus close to the approach of Poutineau and Vermandel (2015) who build a two-country DSGE setup for the euro area and study the transmission of shocks through cross-border banking flows. Quint and Rabanal (2014) use an estimated two-country model fitted to the euro area and study the interaction of monetary and macroprudential policies.

In all of the previous models, financial intermediation is conducted trough traditional banking only. We depart from this literature in that we model heterogeneous financial intermediaries as observed before and during the crisis. We thus contribute to a recent strand of literature considering shadow banking alongside traditional (retail) banking. However, while this strand uses closed-economy setups, we implement shadow banking into a two-country monetary union model. In Gertler et al. (2016), the financial intermediation setup of Gertler and Karadi (2011) and the model of banking instability of Gertler and Kiyotaki (2015) are extended to feature a wholesale banking sector, i.e. shadow banking. The authors consider wholesale banks to be borrowers on the interbank market, i.e. "sponsored" by other banks, and to have comparative advantages in managing financial capital. Retail banks use household deposits and are lenders in the interbank market. The authors forgo the productive side and use a financial setup to study bank runs and intervention policies (both macroprudential and monetary). In Meeks et al. (2017), the interaction of retail banks and shadow banks is based on the ability of shadow banks to transform illiquid loans into tradable assets (ABS) of higher collateral value that are purchased by retail banks. Given this setup, the authors analyze the impact of a liquidity crisis and the possibilities of intervention policies to stabilize business cycles. The model by Verona et al. (2013) considers shadow banking as monopolistic competitive investment banks that provide safe credit to a subset of entrepreneurs. Verona et al. (2013) show that once enriching their setup with shadow banks, the model produces impulse response functions to monetary policy shocks that are more in line with empirical observations. Fève et al. (2019a) deploy a calibrated model with retail and shadow banking to evaluate the impact of different macroprudential policies. Kirchner and Schwanebeck (2017) use a setup with retail and shadow banks in the sense of Gertler et al. (2016) to study the optimal design of unconventional monetary policy measures.

Motivated by the GFC, there is a large strand of literature that examines the role of macroprudential policies in DSGE setups with financial intermediaries. We contribute to this strand by analyzing these policies in the context of shadow banking. Noteworthy examples are Angelini et al. (2014) who use the setup of Gerali et al. (2010) and study optimal macroprudential and monetary policies. To this end, the authors deploy a time-varying capital requirement that follows a policy rule reacting to deviations of a loan-to-output ratio to its steady-state level. The optimal degree of intervention is dependent on the ability to minimize the regulators loss function, either in cooperative or noncooperative behavior with the central bank. Poutineau and Vermandel (2017) use a two-country monetary union model with interbank cross-border loan flows between the core and periphery of the union. The authors implement macroprudential regulation that sets a time-varying capital requirements either reacting to loan supply, loan demand or capital flows. As they study the monetary union case, regulators can act national or union-wide. In contrast, Palek and Schwanebeck (2019) use a two-country monetary union model to study welfare-based optimal monetary and macroprudential policy. In their setup, macroprudential policy is a country-specific countercyclical capital requirement set by the welfare maximizing central bank.

3 The Basic Model

The core framework builds on the stylized two-country model with financial frictions of Dedola et al. (2013). We extend this model by allowing for nominal frictions and by implementing shadow banking. In particular, in contrast to Dedola et al. (2013), the two perfectly symmetric countries belong to a currency union. Each country consists of the following agents: households, capital producers, intermediate goods producers, retailers and financial intermediaries split into retail and shadow banks. The financial sector is modelled in the following way: in both countries, traditional retail banks and shadow banks supply the respective productive sector with financial capital. Additionally, shadow banks are internationally active and provide credit to domestic and foreign intermediate goods producers. Financial frictions follow the approach of Gertler and Karadi (2011) and are modelled as an agency problem in the intermediation of funds. For retail banks, it limits the access to deposits from households and for shadow banks the access to funds from retail banks. In this way, financial frictions affect the availability of funds that banks can allocate to intermediate goods producers.

We normalize the total population to one, where the population on the segment $[0, m)$ belongs to the home country, while the population on $[m, 1]$ belongs to the foreign counterpart. The presentation of the model focuses on country Home. Due to assumed symmetry, foreign equations are equivalent. We denote foreign variables by an asterisk.

3.1 Households

A continuum of representative infinitely-lived households consumes final goods, saves at retail banks and supplies labor to goods producers. Each household consists of three members: workers, retail bankers and shadow bankers. As empirical patters show that international deposit flows are negligible (see Poutineau and Vermandel 2015), households can only save at domestic retail banks. Workers return the wage they earn back to their respective household and so do bankers with their retained earnings once they have to shut down the bank and leave the industry. Bankers who leave become new workers and to keep the family members constant over time, a corresponding fraction of workers becomes new bankers. To start the banking business, each new banker receives startup funds from her respective household.

The representative infinitely-lived household maximizes the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\rho}}{1-\rho} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

with consumption index C_t and labor L_t. The parameters β, ρ, χ, and φ are the discount factor, the inverse of the elasticity of intertemporal substitution, the utility weight on labor, and the inverse Frisch elasticity, respectively. The flow of funds reads

$$C_t + D_t + q_t e_t = W_t L_t + R_{t-1} D_{t-1} + R_{e,t} q_{t-1} e_{t-1} - G(q_t e_t) + \Pi_t - T_t. \tag{2}$$

We follow Gertler et al. (2012) and Nelson and Pinter (2018) and allow households to save in two forms: deposits D_t and bank outside equity e_t priced at q_t. Whereas the former is a liquid demand deposit and risk-free as it is a non-state contingent claim, the latter depicts a claim that is contingent on the cash-flows of the bank and a rather illiquid claim as changes to the portfolio are costly. As mentioned above, the income of the household is composed of the real wage W_t earned on hours worked L_t and gross real returns R_{t-1} and $R_{e,t}$ on savings in the form of domestic deposits D_{t-1} and holding bank outside equity e_{t-1} at price q_{t-1} between $t-1$ to t minus adjustment costs $G(q_t e_t)$ for the equity portfolio. Π_t are net earnings from the ownership of firms, retained earnings from banks and paid startup funds for new bankers while T_t denotes lump-sum taxes.

Maximizing the households utility function subject to the flow of funds constraint yields the first-order conditions for labor supply, consumption and bank equity:

$$U_{C_t} W_t = \chi L_t^{\varphi} \tag{3}$$

$$E_t \Lambda_{t,t+1} R_t = 1 \tag{4}$$

$$E_t \Lambda_{t,t+1} R_{e,t+1} = 1 + G'(q_t e_t). \tag{5}$$

The marginal utility of consumption is defined as

$$U_{C_t} \equiv C_t^{-\rho} \tag{6}$$

and the households stochastic discount factor is

$$\Lambda_{t,t+1} \equiv \beta_t \frac{U_{C_{t+1}}}{U_{C_t}}. \tag{7}$$

The consumption index is defined as

$$C_t \equiv \left[\frac{(C_{H,t})^m (C_{F,t})^{1-m}}{m^m (1-m)^{1-m}} \right], \tag{8}$$

where $C_{H,t}$ and $C_{F,t}$ are consumption bundles of domestic and foreign goods.[1] Let $P_{H,t}$ ($P_{F,t}$) be the producer price index in country H (F) so that the corresponding consumer

[1] The definition implies an elasticity of substitution between the two bundles of goods that is restricted to unity. This so-called "macro" Armington elasticity of one can be justified by recent research as for example Feenstra et al. (2018).

price index is given by $P_t = (P_{H,t})^m (P_{F,t})^{1-m}$. Prices are set in the origin country, but due to the absence of trade barriers, the law of one price holds for each good. Assuming identical preferences in both countries of the monetary union results in the purchasing power parity condition $P_t = P_t^*$. By taking prices as given and by making use of the definition of the terms of trade as the relative price of foreign goods in terms of home goods, i.e. $ToT_t \equiv P_{F,t}/P_{H,t}$, cost minimization leads to the standard demand functions

$$C_{H,t} = mToT_t^{1-m}C_t \tag{9}$$
$$C_{F,t} = (1-m)ToT_t^{-m}C_t. \tag{10}$$

We assume that the adjustment costs for bank equity holdings of households are quadratic and are scaled by the total amount of retail banks' assets $(S_{r,t} + B_{r,t})$. The functional form reads:

$$G(q_t e_t) = \frac{\eta_e}{2}\left(\frac{q_t e_t/(S_{r,t}+B_{r,t})}{qe/(S_r+B_r)} - 1\right)^2 \frac{qe}{(S_r+B_r)}(S_{r,t}+B_{r,t}), \tag{11}$$

where variables without a time subscript denote steady-state values. By defining retail banks' outside equity ratio as

$$\tau_t \equiv \frac{q_t e_t}{S_{r,t}+B_{r,t}}, \tag{12}$$

the marginal portfolio costs are

$$G'(q_t e_t) = \eta_e\left(\frac{\tau_t}{\tau} - 1\right). \tag{13}$$

Using (4) in combination with (5) gives the equity supply curve:

$$E_t\Lambda_{t,t+1}(R_{e,t+1} - R_t) = \eta_e\left(\frac{\tau_t}{\tau} - 1\right). \tag{14}$$

This equation depicts the costs to the household of supplying equity to the banking system. If the marginal adjustment costs increase due to a rise in retail bank's equity ratio, households demand a higher return on their equity holdings compared to deposits. Accordingly, the spread $(R_{e,t+1} - R_t)$ rises.

3.2 Intermediate goods producers

Perfectly competitive goods firms use a Cobb-Douglas production function given by

$$Y_{m,t} = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{15}$$

to produce intermediate output $Y_{m,t}$, that is sold to retailers at the real price $P_{m,t}$. Total factor productivity A_t follows an exogenous autoregressive process in order to capture technology shocks. 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 $(1-\delta)K_t$:

$$S_t = I_t + (1-\delta)K_t. \tag{16}$$

At the beginning of the next period, capital in process is transformed into capital for production purposes according to

$$K_{t+1} = S_t. \tag{17}$$

Since goods producers have no own financial resources at their disposal to rent capital from capital goods producers, they obtain funds (loans) from financial intermediaries in exchange for perfectly state-contingent securities. For simplicity, we assume that the intermediation process between goods producers and banks is frictionless. Banks can perfectly monitor goods producers and enforce all contractual obligations while firms can perfectly commit to pay all future returns to the bank. Each unit of security is a perfect claim on the future payouts of a unit of capital and priced at Q_t, the price for new capital. Accordingly, financial intermediaries are exposed to fluctuations in the price of capital.

Profit maximization of the goods producers leads to the first-order conditions for labor input

$$W_t = (1-\alpha)\frac{P_{m,t}Y_{m,t}}{L_t}, \tag{18}$$

and capital input, formulated as the real return on capital

$$R_{k,t} = \frac{\alpha\frac{P_{m,t}Y_{m,t}}{K_t} + (1-\delta)Q_t}{Q_{t-1}}. \tag{19}$$

As bank loans are claims on the capital, they yield the same return $R_{k,t}$. On the other hand, outside equity can be understood as claims on the banking sector and therefore also claims on capital. Hence, they yield the following real return:

$$R_{e,t} = \frac{\alpha\frac{P_{m,t}Y_{m,t}}{K_t} + (1-\delta)q_t}{q_{t-1}}. \tag{20}$$

3.3 Capital goods firms

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

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{21}$$

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

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{t,t+1} \left\{ Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \right\}. \tag{22}$$

Profit maximization leads to the standard price of capital

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{23}$$

3.4 Retailers

Monopolistically competitive retailers produce final goods by using the intermediate output as input and label it at no cost. Thus, final domestic output Y_t as a CES aggregate of a continuum of retail output is given by

$$Y_t = \left[\int_0^1 \left(Y_t\left(h\right)\right)^{\frac{\varepsilon-1}{\varepsilon}} dh\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{24}$$

where $Y_t\left(h\right)$ denotes the output of retailer h and ε is the elasticity of substitution between goods. Cost minimization leads to

$$Y_t\left(h\right) = \left(\frac{P_{H,t}\left(h\right)}{P_{H,t}}\right)^{-\varepsilon} Y_t,\ P_{H,t} = \left[\int_0^1 \left(P_{H,t}\left(h\right)\right)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{25}$$

To introduce nominal rigidities, we introduce price setting à la Calvo (1983) and assume that only the fraction $1-\zeta$ of retailers is able to adjust their prices each period, whereas the fraction ζ of retailers cannot reset their prices. The retailers optimization problem boils down to choose the optimal price $P^*_{H,t}$ in order to maximize profits following

$$\max E_0 \sum_{t=0}^{\infty} \zeta^i \Lambda_{t,t+1} \left[\frac{\overline{P}_{H,t}}{P_{H,t+1}} - T_m P_{m,t+1} \right] Y_{t+1}(h), \tag{26}$$

where $T_m = (\varepsilon - 1)/\varepsilon$ is a steady-state subsidy financed by lump-sum taxes in order to eliminate steady-state inefficiencies due to monopolistic competition. The first-order condition is given by

$$E_0 \sum_{t=0}^{\infty} \zeta^i \Lambda_{t,t+1} \left[\frac{\overline{P}_{H,t}}{P_{H,t+1}} - \frac{\varepsilon}{\varepsilon - 1} T_m P_{m,t+1} \right] Y_{t+1}(h) = 0 \tag{27}$$

and the domestic aggregate price index evolves according to

$$P_{H,t} = \left[(1-\zeta)(\overline{P}_{H,t})^{1-\varepsilon} + \zeta (P_{H,t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \tag{28}$$

3.5 Financial intermediaries

Within each country, financial intermediaries are responsible for channeling funds from savers (households) to investors (intermediate goods firms). An important feature of integrated currency unions are cross-border interactions of large banks with shadow banking entities that are active in multiple countries. We capture this phenomenon by allowing retail banks to shift parts of their balance sheet, namely interbank credits, to domestic shadow banking entities that are able to invest in both countries. Hence, cross-border financial integration is realized via the shadow banking system which is therefore crucial in transmitting shocks and fluctuations between the countries. In this setup, retail banks collect deposits and bank equity from households and use these funds to make loans to domestic goods producers and domestic shadow banks. Shadow banks are not able to collect deposits or equity from households and are dependent on funds from their sponsoring retail banks. They use interbank credit and retained earnings to make loans to both domestic and foreign intermediate goods producers.

3.5.1 Retail banking

Perfectly competitive retail banks are managed by bankers and owned by households. At the beginning of period t, retail bank j uses deposits $D_{j,t}$ from households other the ones they own, net worth $N_{j,r,t}$ from retained earnings and outside equity $e_{j,t}$ at price q_t to fund loan origination consisting of loans to goods producers $S_{j,r,t}$, priced at Q_t, and interbank loans to the shadow banking system $B_{j,r,t}$. We can write the balance sheet identity during period t as

$$Q_t S_{j,r,t} + B_{j,r,t} = D_{j,t} + q_t e_{j,t} + N_{j,r,t}. \tag{29}$$

Net worth $N_{j,r,t+1}$ evolves as the difference between interest earnings $R_{k,t+1}$ on non-financial loans $S_{j,r,t}$ and earnings $R_{b,t+1}$ from interbank loans $B_{j,r,t}$ to shadow banks net of obligations for deposits $D_{j,t}$ at R_t and outside equity $q_t e_{j,t}$ at $R_{e,t+1}$. It reads

$$\begin{aligned} N_{j,r,t+1} &= (1+T_k) R_{k,t+1} Q_t S_{j,r,t} + R_{b,t+1} B_{j,r,t} - R_t D_{j,t} - R_{e,t+1} q_t e_{j,t} \\ N_{j,r,t+1} &= \left((1+T_k) R_{k,t+1} - R_t - \left(R_{e,t+1} - R_t\right) \tau_{j,t}\right) Q_t S_{j,r,t} + \\ &\quad \left(R_{b,t+1} - R_t - \left(R_{e,t+1} - R_t\right) \tau_{j,t}\right) B_{j,r,t} + R_t N_{j,r,t}, \end{aligned} \tag{30}$$

where T_k is a steady-state subsidy to banks financed by lump-sum taxes in order to eliminate steady-state inefficiencies due to frictional financial intermediation. Hereby, we follow Nelson and Pinter (2018) and implement this subsidy to pin the steady-state credit spread down to zero, i.e. $R_k = R$. Therefore, the steady state of the real side of the model will be equivalent to the one of a real business cycle model. Besides, note that net worth of the retail banker is decreasing in the outside equity ratio $\tau_t(j)$ when $R_{e,t+1} - R_t > 0$.

Whereas net worth is an ensured endowment for the retail banker, the acquisition of deposits and equity from households is dependent on a moral hazard problem between the two parties. It follows Gertler and Karadi (2011) and limits the ability of retail banks to obtain funds by assuming that banks have an incentive to run away with (i.e. divert) a fraction of their balance sheet. In doing so, retail banks extract the fraction θ_r, return it back to their household and announce bankruptcy in the next period since the remaining fraction $1 - \theta_r$ is reclaimed from the other households. Accordingly, households are only willing to supply deposits and equity to banks if they observe that banks will remain active and proceed with doing business in the ongoing periods. Let the discounted future payouts from accumulating net worth and hence the incentive from staying in business be $V_{r,t}$, then the incentive constraint for the retail banker reads

$$V_{j,r,t} \geq \theta_r \left[Q_t S_{j,r,t} + \gamma B_{j,r,t}\right]. \tag{31}$$

The timing is that still in period t but after raising new deposits and equity, banks decide about diverting instead of maximizing the value of net worth. This is noticed by households at the beginning of the next period $t+1$ and immediately turns into bankruptcy for the banker. We are assuming that the ability to divert assets is dependent on the use of funds. Funds used for firm credit supply are governed by θ_r $(0 < \theta_r < 1)$ and funds for the shadow banking sector (interbank loans) are governed by $\theta_r \gamma$ with $(0 < \gamma < 1)$. This means that domestic non-financial loans are easier to divert compared to interbank loans. We think of this as reflecting different collateral values of assets (based on Meeks et al. 2017).

The value function of the retail banker is given by the following Bellman equation:

$$V_{j,r,t} = E_t \Lambda_{t,t+1} \left[(1-\sigma) N_{j,r,t+1} + \sigma V_{j,r,t+1} \right], \tag{32}$$

where σ is the surviving probability and $\Lambda_{t,t+1}$ the discount factor (same as for households since bankers are members of the very same). When bankers have to exit the industry with probability $(1-\sigma)$, they return the acquired net worth back to their household. Otherwise, they continue to maximize the value of the bank.

Retail banks are supervised by a macroprudential regulator that sets the outside equity ratio $\tau_{j,t}$, which we will call the capital buffer, to avoid excessive leverage. As the supply of outside equity from households is increasing in $R_{e,t+1}$ over R_t, the capital buffer in (30) restricts the accumulation of net worth when $R_{e,t+1} - R_t > 0$. Lower levels of net worth reduce the value of the bank in (32), thereby tighten the incentive constraint (31) and reduce credit supply. As the macroprudential authority sets a capital buffer requirement that is identical for all retail banks, we will drop the index j.

The retail banker chooses $S_{j,r,t}$, $B_{j,r,t}$ to maximize (32) subject to (30), (31), and the capital buffer requirement τ_t. We formalize this maximization problem by guessing (and later verifying) that the franchise value of the bank can be written as

$$\begin{aligned} V_{j,r,t} &= \upsilon_{rs,t} Q_t S_{j,r,t} + \upsilon_{rb,t} B_{j,r,t} - \upsilon_{rd,t} D_{j,t} - \upsilon_{re,t} q_t e_{j,t} \\ V_{j,r,t} &= \left(\upsilon_{rs,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t} \right) \tau_t \right) Q_t S_{j,r,t} \\ &\quad + \left(\upsilon_{rb,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t} \right) \tau_t \right) B_{j,r,t} + \upsilon_{rd,t} N_{j,r,t}, \end{aligned} \tag{33}$$

where the coefficients $\upsilon_{rs,t}$, $\upsilon_{rb,t}$, $\upsilon_{rd,t}$, and $\upsilon_{re,t}$ are the marginal values of each balance sheet item except for $N_{j,r,t}$ as the marginal value of net worth is equal to the marginal value of $D_{j,t}$.

The first-order conditions can be combined to yield

$$\left(\upsilon_{rs,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t} \right) \tau_t \right) = \frac{1}{\gamma} \left(\upsilon_{rb,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t} \right) \tau_t \right). \tag{34}$$

The left-hand side expresses the excess return (adjusted for outside equity) for the retail bank of assigning another unit of credit to firms. The right-hand side shows that providing interbank loans has two effects. On the one hand, the retail banker receives an excess return (adjusted for outside equity) of assigning another unit of interbank loan. On the other hand, these loans lead to a relaxation of the incentive constraint governed by γ and the resulting increased willingness of households to supply further deposits. As both effects have to equal the excess return of assigning another unit of credit to firms, the retail banker accepts a lower excess return on interbank loans if the corresponding relaxation effect via γ is strong enough

Combining (34), the guess (33) and the incentive constraint (31) yields a formula for the ratio of total assets to net worth that the households are willing to accept:

$$\frac{Q_t S_{j,r,t} + \gamma B_{j,r,t}}{N_{j,r,t}} = \frac{\upsilon_{rd,t}}{\theta_r - (\upsilon_{rs,t} - \upsilon_{rd,t} - (\upsilon_{re,t} - \upsilon_{rd,t})\,\tau_t)} \equiv \phi_{r,t} \tag{35}$$

which we define as leverage ratio $\phi_{r,t}$. By using this equation together with the Bellman equation (32) and the guess (33), we can rewrite the value function of the retail banker as

$$V_{j,r,t} = E_t \Lambda_{t,t+1} \Omega_{r,t+1} N_{j,r,t+1}, \tag{36}$$

where $\Omega_{r,t+1} = 1 - \sigma + \sigma\left(\upsilon_{rd,t+1} + (\upsilon_{rs,t+1} - \upsilon_{rd,t+1} - (\upsilon_{re,t+1} - \upsilon_{rd,t+1})\,\tau_{t+1})\,\phi_{r,t+1}\right)$ and $N_{j,r,t+1}$ is given by (30). Due to the financial friction, the stochastic discount factor of retail banks differs from that of households by the factor Ω_{rt+1}.

To verify the initial guess, the coefficients of (33) have to satisfy

$$\begin{aligned} \upsilon_{rs,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} (1 + T_k) R_{k,t+1} \\ \upsilon_{rb,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_{b,t+1} \\ \upsilon_{rd,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_t \\ \upsilon_{re,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_{e,t+1}. \end{aligned} \tag{37}$$

These equations together with the "allowed" leverage ratio (35) show how the retail bank is limited in the provision of loans and restricted to its net worth. Note, that the leverage ratio is the same for all retail banks as it does not depend on specific factors of bank j. Hence, we can drop the index j. The leverage ratio is increasing in the excess return on firm credits, $\upsilon_{rs,t} - \upsilon_{rd,t}$, as well as in the marginal value of net worth $\upsilon_{rd,t}$ since both increase the incentive to stay in business and therefore households show a higher willingness to deposit funds. The opposite is true for θ_r: the higher the ability to divert funds, the lower the willingness of households to deposits funds. The lower is γ, the larger the incentive-constraint relaxing effect of interbank loans as retail banks can provide more interbank loans while operating with the same (allowed) leverage ratio. The capital buffer requirement also enters the leverage ratio (35). As mentioned above, an increase in τ_t restricts the accumulation of net worth, given $R_{e,t+1} - R_t > 0$. This lowers the franchise value of the retail bank, and hence tightens the incentive constraint. Households have a lower willingness to deposit funds which is equivalent to a lower accepted leverage ratio.

Aggregate retail banks' net worth in the home country is given by the sum of surviving bankers' net worth which evolves according to (30) and entering bankers' startup funds, which is given by $\xi_r[R_{k,t}Q_{t-1}S_{r,t-1} + R_{b,t}B_{r,t-1}]/(1-\sigma)$ and provided by their respective household. Thus, aggregate net worth evolves according to

$$\begin{aligned} N_{r,t} &= \left((1+T_k)\sigma + \xi_r\right) R_{k,t}Q_{t-1}S_{r,t-1} + \left(\sigma + \xi_r\right) R_{b,t}B_{r,t-1} \\ &\quad -\sigma R_{t-1}D_{t-1} - \sigma R_{e,t}\left(Q_{t-1}S_{r,t-1} + B_{r,t-1}\right)\tau_{t-1}. \end{aligned} \tag{38}$$

3.5.2 Shadow banking

We model shadow banking as a subset of financial intermediation that has access to funds from domestic retail banks. By combining these interbank funds with their own net worth, shadow banks (or wholesale banks) make loans to both domestic and foreign intermediate goods firms. A core difference to retail banks lies in the assumption that shadow banks do not have access to deposits from households. As experienced during the GFC, shadow banking is mainly dependent on sponsoring retail banks and invested in multiple countries.

Accordingly, at the beginning of period t, shadow banker j uses net worth $N_{j,w,t}$ from retained earnings and interbank funds from domestic retail banks $B_{j,w,t}$ to make loans to domestic and foreign intermediate goods producers $Q_tS_{H,j,w,t} + Q_t^*S_{F,j,w,t}$. The balance sheet during period t writes

$$S_{j,w,t} \equiv Q_tS_{H,j,w,t} + Q_t^*S_{F,j,w,t} = N_{j,w,t} + B_{j,w,t}. \tag{39}$$

Net worth in period $t+1$ evolves as the difference between earnings from loans $Q_tS_{H,j,w,t}$ and $Q_t^*S_{F,j,w,t}$ at $R_{k,t+1}$ and $R^*_{k,t+1}$ net off obligations to pay for the acquired funds $B_{j,w,t}$ at rate $R_{b,t+1}$. It evolves as

$$\begin{aligned} N_{j,w,t+1} &= (1+T_k)R_{k,t+1}Q_tS_{H,j,w,t} + R^*_{k,t+1}Q_t^*S_{F,j,w,t} - R_{b,t+1}B_{j,w,t} \\ N_{j,w,t+1} &= \big((1+T_k)R_{k,t+1} - R_{b,t+1} - \big((1+T_k)R_{k,t+1} - (1+T_k^*)R^*_{k,t+1}\big)\,x_{j,w,t}\big)\,S_{j,w,t} \\ &\quad +R_{b,t+1}N_{j,w,t}, \end{aligned} \tag{40}$$

where $x_{j,w,t} \equiv Q_t^*S_{F,j,w,t}/S_{j,w,t}$ denotes the share of foreign loans in the total amount of assets. Note that in order to have an efficient steady state both retail and shadow banks must receive the steady-state subsidy

Similar to retail banks, shadow banks are constrained in their ability to raise funds from domestic retail banks due to a moral hazard problem. Retail banks are only willing to supply funds to shadow banks, if the latter can stick to the following incentive constraint:

$$V_{j,w,t} \geq \theta_w S_{j,w,t}. \tag{41}$$

It compares the gain from remaining in business (the franchise value $V_{j,w,t}$) with the gain from diverting a fraction of the balance sheet θ_w, returning it back to the own household and declaring bankruptcy in the following period. Accordingly, retail banks are only willing to supply interbank funds to shadow banks if they observe that shadow banks will remain active and proceed with doing business in the ongoing periods. We assume that there is no differentiation between domestic and foreign assets. This is similar to the one in Dedola et al. (2013), where retail banks are the only financial intermediaries which face an identical problem. However, we think that this assumption holds even more so for shadow banks since they bundle those assets together to issue $B_{j,w,t}$ which can be thought of as asset-backed securities.

The franchise value function of the shadow banker can also be written as Bellman equation

$$V_{j,w,t} = E_t \Lambda_{t,t+1} \left[(1-\sigma) N_{j,w,t+1} + \sigma V_{j,w,t+1} \right], \tag{42}$$

where σ is the surviving probability of the shadow bank and $\Lambda_{t,t+1}$ the stochastic discount factor, which again is the same as for households. The shadow banker chooses $S_{j,w,t}$, $x_{j,w,t}$ to maximize this franchise value subject to (40), (41). We formalize this maximization problem by using the following linear solution as guess

$$\begin{aligned} V_{j,w,t} &= \upsilon_{ws,t} Q_t S_{H,j,w,t} + \upsilon_{ws*,t} Q_t^* S_{F,j,w,t} - \upsilon_{wb,t} B_{j,w,t} \\ V_{j,w,t} &= \left(\upsilon_{ws,t} - \upsilon_{wb,t} - \left(\upsilon_{ws,t} - \upsilon_{ws*,t} \right) x_{j,w,t} \right) S_{j,w,t} + \upsilon_{wb,t} N_{j,w,t} \end{aligned} \tag{43}$$

where the coefficients $\upsilon_{ws,t}$ and $\upsilon_{ws*,t}$ are the marginal values of loans to domestic and foreign intermediate goods producers while $\upsilon_{wb,t}$ is the marginal value of net worth. The first-order conditions lead to a standard portfolio choice condition

$$\upsilon_{ws,t} = \upsilon_{ws*,t}, \tag{44}$$

stating that both marginal values have to be equalized.

Combining this equation, the conjecture (43) and the incentive constraint (41) yields a formula for the ratio of total assets to net worth that the retail banks are willing to accept:

$$\frac{S_{j,w,t}}{N_{j,w,t}} = \frac{\upsilon_{wb,t}}{\theta_w - \left(\upsilon_{ws,t} - \upsilon_{wb,t} \right)} \equiv \phi_{w,t}, \tag{45}$$

which we define as leverage ratio $\phi_{w,t}$. By using this equation together with the Bellman equation (42) and the guess (43), we can rewrite the value function of the shadow banker as

$$V_{j,w,t} = E_t \Lambda_{t,t+1} \Omega_{w,t+1} N_{j,w,t+1}, \tag{46}$$

where $\Omega_{w,t+1} = 1 - \sigma + \sigma \left(\upsilon_{wb,t+1} + (\upsilon_{ws,t+1} - \upsilon_{wb,t+1}) \, \phi_{w,t+1} \right)$ and $N_{j,w,t+1}$ is given by (40). Due to the financial friction, the stochastic discount factor of shadow banks also differs from that of households by the factor Ω_{wt+1}.

Verifying the initial conjecture (43) leads to the following coefficients

$$\begin{aligned} \upsilon_{ws,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} (1+T_k) R_{k,t+1} \\ \upsilon_{ws*,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} (1+T_k^*) R_{k,t+1}^* \\ \upsilon_{wb,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} R_{b,t+1}. \end{aligned} \tag{47}$$

These equations together with the accepted leverage ratio (45) show how the shadow bank is limited in the provision of loans and restricted to its net worth. As with retail banks, we can drop index j since the leverage ratio is independent from bank-specific factors of bank j. The leverage ratio is increasing in the excess return on firm credits, $\upsilon_{ws,t} - \upsilon_{wb,t}$, as well as in the marginal value of net worth $\upsilon_{wb,t}$ since both increase the incentive to stay in business and therefore retail banks are more willing to provide funds. The opposite is true for θ_w: the higher the ability to divert funds, the lower the willingness of retail banks to grant interbank loans.

Using these coefficients, we can rewrite the portfolio choice condition (44) which is equivalent to the one in the model of Dedola et al. (2013):

$$E_t \left\{ \Lambda_{t,t+1} \Omega_{w,t+1} \left((1+T_k) R_{k,t+1} - (1+T_k^*) R_{k,t+1}^* \right) \right\} = 0.$$

Note that foreign shadow banks face an analogous condition. In a first-order approximation, optimal international asset portfolios $(x_{w,t}, x_{w,t}^*)$ are not defined as $E_t R_{k,t+1} \simeq E_t R_{k,t+1}^*$.[2] Only the steady states x_w, x_w^* enter the model up to first order. These could be derived by various approaches.[3] However, our subsequent analysis of optimal policy shows that it is only relevant whether shadow banks are engaged in both countries or not.[4] This stems from the assumption of symmetric countries. Hence, we also choose a symmetric portfolio allocation.

Aggregate net worth of the shadow banking sector is given by the sum of surviving bankers' net worth which evolves according to (40) and entering bankers' startup funds, which is given by $\xi_w R_{k,t} Q_{t-1} S_{w,t-1}/(1-\sigma)$ and provided by their respective household.

[2] Due to symmetry, the steady-state subsidies will be identical in both countries.

[3] For instance, by using the method developed by Devereux and Sutherland (2011) or by using CES aggregators to simplify the modeling of the international portfolio allocation (e.g. Auray et al., 2018).

[4] Results for this issue are available upon request.

Thus, aggregate net worth evolves according to

$$\begin{aligned} N_{w,t} &= \sigma\left((1+T_k)R_{k,t} - \left((1+T_k)R_{k,t} - (1+T_k^*)R_{k,t}^*\right)x_{w,t-1}\right)S_{w,t-1} \\ &\quad -\sigma R_{wb,t}B_{w,t-1} + \xi_w\left(R_{k,t} - \left(R_{k,t} - R_{k,t}^*\right)x_{w,t-1}\right)S_{w,t-1} \end{aligned} \tag{48}$$

3.6 Equilibrium

The model is closed with the market clearing conditions for goods, non-financial loans as well as interbank funds, and with the policy response functions.

Home final goods market clearing reads

$$Y_t = C_{H,t} + \frac{(1-m)}{m}C_{H,t}^* + \frac{P_t}{P_{H,t}}\left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right]I_t. \tag{49}$$

The market for interbank funds clears when demand by shadow banks equals supply by retail banks:

$$B_{w,t} = B_{r,t} \equiv B_t. \tag{50}$$

The markets for non-financial loans clear when firms' total loan demand meets total loan supply from the banking sector. Thus we get

$$Q_tK_t = Q_tS_{r,t} + Q_tS_{H,w,t} + \frac{(1-m)}{m}Q_tS_{H,w,t}^* \tag{51}$$

$$Q_t^*K_t^* = Q_t^*S_{r,t}^* + Q_t^*S_{F,w,t}^* + \frac{m}{(1-m)}Q_t^*S_{F,w,t}. \tag{52}$$

3.7 Policies and welfare objective

Before we turn the focus on policies, we want to emphasize the implications of purchasing power parity together with a common nominal interest rate. The Fisher equation interrelates the nominal interest rate i_t to the real rate according to

$$R_t = \frac{i_t}{E_t\pi_{t+1}^U}, \tag{53}$$

where $\pi_t^U \equiv P_t/P_{t-1}$ and the superscript U denotes union-wide (aggregate) variables. Due to purchasing power parity, home and foreign consumer price inflation rates are identical: $\pi_t = \pi_t^* = \pi_t^U$. As a result, real interest rates in both countries are equalized: $R_t = R_t^*$. Recall that $E_tR_{k,t+1} \simeq E_tR_{k,t+1}^*$ holds up to first order. When there are no differences in macroprudential policy, i.e. $\tau_t = \tau_t^*$, cross-border financial integration via the shadow banking system leads to an equalization of the marginal values $\upsilon_{rs,t} \simeq \upsilon_{rs,t}^*$,

$\upsilon_{rb,t} \simeq \upsilon^*_{rb,t}$, $\upsilon_{rd,t} \simeq \upsilon^*_{rd,t}$, $\upsilon_{re,t} \simeq \upsilon^*_{re,t}$, $\upsilon_{ws,t} \simeq \upsilon^*_{ws,t}$, $\upsilon_{wb,t} \simeq \upsilon^*_{wb,t}$ and therefore to an equalization of leverage ratios $\phi_{r,t} \simeq \phi^*_{r,t}$ and $\phi_{w,t} \simeq \phi^*_{w,t}$ up to first order due to symmetry. This result is similar to the one obtained by Dedola et al. (2013), but different in its derivation. Here, an internationally active shadow banking sector leads to the described equalization and hence to a cross-border transmission channel.

For the sake of simplicity and tractability, monetary policy is characterized by strict inflation targeting

$$\widehat{i}_t = \kappa_\pi \widehat{\pi}^U_t, \tag{54}$$

where a "^" symbol is used to denote the percentage deviation of a variable from its steady-state value. A union-wide (aggregate) variable $\widehat{z}^U_t$ is defined as the weighted average of national variables, $\widehat{z}^U_t \equiv m\widehat{z}_t + (1-m)\widehat{z}^*_t$. In the analysis of the model, we will also make use of relative variables $\widehat{z}^R_t$ which are defined as $\widehat{z}^R_t \equiv \widehat{z}_t - \widehat{z}^*_t$.

Macroprudential regulation follows the BASEL III-Accords. Based on the experiences of the GFC, these regulations are geared towards improving the quality, composition and consistency of bank equity capital by implementing leverage restrictions and more adequate and resilient capital buffers (Bank for International Settlements 2010). We capture these objectives by implementing a macroprudential regulator that sets a capital buffer based on the outside equity ratio of retail banks. The macroprudential tool used to steer the capital buffer is a policy rule that reacts to changes in credit spreads from its steady-state level as a sign for financial distress. The usage of credit spreads as indicators of financial distress is motivated by empirical evidence. Akinci and Queralto (2017) report that real economic activity and credit spreads tend to move asymmetrically. During crises times when macro variables like GDP or investment drop immensely, credit spreads increase sharply and financial variables like bank equity decrease. Gilchrist and Zakrajsek (2012) report similar evidence and show that credit spreads are appropriate signs of financial turmoil.

In our experiments, the considered disturbances bring about a recession that is characterized by a significant drop in macroeconomic variables, downturns in financial aggregates and accompanied widening in credit spreads. To counteract these developments, macroprudential regulation sets capital buffers. However, using regulatory policies in the setup of a currency union implies considerations of country- vs. union-wide arrangement of such policies. Depending on these arrangements, macroprudential policy either follows a union-wide or two country-specific simple feedback rules in the form of

$$\begin{aligned}
\widehat{\tau}^U_t &= -\kappa^U_\tau(\widehat{R}^U_{k,t+1} - \widehat{R}^U_t) \\
\widehat{\tau}_t &= -\kappa_\tau(\widehat{R}_{k,t+1} - \widehat{R}_t) \\
\widehat{\tau}^*_t &= -\kappa^*_\tau(\widehat{R}^*_{k,t+1} - \widehat{R}^*_t),
\end{aligned} \tag{55}$$

which state that the respective tool countercyclically reacts to changes in the credit spread depending on the weights $\kappa_{\tau}^{U}, \kappa_{\tau}, \kappa_{\tau}^{*}$. Once the economy runs through a recession and credit spreads widen, the response is to reduce capital buffers which leads to an increase in retail banks' "accepted" leverage ratio. This, in turn, allows retail banks to operate their business with lower levels of net worth. The process of deleveraging is moderated.

The parameters for monetary policy (κ_{π}) and macroprudential policy ($\kappa_{\tau}^{U}, \kappa_{\tau}, \kappa_{\tau}^{*}$) are set optimally according to the following objective function that can be derived from a second-order Taylor expansion of households utility functions around the efficient steady state (see Appendix for details):

$$-E_0\left\{\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\mathcal{L}_t\right\}+t.i.p.,$$

where $t.i.p.$ stands for terms independent of policy. Under the assumption of symmetry with regards to real-side variables, the per-period quadratic deadweight loss function is given by

$$\begin{aligned}
\mathcal{L}_t \;=\; & \frac{Y}{C}\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right)\frac{\varepsilon\zeta}{(1-\zeta)(1-\beta\zeta)}\left[(\widehat{\pi}_t^U)^2+m\,(1-m)\,(\widehat{\pi}_t^R)^2\right] \\
& -\frac{Y}{C}\left[(\widehat{Y}_t^U)^2+m\,(1-m)\,(\widehat{Y}_t^R)^2\right]+\frac{\rho}{2}\left[(\widehat{C}_t^U)^2+m\,(1-m)\,(\widehat{C}_t^R)^2\right] \\
& +\frac{Y}{C}(1-\alpha)\,(1+\varphi)\left[(\widehat{L}_t^U)^2+m\,(1-m)\,(\widehat{L}_t^R)^2\right] \\
& +\frac{I}{C}\left[(\widehat{I}_t^U)^2+m\,(1-m)\,(\widehat{I}_t^R)^2\right]+\frac{I}{C}\eta_I\left[(\Delta\widehat{I}_t^U)^2+m\,(1-m)\,(\Delta\widehat{I}_t^R)^2\right] \\
& +\frac{\tau}{C}\,(S_r+B)\,\eta_e\left[(\widehat{\tau}_t^U)^2+m\,(1-m)\,(\widehat{\tau}_t^R)^2\right], \qquad (56)
\end{aligned}$$

where $\Delta\widehat{I}_t^U \equiv \widehat{I}_t^U-\widehat{I}_{t-1}^U$ and $\Delta\widehat{I}_t^R \equiv \widehat{I}_t^R-\widehat{I}_{t-1}^R$.

In this representation, the weights of the respective variables are functions of deep model parameters that we specify in the following section. The variables in the first three lines are the standard target variables and weights for a two-country currency union. Aggregate and relative inflation leads to undesirable union-wide and relative price dispersions as these imply inefficient production of goods. As individuals are averse to fluctuations in consumption and hours worked, these variables also lead to welfare losses. The fourth line enters the loss function due to existence and depreciation of capital and due to the per se costs of adjusting investment.

Note that the loss function is increasing in output conditional on variances in inflation, consumption, labor, and investment as a higher variance could lead to more income making the households better off. As output is linked to the other variables via the resource constraints, one could show that this positive effect is realized by higher volatilities of the other, loss-inducing variables. Thus, by eliminating this variable using e.g. the goods market clearing condition, the allegedly positive effect will turn out to be partly negative. However we will not eliminate further variables from the welfare function as this will make the analysis more complicated by introducing various co-variances.[5] By abstracting from capital, i.e. $\alpha = 0, Y = C, I = 0$ and $\tau = 0$, and by using the production functions as well as the resource constraints to eliminate labor and consumption, we would obtain the standard loss function as, for example, in Benigno (2004) with inflation output and the terms of trade as objectives.

The fifth line enters the loss function due to the existence of portfolio adjustments costs of bank outside equity that households have to bear. As adjusting the equity portfolio in response to fluctuations of retail banks asset side leads to costs for the respective household (see 13), any changes directly transfer into a loss. Given that the outside equity ratio of retail banks is set by the macroprudential regulator, the macroprudential tool directly enters the loss function. Then, using the capital buffers during crises (and moving it from its steady-state level) automatically leads to welfare losses per se. However, the policymaker takes these losses into account when setting the instrument. These losses depend on the steady-state amount of retail banks' asset side and therefore on the size of the shadow banking sector.

In the case of merely a union-wide macroprudential tool, i.e. the policymaker has only the two aggregate tools $\widehat{i}_t$ and $\widehat{\tau}_t^U$, relative variables cannot be addressed. Fluctuations in relative variables still create welfare losses but the policymaker ignores them by dropping differentials from the objective function.

4 Dynamics

4.1 Calibration

This section represents the parametrization of our model. For most of the parameters for households, goods producers and capital producers we follow, among others, Gertler and Karadi (2011) and use common standard values. Table 1 shows the respective values. In our benchmark scenario, the countries are of equal size, i.e. $m = 0.5$, and the parameters from Table 1 apply to both countries.

To be more precise: the time interval is a quarter. The household discount factor β is 0.99 and implies a steady-state risk-free rate of roughly 4.1% per year. A relative

[5] See Edge (2004) for further details.

Households		
Discount factor	β	0.99
Relative utility weight of labor	χ	3.713
Inverse Frisch elasticity of labor supply	φ	0.276
Elasticity of equity spread to capital buffer	η_e	1
Goods producers		
Capital share in production	α	0.33
Depreciation rate	δ	0.025
Capital producers		
Elasticity of investment	η_I	1.728
Retailers		
Elasticity of substitution between goods	ε	4.167
Calvo parameter	ζ	0.779
Financial intermediaries in the benchmark scenario		
Survival probability	σ	0.90
Divertable fraction of assets in retail banking	θ_r	0.2012
Divertable fraction of assets in shadow banking	θ_w	0.1475
Relative divertibility of retail banks' interbank loans	γ	0.25
Proportional startup transfer to new retail bankers	ξ_r	0.0111
Proportional startup transfer to new shadow bankers	ξ_w	0.0095
Steady-state capital buffer	τ	0.05

Table 1: Parametrization

utility weight of labor of 3.713 ensures $L = L^* = 1/3$. The Frisch elasticity of labor supply φ is 0.276. For the elasticity of the equity spread to the capital buffer, we follow Nelson and Pinter (2018) by setting η_e to 1 which rather provides an upper bound for this effect. The remaining values of the parametrization of the real side of the model (intermediate goods firms, capital producers and retailers) are standard.

The parameters that determine the financial setup are chosen in line with the shadow banking model of Meeks et al. (2017). In particular, the surviving rate of retail banks and shadow banks, σ, is chosen to generate a dividend payout rate of 10%. Banks' relevant annual spread between non-financial loans and the risk-free rate, $(1+T_k)R_k-R$, is set to 100 basis points which is also in line with the euro area model of Lama and Rabanal (2014). As $R_k = R$, the steady state of the real side of the model is equivalent to the one of an efficient real business cycle model. The relevant spread for shadow banks, $(1 + T_k)R_k - R_b$, is set to 75 basis points. To replicate the extraordinary high degree of leverage in the shadow banking sector, we calibrate the leverage ratio for retail banks to 5.2 and for shadow banks to 8. However, as seen during the recent crisis, this is a rather conservative value. Furthermore, in our benchmark scenario, we target a size of the shadow banking sector of 25% of total loan origination/capital, i.e. $S_w/K = 0.25$. This entails a ratio of interbank loans to non-financial loans B/S_r of 0.3 and a ratio of retail bank non-financial loans to inside and outside equity, $QS_r/(N_r + qe)$, of 4. Following Nelson and Pinter (2018), the steady-state capital buffer τ equals 5%. The parameters θ_r, θ_w, γ, ξ_r, and ξ_w are set to match the mentioned targets.

As mentioned above, the steady state of our model is efficient due to subsidies. Hence, frictions due to retail or shadow banks or demanding a certain capital buffer have no welfare effect in the steady state. However, this modeling approach allows us to analyze the dynamics of different scenarios regarding the financial side for identical real-side steady states. In the following, we compare our described benchmark scenario with the scenarios of national shadow banking (no financial integration) and no shadow banking at all. In the former two cases, we obtain a steady-state value for the overall leverage ratio of the banking system, $QK/(N_r + N_w)$, of 5.9. In the case of no shadow banks, only national retail banks are active in the banking sector providing credit to domestic firms. In this scenario, we set θ_r and ξ_r to 0.2095 and 0.0141 respectively, in order to have the identical overall leverage ratio of the banking system, i.e. $QK/N_r = 5.9$.

The shocks could occur either as union-wide or as country-specific disturbances. The technology shocks follow AR (1) processes with autoregressive factors of 0.8 and standard deviations of 0.01. The net worth shocks are transitory 10% shocks.

4.2 International transmission of shocks

Before we present the analysis of the impulse responses to the disturbances, we want to make the reader aware of the nature of the two kinds of shocks and the role of international integration in the transmission processes. The first is a negative shock to the total factor productivity and the second a shock to net worth of retail banks. We have chosen these shocks to reflect a real-side shock and a financial-side shock.

The shock to the total factor productivity, i.e. productivity shock, is a standard disturbance in the DSGE-literature and recently used in Gertler and Karadi (2011) or Nelson and Pinter (2018). It reflects an exogenous supply-side disturbance and directly hits the production function of intermediate goods producers. The immediate impact on output is clearly destructive as investment falls, among others, due to a rise in credit spreads. This is a consequence of the negative impact on capital and hence transmitted to financial intermediaries who hold capital as collateral (assets) on their balance sheet. They are instantly exposed to the shock and the resulting fluctuation in asset values. In turn, financial intermediaries respond with adjustments to their net worth to compensate for the losses on their asset side. In the consequence, the economy passes through a deep recession. [6]

The second disturbance emerges within the financial system and is a negative shock to the net worth of retail banks as for example introduced by Nelson and Pinter (2018). This disturbance is purely financial in nature. It hits retail banks' aggregate net worth and thereby destroys regulatory bank capital. This forces retail banks to reduce their asset holdings to levels that correspond to their post-shock net worth level. The ensuing consequence for retail banks is to adjust loan origination to the productive sector what in turn depresses real economic activity.

The international implications of these shocks vary with the degree of real and financial integration. Country-specific shocks can induce a synchronization of macroeconomic variables if the integration of the real and financial sphere is sufficiently large. As the next section shows, there are, however, differences between purely financial (net worth) and real (technology) shocks. What arises as a natural question then is to what extent macroprudential measures are able to mitigate the country-specific and union-wide effects of the shocks and how they interact with monetary policy. It is thus of interest to study the impact of country-specific and union-wide policy coordination given different levels of real and financial integration. We report the findings in the following.

4.3 Impulse response analysis

Our benchmark scenario is a world with full integration of the financial sphere due to internationally active shadow banks, i.e. they supply credit to domestic and foreign firms. For each shock, we compare our benchmark with the scenarios of national shadow banking (no financial integration) and no shadow banking at all. As union-wide shocks under the assumption of symmetry would resemble closed-economy scenarios that have

[6] Sims (2011) points out that the meaningfulness of technology shocks as drivers of business cycles crucially hinges on the concept of technology being an observable variable. As it is, however, not readily observable since measurements require data and theoretical approaches, its role is questioned. To overcome these shortcomings and to find an adequate disturbance for the GFC, a frequent approach to model large-scale downturns is the usage of capital quality shocks (see e.g. Gertler and Karadi 2011, Dedola et al. 2013 or Kirchner and Schwanebeck 2017). The impulse responses generated by this shock reveal a destructive impact on the model and enable to study crises of comparable magnitude to the GFC. However, this comes with drawbacks (see e.g. Krenz 2018). The destructive impact of the shock is chiefly caused by its implementation into the model. As it simultaneously hits the production function (like a technology shock), the process of capital accumulation and the balance sheet of banks via the impact on capital, the shock operates through multiple channels and induces large downturns with persistent impact. We want to avoid such transmission mechanisms resulting from capital quality shocks and rather focus on technology as a source of disturbance.

already been analyzed in the literature (see, for instance, Gertler et al., 2016 and Meeks et al., 2017), we focus our analysis on idiosyncratic shocks to the home country.

Home technology shock: Figure 1 and 2 show the home technology shock. The immediate reactions are drops in output, consumption, and investment exacerbated by increases in credit spreads and the policy rate. As inflation increases due to higher marginal costs of intermediate goods firms and since home country inflation drives aggregate inflation, optimal monetary policy sets a higher nominal interest rate. The initial downturns are followed by a destruction of the capital stock. As already pointed out by Gertler and Karadi (2011) or Krenz (2018), the impact of financial intermediation on the downturn caused by a technology shock is rather small. Accordingly, the model response is largely driven by changes in real variables. However, the financial accelerator can be described in the following way *(no shadow banking).* As capital and investment fall in the aftermath of the shock, so does the price of capital. This now brings about a transmission to the financial sector since financial intermediaries (only retail banks) hold capital as collateral on their balance sheet and supply the productive sector with credit. The lower capital stock and the accompanied devaluation of the capital price destroys banks' net worth. This induces a fire sale of assets in order to meet the leverage ratio constraint which eventually results in a lower credit supply.

Although not hit by the shock, the repercussions are transmitted to foreign via international trade, i.e. the drop in demand for goods. The on impact decreases in capital and investment are comparable to in home and force foreign to run through a similar recession, but less severe compared to home.

Once the flow of credit to the real sector is divided between retail and shadow banks *(national shadow banking)*, the shock is more destructive as the financial accelerator becomes stronger. Shadow banking obviously acts as a shock amplifier. The drop in output is larger and the recession is more persistent. Both financial intermediaries reduce net worth. Retail banks can moderate the effect on their balance sheet by reducing interbank lending (shifting losses to shadow banks) and increase lending to firms what in turn improves their franchise value. For shadow banks, the negative effect of the shock is strengthened by their higher degree of leverage and retail banks cutting back interbank funds. As a major financing source disappears, shadow banks fire sale assets and reduce lending. As shadow credit intermediation drops and retail banks cannot fully compensate the reduction, the output loss increases. As mentioned, foreign feels the repercussions through the trade channel. Although smaller in magnitude, the effect of shadow banking is destructive. Without financial integration, foreign is thus partly protected from too stark fluctuations at the real side. To sum up, in the presence of real shocks, national shadow banking acts as an additional friction in the financial sector, it amplifies the repercussions.

Once shadow banking supplies domestic and foreign firms with credit, the model features full integration *(benchmark scenario)*. What we observe is that the change in the amplification of real shocks through financial integration is small. The main mechanism of transmission remains the international consumption channel. However, home is now hit harder once opening the financial side. The immediate drop in output is stronger as investment and capital both decrease more. The latter is a direct consequence of an increase in the credit spread. As it widens, it makes investment less attractive. However, retail banks are able to benefit by increasing loan supply to the productive sector as this helps them to improve their franchise value. While retail banks partly benefit, shadow banks do not. A reduction in interbank funding by retail banks worsens their financing structure and forces them to reduce credit supply. Their net worth drops.

Foreign now benefits from the introduction of financial integration. The impact on output is clearly positive as a result of a reduction in the drop in investment and capital. The latter drops less as the widening in relevant credit spreads decreases. Although retail banks reduce credit supply to firms, they increase interbank funds to shadow banks. This, combined with a decrease in the leverage ratio, helps shadow banks to increase credit supply and reduce the negative impact on their net worth. While the forces of financial integration tend to cushion the transmission of a real shock, the mechanisms at work help to stabilize the variables in the welfare objective (56) as the benefits of foreign outweigh the losses of home.

Home net worth shock: Figure 3 and 4 show the results for a retail bank net worth shock in the home country. This shock is purely financial in nature and, accordingly, takes full effect at the financial side of the model. Retail banks hold the entire capital stock and the sudden reduction of their net worth is followed by massive fire sales of assets, a downward spiral in asset prices and a destruction of the capital stock *(no shadow banking)*. The effects are fully transmitted throughout the economy and the impact of this financial shock is clearly destructive. Although not hit by the shock, the repercussions are transmitted to foreign via the international trade in goods. However, the effect is outweighed by expansionary monetary policy. Since the decrease in home inflation drives aggregate inflation, the central bank lowers the interest rate. Hence, foreign undergoes a mild boom.

Now, once the capital stock is divided between retail and shadow banks *(national shadow banking)*, the impact of the sudden reduction in retail banks' net worth is moderated by their lower fraction of managed capital. Although retail banks extend interbank lending to shadow banks to moderate the negative impact on their franchise value, the drop in the price of capital spills over to the shadow banking sector, forcing them to start a deleveraging process. Hence, net worth and credit supply by shadow banks drop in the aftermath of the shock, but roughly three periods after the initial disturbance they are able to expand credit supply to firms to positive levels. Thus, overall credit supply and therefore capital decrease by a lower amount and the negative effect on output can be moderated. As the decrease in home inflation is smaller, the decrease in the policy rate can be smaller to stabilize union inflation. As monetary policy is the main transmission channel, the boom in foreign is smaller even under a stronger financial accelerator. Hence, in the face of a net worth shock, shadow banking moderates the downturn and acts as a shock absorber.

When shadow credit intermediation is extended to an international level *(benchmark scenario)*, foreign is now fully exposed to the shock through the forces of financial integration that bring about a perfect equalization of spreads and leverage ratios in the shadow banking sector. Given the synchronized financial side of the model, this purely financial shock has now identical real-side effects in both countries. The consequence of the idiosyncratic shock in home is a truly global recession with synchronized downturns in investment, employment, and output in both countries which cannot be corrected by monetary policy as the nominal interest rate is too blunt to offset financial disturbances.

Proposition 1 *In the case of shocks to the real sphere, the existence of shadow banking intensifies the financial accelerator effects and operates as a shock amplifier. Financial integration cushions the transmission to foreign. During financial shocks, shadow banking under financial autarky rather operates as shock absorber as it can partly compensate the losses incurred by retail banks. Financial integration induces a union-wide recession.*

Proof. See text. ■

Accordingly, what we observe is that in all of the considered scenarios, monetary policy at the union-level is not able to adequately address the financial effects of the disturbances. There seems to be a clear role for macroprudential policy.

4.4 Implications for the conduct of macroprudential policy

Continuing the analysis of the idiosyncratic shocks above, we focus on the case of full financial integration and allow for either a country-specific or union-wide macroprudential tool. The policymaker optimizes both the monetary as well as the macroprudential policy rules according to the welfare objective (56). This implies full coordination of both policies which is an appropriate assumption for a monetary union as the euro area (see e.g. Palek and Schwanebeck 2019).

As a result of cross-border financial integration via shadow banks, the main financial variables are perfectly aligned internationally (see figures 1-4). Hence, any shock leads to identical movements in leverage ratios and credit spreads in both countries. Introducing macroprudential policy as a financial instrument at the national level could change this result. However, by following a welfare objective that takes both countries into account, it is optimal to reduce relative gaps between the members of the monetary union instead of creating new relative differences in financial variables. Thus, the prudential policy reactions have to be identical in both countries. This is equivalent to having a union-wide tool only.

Proposition 2 *In the case of full financial integration, there are no additional welfare gains from having country-specific macroprudential tools.*

Proof. See text. ■

To illustrate the stabilization effects of a union-wide macroprudential tool (or national tools that are set identically), we plot graphs symbolizing the actual gap of comparing the scenario with macroprudential policy (P) to the one without this policy (nP), in which there is solely optimized monetary policy. For instance, if a variable shows a drop due to a shock, an increase in this gap would display a lower decrease under macroprudential policy. On the other hand, if a variable increases following a shock, an increase in the gap would show that the variable rises even more under prudential policy.

While the solid line in figures 1-4 illustrate the repercussions of both shocks under cross-border financial integration via shadow banks, figures 5 and 6 show the corresponding gaps or changes due to macroprudential policy for the home technology and home net worth shock. As the union-wide tool affects both economies via the already perfectly harmonized financial sphere, it has identical stabilization effects in both countries. Hence, the figures only display home variables as the gaps are identical for foreign.

Home technology shock and macroprudential regulation: As a direct consequence of the macroprudential intervention, the drop in retail banks' net worth can be reduced since the policy positively affects the (allowed) leverage ratio. While this would normally benefit credit supply by retail banks, they rather use the policy to slightly reduce credit origination and shift assets through the interbank market to shadow banks. Shadow banks, in turn, benefit and can increase their loan supply to the productive sector. Credit spreads decrease and the overall influence on credit supply is positive. Hence, the reduction in capital can be moderated (positive gap). In turn, the effect on output is positive which would eventually lead to more inflation. However, as macroprudential policy moderates the targets of the welfare objective besides inflation, monetary policy can react more aggressively. Under macroprudential policy, the increase in the monetary policy rate is slightly higher in order to stabilize the increase in union inflation to a larger extent. The higher interest rate leads to a further drop in Y on impact. In the subsequent periods, the positive effect of macroprudential policy on capital dominates this negative effect of monetary policy. Hence, we obtain a stabilization effect (positive gap).

Home net worth shock and macroprudential regulation: In contrast to the technology shock, the origin of this shock is the financial sector. As a consequence, the macroprudential tool is more effective in stabilizing the welfare targets. The transmission channel of macroprudential policy is the same as above, eventually stabilizing the capital stock and thereby stabilizing output. As this shock leads to lower union inflation, the inflationary output-stabilizing effect of macroprudential policy also stabilizes inflation. Hence, monetary policy reduce the interest rate by a lesser amount. However, this effect is outweighed by macroprudential policy which results in an overall positive output response.

So far we have discussed the implication of full financial integration via shadow banks for macroprudential policy under these two idiosyncratic shocks. Next, we turn to the implications of other scenarios regarding the modelling of shadow banks. We also allow for union-wide shocks to identify the gains from having a union-wide macroprudential tool. Obviously, there are no gains from country-specific tools in these cases and due to symmetry, financial integration does not affect the outcomes. Table (2) shows the welfare losses and optimized policy parameters under different scenarios and for different instrument sets. Losses are expressed in percentage points and have to be interpreted as fraction of steady-state consumption that must be given up to equate welfare in the stochastic economy to that in a deterministic steady state.

To begin with, we want to focus our attention on the impact of shadow banking on welfare results. The question of interest is how the household welfare is dependent on the structure of the financial system given different shocks and policy responses. Proposition 3 highlights the main outcomes.

Proposition 3 *Under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. Then, neither financial integration nor macroprudential policy can compensate the additional losses. Under a financial shock, shadow banking (domestic and international) reduces welfare losses. Macroprudential policy leads to further welfare gains.*

Proof. See text below. ■

Table (2) shows the respective welfare losses. To be precise, we compare the losses for an idiosyncratic technology shock in line 1 for noS vs. S vs. FI with the corresponding losses in line 3, when a union-wide macroprudential tool (τ^U) complements monetary policy. What we observe is that once shadow banking takes over a fraction of domestic credit origination, the loss incurred by households increases from 2.89 to 3.09. Acting under full financial integration then leads to a reduction in the welfare loss to 3.05, but this number clearly remains above levels observed without shadow banking (noS). These effects are a direct consequence of the fact that the introduction of shadow banking magnifies the financial accelerator effect. In a world without shadow banking, only retail banks are subject to the financial friction that drives an inefficient wedge between borrowing and lending rates. Once shadow banking takes over a fraction of credit supply, this effect is strengthened, the financial accelerator becomes more powerful. Accordingly, welfare losses must necessarily increase given a shock to the real sphere. In a financially integrated union, these losses slightly decrease as the forces of financial integration cushion the negative effects of the shock. However, this can only partly offset the incurred losses. Considering now the scenario with monetary policy and a union-wide macroprudential tool (τ^U), hence the losses in line 3 (3.00 and 2.96), it gets obvious that the welfare stabilizing effect of the macroprudential tool is never sufficiently large to reduce the household losses to levels observed without shadow banking (compare any, 2.89 or 2.83). This obviously stems from the fact that shadow banking is per definition unregulated and thus an additional vulnerability of the system and a risk to financial stability. Hence, a macroprudential regulator equipped with entity-based tools (i.e. geared towards the regular banking sector) can only indirectly affect inefficiencies and vulnerabilities originating from the shadow banking sector. As such, shadow banking can be interpreted as a additional disturbance per se.

However, considering the case of a shock to retail banks' net worth puts another complexion on things. What we observe now is that once shadow banking takes over a fraction of domestic credit origination (line 1, idiosyncratic net worth shock), the loss incurred by households decreases from 7.03 to 4.44. Acting under full financial integration again reduces the incurred loss to 1.26. Obviously, shadow banking now acts as a shock absorber and moderates the downturn what in turn leads to welfare improvements. As already discussed in the former sections, this is a direct consequence of shadow banking taking over a fraction of the capital stock through credit intermediation. The absolute impact on retail banks' net worth remains unchanged but the relative strength of the impact on the economy is reduced as they now hold less capital. Considering now the scenario with monetary policy and a union-wide macroprudential tool (τ^U), hence the losses in line 3 (4.34 and 1.16), we observe that the union-wide macroprudential tool now unfolds welfare stabilizing effects that are sufficiently large to reduce the household losses for every observed scenario (without and with shadow banking). However, this result certainly hinges on the fact that we abstract from modeling any costs (i.e. efficiency losses) or disturbances arising from the existence of shadow banking or additional uncertainty due to the lack of regulation in this sector. Considering costs or disturbances arising in the shadow banking sector could eventually lead to welfare losses due to the existence of shadow banking.

We now want to turn the focus of attention on the design of macroprudential policy. The question of interest is how the household welfare is dependent on the design of macroprudential policy given varying structures of the financial system. Our findings are summarized in the following.

Proposition 4 *A union-wide macroprudential regulation is welfare improving for both real and financial shocks, the forces of financial integration even facilitate its effectiveness. The gains are the largest for a financial shock. Country-specific macroprudential tools are only beneficial under financial autarky or absent shadow banks.*

Proof. See text below. ■

Again, Table (2) shows the respective welfare losses. To be precise, we compare the losses in line 1 for S vs. FI (3.09 vs. 3.05 and 4.44 vs. 1.26) with the corresponding losses in line 3 (3.00 vs. 2.96 and 4.43 vs. 1.16), when a union-wide macroprudential tool (τ^U) complements monetary policy. Although the improvements are larger under the net worth shock and, in general, should be larger for idiosyncratic financial shocks, a union-wide macroprudential regulation (in combination with monetary policy) is effective in reducing the incurred welfare losses of households in all of the considered cases. The fact that we observe the gains to be larger for financial shocks then for real shocks can be ascribed to the objective and especially the point of intervention of macroprudential regulation. As it is designed to increase the resilience and hence the stability of the financial system and works through the leverage ratio and hence the balance sheet of retail banks (see 35), it is necessarily most effective against disturbances emanating from the financial sphere. Due to the harmonization of the financial spheres of both countries, the effectiveness even increases. Disturbances arising from the real sphere can be addressed, but less effectively. While not exclusively, this calls for a purposeful usage of fiscal policies.

Furthermore, taking a closer look at the interaction of monetary and macroprudential policy, we observe that if macroprudential policy is coordinated at the union-level, the response of monetary policy to inflation is more aggressive. This can be seen by comparing the optimal parameter value for monetary policy κ_π in line 2 for idiosyncratic technology and net worth shocks (4.42 and 7.08, respectively) with the κ_π-values in line 4 (4.97 and 7.28). Obviously, due to macroprudential policy, monetary policy can put a larger weight on its primary objective inflation which reduces the welfare loss of households. This supports the positive effects of macroprudential policy and results in welfare improvements.

Finally, our welfare analysis reveals that switching from union-wide to country-specific macroprudential tools entails advantages only if considering countries in financial autarky or absent shadow banking. However, we then observe these gains to be larger for financial shocks than for real shocks.

As we only consider the extreme cases of no financial integration and full financial integration under full coordination, these results rather show the lower and the upper

scenario		technology shock					net worth shock				
		union		idiosyncratic			union		idiosyncratic		
		no S	S/FI	no S	S	FI	no S	S/FI	no S	S	FI
i	Loss	3.72	4.52	2.89	3.09	3.05	8.14	5.05	7.03	4.44	1.26
	κ_π	5.24	4.42	5.24	4.42	4.42	6.91	7.08	6.91	7.08	7.08
i, τ^U	Loss	3.51	4.16	2.83	3.00	2.96	7.44	4.62	6.86	4.34	1.16
	κ_π	5.74	4.97	5.74	4.97	4.97	6.99	7.28	6.99	7.28	7.28
	κ_τ^U	0.74	0.99	0.74	0.99	0.99	0.47	0.43	0.47	0.43	0.43
i, τ, τ^*	Loss			2.78	2.93	2.96			5.94	3.71	1.16
	κ_π			5.74	4.97	4.97			6.85	7.11	7.28
	κ_τ			0.05	0.17	0.99			0.71	0.68	0.43
	κ_τ^*			1.53	1.99	0.99			4.46	5.55	0.43

Table 2: Welfare losses under the scenarios: no shadow banks (no S), with shadow banks but no financial integration (S), and full financial integration (FI)

bounds of the "first-best" welfare gains. While national macroprudential policy is beneficial in cases of no shadow banking or at least no integration via the financial side, these benefits seem to vanish with the degree of financial integration. As the former two cases are rather unrealistic scenarios for monetary unions such as the euro area or the U.S., the additional welfare gains from having country-specific macroprudential policy seems to be rather scarce or even questionable. It is plausible to assume that once integrated at the financial side to a certain degree, macroprudential policy needs to be coordinated at the supranational level. In a world with country-specific rules and missing common regulatory arrangements, differences in regulations would induce regulatory arbitrage causing cross-country substitution and relocation effects and possibly a worsening of the effects of shocks. In addition, there is a clear role for governance considerations and political issues. The possibility of political fall-outs at the national level favors macroprudential regulation at a supranational level. For reasons of unpopularity of tighter regulations, e.g. disadvantages of banking competition, macroprudential policy could be inactive at the national level. These political-economy considerations are beyond the scope of our analysis. Gros and Schoenmaker (2014) as well as Schoenmaker (2013) address some of these institutional arrangement issues for the euro area. A starting point for theoretical consideration can be found in De Paoli and Paustian (2017). They analyze strategic interdependencies in a single-country setting with retail banking.

5 Conclusion

In this paper we study the interaction of international shadow banking with optimized monetary and macroprudential policy in a two-country currency union DSGE model. In our benchmark setup, we allow for financial integration through international shadow banks that are, besides domestic credit intermediation, able to extend cross-border credits to foreign firms. As a result the financial sectors are aligned internationally and any shock leads to identical movements in leverage ratios and credit spreads in both countries.

We can draw the following conclusions: Our analysis shows that in the presence of shocks to the real sphere, the existence of shadow banking intensifies the financial accelerator effects. Shadow banks, highly leveraged and dependent on retail banking funds, appear to be an additional source of instability and thus operate as a shock amplifier. However, our analysis also reveals that during financial shocks, shadow banking under financial autarky rather operates as shock absorber. In this scenario, it can partly compensate the losses incurred by retail banks and thereby unfold its stabilizing effect.

In terms of the optimal design of macroprudential policy, our analysis demonstrates that regulation situated at the country-level is only beneficial under financial autarky or absent shadow banking. A sufficiently large stabilization of the relevant household welfare measure is only achieved once macroprudential regulation acts union-wide hence coordinated. Such a supranational macroprudential regulation that symmetrically intervenes in both countries of the union is able to effectively counteract the negative consequences of the observed shocks. While the gains are larger for financial shocks than for real shocks, they are even facilitated through the forces of financial integration. This result seems plausible since a macroprudential regulation that is based on BASEL III is primarily designed to address systemic risk in the banking sector and hence financial stability (see e.g. BIS 2010). A policy designed to counteract the build-up of bank exposure is thus highly effective given shocks emanating from this very sector. Furthermore, the follow-up effect of union-wide macroprudential regulation is a more stringent setting of the policy rate through monetary policy. Since financial stability is cared for by the macroprudential regulator, monetary policy is now able to react more aggressively to its primary objective inflation. Moreover, our welfare analysis shows that under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. In such a case, neither financial integration nor macroprudential policy can compensate the additional losses. As the shadow banking sector in our model (and in general) is unregulated and highly leveraged, it constitutes a vulnerability to the stability of the financial system. A macroprudential regulator equipped with an entity-based regulation approach as in our case thus only indirectly affects the vulnerabilities originating from this sector.

However, our analysis leaves room for several interesting extensions but that are beyond the scope of this paper. While we consider financial integration via shadow banks that are engaged in both countries, an asymmetric approach with unilateral financial flows in the sense of Nuguer (2016) could change the conduct of macroprudential policy in a monetary union. Another interesting extension would be the aforementioned political-economy considerations and strategic interactions between the central bank and macroprudential authorities as in De Paoli and Paustian (2017). In a heterogeneous union like the euro area, these considerations are especially important as member countries might be in favor of different (monetary and) macroprudential objectives. It would thus be interesting to take into account game theoretical issues for the optimal arrangement of such policies. It seems very likely that these issues would even more favor macroprudential policy-making at the union level. We leave these questions for future research.

Appendix: Union's Welfare Loss

Let X_t be a generic variable and X its steady state. Then, we define $\widehat{X}_t$ as the log deviation of X_t around X, $\widehat{X}_t = \log(X_t/X)$. Hence, using a second-order Taylor approximation yields

$$\frac{X_t - X}{X} = \exp(\widehat{X}_t) - 1 \simeq \widehat{X}_t + \frac{1}{2}\widehat{X}_t^2.$$

In the following, we will drop terms independent of policy (e.g. stand-alone shock terms) and terms of third and higher order.

The policy maker's welfare objective is defined as the unconditional expectation of home and foreign households' average lifetime utility. Starting from the period utility function

$$\begin{aligned} mU(C_t, L_t) + (1-m)U(C_t^*, L_t^*) \equiv U_t^U &= m\left[\frac{C_t^{1-\rho}}{1-\rho} - \chi\frac{L_t^{1+\varphi}}{1+\varphi}\right] \\ &+(1-m)\left[\frac{(C_t^*)^{1-\rho}}{1-\rho} - \chi\frac{(L_t^*)^{1+\varphi}}{1+\varphi}\right], \end{aligned}$$

we obtain the following second-order approximation:

$$\begin{aligned} U_t^U \simeq\ & U^U + U_C C\left[m\frac{C_t - C}{C} + (1-m)\frac{C_t^* - C}{C}\right] \\ & +\frac{1}{2}U_{CC}C^2\left[m\left(\frac{C_t - C}{C}\right)^2 + (1-m)\left(\frac{C_t^* - C}{C}\right)^2\right] \\ & . - U_L L\left[m\frac{L_t - L}{L} + (1-m)\frac{L_t^* - L}{L}\right] \\ & . - \frac{1}{2}U_{LL}L^2\left[m\left(\frac{L_t - L}{L}\right)^2 + (1-m)\left(\frac{L_t^* - L}{L}\right)^2\right], \end{aligned}$$

where $C = C^*, L = L^*$ due to symmetry and therefore $U = U^* = U^U$ as well as $U_C = U_{C^*}$, $U_{CC} = U_{C^*C^*}$, $U_L = U_{L^*}$, $U_{LL} = U_{L^*L^*}$.

Rearranging the terms and using log deviations yields

$$\begin{aligned}\frac{U_t^U - U^U}{U_C C} &\simeq m\widehat{C}_t + (1-m)\widehat{C}_t^* + \frac{1-\rho}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] \\ &\quad -\frac{U_L L}{U_C C}\left(m\widehat{L}_t + (1-m)\widehat{L}_t^* + \frac{1+\varphi}{2}\left[m\widehat{L}_t^2 + (1-m)\left(\widehat{L}_t^*\right)^2\right]\right).\end{aligned}$$

Labor market clearing in an efficient steady state reads

$$\frac{U_L}{U_C} = (1-\alpha)\frac{Y}{L},$$

which leads to

$$\begin{aligned}\frac{U_t^U - U^U}{U_C C} &\simeq m\widehat{C}_t + (1-m)\widehat{C}_t^* + \frac{1-\rho}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] \\ &\quad -(1-\alpha)\frac{Y}{C}\left(m\widehat{L}_t + (1-m)\widehat{L}_t^*\right) \\ &\quad -\frac{1}{2}(1-\alpha)(1+\varphi)\frac{Y}{C}\left[m\widehat{L}_t^2 + (1-m)\left(\widehat{L}_t^*\right)^2\right]\end{aligned}$$

We can eliminate the linear consumption term by using the aggregate resource constraint which can be derived by combining the budget constraints of all agents of the model. We obtain the following approximation

$$\begin{aligned}m\widehat{C}_t + (1-m)\widehat{C}_t^* &= -\frac{1}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] + \frac{Y}{C}\left(m\widehat{Y}_t + (1-m)\widehat{Y}_t^*\right) \\ &\quad +\frac{1}{2}\frac{Y}{C}\left[m\widehat{Y}_t^2 + (1-m)\left(\widehat{Y}_t^*\right)^2\right] \\ &\quad -\frac{I}{C}\left(m\widehat{I}_t + (1-m)\widehat{I}_t^* + \frac{1}{2}\left[m\widehat{I}_t^2 + (1-m)\left(\widehat{I}_t^*\right)^2\right]\right) \\ &\quad -\frac{1}{2}\frac{I}{C}\eta_i\left[m\left(\widehat{I}_t - \widehat{I}_{t-1}\right)^2(1-m)\left(\widehat{I}_t^* - \widehat{I}_{t-1}^*\right)^2\right] \\ &\quad -\frac{1}{2}\frac{\tau}{C}(S_r + B)\,\eta_e\left[m\widehat{\tau}_t{}^2 + (1-m)(\widehat{\tau}_t^*)^2\right].\end{aligned}$$

The linear terms in labor can be eliminated by the use of the production function of both countries combined with price dispersion resulting from retailers. These read

$$\left[\int_0^1 \left(\frac{P_{H,t}(h)}{P_{H,t}}\right)^{-\varepsilon} di\right] Y_t = A_t K_{t-1}^{\alpha} L_t^{1-\alpha}$$

$$\left[\int_0^1 \left(\frac{P_{F,t}(f)}{P_{F,t}}\right)^{-\varepsilon} di\right] Y_t^* = A_t^* \left(K_{t-1}^*\right)^{\alpha} \left(L_t^*\right)^{1-\alpha}.$$

Approximating and rearranging yields

$$\widehat{L}_t = \frac{1}{1-\alpha}\left(\widehat{Y}_t - \widehat{A}_t - \alpha \widehat{K}_{t-1} + \frac{1}{2}\varepsilon\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right) var_h \widehat{p}_t(h)\right)$$

$$\widehat{L}_t^* = \frac{1}{1-\alpha}\left(\widehat{Y}_t^* - \widehat{A}_t^* - \alpha \widehat{K}_{t-1}^* + \frac{1}{2}\varepsilon\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right) var_f \widehat{p}_t(f)\right).$$

Hence,

$$\begin{aligned}
\frac{U_t^U - U^U}{U_C C} \simeq\ & \frac{Y}{C} m \left(\alpha \widehat{K}_{t-1} - \frac{I}{Y}\widehat{I}_t\right) + \frac{Y}{C} m \left(\alpha \widehat{K}_{t-1}^* - \frac{I}{Y}\widehat{I}_t^*\right) \\
& - m \frac{1}{2}\frac{Y}{C}\varepsilon\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right) var_h \widehat{p}_t(h) \\
& - (1-m)\frac{1}{2}\frac{Y}{C}\varepsilon\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right) var_f \widehat{p}_t(f) \\
& + \frac{1}{2}\frac{Y}{C}\left[m\widehat{Y}_t^2 + (1-m)\left(\widehat{Y}_t^*\right)^2\right] \\
& - \frac{1}{2}\rho\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] \\
& - \frac{1}{2}(1-\alpha)(1+\varphi)\frac{Y}{C}\left[m\widehat{L}_t^2 + (1-m)\left(\widehat{L}_t^*\right)^2\right] \\
& - \frac{1}{2}\frac{I}{C}\left[m\widehat{I}_t^2 + (1-m)\left(\widehat{I}_t^*\right)^2\right] \\
& - \frac{1}{2}\frac{I}{C}\eta_i\left[m\left(\widehat{I}_t - \widehat{I}_{t-1}\right)^2 (1-m)\left(\widehat{I}_t^* - \widehat{I}_{t-1}^*\right)^2\right] \\
& - \frac{1}{2}\frac{\tau}{C}(S_r + B)\,\eta_e\left[m\widehat{\tau}_t^{\,2} + (1-m)\left(\widehat{\tau}_t^*\right)^2\right].
\end{aligned}$$

To eliminate the remaining first-order terms we follow the approach of Edge (2003).

Recall that in an efficient steady state it holds that

$$\begin{aligned} I &= \delta K \\ R &= \frac{1}{\beta} = R_k = \alpha \frac{Y}{K} + (1-\delta), \end{aligned}$$

which can be combined to yield

$$\frac{I}{Y} = \frac{\alpha\beta\delta}{1-\beta\left(1-\delta\right)}.$$

Furthermore, log-linearizing the equation for the evolution of capital results in

$$\widehat{K}_t = \delta \widehat{I}_t + \left(1-\delta\right) \widehat{K}_{t-1}.$$

Now we can rewrite the linear terms as follows

$$\begin{aligned} \alpha \widehat{K}_{t-1} - \frac{I}{Y} \widehat{I}_t &= \alpha \widehat{K}_{t-1} - \frac{\alpha\beta\delta}{1-\beta\left(1-\delta\right)} \widehat{I}_t \\ &= \alpha \widehat{K}_{t-1} - \frac{\alpha\beta}{1-\beta\left(1-\delta\right)} \left[\widehat{K}_t - \left(1-\delta\right)\widehat{K}_{t-1}\right] \\ &= \frac{\alpha}{1-\beta\left(1-\delta\right)} \left[\widehat{K}_{t-1} - \beta \widehat{K}_t\right]. \end{aligned}$$

Since overall utility is a discounted sum of period utility, we can simplify this further:

$$\begin{aligned} E_0 \sum_{t=0}^{\infty} \beta^t \left(\alpha \widehat{K}_{t-1} - \frac{I}{Y} \widehat{I}_t\right) &= \frac{\alpha}{1-\beta\left(1-\delta\right)} E_0 \left[\begin{array}{c} \widehat{K}_0 - \beta \widehat{K}_1 + \beta\left(\widehat{K}_1 - \beta \widehat{K}_2\right) \\ +\beta^2 \left(\widehat{K}_2 - \beta \widehat{K}_3\right) + ... \\ +\beta^t \left(\widehat{K}_t - \beta \widehat{K}_{t+1}\right) + ... \end{array}\right] \\ &= \frac{\alpha}{1-\beta\left(1-\delta\right)} E_0 \widehat{K}_0. \end{aligned}$$

As $\widehat{K}_0$ is assumed to be independent of policy, these linear terms can be dropped. The same can be applied for $\left(\alpha \widehat{K}^*_{t-1} - \frac{I}{Y} \widehat{I}^*_t\right)$

Finally, it can be shown (see e.g. Woodford, 2003, chap. 6) that

$$\begin{aligned} E_0 \sum_{t=0}^{\infty} \beta^t var_h \widehat{p}_t(h) &= \frac{\zeta}{(1-\zeta)(1-\beta\zeta)} E_0 \sum_{t=0}^{\infty} \beta^t (\widehat{\pi}_t)^2 \\ E_0 \sum_{t=0}^{\infty} \beta^t var_f \widehat{p}_t(f) &= \frac{\zeta}{(1-\zeta)(1-\beta\zeta)} E_0 \sum_{t=0}^{\infty} \beta^t (\widehat{\pi}_t^*)^2 \end{aligned}$$

Using these expressions, the welfare function can be written as

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{U_t^U - U^U}{U_C C} \right\} = -E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{2} \mathcal{L}_t \right\} + t.i.p.,$$

where

$$\begin{aligned} \mathcal{L}_t = \; & \frac{Y}{C} \left(1 + \frac{\varepsilon\alpha}{1-\alpha}\right) \frac{\varepsilon\zeta}{(1-\zeta)(1-\beta\zeta)} \left[(\widehat{\pi}_t^U)^2 + m(1-m)(\widehat{\pi}_t^R)^2 \right] \\ & - \frac{Y}{C} \left[(\widehat{Y}_t^U)^2 + m(1-m)(\widehat{Y}_t^R)^2 \right] + \frac{\rho}{2} \left[(\widehat{C}_t^U)^2 + m(1-m)(\widehat{C}_t^R)^2 \right] \\ & + \frac{Y}{C}(1-\alpha)(1+\varphi) \left[(\widehat{L}_t^U)^2 + m(1-m)(\widehat{L}_t^R)^2 \right] \\ & + \frac{I}{C} \left[(\widehat{I}_t^U)^2 + m(1-m)(\widehat{I}_t^R)^2 \right] + \frac{I}{C}\eta_I \left[(\Delta\widehat{I}_t^U)^2 + m(1-m)(\Delta\widehat{I}_t^R)^2 \right] \\ & + \frac{\tau}{C}(S_r + B)\eta_e \left[(\widehat{\tau}_t^U)^2 + m(1-m)(\widehat{\tau}_t^R)^2 \right], \end{aligned}$$

in which we make use of the relation $m\widehat{z}_t^2 + (1-m)(\widehat{z}_t^*)^2 = (\widehat{z}_t^U)^2 + m(1-m)(\widehat{z}_t^R)^2$ for any pair of variables $\widehat{z}_t, \widehat{z}_t^*$.

References

[1] Abad, Jorge, Marco D'Errico, Neill Killeen, Vera Luz, Tuomas Peltonen, Richard Portes, and Teresa Urbano (2017): "Mapping the interconnectedness between EU banks and shadow banking entities", European Systemic Risk Board Working Paper No 40.

[2] Akinci, Ozge, and Albert Queralto (2017): "Credit Spreads, Financial Crises, and Macroprudential Policy", Federal Reserve Bank of New York Staff Papers No. 802.

[3] Angelini, Paolo, Stefano Neri, and Fabio Panetta (2014): "The interaction between capital requirements and monetary policy", *Journal of Money, Credit and Banking* 46, no. 6: 1073-1112.

[4] Auray, Stéphane, Aurélien Eyquem, and Xiaofei Ma (2018): "Banks, sovereign risk and unconventional monetary policies", *European Economic Review* 108: 153-171.

[5] Bank for International Settlements (2010): "Basel III: A global regulatory framework for more resilient banks and banking systems", December 2010.

[6] Benigno, Pierpaolo (2004): "Optimal monetary policy in a currency area", *Journal of International Economics* 63, no. 2: 293-320.

[7] Calvo, Guillermo A (1983): "Staggered prices in a utility-maximizing framework", *Journal of Monetary Economics* 12, no. 3: 383-398.

[8] Cecchetti, Stephen G., and Paul Tucker (2016): "Is there macroprudential policy without international cooperation?", CEPR Discussion Paper No. DP11042.

[9] Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005): "Nominal rigidities and the dynamic effects of a shock to monetary policy", *Journal of Political Economy* 113, no. 1: 1-45.

[10] Claessens, Stijn (2017): "Global banking: Recent developments and insights from research", *Review of Finance* 21, no. 4: 1513-1555.

[11] Dedola, Luca, Peter Karadi, and Giovanni Lombardo (2013): "Global implications of national unconventional policies", *Journal of Monetary Economics* 60 (1): 66-85.

[12] De Paoli, Bianca, and Matthias Paustian (2017): "Coordinating Monetary and Macroprudential Policies" *Journal of Money, Credit and Banking* 49(2-3): 319-349.

[13] Devereux, Michael B. and Sutherland, Alan (2011): "Country portfolios in open economy macro-models", *Journal of the European Economic Association*, 9(2), pp.337-369.

[14] Edge, Rochelle M.(2003): "A utility-based welfare criterion in a model with endogenous capital accumulation", Board of Governors of the Federal Reserve System Finance and Economics Discussion Series Working Paper No. 2003-66.

[15] Emter, Lorenz, Martin Schmitz, and Marcel Tirpák (2019): "Cross-border banking in the EU since the crisis: What is driving the great retrenchment?", *Review of World Economics* 155, no. 2: 287-326.

[16] Feenstra, Robert, Philip A. Luck, Maurice Obstfeld, and Katheryn Russ (2018): "In Search of the Armington Elasticity", *Review of Economics and Statistics* 100, no. 1: 135-150..

[17] Fève, Patrick, Alban Moura, and Olivier Pierrard (2019): "Shadow banking and financial regulation: A small-scale DSGE perspective", *Journal of Economic Dynamics and Control* 101: 130-144.

[18] Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M. Signoretti (2010): "Credit and Banking in a DSGE Model of the Euro Area", *Journal of Money, Credit and Banking* 42: 107-141.

[19] Gertler, Mark, and Peter Karadi (2011): "A model of unconventional monetary policy", *Journal of Monetary Economics* 58 (1): 17-34.

[20] Gertler, Mark, and Nobuhiro Kiyotaki (2011): "Financial intermediation and credit policy in business cycle analysis", *Handbook of Monetary Economics* 3A: 547-599.

[21] Gertler, Mark, and Nobuhiro Kiyotaki (2015): "Banking, liquidity, and bank runs in an infinite horizon economy", *American Economic Review* 105, no. 7: 2011-43.

[22] Gertler, Mark, Nobuhiro Kiyotaki, and Albert Queralto (2012): "Financial crises, bank risk exposure and government financial policy", *Journal of Monetary Economics* 59: 17-34.

[23] Gertler, Mark, Nobuhiro Kiyotaki, and Andrea Prestipino (2016): "Wholesale banking and bank runs in macroeconomic modelling of financial crises", *Handbook of Macroeconomics* 2: 1345-1425.

[24] Gilchrist, Simon and Egon Zakrajsek (2012): "Credit Spreads and Business Cycle Fluctuations", *American Economic Review* 102(4): 1692–1720.

[25] Gros, Daniel, and Dirk Schoenmaker (2014): "European Deposit Insurance and Resolution in the Banking Union", *Journal of Common Market Studies* 52(3): 529-546.

[26] Imbs, Jean (2010): "The first global recession in decades", IMF economic review 58, no. 2: 327-354.

[27] Kirchner, Philipp (2020): On shadow banking and financial frictions in DSGE modeling, MAGKS Joint Discussion Paper Series in Economics No. 19-2020.

[28] Kirchner, Philipp and Benjamin Schwanebeck (2017): "Optimal Unconventional Monetary Policy in the Face of Shadow Banking", MAGKS Joint Discussion Paper Series in Economics No. 25-2017.

[29] Kiyotaki, Nobuhiro, and John Moore (2012): "Liquidity, business cycles, and monetary policy", National Bureau of Economic Research No. w17934.

[30] Krenz, Johanna (2018): "Unconventional Monetary Policy in a Monetary Union", BDPEMS Working Paper Series # 2018-01.

[31] Lama, Ruy, and Pau Rabanal (2014): "Deciding to enter a monetary union: the role of trade and financial linkages", *European Economic Review* 72: 138-165.

[32] Levine, Paul, and Diana Lima (2015): "Policy mandates for macro-prudential and monetary policies in a new Keynesian framework", *ECB Working Paper* No. 1784.

[33] Meeks, Roland, Benjamin D. Nelson, and Piergiorgio Alessandri (2017): "Shadow banks and macroeconomic instability", *Journal of Money,Credit and Banking*, 49, no. 7: 1483-1516.

[34] Nelson, Benjamin, and Gabor Pinter (2018): "Macroprudential capital regulation in general equilibrium", Bank of England Working Paper No. 770.

[35] Nuguer, Victoria (2016): "Financial Intermediation in a Global Environment", *International Journal of Central Banking* 12 (3): 291-344.

[36] Palek, Jakob, and Benjamin Schwanebeck (2019): "Optimal monetary and macroprudential policy in a currency union." *Journal of International Money and Finance* 93: 167-186.

[37] Perri, Fabrizio, and Vincenzo Quadrini (2018): "International recessions", *American Economic Review* 108, no. 4-5: 935-84.

[38] Poutineau, Jean-Christophe, and Gauthier Vermandel (2015): "Cross-border banking flows spillovers in the Eurozone: Evidence from an estimated DSGE model", *Journal of Economic Dynamics and Control* 51: 378-403.

[39] Poutineau, Jean-Christophe, and Gauthier Vermandel (2017): "Global banking and the conduct of macroprudential policy in a monetary union", *Journal of Macroeconomics* 54: 306-331.

[40] Quint, Dominic, and Pau Rabanal (2014): "Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area", *International Journal of Central Banking* 10(2): 169-236.

[41] Schoenmaker, Dirk (2013): *Governance of International Banking: The Financial Trilemma*, Oxford University Press.

[42] Sims, Eric (2011): "Permanent and transitory technology shocks and the behavior of hours: A challenge for DSGE models", University of Notre Dame.

[43] Smets, Frank, and Raf Wouters (2003) "An estimated dynamic stochastic general equilibrium model of the euro area", *Journal of the European Economic Association* 1, no.5: 1123-1175.

[44] Smets, Frank, and Raf Wouters (2007): "Shocks and frictions in US business cycles: A Bayesian DSGE approach", *American Economic Review* 97, no. 3: 586-606.

[45] Verona, Fabio., Manuel M. F. Martins, and Ines Drumond (2013): *"(Un) anticipated Monetary Policy in a DSGE Model with a Shadow Banking System",* International Journal of Central Banking 9, no. 3: 78-124.

[46] Woodford, Michael (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

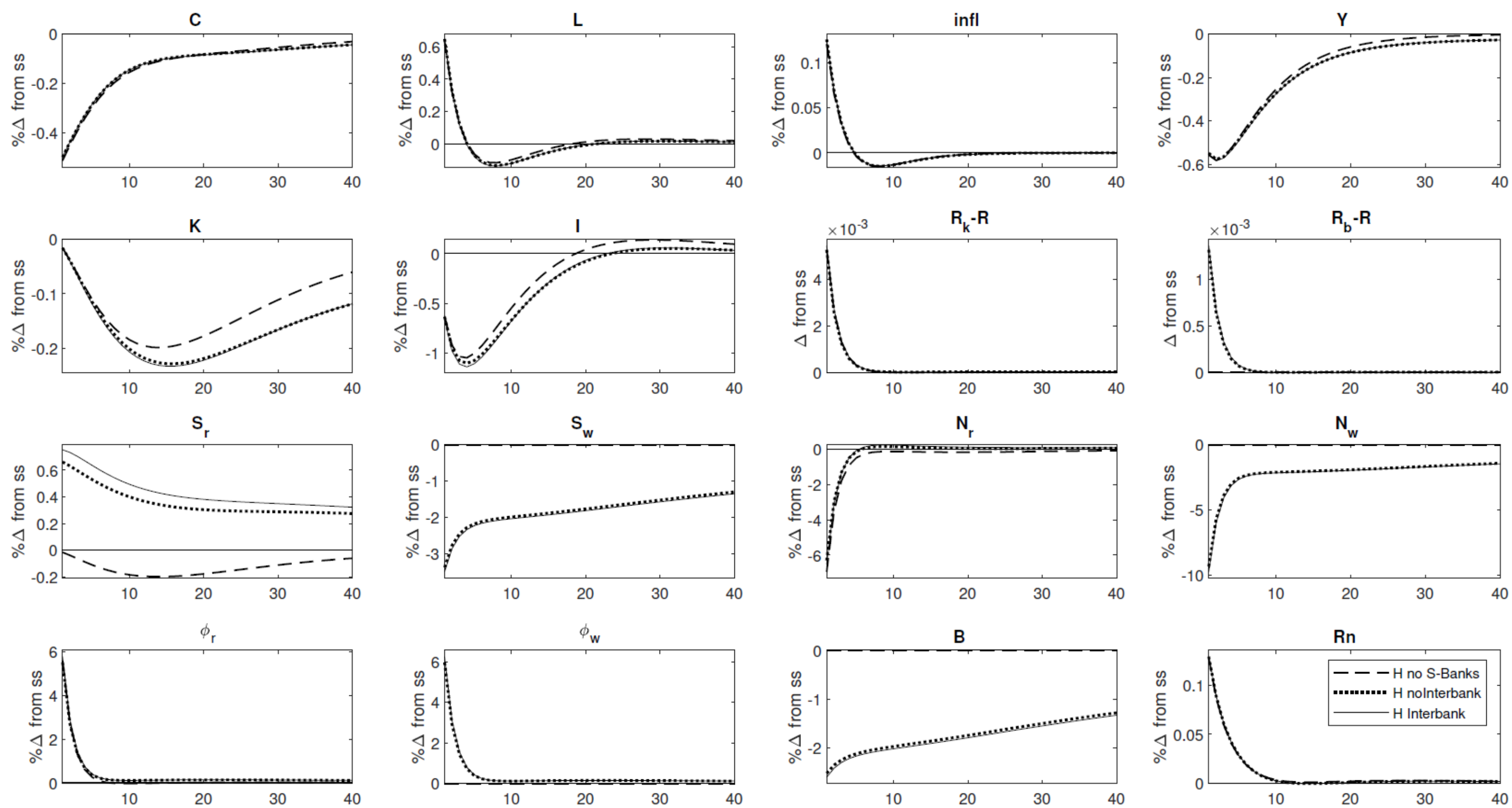

Figure 1: Country home: technology shock in home

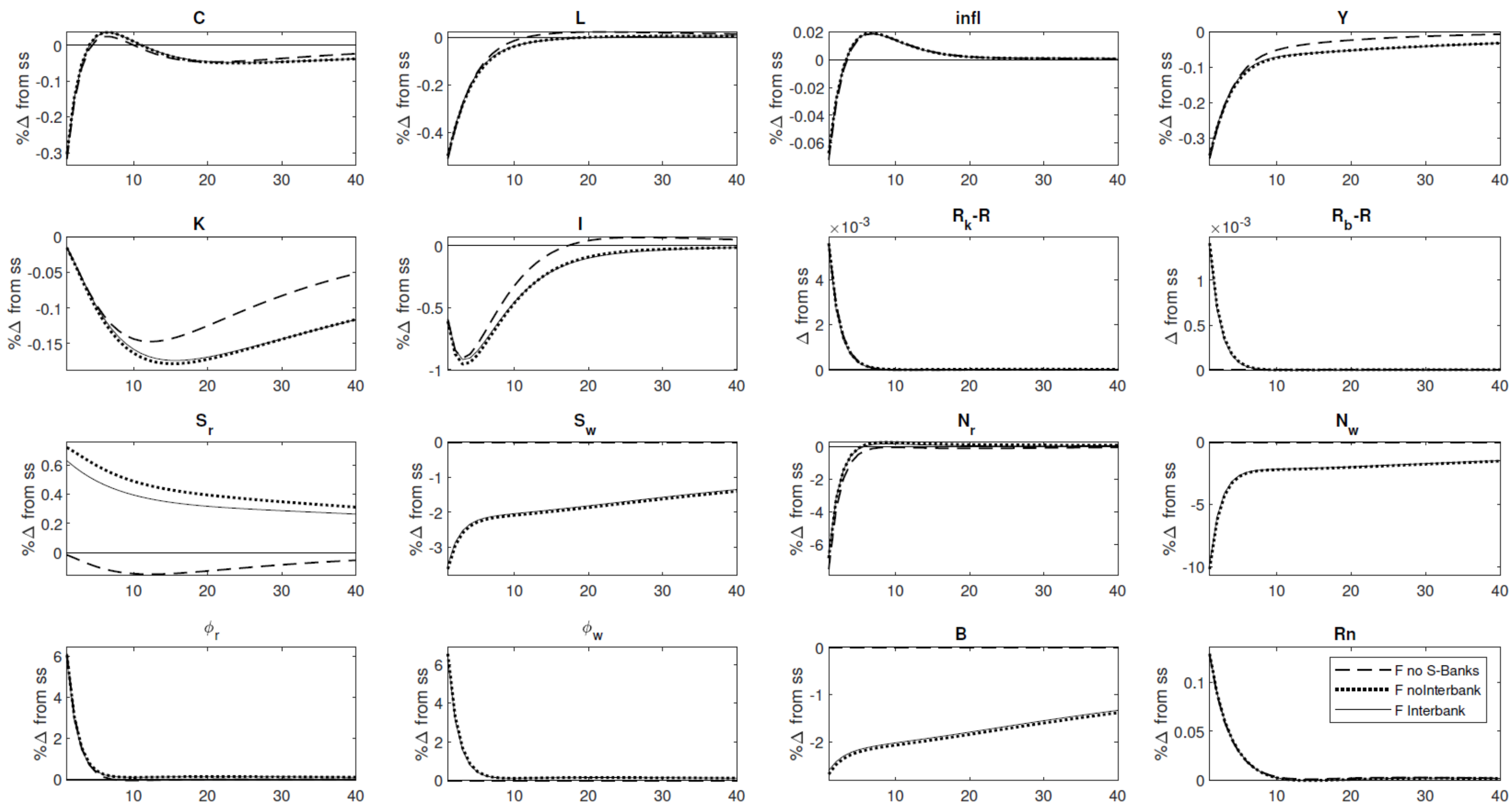

Figure 2: Country foreign: technology shock in home

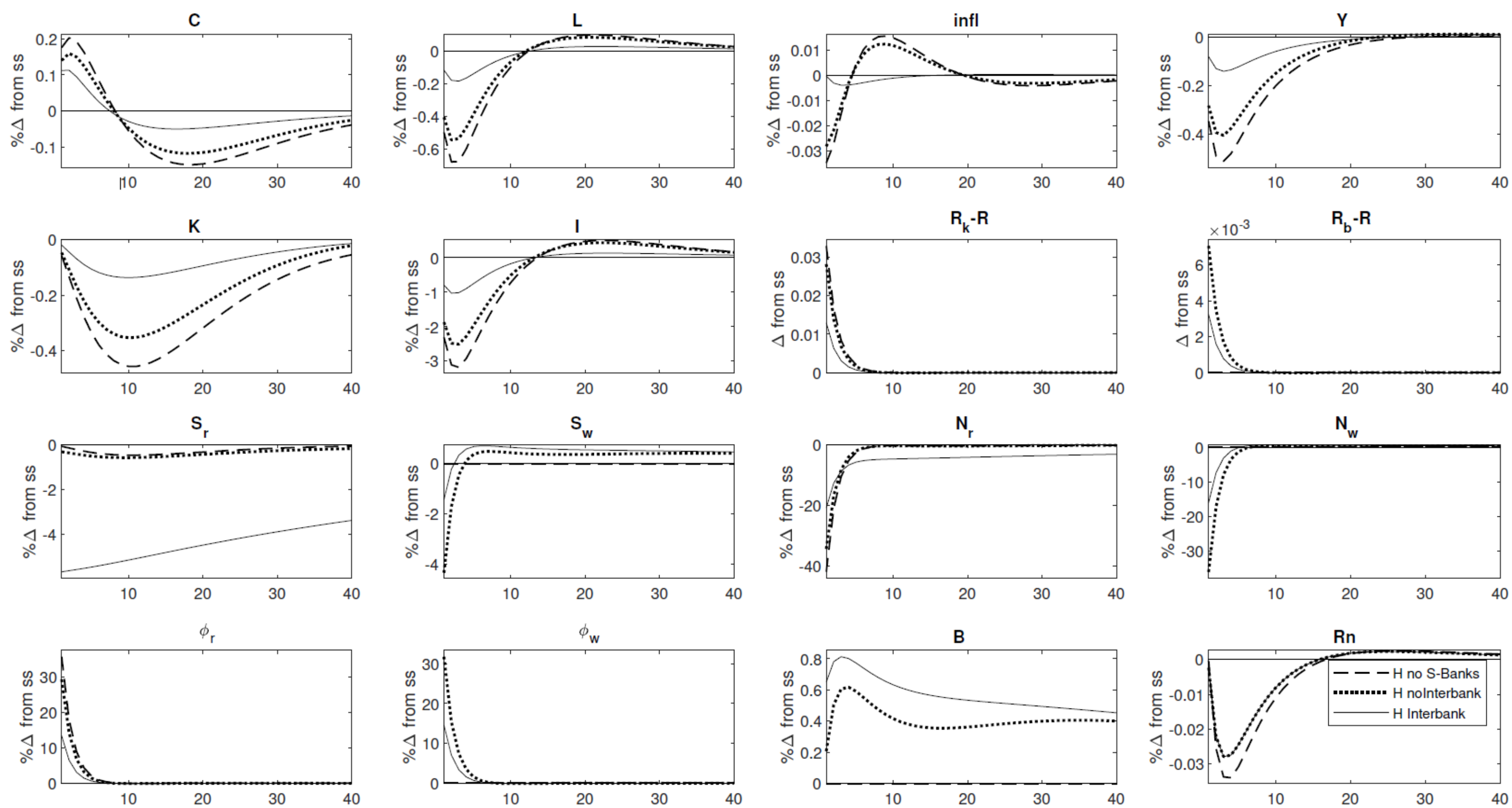

Figure 3: Country home: net worth shock in home

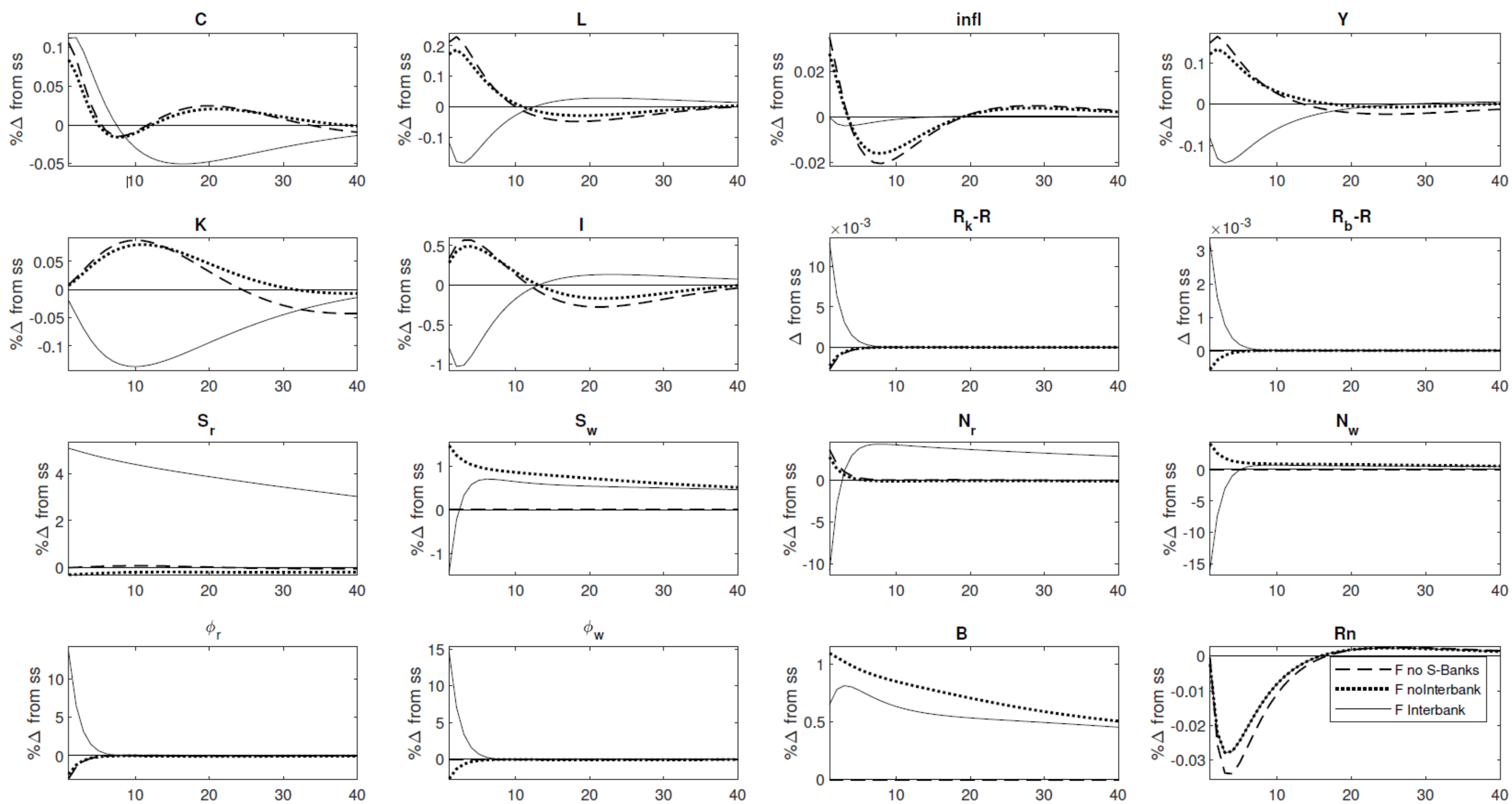

Figure 4: Country foreign: net worth shock in home

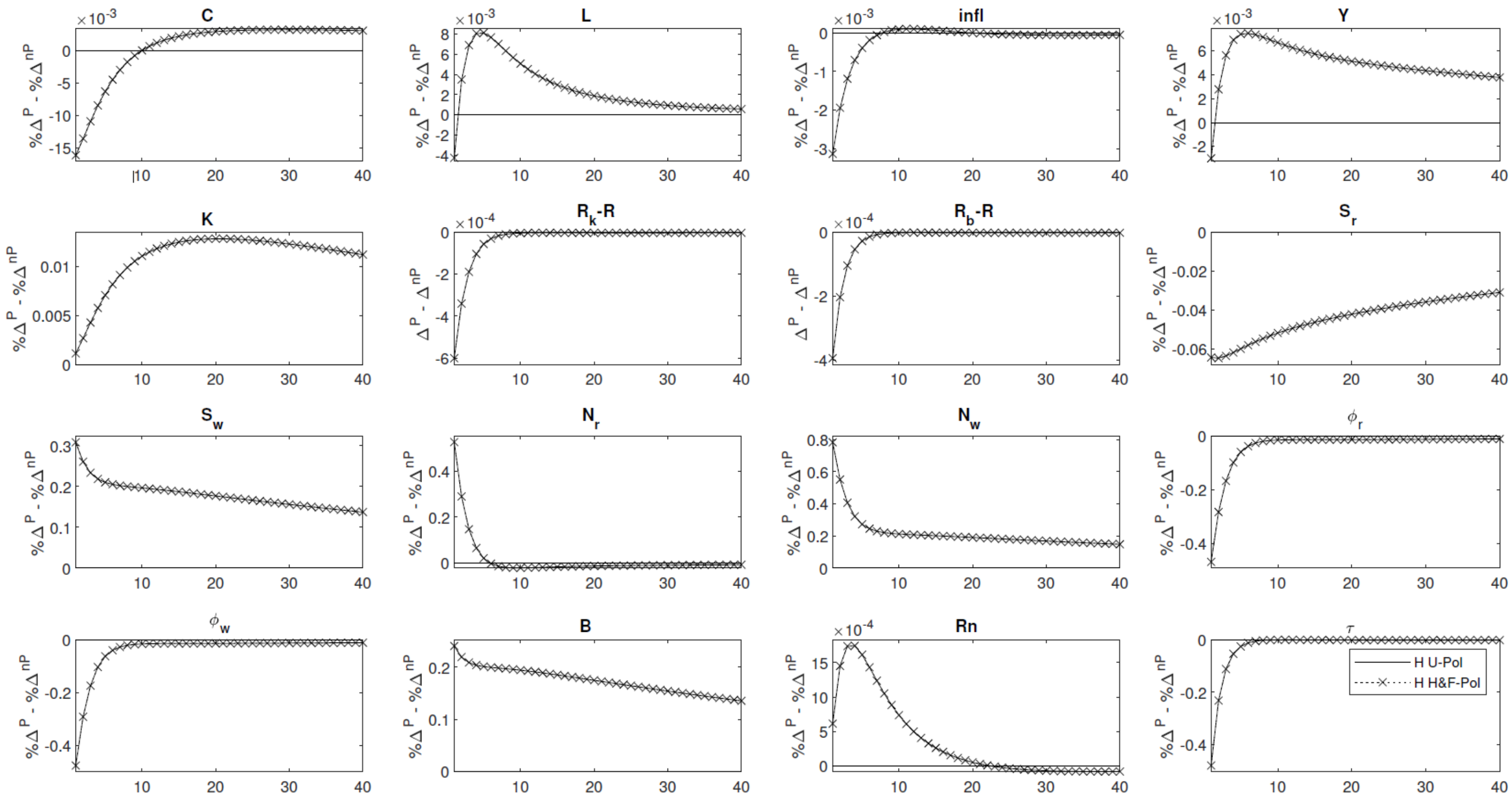

Figure 5: Country home: Union (U-Pol) and Country-Specific (HF-Pol) macroprudential regulation to a technology shock

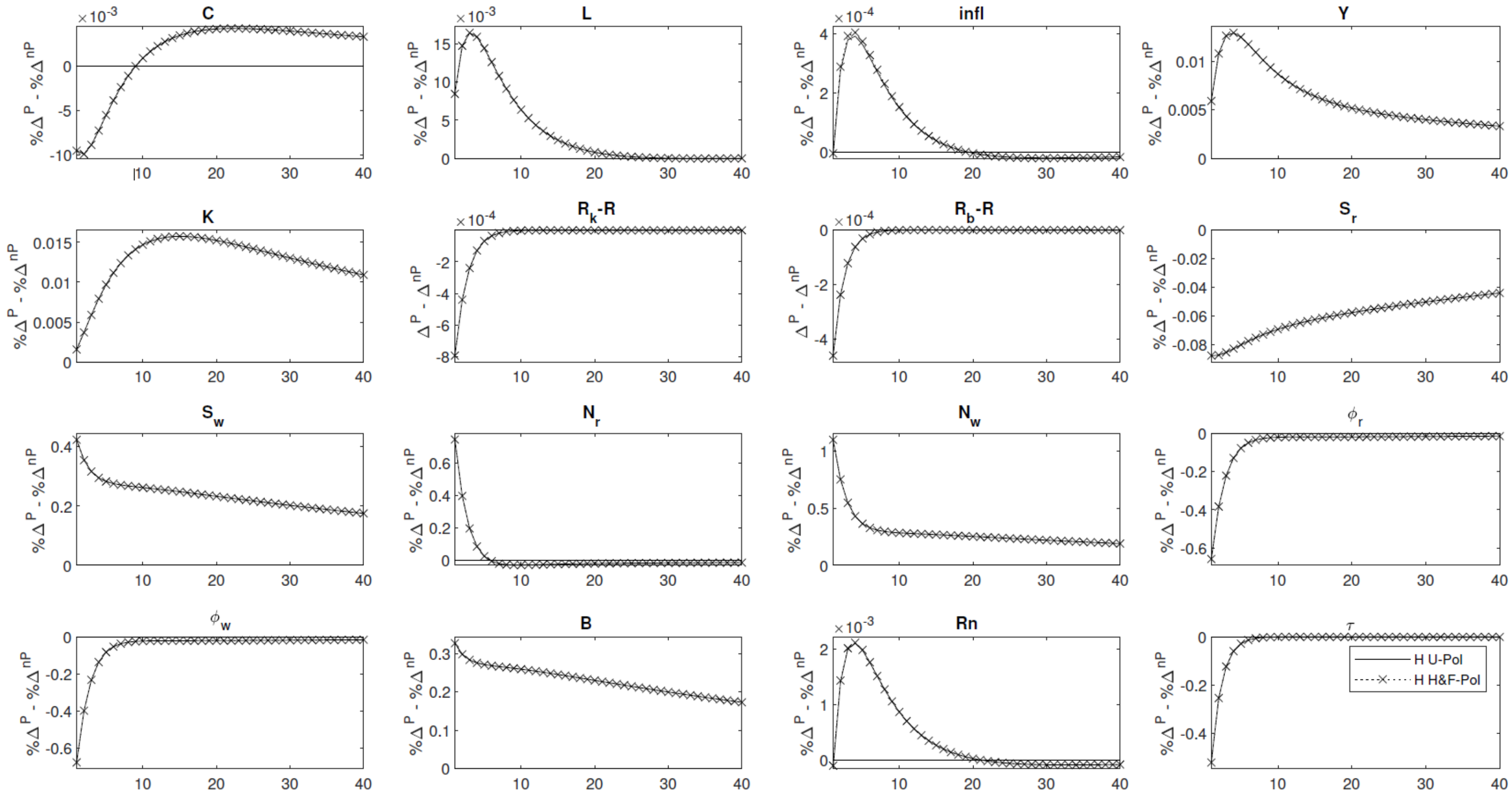

Figure 6: Country home: Union (U-Pol) and Country-Specific (HF-Pol) macroprudential regulation to a net worth shock