Macroprudential Policy Coordination in a Currency Union

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Abstract

Using a game-theoretic approach, the benefits of macroprudential policy coordination are evaluated in a two-country model of a currency union with financial frictions. The gains from coordination are measured by comparing outcomes under a centralized regime, where a common regulator sets a macroprudential tax on loans to maximize union-wide welfare, and a decentralized regime, where each regulator sets the tax independently to maximize own-country welfare. Numerical experiments show that, in response to financial shocks, coordination involves increased activism in the country where the shock originates (*keeping one's house in order*). However, while union-wide gains from coordination are positive when country-specific instrument rules are set, a *one-size-fits-all* policy makes the union worse off when member countries are asymmetric in size and structure. Under both the centralized and the decentralized regimes, getting monetary policy to lean too aggressively against the financial cycle may be counterproductive. The broad implications of the analysis for macroprudential policy coordination and the central bank's mandate in the euro area are also discussed.

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1 Introduction

Increased interconnectedness of financial institutions and markets, and more highly correlated financial shocks, have intensified cross-border spillovers—as well as so-called "spillbacks," as documented by the Bank for International Settlements (2016) and the International Monetary Fund (2016)—and have led to renewed calls to strengthen prudential regulation and supervision of financial institutions, both within and between countries. These policies have been viewed by some observers to be essential to mitigate the substantial risks associated with international financial integration, and the potentially large economic costs that countries may face when crises occur and are propagated across borders.

At the same time, there has been increased recognition that differences in national regulatory regimes and policies across countries can themselves become a source of, and conduit for, international spillovers. In particular, by triggering cross-border regulatory arbitrage, differences in macroprudential rules may lead to sharp swings in capital flows and magnify the international propagation of real and financial shocks, through changes in asset prices and collateral values.[1] When financial cycles are not well synchronized across countries, or systemic intermediaries can evade at little cost policy actions taken by national authorities, the overall combination of macroprudential policies may be suboptimal—even when each country's policy is optimal at the national level. As a result, financial instability risks may worsen at the level of the global economy. The question arises therefore as to whether formal coordination of these policies between countries—beyond the reciprocity agreements promoted by the Basel III Accord in the context of capital requirements, for instance—could help to promote global financial stability.

Recent analytical contributions have indeed identified several channels through which cross-country coordination of macroprudential policies could mitigate the adverse effects of cross-border spillovers and raise global welfare.[2] Some of these contribu-

[1]See Aiyar et al. (2014), Beirne and Friedrich (2014), and Buch and Goldberg (2017) for empirical evidence on the channels through which national macroprudential policies can generate cross-border spillovers and their magnitude.

[2]A long-standing strand of the literature has focused on the scope for, and the benefits from, international coordination of *monetary* policies. See Pappa (2004), Benigno and Benigno (2008), Liu and Pappa (2008), Coenen et al. (2009), Kolasa and Lombardo (2014), Banerjee et al. (2016), and Fujiwara and Teranishi (2017) for specific contributions, as well as Taylor (2013), Eichengreen (2014), and Engel (2016) for a broader perspective. Even though many of the models used in that literature

tions, including those of Bengui (2014), Jeanne (2014), Korinek (2014, 2017), and Kara (2016), are based on small analytical models. A growing number of others are based on two-country dynamic stochastic general equilibrium (DSGE) models with financial market imperfections and include Kollmann et al. (2011), Kollmann (2013), Rubio (2014), Quint and Rabanal (2014), Mendicino and Punzi (2014), Brzoza-Brzezina et al. (2015), Poutineau and Vermandel (2015, 2017), Rubio and Carrasco-Gallego (2016), Cuadra and Nuguer (2018), Palek and Schwanebeck (2019), and Agénor et al. (2021).[3]

Of particular interest to us in this study are those contributions focusing on a currency union with national policymakers and a common central bank, both of which possibly taking on a macroprudential regulatory role as an additional mandate. A key question in that context has been at which institutional level (national or supranational) should macroprudential regulation be conducted. This issue is especially important in a currency union with a *one-size-fits-all* monetary policy and where business cycles are not fully synchronized—prompting some observers to argue that pro-active domestic macroprudential policies are needed not only from the perspective of financial stability but also output stability, given the impact of macroprudential instruments on credit, and the pervasive demand- and supply-side links between credit and economic activity.[4]

Rubio (2014), for instance, explored how loan-to-value (LTV) ratios, endogenously related to changes in output and house prices, should be set in such as an environment. Her results emphasized the importance of asymmetries for the conduct of macroprudential policies in a monetary union, especially when heterogeneity results in differences in aggregate volatility. In the same vein, Rubio and Carrasco-Gallego (2016) found that, compared to the case where an LTV macroprudential policy is implemented at the level of a single member country, the welfare gain is larger if all members of the union (or a common supranational entity) implement it in coordinated fashion. At the same time, the additional welfare gain from introducing country-specific macroprudential appears to be small. Brzoza-Brzezina et al. (2015) also examined the effectiveness of LTV ratios as a (borrower-based) macroprudential policy instrument, linked to changes in

do not account explicitly for financial frictions and regulatory regimes, some of their broader results (as discussed later) are relevant for the ongoing debate on macroprudential policy coordination across countries.

[3] Some of these contributions have also looked at the combination of monetary and macroprudential policies, an issue that we address later on.

[4] See, for instance, Sergeyev (2016) and Gelain and Ilbas (2017).

credit, house prices, and output, under the assumption that core and periphery union members are impacted by asymmetric shocks. Their results showed that centralized macroprudential policy can substantially lower the magnitude of credit and output fluctuations in the periphery. In addition, they found that, from a welfare perspective, decentralized macroprudential policy is more effective than a common policy.[5]

By contrast, Quint and Rabanal (2014), focused on the case where a "generic", lender-based macroprudential instrument influences credit market conditions by affecting directly the fraction of liabilities that banks can lend. They found that, under a variety of scenarios, the introduction of a macroprudential rule would help to reduce macroeconomic volatility and improve union-wide welfare, thereby partially substituting for the lack of national autonomy in the conduct of monetary policies. Palek and Schwanebeck (2019) also considered the case where the regulatory policy instrument affects the borrowing costs faced by entrepreneurs. Their results showed that macroprudential policy is effective at mitigating fluctuations at the union level under a variety of scenarios, thereby improving welfare. By contrast, Poutineau and Vermandel (2017), in a model which focuses on countercyclical capital buffers as the macroprudential instrument, found that it is optimal to conduct policy at the country rather than the union level when credit cycles are asymmetric—even when cross-border linkages through interbank lending are strong.

The purpose of this paper is threefold. First, it aims to contribute to a better understanding of the cross-border spillover effects of macroprudential policy in a currency union where credit and capital markets are imperfect and housing plays a key role as collateral for loans. Second, it aims to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in a currency union, relative to the case where countries pursue independently their own policies. Third, we consider whether the mandate of the common central bank should allow for a direct interest rate response to national financial imbalances. In contrast with most of the contributions discussed earlier, which do not explicitly account for strategic interactions, we address these issues in an explicit game-theoretic framework. Specifically, we compare the properties of two alternative, explicit mandates for macroprudential policy, in the form of a simple, implementable rule: the case where the policy is delegated to a common

[5]In practice, however, it is hard to think of sectoral, borrower-based macroprudential instruments (such as LTV ratios or debt-to-income ratios) as being set by a centralized institution in a currency union, because of significant institutional differences between national housing markets.

regulator (the cooperative equilibrium or *centralized regime*), and the case where it is delegated to the individual member countries (the noncooperative Nash equilibrium or *decentralized regime*), with the common central bank retaining control of monetary policy. This separation of mandates is consistent with the fact that, in practice, distinct institutions are often made responsible for achieving narrower goals on the grounds of accountability (see Committee on the Global Financial System (2016) and Calvo et al. (2018)). Our main focus—beginning with the case where union members are perfectly symmetric—is on understanding whether delegating the setting of the macroprudential instrument to the common central bank helps to reduce the magnitude of cross-border spillovers and stabilize better than when individual countries pursue their own policies. In addition, we also consider whether it is optimal for the central bank to lean against the financial cycle.

Our main results can be summarized as follows. First, based on a comparison between the decentralized regime (in which regulators in each country set the macroprudential instrument to maximize own welfare) and the centralized regime (where the common regulator sets either a uniform value or separate values for the macroprudential instrument to maximize union-wide welfare), show that coordination, when instruments are set separately, always involves a stronger response in the country where the shock originates, and this allows the other country to react less—compared to when regulators act independently. Thus, coordination involves a more aggressive response (*keeping one's house in order*) for the country that is directly affected by the disturbance. While the gains from coordination, from the perspective of the union as a whole, are positive when separate instruments are used by the common regulator, they tend to be relatively small. Intuitively, the ability of the common regulator to internalize spillovers to the foreign country, and spillbacks to the home country, when setting the common macroprudential instrument generates a stabilization benefit that translates into higher welfare. At the same time, when member countries are subject to asymmetric financial shocks, a *one-size-fits-all* policy of setting a uniform value of the macroprudential instrument is suboptimal. Moreover, depending on the origin of the shock and the cost of instrument manipulation, some member countries may be worse off under cooperation, even when the union as a whole benefits from it. Thus, coordination may not be Pareto-improving.

By and large, these results continue to hold both when the union members are symmetric in size and structure and when they differ in both respects (in line with some of the core-periphery models of currency unions alluded to earlier). The key difference in the latter case is that, when financial shocks occur in the core only, asymmetries in size and structure magnify the difference in the policy responses of the periphery regulator under the decentralized regime and the centralized regime with a uniform instrument, making a *one-size-fits-all* policy even worse as the union now loses from cooperation. Under asymmetry, a global supply shock (which can be viewed as capturing the disruptive effects of the Covid-19 pandemic on global value chains) has similar effects.

Second, in response to symmetric or asymmetric financial shocks, the optimal degree to which the common central bank should lean against the area-wide financial conditions is fairly low. The reason is that the common monetary policy, when it responds too aggressively to union-wide credit developments associated with shocks occurring in a particular country, creates a negative externality for the other member countries; to address this externality, other countries respond through offsetting changes in their macroprudential policy stance. This occurs both in the decentralized regime, and in the centralized regime when macroprudential policy instruments are set separately. Our argument as to why *leaning against the wind* too aggressively may be counterproductive in a currency union stands apart from those that have been commonly proposed to keep the focus of monetary policy squarely on achieving its inflation target.

The remainder of the paper proceeds as follows. Section 2 describes the model, with a focus on the financial side. Macroprudential regulation takes the form of a time-varying tax on bank loans. As in some recent contributions, including Quint and Rabanal (2014) and Kiley and Sim (2017), for instance, such a tax can be viewed as a generic specification consistent with how two major macroprudential instruments, capital requirements and dynamic provisions, operate in terms of their impact on the cost of bank borrowing (see Claessens (2015) and Agénor (2020)). As a result, analytical tractability is enhanced, while a key aspect of the transmission channel of macroprudential policy is preserved. Model equilibrium is discussed in Section 3 and a core parameterization is presented in Section 4. Our goal here is not to match any particular set of data, but rather to characterize (using as much as possible standard parameter values) some qualitative properties of the model. At the same time, our choice of parameters reflects to a significant extent recent estimates for the euro area. The results of asymmetric financial and monetary policy shocks are described in Section 5. The gains from coordination, calculated by solving for welfare-maximizing policies under the alternative institutional mandates described earlier, are examined in Section 6. A simple implementable rule, linking changes in the macroprudential instrument to deviations in the credit-to-output ratio, is defined, both at the national and union-wide levels. The performance of the simple rule is also compared to the Ramsey optimal policy. Some robustness checks, including asymmetries across member countries and the response to global supply and demand shocks, are reported in Section 7, whereas Section 8 extends the analysis to consider the joint determination of optimal monetary and macroprudential policies. Even though (as noted earlier) the model is not built and parameterized to match exactly all the key features of a particular currency union, the broad policy implications of our analysis for the euro area, and the institutional mandate of the European Central Bank, are discussed in Section 9. The last section identifies some potentially fruitful directions in which our analysis can be further extended.

2 The Model

The world economy consists of two countries, called home and foreign, which are joined in a currency union. Thus, both countries use the same currency and delegate their monetary policy to a common monetary authority. Countries are initially asumed to be symmetric in all respects. They trade in goods and government bonds (the latter subject to a cost), but markets in cash and credit are segmented. Thus, financial markets are imperfectly integrated.

Each country is populated by six categories of agents: a representative household, a continuum of monopolistic (IG) firms producing intermediate goods, a representative nontradable final good (FG) producer, a representative capital good (CG) producer, a continuum of commercial banks, and the government. There are also a common central bank and domestic financial regulators, which may or may not (depending on the policy regime) set macroprudential instruments at the national level. When macroprudential policy coordination is required, the common central bank acts as the union-wide financial regulator as well. Neither firms nor banks, in either country, can lend and borrow internationally.

Each country uses capital and labor to produce a continuum of intermediate goods, which are imperfect substitutes to a continuum of imported intermediate goods. As in a number of contributions (see Kollmann (2003), Bergin et al. (2007), Huang and Liu (2007), and Gong et al. (2016), for instance), trade within the union occurs only at the level of intermediate goods and both categories of goods are combined in each country to produce a homogeneous final good. These goods are used only for local consumption and investment. Physical capital and labor are not mobile internationally.

In what follows we describe the home economy; where relevant, descriptions of the foreign economy are also provided.

2.1 Households

Households in both countries have identical preferences. The objective of the representative household in the home country is to maximize[6]

$$U_t^H = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ \frac{(C_{t+s}^H)^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} - \eta_N \int_0^1 \frac{(N_{t+s}^{H,j})^{1+\psi_N}}{1+\psi_N} dj + \ln[(x_{t+s}^H)^{\eta_x} (A_{t+s}^H)^{\eta_A}] \right\}, \quad (1)$$

where C_t^H is consumption of the home final good, $N_t^H = \int_0^1 N_t^{H,j} dj$, the share of total time endowment (normalized to unity) spent working, with $N_t^{H,j}$ denoting the number of hours of labor provided to home IG producer j, x_t^H a composite index of real monetary assets, A_t^H the stock of housing, $\Lambda \in (0,1)$ a discount factor, $\varsigma > 0$ the intertemporal elasticity of substitution in consumption, $\psi_N > 0$ the inverse of the Frisch elasticity of labor supply, $\mathbb{E}_t$ the expectation operator conditional on the information available at the beginning of period t, and $\eta_N, \eta_x, \eta_A > 0$.

The composite monetary asset consists of real cash balances, m_t^H, and real bank deposits, d_t^H, both measured in terms of the price of home final output, P_t^H:

$$x_t^H = (m_t^H)^{\nu} (d_t^H)^{1-\nu}, \quad (2)$$

where $\nu \in (0,1)$.[7]

The household's flow budget constraint is

$$m_t^H + d_t^H + b_t^{HH} + b_t^{HF} + p_t^{HA} \Delta A_t^H \quad (3)$$

[6] Throughout the paper, the superscripts H and F are used to refer to home and foreign country variables, respectively.

[7] We account for both cash and deposits because, as discussed later on, the equilibrium condition of the money market is used to solved for the bond rate.

$$= w_t^H N_t^H - T_t^H - C_t^H + \frac{m_{t-1}^H}{1+\pi_t^H} + (\frac{1+i_{t-1}^{HD}}{1+\pi_t^H})d_{t-1}^H + (\frac{1+i_{t-1}^{HB}}{1+\pi_t^H})b_{t-1}^{HH}$$
$$+(1+i_{t-1}^F)b_{t-1}^{HF} + J_t^{HI} + J_t^{HK} + J_t^{HB},$$

where $p_t^{HA} = P_t^{HA}/P_t^H$ is the real price of housing (with P_t^{HA} the nominal price), $1+\pi_t^H = P_t^H/P_{t-1}^H$, b_t^{HH} (b_t^{HF}) real holdings of one-period, noncontingent home (foreign) government bonds, i_t^{HD} the interest rate on bank deposits, i_t^{HB} the interest rate on home government bonds, i_t^F the premium-adjusted (or *effective*) interest rate on foreign government bonds, w_t^H the economy-wide real wage, T_t^H real lump-sum taxes, J_t^{HI}, J_t^{HK}, and J_t^{HB}, profits of the IG producer, the CG producer, and commercial banks, respectively. For simplicity, housing does not depreciate.

To capture imperfect international financial integration, we assume that home households face intermediation costs when taking a position on the foreign bond market. The effective rate of return on foreign bonds is thus given by

$$1 + i_t^F = (1 + i_t^{FB})(1 - \theta_t^{HF}), \tag{4}$$

where i_t^{FB} is the unadjusted foreign bond rate and θ_t^{HF} a financial intermediation premium, which increases with the household's own stock of foreign bonds:

$$\theta_t^{HF} = \frac{\theta_0^B}{2} b_t^{HF}, \tag{5}$$

with $\theta_0^B > 0$ a symmetric cost parameter.

The home household maximizes (1) with respect to C_t^H, N_t^H, m_{t+1}^H, d_{t+1}^H, b_{t+1}^{HH}, b_{t+1}^{HF}, and A_{t+1}^H, subject to (2) to (5), taking period-$t-1$ variables as well as w_t^H, T_t^H, and real profits as given. The first-order conditions are

$$(C_t^H)^{-1/\varsigma} = \Lambda \mathbb{E}_t \left\{ (C_{t+1}^H)^{-1/\varsigma} (\frac{1+i_t^{HB}}{1+\pi_{t+1}^H}) \right\}, \tag{6}$$

$$N_t^H = [\frac{w_t^H (C_t^H)^{-1/\varsigma}}{\eta_N}]^{1/\psi_N}, \tag{7}$$

$$m_t^H = \frac{\eta_x \nu (C_t^H)^{1/\varsigma}(1+i_t^{HB})}{i_t^{HB}}, \tag{8}$$

$$d_t^H = \frac{\eta_x (1-\nu)(C_t^H)^{1/\varsigma}(1+i_t^{HB})}{i_t^{HB} - i_t^{HD}}, \tag{9}$$

$$\frac{p_t^{HA}}{(C_t^H)^{1/\varsigma}} = \frac{\eta_A}{A_t^H} + \Lambda \mathbb{E}_t [\frac{p_{t+1}^{HA}}{(C_{t+1}^H)^{1/\varsigma}}], \tag{10}$$

$$b_t^{HF} = \frac{i_t^{FB} - i_t^{HB}}{\theta_0^B (1 + i_t^{FB})}. \quad (11)$$

Equation (6) is the Euler equation, whereas (7) to (9) define labor supply and the demand functions for cash and deposits. Equation (10) is the intertemporal condition for housing, whereas (11) defined the demand for foreign bonds by home households.

Foreign households face a resource allocation problem similar to the one faced by home households. In particular, their demand for home bonds is given by

$$b_t^{FH} = \frac{i_t^{HB} - i_t^{FB}}{\theta_0^B (1 + i_t^{HB})}. \quad (12)$$

Equations (11) and (12) imply that interest parity ($i_t^{HB} = i_t^{FB}$), or perfect capital mobility, obtains when $\theta_0^B \to 0$.

2.2 Production

The production side of the model (which involves production of the final good, production of intermediate goods, and the production of capital goods) is fairly standard and is presented in detail in Appendix A, with a solution of the CG producer's optimization problem given in Appendix B. In brief, production of the home final good, Y_t^H, requires combining a basket of domestically-produced differentiated intermediate goods sold at home, Y_t^{HH}, with a basket of imported intermediate goods produced abroad (that is, foreign exports), Y_t^{FH}. Cost minimization yields therefore the demand for each variety $j \in (0, 1)$ of intermediate goods, Y_{jt}^i, with $i = HH, FH$ as a function of the price each good j, P_{jt}^i, relative to the aggregate price, P_t^i, and total demand, Y_t^i. The price of the home final good, P_t^H, is thus a function of P_t^{HH} and P_t^{FH}, and similarly for P_t^F. In addition, assuming no transportation costs, the law of one price implies that the home price of imported good j is such that $P_{jt}^{FH} = P_{jt}^{FF}$; conversely, $P_t^{HF} = P_t^{HH}$. Market-clearing requires that total output of home intermediate good j must be equal to the world demand for that good, that is, the sum of the home and foreign demands for home good j. Finally, the aggregate capital stock, $K_t^H = \int_0^1 K_{jt}^H dj$, is obtained by combining gross investment with the existing stock, adjusted for depreciation and adjustment costs. Purchases of investment goods, I_t^H, must be paid for in advance. The CG producer must therefore borrow from the bank $l_t^H = I_t^H$. The household makes its exogenous housing stock, $\bar{A}^H$, available without any direct charge to the CG firm that it owns, which uses it as collateral to secure loans.[8] Repayment of these loans is uncertain and occurs with probability $q_t^H \in (0,1)$. In case of default, lenders can seize the housing collateral pledged by borrowers.

2.3 Commercial Banks

The balance sheet of home bank $i \in (0,1)$ is given by

$$l_t^{H,i} + RR_t^{H,i} = d_t^{H,i} + l_t^{HB,i}, \tag{13}$$

where $l_t^{HB,i}$ is borrowing from the common central bank and $RR_t^{H,i}$ required reserves, which are set as a fraction $\mu \in (0,1)$ of deposits and earn no interest:

$$RR_t^{H,i} = \mu d_t^{H,i}. \tag{14}$$

The market for deposits is competitive, and deposits and central bank liquidity are perfect substitutes. This ensures therefore that, $\forall i$, the following no-arbitrage condition holds:

$$i_t^{HD,i} = (1-\mu) i_t^R, \tag{15}$$

where i_t^R is the marginal cost of borrowing from the central bank, which we define as the refinance rate.

By contrast, monopolistic competition prevails in the loan market. The demand for loans by bank i, $l_t^{HF,i}$, is given by the downward-sloping curve

$$l_t^{H,i} = (\frac{1+i_t^{HL,i}}{1+i_t^{HL}})^{-\zeta_L} l_t^H, \tag{16}$$

where $i_t^{HL,i}$ is the rate on the loan extended by bank i, $l_t^H = [\int_0^1 (l_t^{H,i})^{(\zeta_L - 1)/\zeta} di]^{\zeta_L/(\zeta_L - 1)}$ the amount borrowed by the representative CG producer (corresponding to the level of investment, as noted earlier), with $\zeta_L > 1$ denoting the elasticity of substitution between differentiated loans, and $1 + i_t^{HL} = [\int_0^1 (1+i_t^{HL,i})^{1-\zeta_L} di]^{1/(1-\zeta_L)}$ the aggregate loan rate.

Bank i's expected profits at the end of period t (or beginning of $t+1$) are defined as

$$\mathbb{E}_t J_{t+1}^{HB,i} = q_t^{H,i}(1+i_t^{HL,i})(1-\tau_t^H) l_t^{H,i} + (1-q_t^{H,i}) \kappa^i p_t^{HA} \bar{A}^H \tag{17}$$

[8] Because all profits made by each CG producing firm are assumed to be returned lump-sum to its owner, the assumption that housing is made available free of charge has no bearing on the results.

$$-(1+i_t^{HD,i})d_t^{H,i} - (1+i_t^R)l_t^{HB,i} + RR_t^{H,i} + \Omega_t^{H,i} - x_t^{HM,i},$$

where $\tau_t^H \in (0,1)$ is the tax rate on the gross value of loans imposed for macroprudential reasons, $\kappa^i \in (0,1)$ the fraction of the value of the housing collateral $p_t^{HA}\bar{A}^H$ that can be seized in case of default (which occurs with probability $1-q_t^{H,i}$), $\Omega_t^{H,i}$ the revenue of the loan tax, transferred back in lump-sum fashion to bank i, and $x_t^{HM,i}$, the total monitoring cost faced by bank i. The other terms in (17) are self explanatory.

In line with the micro-banking literature (see Allen et al. (2011) and Dell'Ariccia et al. (2014)), we assume that monitoring costs are endogenous and that monitoring effort is related one-to-one with the probability of repayment.[9] Specifically, the total cost is defined as

$$x_t^{HM,i} = \Phi_H()\frac{(q_t^{H,i})^2}{2}l_t^{H,i}, \tag{18}$$

where $\Phi_H()$ is a (unit) cost function, which depends on the average collateral-loan ratio and cyclical output.[10]

Bank i sets the repayment probability and the (gross) lending rate so as to maximize expected profits:[11]

$$q_t^{H,i}, 1+i_t^{HL,i} = \arg\max \mathbb{E}_t J_{t+1}^{HB,i}. \tag{19}$$

As shown in Appendix C, solving (19) subject to (13), (16), (17), and (18) yields, in a symmetric equilibrium,

$$1+i_t^{HL} = \left(\frac{\zeta_L}{\zeta_L-1}\right)\frac{1+i_t^R}{(1-\tau_t^H)q_t^H}\epsilon_t^L, \tag{20}$$

$$q_t^H = \left(\frac{\kappa\mathbb{E}_t p_{t+1}^{HA}\bar{A}^H}{l_t^H}\right)^{\varphi_1}\left(\frac{Y_t^H}{\tilde{Y}^H}\right)^{\varphi_2}, \quad \varphi_1, \varphi_2 > 0 \tag{21}$$

where ϵ_t^L is a credit spread shock which follows an $AR(1)$ process of the form $\epsilon_t^L = \epsilon_{t-1}^{\rho^L}\exp(\xi_t^L)$, with $\rho^L \in (0,1)$ and $\xi_t^L \sim \mathbf{N}(0, \sigma_{\xi^L})$, and $\tilde{Y}^H$ is the steady-state level of home final output. Thus, the repayment probability is positively related to both the expected value of collateral relative to the volume of loans and the cyclical position of the economy. In addition, a higher macroprudential tax (an increase in τ_t^H) raises the loan rate and reduces the demand for credit.

[9] As noted by Allen et al. (2011), the one-to-one relationship between monitoring effort and the repayment probability can be interpreted as meaning that the lender observes information about a borrower and then uses it to help improve the borrower's performance. The important point here is that monitoring is also desirable from the borrower's perspective.

[10] As discussed in Appendix C, the collateral-loan ratio reflects a combination of moral hazard effects, whereas the cyclical position of the economy reflects the fact that (unit) monitoring costs tend to be relatively low in boom times.

[11] Borrowing from the common central bank is determined residually from (13).

2.4 Government

The net income received by the union's central bank on each country's bank borrowing, $i_t^R l_t^{HB}$ and $i_t^R l_t^{FB}$, is transferred back to each national government. The home government budget constraint is thus given by

$$b_t^H = G_t^H - T_t^H + (1 + i_{t-1}^{HB})\frac{b_{t-1}^H}{1+\pi_t^H} - i_{t-1}^R \frac{l_{t-1}^{HB}}{1+\pi_t^H}, \tag{22}$$

where $b_t^H = b_t^{HH} + b_t^{FH}$ is the real stock of riskless one-period bonds held by home and foreign households, and G_t^H real expenditure on home final goods, which represents a fraction $\psi \in (0, 1)$ of home output:

$$G_t^H = \psi Y_t^H. \tag{23}$$

In what follows the government in each country is assumed to keep its real stock of debt constant and to balance its budget by adjusting lump-sum taxes.

2.5 Common Central Bank

The common central bank operates a standing facility, which involves a perfectly elastic supply of (uncollateralized) loans to home and foreign banks, l_t^{HB} and l_t^{FB} respectively, at the prevailing refinance rate. It pays no interest on required reserves. It also supplies cash to households and firms in both countries. The balance sheet of the central bank (measured in home prices) is thus given by

$$l_t^{HB} + (\frac{P_t^F}{P_t^H})l_t^{FB} = m_t^{Hs} + RR_t^H + (\frac{P_t^F}{P_t^H})(m_t^{Fs} + RR_t^F) + nw_t, \tag{24}$$

where m_t^{Hs} (m_t^{Fs}) is the total supply of cash to the home (foreign) country and nw_t the central bank's net worth.

Because there is no bank borrowing across union members, changes in the supply of currency in the home country reflect only endogenous changes in home monetary conditions:

$$m_t^{Hs} = \frac{m_{t-1}^{Hs}}{1+\pi_t^H} + (l_t^{HB} - \frac{l_{t-1}^{HB}}{1+\pi_t^H}) - (RR_t^H - \frac{RR_{t-1}^H}{1+\pi_t}), \tag{25}$$

with an analogous equation for the foreign country.

The refinance rate is set on the basis of a weighted average of inflation and output in the two countries:

$$\frac{1+i_t^R}{1+\tilde{\imath}^R} = (\frac{1+i_{t-1}^R}{1+\tilde{\imath}^R})^\chi \left\{ [\frac{(1+\pi_t^H)^{\upsilon/2}(1+\pi_t^F)^{1-\upsilon/2}}{1+\pi^T}]^{\varepsilon_1} [(\frac{Y_t^H}{\tilde{Y}^H})^{\upsilon/2}(\frac{Y_t^F}{\tilde{Y}^F})^{1-\upsilon/2}]^{\varepsilon_2} \right\}^{1-\chi} \epsilon_t^R, \tag{26}$$

where $\tilde{\imath}^R$ is the steady-state value of the policy rate, $\pi_t^F = P_t^F/P_{t-1}^F - 1$, $\pi^T \geq 0$ the union-wide inflation target, $\chi \in (0,1)$, $\varepsilon_1, \varepsilon_2 > 0$, ϵ_t^R a monetary policy shock which follows an $AR(1)$ process of the form $\epsilon_t^R = \epsilon_{t-1}^{\rho^R} \exp(\xi_t^R)$, with $\rho^R \in (0,1)$ and $\xi_t^R \sim \mathbf{N}(0, \sigma_{\xi^R})$, and $0 < \upsilon \leq 2$ measures the weight attached to the home country. When $\upsilon = 1$, countries have equal weights.

The production structure and the main real and financial flows between agents are summarized in Figure 1.

3 Equilibrium and Steady State

As shown in Appendix A, in a symmetric equilibrium all IG firms in both countries produce the same output, prices are the same across firms, and total output of intermediate goods must be equal to world demand for these goods. In addition, equilibrium in the market for final goods requires that output be equal to domestic absorption, inclusive of price adjustment costs.

The equilibrium condition of the home currency market is given by

$$m_t^H = m_t^{Hs}, \tag{27}$$

which can be solved, using (8) and (25), for the nominal bond rate.

The equilibrium condition of the housing market is

$$\bar{A}^H = A_t^H, \tag{28}$$

which can be solved, using (10), for real house prices.

In equilibrium, net trade in government bonds (or, equivalently, the world net supply of bonds) must be zero, so that

$$b_t^{HH} + b_t^{FH} = 0, \qquad b_t^{FF} + b_t^{HF} = 0. \tag{29}$$

In a two-country world, current account surpluses and deficits must be zero:

$$CA_t^H + CA_t^F = 0, \tag{30}$$

with the home country's current account (at current prices) defined as[12]

$$CA_t^H = P_t^{HH} Y_t^{HF} - P_t^{FH} Y_t^{FH} + i_{t-1}^F P_{t-1}^F b_{t-1}^{HF} - i_{t-1}^H P_{t-1}^H b_{t-1}^{FH}, \tag{31}$$

[12] Consolidating all the budget constraints also yields (recalling that the nominal exchange rate is normalized to unity) $CA_t^H = (P_t^H b_t^{HF} - P_{t-1}^H b_{t-1}^{HF}) - (P_t^F b_t^{FH} - P_{t-1}^F b_{t-1}^{FH})$, where increases in holdings of the home country's foreign bonds correspond to a capital outflow for the home country (or an inflow for the foreign country), whereas increases in holdings of the foreign country's home bonds correspond to a capital inflow for the home country.

where Y_t^{HF}, exports of intermediate goods by the home country, correspond to the foreign country's imports; Y_t^{FH}, home imports, correspond to the foreign country's exports of intermediates; and i_t^H (symmetrically to (4) and (5)) is the premium-adjusted home bond rate, defined as

$$1 + i_t^H = (1 + i_t^{HB})(1 - \theta_t^{FH}), \tag{32}$$

with θ_t^{FH} denoting the financial intermediation premium, given by

$$\theta_t^{FH} = \frac{\theta_0^B}{2} b_t^{FH}. \tag{33}$$

The nonstochastic steady-state solution of the model (which is fairly standard, except for the financial side) is derived and discussed in Appendix D.[13]

4 Parameterization

To study the properties of the model, we parameterize it using standard values used in the literature on small open-economy and two-country models—especially those focusing on the euro area, for which a number of recent papers provide estimates obtained with Bayesian techniques. In addition, for some of the parameters that are deemed critical from the perspective of this study, sensitivity analysis is reported later on. In the benchmark parameterization, we assume that the two countries are identical.

The discount factor Λ is set at the standard value of 0.99, which gives a steady-state annualized real (and nominal, given zero inflation in the steady state) interest rate of about 1 percent. The intertemporal elasticity of substitution is 0.5, in line with the empirical evidence discussed by Braun and Nakajima (2012), for instance, and the calibrated value used by Brzoza-Brzezina et al. (2015) for their core-periphery model of the euro area (see also Thimme (2017)). The preference parameter for leisure, η_N, is set at 25, to ensure that in the steady state households devote one third of their time endowment to market activity, a fairly common benchmark in the literature (see Corsetti et al. (2014), Christoffel and Schabert (2015), and Poutineau and Vermandel (2015), for instance). The parameter for composite monetary assets, η_x, is set at a low value, 0.001, to capture the common assumption in the literature that their direct

[13] We assume that policymakers have no access to lump-sum subsidies to eliminate the short- and long-run costs distortions associated with monopolistic competition and financial frictions. In that sense, the steady state is inefficient.

utility benefit is negligible (see, for instance, Coenen et al. (2009) and Christoffel and Schabert (2015)). The housing preference parameter, η_A, is set at 0.1, which is the same value used, for instance, by Rubio and Carrasco-Gallego (2016). The share parameter in the index of money holdings, ν, which corresponds to the relative share of cash in narrow money, is set at 0.2 to capture a significantly higher use of deposits in transactions, compared to cash. The cost parameter related to foreign (home) bond holdings by home (foreign) households, θ_0^B, is set at 0.05. This value is consistent with a relatively high, albeit imperfect, degree of capital mobility. The Frisch elasticity of labor supply is set at 0.71 for both countries (implying that ψ_N is equal to 1.4), which is in line with estimates for the euro area.

The distribution parameter between home and imported intermediate goods in the production of the final good, Λ_I, is set at 0.7, to capture the case of a country where imports are initially about a third of GDP, as in Tomura (2010) and Dräger and Proaño (2020), for instance. The elasticity of substitution between baskets of domestic and imported composite intermediate goods, η, is set at 3, a fairly standard value, which implies that these goods are substitutes in the production of the final good. The elasticities of substitution between home intermediate goods among themselves, θ_{HH}, and imported goods among themselves, θ_{FF}, are both set equal to 10. The same value is used by Quint and Rabanal (2014), for instance.

The share of capital in domestic output of intermediate goods, α, is set at 0.35, a fairly common value. The adjustment cost parameter for prices of domestic intermediate goods, ϕ_I, is set at 74.5 to capture a relatively high degree of nominal price stickiness. This value is close to the average value initially estimated by Ireland (2001, Table 3) and implies a Calvo-type probability of not adjusting prices of approximately 0.71 percent per period, or equivalently an average period of price fixity of about 3.5 quarters. These figures are consistent with the point estimates of Quint and Rabanal (2014, Table 2) and Christoffel and Schabert (2015, Table 2) for the euro area. They are also in the range of values estimated by Gerali et al. (2010) and Darracq Pariès et al. (2011). The capital depreciation rate, δ_K, is set at a quarterly rate of 0.025, which is in the span of values typically used in the literature (see, for instance, Christiano et al. (2010), Gerali et al. (2010), Kolasa and Lombardo (2014), and Mendicino and Punzi (2014)). The adjustment cost incurred by the CG producer for transforming investment into capital, Θ_K, is set at 14, in order to match the fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as GDP in the euro area. This value is also close to the upper bound estimated by Gerali et al. (2010, Table 2A) for the euro zone.

Regarding commercial banks, the parameter that determines the effective collateral-loan ratio, κ, is set at 0.6, to capture the fact that debt enforcement procedures are relatively costly, as documented by Djankov et al. (2008). The elasticity of the repayment probability is set at $\varphi_1 = 0.05$ initially with respect to the effective collateral-loan ratio and at $\varphi_2 = 0.2$ with respect to deviations in output from its steady state. The elasticity of substitution ζ_L is set at 4.5, as in Dib (2010), for instance. This implies a markup over the cost of funds of 28.6 percent.

The degree of persistence in the central bank's policy response, χ, is set at 0.8, whereas the responses of the base policy rate to inflation and output deviations, ε_1 and ε_2, are set at 1.6 and 0.04, respectively. These values represent averages of the estimates reported by Brzoza-Brzezina et al. (2015, Table 1), Quint and Rabanal (2014, Table 2), and Christoffel and Schabert (2015, Table 2) for the euro area. The required reserve ratio, μ, is set at 0.02, consistent with the value reported by Christoffel and Schabert (2015, Table 1) for the euro area.

The share of noninterest government spending in final output, ψ, is set at 0.18, again as in Christoffel and Schabert (2015). This value is also close to the value of 0.2 used by Christiano et al. (2010), Corsetti et al. (2014), and Darracq Pariès et al. (2019), for instance, as well as several other contributions. Finally, the autocorrelation coefficients of the credit spread and monetary policy shocks, $\rho^{L:}$ and ρ^{R}, are set at 0.8 and 0.0, respectively.

Parameter values are summarized in Table 1, whereas initial steady-state values of key variables (given the assumption that the countries are symmetric) are shown in Table 2.

5 Experiments

To illustrate the properties of the model, and given the focus of this paper on macroprudential policy, we briefly examine the transmission of two types of shocks: an expansionary financial shock, in the form of a negative credit spread shock in either the home country or both countries, and an expansionary monetary policy, in the form of a transitory reduction in the refinance rate. In both cases, we assume for the moment that countries are of the same size, so that $\upsilon = 1$.[14]

5.1 Financial Shock

The results of a negative credit spread shock (a drop in ϵ_t^L) in the home country are illustrated in Figure 2. The direct effect of this shock is to lower the loan rate and to stimulate investment at home. This leads to an expansion in aggregate demand and to higher inflation. Because the initial impact is also an increase in average inflation, the common central bank raises the policy rate, which tends to increase market interest rates at home and abroad. Nevertheless, the increase in inflation is such that in the home country the (expected) real bond rate falls initially, thereby raising consumption today and house prices. The increase in investment and consumption at home implies that the net effect on aggregate demand is positive. At the same time, the higher policy rate mitigates the initial drop in the loan rate in the home country and raises the cost of borrowing in the foreign country.[15] Nevertheless, the immediate effect is not strong and is partly offset by expectations of a future reduction in the loan rate. The result is higher investment, which combines with consumption to increase aggregate demand and output abroad. In addition to the monetary policy channel, the cross-border propagation of the home country shock occurs through trade in intermediate goods, which is driven by changes in the relative price of home and foreign goods.

Figure 3 considers the case of a symmetric financial shock. Qualitatively, the transmission mechanism is similar to what obtains with an asymmetric shock for the home country; the key differences are that the increase in consumption in both countries, and investment in the foreign country, are significantly larger, despite a stronger inflationary effect in both cases. The other difference is that the repayment probability in the foreign country now falls (because of a larger increase in investment, and thus a lower collateral-loan ratio), which mitigates slightly the initial drop in the loan rate.

[14] Additional shocks, and the case of asymmetries in economic size and structure, will be considered in our robustness analysis.

[15] In the foreign country, the increase in output raises the repayment probability, which should normally lead to a lower loan rate; however, this effect is dominated by the increase in the refinance rate.

5.2 Monetary Policy Shock

The results of a temporary reduction in the refinance rate (a drop in ϵ_t^R) are displayed in Figure 4. The direct effect of this shock is once again a reduction in the loan rate, this time in both countries, and an expansion in investment. This raises aggregate demand and inflation, which induces the central bank to raise the refinance rate—thereby mitigating the initial drop in the cost of borrowing. The expected real bond rate falls also and induces households to shift consumption to the present. The increase in demand for housing services leads to an increase in house prices; despite the increase in borrowing for investment, the collateral-loan ratio increases, thereby raising the repayment probability. In turn, this contributes to a further reduction in the loan rate and an expansion of output in both countries. Thus, the monetary policy shock has qualitatively similar effects as a symmetric credit spread shock.

The foregoing discussion has assumed that countercyclical policy is implemented only through a common monetary policy. We now turn to the case where macroprudential policy also responds endogenously, and independently, under alternative institutional mandates. We also study the gain from cooperation, relative to the case when regulators in each member country acts independently.

6 Macroprudential Policy Coordination

As discussed in the introduction, the key issue that we want to address in this paper is whether, in a currency union, conducting macroprudential policy (in the form of a countercyclical tax on lending) at the level of the union, instead of its individual members, is welfare improving. To do so, we compare outcomes under two alternative mandates, while assuming initially that monetary policy is conducted independently by the common central bank, following a standard Taylor rule. The first is the *decentralized regime,* where countries pursue independent policies and set the macroprudential instrument unilaterally. In a situation akin to a Nash bargaining game, each regulator sets its own optimal macroprudential rule, taking as given the behavior of the other regulator. A Nash equilibrium in this setting is a combination of home and foreign macroprudential instruments—or, more accurately, response parameters in macroprudential tax rules, as shown later—for which neither country can unilaterally deviate from and gain by doing so. The second is the *centralized* (or *cooperative*) *regime* where either a single or separate macroprudential tax rates are set for both countries by the common central bank, which also acts as the global regulator.

6.1 Policy Rule and Coordination Gains

Under both regimes, we consider a simple implementable policy rule, delegated through an institutional mandate, whereby changes in the macroprudential instrument are related to an operational or *intermediate target* for financial (in)stability—deviations in the ratio of bank loans to final output. The focus on that variable is consistent with the large body of evidence suggesting that fluctuations in credit have been consistently associated with episodes of financial distress (see, for instance, Aikman et al. (2015) and Taylor (2015)).[16] Specifically, in the first regime, changes in the macroprudential tax rate in each country $i = H, F$ are driven by:[17]

$$\frac{1+\tau_t^i}{1+\tilde{\tau}^i} = (\frac{1+\tau_{t-1}^i}{1+\tilde{\tau}^i})^{\chi_1} \left\{ (\frac{l_t^i/Y_t^i}{\tilde{l}^i/\tilde{Y}^i})^{\chi_2^{D,i}} \right\}^{1-\chi_1}, \tag{34}$$

where $\chi_1 \in (0,1)$ is a persistence parameter and $\chi_2^{D,i} > 0$ is the response parameter to deviations in the credit-to-output ratio.[18]

In this regime, the financial regulator in each country determines the optimal value of $\chi_2^{D,i}$ so as to maximize its own country's conditional welfare (that is, expected welfare conditional on the initial state being the non-stochastic steady state) only, adjusted—in contrast to Woodford (2003, chapter 3), Debortoli et al. (2019), and Agénor et al. (2021), for instance—for the cost of *changes* in the macroprudential tax:

$$W_t^i = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u(C_{t+s}^i, N_{t+s}^i, x_{t+s}^i) - \varkappa_W \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\tau_{t+s}^i - \tau_{t+s-1}^i)^2, \tag{35}$$

where $\varkappa_W \geq 0$ is a parameter, common to both members, that measures the magnitude of the welfare cost associated with changes in the use of the macroprudential instrument, and $u()$ is the period utility function, which is given from (1) as

[16] See also Agénor (2020, chapter 5) for a more detailed discussion of the rationale for this type of rules.

[17] As can be inferred from (34), as well as (37) and (39) below, the values of the optimal response parameters do not affect the steady-state level of the macroprudential tax, only its cyclical properties.

[18] Darracq Pariès et al. (2019) also considered a macroprudential policy rule in which the instrument responds to deviations in the credit-to-output ratio.

$u() \simeq (1-\varsigma^{-1})^{-1}(C_t^i)^{1-\varsigma^{-1}} - \eta_N(1+\psi_N)^{-1}(N_t^i)^{1+\psi_N} + \eta_x \ln x_t^i$.[19] Thus, the solution is[20]

$$\chi_2^{H,D} = \arg\max W_t^H\big|_{\chi_2^F=\chi_2^{F,D}}, \quad \chi_2^{F,D} = \arg\max W_t^F\big|_{\chi_2^H=\chi_2^{H,D}}. \tag{36}$$

In the second regime, and assuming separate instrument setting for *each* member, the common policy responds to a geometric average of country-specific credit-to-output ratios:

$$\frac{1+\tau_t^i}{1+\tilde{\tau}^i} = (\frac{1+\tau_{t-1}^i}{1+\tilde{\tau}^i})^{\chi_1}\left\{[(\frac{l_t^H/Y_t^H}{\tilde{l}^H/\tilde{Y}^H})^{\chi_2^{H,C}}]^{\upsilon/2}[(\frac{l_t^F/Y_t^F}{\tilde{l}^F/\tilde{Y}^F})^{\chi_2^{F,C}}]^{1-\upsilon/2}\right\}^{1-\chi_1}. \tag{37}$$

The common central bank sets now $\chi_2^{H,C}$ and $\chi_2^{F,C}$, so as to maximize a weighted sum of national welfare functions:

$$\chi_2^{H,C}, \chi_2^{F,C} = \arg\max[\frac{\upsilon}{2}W_t^H + (1-\frac{\upsilon}{2})W_t^F], \tag{38}$$

Alternatively, we also consider the case where the central bank—just as it does for monetary policy—follows a *one-size-fits-all* policy and sets a uniform, union-wide macroprudential tax rate, based on the rule:

$$\frac{1+\tau_t}{1+\tilde{\tau}} = (\frac{1+\tau_{t-1}}{1+\tilde{\tau}})^{\chi_1}\left\{[(\frac{l_t^H/Y_t^H}{\tilde{l}^H/\tilde{Y}^H})^{\upsilon/2}(\frac{l_t^F/Y_t^F}{\tilde{l}^F/\tilde{Y}^F})^{1-\upsilon/2}]^{\chi_2^C}\right\}^{1-\chi_1}, \tag{39}$$

and chooses χ_2^C so as to maximize once again joint welfare:

$$\chi_2^C = \arg\max[\frac{\upsilon}{2}W_t^H + (1-\frac{\upsilon}{2})W_t^F], \tag{40}$$

We measure the gain (or lack thereof) from coordination by calculating the relative welfare gain, as measured by $(W_t^C - W_t^N)/W_t^N$, where W_t^N is welfare under Nash and W_t^C welfare under cooperation, both at the level of each country and for the union as a whole. These calculations are performed under commitment, that is, under the assumption that regulators (individually and jointly) have the ability to deliver on past promises—no matter what the current situation is today. We also follow common practice and solve for open-loop equilibria in the decentralized regime.[21] In standard

[19] In calculating welfare, we have ignored the stock of housing given that it is constant in equilibrium—and so is its utility benefit.

[20] For computational simplicity, we assume that the persistence parameter χ_1 is not solved for optimally. As noted later on, using alternative "high" and "low" values of χ_1 has only a limited impact on the calculation of welfare gains.

[21] In an open-loop equilibrium, players cannot observe the current play of the other players and therefore cannot react to deviations from the equilibrium path. This makes the problem more tractable because the dynamic Nash problem can be rewritten as a static game. Policymakers specify a complete strategy at time $t = 0$ and need not consider deviations from it for $t > 0$.

fashion, these welfare calculations are based on a second-order approximation to both the household's period utility function around the deterministic steady state and a second-order approximation to the model characterizing the economy (see Appendix E).

6.2 Results for the Benchmark Case

Columns 1 and 3 of Table 3 shows the results for the home financial shock discussed earlier for the benchmark set of parameters, symmetric countries ($\upsilon = 1$), and for two values of the cost parameter for instrument volatility, $\varkappa_W$ in (35), 0.1 and 0.4. In both cases we set the degree of persistence in the individual country and common rules, χ_1, to a fairly high value, 0.8, and use a grid step of 0.1 in the interval $(-0.5, 10)$.[22] The table reports three sets of optimal values of χ_2: those obtained under Nash and those obtained under centralization, with either uniform or separate instruments, as discussed earlier. Columns 1 to 4 in Table 4 present asymptotic standard deviations of key variables under alternative policy regimes (no macroprudential policy activism, Nash, coordination with a single instrument, and coordination with separate instruments), again for the benchmark set of parameters.

The results show, first, that an interior solution always exists for the optimal response parameter, χ_2, as long as the cost parameter attached to instrument volatility in the welfare function, $\varkappa_W$, is positive. The intuition is as follows. Initially, as the policy is implemented, volatility falls, because it stabilizes credit and investment, as well as market interest rates and consumption. Thus, household welfare improves significantly. However, as the policy becomes more aggressive, the marginal cost of instrument manipulation also increases. Beyond a certain point, this cost dominates the marginal gain in terms of household welfare. Consequently, there exists an optimal value for the response parameter to the credit-to-output ratio under all three regimes. Second, the magnitude of the cost parameter $\varkappa_W$ affects the optimal policy response, as shown by the difference between columns 1 and 3 in Table 3.

The second important result is that the effect of coordination is to induce the country where the shock originates to pursue a more aggressive policy. Intuitively,

[22] Experiments with an alternative value of 0.01 for the grid step, and a lower degree of persistence, $\chi_1 = 0.2$, did not affect qualitatively the results. The latter serves mainly to scale the response parameters. The smaller negative value for the grid search is used because of computational constraints.

the common regulator internalizes the effects of credit fluctuations (occurring through spillovers to the foreign country and spillbacks to the home country) in both members and is therefore able to generate a superior outcome for the union as a whole—regardless of whether uniform or separate macroprudential rules are set for the two members. Surprisingly, this can be done without inducing a loss for the home country, despite the fact that the volatility of the macroprudential tax (and therefore the cost of instrument manipulation) is an order-of-magnitude greater than for the foreign country (see Table 4). The effect of increased home-country activism under coordination is to reduce the burden placed on the foreign country in countering spillover effects. The result is significant gains for the foreign country and the union as a whole, relative to the decentralized policy. The policy of *keeping-one's-house-in-order* works as a guiding principle as well when the cost of instrument manipulation is larger, that is, $\varkappa_W = 0.4$. Indeed, comparing coordination in the low versus high-cost cases, it is apparent that the policy of *keeping-one's-house-in-order* continues to perform well; however, there are differences when the cost of instrument manipulation increases. Coordination continues to imply higher home-country activism than the decentralized regime, but at much lower levels than the low-cost case. To compensate, the foreign country must pick up the slack and react more. Put differently, with an asymmetric financial shock, when the cost of instrument manipulation increases, there is *burden sharing* in policy responses when instruments are set separately—whether countries act independently or in coordination. The country where the shock occurs intervenes less, whereas the other country does more. Under centralization, when only one instrument is set, it is optimal to intervene less across the board when it is more costly to do so.

Moreover, comparing coordination with separate instruments to the case of a single uniform instrument, we see that the common regulator chooses again to enact the *keeping-one's-house-in-order* policy—instigating a common instrument choice equal to the home-country's optimal response under separate instruments. Necessarily, then, the foreign country's choices are suboptimal—hence the reduced gains.[23] Thus, while separate instruments are preferable, in the case of asymmetric financial shocks, the effectiveness of *keeping-one's-house-in-order* is sufficiently strong that it generates a gain from coordination, even if it implies that the foreign country's response is suboptimal

[23]When the cost of instrument manipulation is low, the effect of suboptimal choice is that much smaller, hence the reduction in gain for the foreign country is minimal.

compared to what it would find desirable when acting independently.

Third, as shown in Table 4, volatility under a wide range of macroeconomic and financial variables is significantly lower (except, of course, for the macroprudential policy instrument) under both decentralization and centralization, compared to the case where there is no policy response to the shock. This is also the case for the union-wide variables (the refinance rate, inflation, and output) that are displayed in the table. Moreover, consistent with the previous discussion, there are relatively small differences, in general, between uniform and separate instruments under centralization—except for the tax rate on loans, and the loan rate itself, for the foreign country. These results suggest that a policy loss approach, based on the assumption that the common central bank seeks to minimize the volatility of union-wide output and inflation, as well as a financial aggregate (such as the loan-to-output ratio) would give results similar to the welfare-based results discussed earlier—as long as the cost of instrument manipulation is not too large.

Finally, columns 2 and 4 in Table 3 also show the results for the symmetric financial shock, as discussed earlier. Given the symmetric structure of the model, policy responses in both countries under the centralized regime with uniform and separate instruments are the same, regardless of the cost of instrument manipulation. However, there are still gains from coordination, because under that regime regulators in both countries intervene more relative to the decentralized regime. As with the case of an asymmetric financial shock, the magnitude of the gain is larger when the cost of instrument manipulation is higher.

6.3 Comparison with the Ramsey Policy

To assess the performance of our optimal simple macroprudential policy rule with inertia, we also solve a Ramsey problem under which the central planner chooses state-contingent allocations, the policy instruments, and prices to maximize welfare, subject to the first-order conditions of the private agents and the market equilibrium conditions. To conduct this analysis we take again a second-order approximation of all model equations, including the first-order conditions of the welfare maximization problem of the Ramsey planner. Following Woodford (2002, 2003), we focus on optimal commitment from a timeless perspective.[24] The optimal Ramsey policy is defined in terms of setting the two tax rates, τ_t^H and τ_t^F, under coordination, with a zero instrument manipulation cost, that is, $\varkappa_W = 0$. The toolbox provided by Bodenstein et al. (2019) are used for all computations.

The results show that the principle of *keeping-one's-house-in-order* still holds: under coordination, and with instruments set separately, the country where the shock originates is far more reactive than the other country. And, not surprisingly, the welfare gain associated with the Ramsey policy is considerably higher than what is obtained under cooperation with separate instruments. At the same time, however, the very fact that the country where the shock occurs responds more aggressively under coordination means that the volatility of its policy instrument is now also considerably larger, as shown in the last column of Table 4. This means that, in practice, when policymakers are concerned about the possibility that abrupt policy changes can destabilize markets, implementing the Ramsey policy may be difficult. Indeed, attaching a cost to instrument volatility in the central bank's objective function, alongside welfare (as we did earlier), could mitigate significantly the gain associated with the Ramsey policy and could militate in favor of using a simple implementable rule with inertia. As noted earlier, such a rule performs fairly well relative to no activism.

7 Robustness Checks

To assess the robustness of the previous results in terms of the gains from coordination, we perform sensitivity analysis with respect to country size and structure (which includes asymmetries in financial frictions) and the response to global supply and demand shocks.

7.1 Asymmetric Country Size and Structure

In the foregoing discussion it was assumed that union members are perfectly symmetric in size and structure. This provides a useful benchmark to study the benefits (or lack thereof) of coordination in a currency union. However, with an eye on the policy

[24] Our model features distortions due to monopolistic competition on the goods market and financial frictions in the banking sector. As noted earlier, we assume that lump-sum subsidies are not available, so the (nonstochastic) decentralized equilibrium is not efficient. Instead, as in most of the literature, we evaluate welfare around a distorted steady state and the (constrained) Ramsey planner can only achieve the second-best allocation.

implications of the model (which are discussed later on), it is useful to consider a "core-periphery" setting, where union members can differ in size, while keeping the same structure, and the case where they can differ in both size and structure.

Consider first the case where the home country is relatively large compared to the foreign country. Specifically, we set $n = 0.75$, which means that the core (home) country is three times larger than the periphery (foreign) country. At the same time, all structural parameters are kept at the same baseline values summarized in Table 1. To assess the implications of size for the gains from macroprudential policy coordination, we also set $\upsilon = 1.5$ in the instrument rules (37) and (39) and the welfare objective functions (38) and (40), as well as in the common central bank's interest rate rule (26). This allows us therefore to consider the impact of size on the optimal cooperative policy, asd well as the possible role of the monetary policy channel.

The results are shown in the lower part of Table 3. The effect of reducing the economic weight of the foreign country is that it must respond more to the asymmetric financial shock, both in the centralized and decentralized regimes. With a small instrument cost, this is achieved without any discernible effect on the gain from coordination. These results hold *a fortiori* with a larger instrument cost, with the foreign country (the periphery) responding now as much as it can in the decentralized regime ($\chi_2^F = 10$), wiping out in the process any gains to coordination. With a uniformly-set instrument, the common regulator chooses to respond at a level that matches the larger home country's optimum—thereby preventing the foreign country from reacting sufficiently to maximize its own welfare. As a result, the foreign country incurs a significant welfare loss. As before, with a symmetric financial shock these effects are muted, regardless of the instrument cost.

Consider now the case where countries differ not only in terms of size (with $n = 0.75$, as before) but also, as in Quint and Rabanal (2014) and Brzoza-Brzezina et al. (2015), for instance, in terms of structural parameters. Specifically, we assume that the larger country (the core) retains all the structural characteristics summarized by the parameters in Table 1, whereas the smaller country (the periphery) now differs with respect to the following parameters: the share of intermediate goods in production of the final good is lower (or, equivalently, imports are higher, $\Lambda_I = 0.6$, instead of 0.7); the elasticity of substitution between baskets of intermediate goods is lower ($\eta = 2.5$, instead of 3); and the degree of price stickiness, as measured by the adjustment cost parameter, is higher ($\phi_I = 100$, instead of 74.5). In addition, we assume that financial frictions are stronger in the periphery; this is captured by taking the elasticities of the repayment probability with respect to the collateral-loan ratio and cyclical output in the repayment probability, defined in (21), to be significantly higher than for the core, with $\varphi_1 = 0.1$ and $\varphi_2 = 0.4$, instead of 0.05 and 0.2, respectively. In short, the periphery's economy is more open to trade, less flexible on the supply side, and more subject to (real and financial) frictions, than the core's economy.

The results are shown in Table 5, for the case of an asymmetric financial shock in the home and foreign countries. The upper part of the table corresponds to the case where the asymmetry in size is also reflected in the Taylor rule (as considered earlier, $\upsilon = 1.5$), whereas the lower part, for comparative purposes, corresponds to the case where "one country, one vote" applies in the policy decisions of the common central bank, so that $\upsilon = 1$, as in the symmetric case.

When the shock occurs in the home country, it is optimal for the core to react in countercyclical fashion, whereas for the periphery the optimal response is *procyclical*. This occurs both when countries act independently and when they cooperate, and instruments are set separately. The reason is that because of the common monetary policy, the home country-specific shock induces the central bank to raise the refinance rate, which creates an externality for the foreign country; this contractionary bias is, in a sense, undone by *lowering* the macroprudential tax rate. This result obtains regardless of the cost of instrument manipulation and whether the weight of the home country in the Taylor rule is asymmetric, as before (upper part of Table 5), or symmetric (lower part of Table 5). However, the union as a whole does not benefit in any significant way. In fact, when instruments are set uniformly, the loss for the union is fairly significant. The periphery almost invariably loses as well. The reason is that coordination induces the periphery to act less procyclically than it would choose to under the decentralized regime.

When the shock occurs in the foreign country, the home country does not suffer from the negative externality associated with the common monetary policy. The absence of this contractionary bias means that both countries respond countercyclically, as in the case of symmetric countries considered in Table 3. This time, while the periphery (the country where the shock originates) always loses from coordination, the core, and the union as a whole, always gain—regardless of the instrument manipulation cost, and independently of whether the Taylor rule is based on equal weights or not. Intuitively, the greater weight attached to welfare of core households in the union's decisions means that under coordination (regardless of whether instruments are set uniformly or separately) the periphery is induced to react more than it would do when acting independently; as a result, it incurs a significant loss. These results differ substantially from those reported in Table 3, when countries and symmetric in size and structure; in that case, a foreign shock has the exact same effects as a home shock, and the country where the shock occurs always benefits from coordination. In addition, the gain for the union as a whole is negligible. In the present case, the union may actually be worse off if coordination involves setting a uniform macroprudential tax.

In sum, given the type of asymmetries that we have considered, *keeping one's house in order* still holds. Periphery countries benefit most if they are able to act procyclically in response to core shocks to counter the externality associated with a common monetary policy. In that case, single instrument cooperation generates losses for the union as a whole and countries would be better off acting independently.

7.2 Global Demand and Supply Shocks

To examine the benefits of macroprudential policy coordination in response to real disturbances, we consider transitory global demand and supply shocks, which can both be viewed as capturing some of the adverse effects of the Covid-19 pandemic. The first is implemented as a direct, symmetric negative shock to household expenditure in both countries, which can be viewed as reflecting the contraction in income and employment due to government-mandated lockdowns.[25] The second is implemented by considering a negative, symmetric shock to output of intermediate goods, Y_{it}^{HI}, in each country. This shock can be viewed as capturing the worldwide effect of disruptions in the operation of global value chains (linked to early lockdowns in pandemic-affected countries), which in turn led to shortages in critical inputs to manufacturing sectors in other countries. For clarity, these shocks are considered separately.[26] The results are

[25] See Christelis et al. (2020) and the references therein for evidence on the impact of the Covid-19 crisis on household consumption in some of the euro area countries.

[26] The consumption demand shock is implemented by multiplying the first term in (1) by the term ϵ_t^C, whereas the supply shock is implemented by introducing the multiplicative term ϵ_t^Y in (A8). Both shocks are assumed to follow an $AR(1)$ process of the form $\epsilon_t^j = \epsilon_{t-1}^{\rho^j} \exp(\xi_t^j)$, with $\rho^j \in (0,1)$ and $\xi_t^j \sim \mathbf{N}(0, \sigma_{\xi^L})$, for $j = C, Y$. In both cases, $\rho^j = 0.8$.

shown in Table 6, for both the benchmark case of symmetric countries and the case of asymmetric countries, both in size and structure, as characterized earlier.

Consider first the negative demand shock. Its transmission process is fairly familiar. The downward pressure on prices leads to a reduction in the policy rate. This, in turn, lowers the loan rate and raises investment, which mitigates the initial contraction in aggregate demand. The shock is further transmitted across borders through trade and financial linkages, as well as the monetary policy channel. The results show that the optimal policy response, under both the centralized and the decentralized regimes, is to *reduce* the tax rate on loans, because the loan-to-output ratio actually falls; that is, the optimal χ_2 is *negative*, regardless of the policy regime. But because the shock affects both countries in the same way, when countries are symmetric, there are no benefits in coordinating macroprudential policy responses—regardless of whether instruments are set uniformly or separately. The same results obtain when countries are asymmetric in size and structure; in particular, the macroprudential policy response is procyclical (regardless of the policy regime) and there are no discernible gains from coordination.

Consider next the negative supply shock. The transmission of this shock to the economy is similar to that of a productivity shock and is also fairly standard. The contraction in output lowers the repayment probability and raises the loan rate, while, this time, raising inflation. In turn, higher inflation induces the common central bank to raise the policy rate. The nominal bond rate also increases and, given our calibration, exceeds the rise in the (one-period ahead) inflation rate—thereby raising the real bond rate and inducing households to spend less today. The contraction in consumption is associated with lower demand for housing services, which reduces house prices and collateral values. The loan rate therefore rises further, magnifying in the process the initial contraction in output. Again, cross-border transmission occurs, through trade, financial and the monetary policy channels. The results of the optimal analysis show that the macroprudential policy response is now countercyclical, in both the symmetric and asymmetric cases. Moreover, there are no discernible gains for the union from coordination in the symmetric case (as expected), regardless of how instruments are set, or under the asymmetric case with separate instruments. When coordination involves setting instruments uniformally, the same result to what was obtained with the financial shock holds: this time, not only is the union worse off from coordination, so are the members of the union.

8 Monetary and Macroprudential Policies

Our last experiments consist of studying the joint determination of monetary and macroprudential policy rules. This issue has been the subject of a large literature. In particular, there has been much discussion of the extent to which these two policies should be coordinated in response to shocks, and whether monetary policy should *lean against the wind*, that is, respond directly to financial imbalances, with various observers offering very different views.[27] At the same time, only a few contributions have studied these issues the context of currency unions. For instance, Darracq Pariès et al. (2019) studied the joint optimization of an interest rate policy rule and countercyclical capital requirements rules; however, they considered only a standard interest rate rule and therefore do not discuss whether monetary policy should also be used to lean against the financial cycle. Kockerols and Kok (2019), dwelling on the model in Darracq Pariès et al. (2011), did consider whether the central bank should *lean against the wind* in a currency union, but their analysis is based on an *ad hoc* loss function approach. Both Mendicino and Punzi (2014) and Quint and Rabanal (2014) found that welfare improves when the central bank reacts to credit developments, but the main reason why *leaning against the wind* is optimal is because of differences in the welfare effects of interest rates between savers and borrowers.

Consider then the first issue, whether monetary and macroprudential policies should be determined jointly. In the present context, this means essentially solving simultaneously for the optimal parameters of the Taylor rule (41) and the countercyclical macroprudential rule (34). For tractability, and assuming that the inflation mandate of the central bank is preeminent, we focus on solving jointly for the parameters ε_1 and χ_2^i in these equations, keeping the response parameter to the output gap, ε_2, and the degrees of persistence, χ and χ_1, constant. To facilitate numerical computations, the choice of ε_1 is conducted in the interval (1.1, 4), with a grid step of 0.1, with the lower bound imposed to ensure that the Taylor principle holds. The choice of χ_2^i is conducted as before. We consider again a negative credit spread shock occurring in the home country.

The results show that, compared to the calibrated value of $\varepsilon_1 = 1.6$, the optimal value of that coefficient when it is chosen jointly with χ_2^i is equal to the lower bound

[27] See Adrian and Liang (2018), Agénor and Flamini (2019), Ajello et al. (2019), and Agénor (2020, chapter 5), for a discussion and further references to the literature.

1.1, whereas $\chi_2^{i,N} = (0.3, 0)$ and $\chi_2^{i,C} = (0.3, 0.5)$. Put differently, when policymakers can rely on macroprudential policy—regardless of whether this involves coordination or not—it is optimal for monetary policy to respond less aggressively to inflation deviations from target. Intuitively, because the policy interest rate and the macroprudential instrument operate through the same channel (the cost of credit), their effects are transmitted to aggregate demand and inflation in similar fashion. In a sense, the instruments are (partial) substitutes. This result is consistent with the previous literature focusing on closed economies.[28]

Consider now the second issue, the extent to which the central bank should *lean against the wind*. To study this case, we assume that the central bank's policy rule takes now the form

$$\frac{1+i_t^R}{1+\tilde{\imath}^R} = (\frac{1+i_{t-1}^R}{1+\tilde{\imath}^R})^{\chi} \left\{ [\frac{(1+\pi_t^H)^{\upsilon/2}(1+\pi_t^F)^{1-\upsilon/2}}{1+\pi^T}]^{\varepsilon_1} \right. \tag{41}$$

$$\left. \times\ [(\frac{Y_t^H}{\tilde{Y}^H})^{\upsilon/2}(\frac{Y_t^F}{\tilde{Y}^F})^{1-\upsilon/2}]^{\varepsilon_2}(\frac{l_t^H/Y_t^H}{\tilde{l}^H/\tilde{Y}^H})^{\upsilon/2}(\frac{l_t^H/Y_t^H}{\tilde{l}^H/\tilde{Y}^H})^{1-\upsilon/2}]^{\varepsilon_3} \right\}^{1-\chi} \epsilon_t^R,$$

where $\varepsilon_3 \geq 0$. Thus, the central bank responds also to deviations in the credit-to-output ratio—for the same reason that the regulator does. The issue now is to determine the optimal value of χ_2^i in the macroprudential policy rule (34), as ε_3 in the augmented Taylor rule (41) increases, holding the other parameters (ε_1, ε_2, χ, and χ_1) constant, and whether there are gains from macroprudential policy cooperation.

Consider again a negative credit spread shock occurring in the home country. Figure 5 shows the optimal macroprudential policy responses (under the decentralized regime and the two types of centralized regimes), that is, the values of χ_2^i, as a function of the degree of *leaning against the wind*, that is, the parameter ε_3.[29] It also shows the welfare gain from centralization, relative to decentralization, for the union as a whole. The parameter ε_3 is varied in the interval (0, 0.5), with a grid step of 0.05. For $\varepsilon_3 = 0$, the results correspond, of course, to those reported in the upper part of Table 3.

The results show that, at first, as ε_3 increases, the optimal macroprudential policy response is weaker; with the central bank taking on a greater responsibility in terms of mitigating credit conditions, regulators in both countries react less. There is therefore some degree of substitution between instruments. However, beyond a certain point,

[28] See (2020, chapter 5), and the references therein, for a discussion.
[29] In all cases, the parameter $\varkappa_W$ is kept at 0.4.

the situation becomes quite different across regimes. In the decentralized regime, the macroprudential policy response stabilizes at a positive value for the home country. Intuitively, beyond a certain value, a common monetary policy cannot serve as a substitute for independent macroprudential policy; a more aggressive use of the former generates too much volatility in bond rates and consumption, whereas the latter operates mostly through the loan rate and investment. As a result, further increases in ε_3 have no effect on the optimal response parameter of the regulator in the home country.

In addition, the response of the foreign regulator turns *negative* beyond a certain degree of *leaning against the wind* ($\varepsilon_3 > 0.05$ when regulators act independently). The reason is that in that country the contractionary effect of the increase in the refinance rate (driven by the shock originating in the home country) eventually dominates the initial expansionary cross-border effect of the shock, which implies that, to mitigate the adverse effect of a contraction in credit and output, and eventually consumption, it is optimal for the foreign regulator, when it acts independently, to *lower* the tax on loans. In a sense, macroprudential policy is used once again to offset the negative externality associated with the *one-size-fits-all* monetary policy, which is driven now in part by credit conditions in the union as a whole. Under centralization and separate instrument setting, a similar result holds: while the response for the home country stabilizes at a positive value, beyond $\varepsilon_3 > 0.1$ the response of the foreign country turns negative and stabilizes once again at a negative value. When the macroprudential policy tool is set uniformly, at first the optimal response parameter of the macroprudential policy rule mimics what obtains under the separate instrument case; however, as ε_3 continues to increase, the optimal χ_2 also increases, and stabilizes at an even higher value.

The result, as shown in the lower part of Figure 5, is that the welfare gain from coordination for the union as a whole follows an inverted U-shaped pattern: as monetary policy reacts more aggressively to credit developments, the home country (where the shock occurs) gains significantly from coordination; at first, this dominates any loss incurred by the foreign country. However, beyond the optimal degree of *leaning against the wind*, $\varepsilon_3 = 0.05$, the reverse occurs ~~and the union as a whole is worse off~~. This result holds regardless of whether instruments are chosen separately or uniformly under centralization: in the former, the gain remains positive at the upper bound of ε_3, but in the latter, because the foreign regulator is forced to respond positively (rather than negatively), the union as a whole is worse off when $\varepsilon_3 > 0.25$.

The key point, therefore, is that monetary and macroprudential policies operate as partial substitutes—in the sense that the two instruments are adjusted in opposite directions—when the degree of *leaning against the wind* is low. However, as the central bank continues to lean against credit fluctuations, macroprudential policy responses begin to diverge between the two countries—especially so under cooperation. The reason is that the common monetary policy, when it responds too aggressively to union-wide credit developments, is contractionary and creates a negative externality for the country where the shock doesn't occur; this externality is, in a sense, "neutralized" through a more accommodating macroprudential policy stance in that country. Given the cost of instrument manipulation, the more the central bank leans against credit fluctuations, the larger the welfare loss from coordination for the foreign country, and the smaller the gain for the union. Put differently, even though interactions between monetary and macroprudential policies may be more pronounced in a monetary union where monetary policy, by definition, is focused on area-wide economic and financial conditions, this does not mean that countries and the union are better off by having monetary policy focus aggressively on financial imbalances; indeed, depending on the nature and direction of shocks, this may be counterproductive from a welfare perspective.

This argument against an excessively aggressive *leaning against the wind* policy in a currency union does not depend, as in the literature on single, closed economies, on a possible adverse impact on the central bank's response to the main objective of monetary policy, that is, inflation, or heterogeneity across agents, as noted earlier. At the same time, our analysis is consistent with the discussion in Kockerols and Kok (2019), who considered interactions between *leaning against the wind* and macroprudential regulation in the euro area. Using an ~~*ad hoc*~~ loss function for policymakers, they found that while macroprudential policy has net marginal benefits in addressing risks to financial stability, monetary policy has net marginal costs. The key difference is that our analysis shows that these marginal benefits and costs depend in nonlinear fashion on the macroprudential policy response, and that this nonlinearity explains why there exists an optimal degree of *leaning against the wind* in a currency union.

9 Policy Implications

Our analysis helps to shed some light on the benefits (or lack thereof) of macroprudential policy coordination in currency unions in general, and in the euro area more specifically. In fact, the model captures several of the core structural features of the euro area, including trade in intermediate goods and high (albeit imperfect) capital mobility. Indeed, bilateral trade in intermediate inputs represents a very large share of overall trade flows in goods and services between members of the euro area and between European countries in general (see Miroudot et al. (2009) and Degain et al. (2017))). There is also ample empirical evidence suggesting that, despite significant progress in financial integration since the launch of the common currency in 1999—particularly in the equity and corporate bond markets—the cost of adjusting cross-border financial positions remains substantial (see Coeurdacier and Rey (2013) and European Central Bank (2015)) and that credit markets remain insufficiently integrated as a result of idiosyncratic differences in bank practices (in credit risk assessment, for instance), national laws and regulations, and market fragmentation (see Weill (2009) and European Central Bank (2015)). In addition, even though there appears to have been convergence in *nominal* interest rates, persistent differentials in inflation imply that *real* interest rates continue to move apart. This evidence is consistent with our assumption that capital mobility, although high, is not perfect. Moreover, the fact that financial structures continue to differ significantly among European countries, particularly with respect to contract enforcement costs, explains the persistence of *home bias* in lending to (and borrowing by) non-financial corporations. These features are all captured in the model.

The evidence also suggests that business and financial cycles remain imperfectly synchronized among member countries (see Giannone et al. (2009), Merler (2015) and Stremmel (2015)), suggesting that idiosyncratic or asymmetric shocks (of the type considered earlier) continue to be a major factor in macroeconomic fluctuations in individual countries. Finally, our generic tax on lending captures well the cost effect of capital requirements—the key instrument of macroprudential regulation in the euro area. Indeed, the assumption in the model that macroprudential policy operates through the same price-based channel as monetary policy is consistent with the evidence provided by Tressel and Zhang (2016) for the euro area, with respect to instruments that affect the cost of bank capital.[30] In addition, our parameterization is largely based on studies that have focused on the euro area.

Specifically, our analysis has two main implications for the euro area. The first relates to the institutional design of macroprudential regulation. At the present time, there are four layers of decision-making regarding macroprudential regulation in the European Union: the European Banking Authority (EBA, established in January 2011), the European Systemic Risk Board (ESRB, established in December 2010), the European Central Bank (ECB), and national authorities. The ESRB is responsible for the macroprudential oversight of the financial system, primarily by issuing warnings and recommendations. In November 2014 the Single Supervisory Mechanism (SSM), under which the ECB took on bank and prudential supervisory duties (alongside its previous responsibility for price stability) for the countries that participate in the banking union initiated in 2012—mostly those of the eurozone—became operative. The objective was to ensure that the SSM and the ECB would interact, with the SSM focusing on microprudential policy and the ECB on monetary policy, in accordance with the *separation principle*. However, the ECB as the Single Supervisor has mandatory powers over the banking system as well as the power to set tighter regulatory requirements than national authorities, according to SSM Regulation No. 468 of April 2014.[31] The coexistence of these various layers of decision-making makes the euro area's institutional architecture fairly complex and raises *prima facie* concerns about coordination, information sharing, and communication in practice (Buch and Weigert (2019)).[32] On the issue of coordination specifically, our analysis has implications for interactions between the ECB and national authorities. When faced with asymmetric financial shocks, a high degree of centralization in macroprudential responses may be optimal when countries share similar structural characteristics. Moreover, in that context setting countercyclical policy instruments separately for each country by the common regulator is preferable to a

[30] See, for instance, Darracq Pariès et al. (2019) for a formal analysis of capital requirements in the euro area. Nevertheless, our model does not account for cross-border bank lending, an increasingly important feature of financial linkages in the euro zone. This issue is discussed further in the conclusion.

[31] In particular, the ECB may go beyond specific macroprudential measures—capital instruments, including countercyclical capital buffers and capital surcharges on systemically important institutions, risk weights on real estate exposures, as well as liquidity instruments, such as liquidity coverage ratios—if it considers actions by national authorities to be insufficient to mitigate systemic financial risks.

[32] See European Systemic Risk Board (2014, 2020). Evrard et al. (2018) provided a discussion of prospective revisions to the macroprudential policy framework of the euro area.

one-size-fits-all policy. However, the gain from coordination may not be very large; in fact, if asymmetries in financial frictions are large across countries, it may be optimal for countries to act independently if the only coordination mechanism available involves setting a uniform instrument. When countries differ in size and structure, and shocks are symmetric, macroprudential policy coordination yields little benefits—if at all; but when they differ in both dimensions (consistent with the "core-periphery" view of the euro area), a *one-size-fits-all* policy remains sub-optimal, both from the perspective of the union as a whole and individual member countries.

The second implication relates to the whether the ECB should lean against financial cycles. In the current euro area institutional set-up, the monetary policy authority responds to changes in the area-wide inflation and output gaps (consistent with the interest rate rule specified earlier), while national macroprudential policy authorities have primary responsibility to respond to country-specific financial stability shocks. Our analysis suggests that giving the ECB a mandate to pursue financial stability by responding directly to measures of financial imbalances in the euro area as a whole could be counterproductive in responding to asymmetric shocks. The reason is that the common monetary policy, when it *leans against the wind* by responding too aggressively to union-wide credit developments, creates a negative externality: it may generate a *contractionary* or *expansionary bias* (depending on the direction of the shock), which may induce countries where the shock doesn't occur to use macroprudential policy to offset that impact. Monetary and macroprudential policies are thus adjusted inefficiently in opposite directions. In a sense, when monetary policy leans too strongly against union-wide financial sector developments, it creates a trade-off between national and union-wide financial stability. This argument against an aggressive *leaning against the wind* strategy in a currency union is an important consideration in the ongoing debate about reforming the institutional mandate of the ECB and militates in favor of a clear separation of the goals that should be attributed to the monetary authority and the macroprudential authority—independently of whether macroprudential policies should be coordinated or not.

10 Concluding Remarks

The purpose of this paper was to contribute, using a game-theoretic approach, to a better understanding of the spillover effects of macroprudential policy in a currency union and to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in that setting, relative to the case where member countries pursue independent policies. In the model, countries are linked structurally through international trade in intermediate goods and capital flows through bond markets. Both domestic credit market and world capital market imperfections are accounted for. A common central bank sets the refinance rate on the basis of a union-wide Taylor rule. Various extensions were considered, including the case where countries have asymmetric size and structure. The joint determination of monetary and macroprudential policies was also discussed.

Our main results were summarized in the introduction. To conclude, it is worth noting that, to enhance the analysis of cross-border transmission of financial shocks, our model could be extended to account for a union-wide (global) bank lending to home and foreign banks, as in Kollmann et al. (2011), Ueda (2012), Kollmann (2013), Alpanda and Aysun (2014) Banerjee et al. (2016), Nuguer (2016), and Dräger and Proaño (2020), for instance, or alternatively an interbank market where national banks lend to each other, as, for instance, in Poutineau and Vermandel (2015, 2017), and Darracq Pariès et al. (2019). In some of these models, banks pay their depositors a premium over the marginal cost of loanable funds, and this spread is an increasing function of banks' leverage. As a result, the loan rate faced by entrepreneurs in each country would depend not only on borrowers' leverage (as in standard financial accelerator models) but also on banks' leverage. Therefore, shocks that affect banks' net worth would have a similar, symmetric effect on risk premia. More generally, this literature suggests that models in which financial frictions only apply to domestic contracts—as is the case in this paper—may not be sufficient for generating a quantitatively large foreign response to domestic shocks. To do so financial frictions many need to be incorporated into international financial contracts as well. At the same time, accounting for this type of frictions could magnify the gains from international macroprudential coordination.

Appendix A
Production Side and Goods Market Equilibrium

This Appendix describes the production of the final good, the production of intermediate goods, and the production of capital goods. The presentation is made for the home country, results for the foreign country are similar.

Final Good Production

To produce the home final good, Y_t^H, a basket of domestically-produced differentiated intermediate goods sold at home, Y_t^{HH}, is combined with a basket of imported intermediate goods produced abroad (that is, foreign exports), Y_t^{FH}:

$$Y_t^H = [\Lambda_I (Y_t^{HH})^{(\eta-1)/\eta} + (1-\Lambda_I)(Y_t^{FH})^{(\eta-1)/\eta}]^{\eta/(\eta-1)}, \tag{A1}$$

where $0.5 < \Lambda_I < 1$, to capture home bias in final good production, and $\eta > 0$ is the elasticity of substitution between the two baskets, each of which defined as

$$Y_t^i = \left\{ \int_0^1 [Y_{jt}^i]^{(\theta_i-1)/\theta_i} dj \right\}^{\theta_i/(\theta_i-1)}. \quad i = HH, FH \tag{A2}$$

In this expression, $\theta_i > 1$ is the elasticity of substitution between intermediate home goods among themselves ($i = HH$), and imported goods among themselves ($i = FH$), and Y_{jt}^i is the quantity of type-j intermediate good of category i, with $j \in (0,1)$.

Cost minimization yields the demand for each variety j of intermediate goods:

$$Y_{jt}^i = (\frac{P_{jt}^i}{P_t^i})^{-\theta_i} Y_t^i, \quad i = HH, FH \tag{A3}$$

where P_{jt}^{HH} (P_{jt}^{FH}) is the home price of home (imported) intermediate good j, and P_t^{HH} and P_t^{FH} are price indices, which are given by

$$P_t^i = \left\{ \int_0^1 (P_{jt}^i)^{1-\theta_i} dj \right\}^{1/(1-\theta_i)}. \quad i = HH, FH \tag{A4}$$

Demand functions for baskets of home and foreign goods are

$$Y_t^{HH} = \Lambda_I^\eta (\frac{P_t^{HH}}{P_t^H})^{-\eta} Y_t^H, \quad Y_t^{FH} = (1-\Lambda_I)^\eta (\frac{P_t^{FH}}{P_t^H})^{-\eta} Y_t^H, \tag{A5}$$

where P_t^H is the price of home final output, given by

$$P_t^H = [\Lambda_I^\eta (P_t^{HH})^{1-\eta} + (1-\Lambda_I)^\eta (P_t^{FH})^{1-\eta}]^{1/(1-\eta)}, \tag{A6}$$

with an analogous expression for the price of final output abroad, P_t^F.

Assuming no transportation costs between countries, and no rigidities, the law of one price implies that the home price of imported good j is given by

$$P_{jt}^{FH} = P_{jt}^{FF}, \tag{A7}$$

where P_{jt}^{FF} is the price of foreign intermediates, set in the foreign country. However, because of home bias in production, P_t^H and P_t^F in general differ from each other; their ratio defines the real exchange rate.

Production of Intermediate Goods

Home output of intermediate home good j, Y_{jt}^{HI}, is sold on a monopolistically competitive market and is produced by combining labor, N_{jt}^H, and capital, K_{jt}^H:

$$Y_{jt}^{HI} = \epsilon_t^Y (N_{jt}^H)^{1-\alpha} (K_{jt}^H)^{\alpha}, \tag{A8}$$

where $\alpha \in (0,1)$ and ϵ_t^Y is a common technology shock, which follows an $AR(1)$ process of the form $\epsilon_t^Y = \epsilon_{t-1}^{\rho^Y} \exp(\xi_t^Y)$, where $\rho^Y \in (0,1)$, and $\xi_t^Y \sim \mathbf{N}(0, \sigma_{\xi^Y})$.

Capital is rented from a randomly matched CG producer at the rate r_t^{HK} and paid for after the sale of output. Cost minimization yields the capital-labor ratio and the unit real marginal cost, mc_t^H, as

$$\frac{K_{jt}^H}{N_{jt}^H} = (\frac{\alpha}{1-\alpha})(\frac{w_t^H}{r_t^{HK}}) \quad \forall i, \tag{A9}$$

$$mc_t^H = \frac{\left(w_t^H\right)^{1-\alpha} \left(r_t^{HK}\right)^{\alpha}}{\alpha^{\alpha} \left(1-\alpha\right)^{1-\alpha} \epsilon_t^Y}. \tag{A10}$$

Each firm j chooses a sequence of prices so as to maximize the discounted present value of its profits:

$$\{P_{jt+s}^{HH}\}_{s=0}^{\infty} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \lambda_{t+s} J_{jt+s}^{HI}, \tag{A11}$$

where $\Lambda^s \lambda_{t+s}$ measures the marginal utility value to the representative home household of an additional unit of real profits, J_{jt+s}^{HI}, received in the form of dividends at $t+s$. In Rotemberg fashion, prices are costly to adjust; profits are thus defined as

$$J_{jt}^{HI} = (\frac{P_{jt}^{HH}}{P_t^{HH}}) Y_{jt}^{HI} - mc_t^H Y_{jt}^{HI} - \frac{\phi_I}{2} (\frac{P_{jt}^{HH}}{P_{jt-1}^{HH}} - 1)^2 Y_t^{HI}, \tag{A12}$$

where $\phi_I \geq 0$.

Using (A3), the first-order condition for this problem takes the standard form

$$(1-\theta_{HH})(\frac{P_{jt}^{HH}}{P_t^{HH}})^{-\theta_{HH}} \frac{1}{P_t^{HH}} + \theta_{HH}(\frac{P_{jt}^{HH}}{P_t^{HH}})^{-\theta_{HH}-1} \frac{mc_t^H}{P_t^{HH}} \tag{A13}$$

$$-\phi_I \left\{ (\frac{P_{jt}^{HH}}{P_{jt-1}^{HH}} - 1) \frac{1}{P_{jt-1}^{HH}} \right\} + \Lambda \phi_I \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (\frac{P_{jt+1}^{HH}}{P_{jt}^{HH}} - 1) \frac{P_{jt+1}^{HH}}{(P_{jt}^{HH})^2} \frac{Y_{t+1}^{HH}}{Y_t^{HH}} \right\} = 0.$$

The law of one price implies that the price of home intermediate goods sold abroad (that is, the price of home exports), P_t^{HF}, is equal to the home price:[33]

$$P_t^{HF} = P_t^{HH}. \tag{A14}$$

[33] From (A7) and (A14), the terms of trade are thus given by $P_t^{HF}/P_t^{FH} = P_t^{HH}/P_t^{FF}$. By log-linearizing (A6) and the equivalent definition of P_t^F, it can be shown that deviations in the real exchange rate are proportional to deviations in the terms of trade between the two countries.

As noted earlier, trade between the two countries occurs only at the level of intermediate goods. The market-clearing condition equates therefore total output of home intermediate good j with world demand for that good, that is, the sum of the home and foreign demands for home good j:

$$Y_{jt}^{HI} = Y_{jt}^{HH} + Y_{jt}^{HF}, \tag{A15}$$

with, similar to (A3), $Y_{jt}^{HF} = (P_{jt}^{HF}/P_t^{HF})^{-\theta_i} Y_t^{HF}$ denoting home exports. A similar condition holds for foreign production of each intermediate good j:

$$Y_{jt}^{FI} = Y_{jt}^{FF} + Y_{jt}^{FH}, \tag{A16}$$

with Y_{jt}^{FH} (home imports) given by (A3).[34]

Capital Good Production

The aggregate capital stock, $K_t^H = \int_0^1 K_{jt}^H dj$, is obtained by combining gross investment, I_t^H, with the existing stock, adjusted for depreciation and adjustment costs:

$$K_{t+1}^H = I_t^H + \left\{1 - \delta_K - \frac{\Theta_K}{2}(\frac{K_{t+1}^H - K_t^H}{K_t^H})^2\right\} K_t^H, \tag{A17}$$

where $\delta_K \in (0,1)$ is the depreciation rate and $\Theta_K > 0$.

Investment goods must be paid for in advance. The CG producer must therefore borrow from the bank $l_t^H = I_t^H$. The household makes its exogenous housing stock, $\bar{A}^H$, available without any direct charge to the CG producer, who uses it as collateral against which it borrows from the bank.[35] Repayment is uncertain and occurs with probability $q_t^H \in (0,1)$. Expected repayment is thus $q_t^H(1+i_t^{HL})I_t^H + (1-q_t^H)\kappa p_t^{HA}\bar{A}^H$, where $\kappa \in (0,1)$ is the share of the housing stock that can be effectively pledged as collateral.

Subject to (A17) and $l_t^H = I_t^H$ the CG producer chooses the level of capital K_{t+1}^H so as to maximize the value of the discounted stream of dividend payments to the household. As shown in Appendix B, the solution to this problem yields[36]

$$\mathbb{E}_t r_{t+1}^{HK} \simeq q_t^H(1+i_t^{HL})\mathbb{E}_t\left\{[1+\Theta_K(\frac{K_{t+1}^H}{K_t^H} - 1)](\frac{1+i_t^{HB}}{1+\pi_{t+1}^H})\right\} \tag{A18}$$

$$-\mathbb{E}_t\left\{q_{t+1}^H(1+i_{t+1}^{HL})\left\{1 - \delta_K + \frac{\Theta_K}{2}[(\frac{K_{t+2}^H}{K_{t+1}^H})^2 - 1]\right\}\right\}.$$

[34] Note that we also have in value terms $P_t^{HI}Y_t^{HI} = P_t^{HH}Y_t^{HH} + P_t^{HF}Y_t^{HF}$, where P_t^{HI} is the output price of intermediate goods. But given that from (A14) $P_t^{HF} = P_t^{HH}$, and given (A15), this condition boils down to $P_t^{HI} = P_t^{HH}$, which justfies specifying the optimization problem of the IG producer in (A11) directly in terms of P_t^{HH}.

[35] Because all profits made by the CG producer are assumed to be returned lump sum to its owner, the assumption that housing is made available free of charge is for simplicity only.

[36] Equation (A18) boils down to the standard arbitrage condition $\mathbb{E}_t r_{t+1}^{HK} = \mathbb{E}_t[(1+i_t^{HB})/(1+\pi_{t+1}^H)] + \delta$ in the absence of borrowing and adjustment costs.

Goods market equilibrium

In a symmetric equilibrium, all intermediate-good firms, at home and abroad, produce the same output and prices are the same across firms. Thus, the market-clearing conditions (A15) and (A16) for good j also imply that total output of home and foreign intermediate goods be equal to world demand for those goods:

$$Y_t^{HI} = Y_t^{HH} + Y_t^{HF}, \qquad Y_t^{FI} = Y_t^{FF} + Y_t^{FH}. \tag{A19}$$

Equilibrium in the market for final goods in the home country requires that output be equal to absorption, inclusive of price adjustment costs:

$$Y_t^H = C_t^H + G_t^H + I_t^H + \frac{\phi_I}{2}(\frac{P_t^{HH}}{P_{t-1}^{HH}} - 1)^2(\frac{P_t^{HH}}{P_t})Y_t^{HI}. \tag{A20}$$

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Table 1
Benchmark Parameterization: Key Values

Parameter	Value	Description
Household		
Λ	0.99	Discount factor
ς	0.5	Elasticity of intertemporal substitution
η_N	25.0	Preference parameter for leisure
η_x	0.001	Preference parameter for money holdings
η_A	0.1	Preference parameter for housing
ψ_N	1.4	Inverse of Frisch elasticity of labor supply
ν	0.2	Share parameter in index of money holdings
θ_0^B	0.05	Cost parameter, international financial intermediation
Production		
Λ_I	0.7	Share of home IG goods in final output
η	3	Elasticity of substitution, baskets of IG goods
θ_{HH}, θ_{FF}	10.0	Elasticity of demand, intermediate goods
α	0.35	Share of capital, domestic intermediate goods
ϕ_I	74.5	Adjustment cost parameter, domestic IG prices
δ_K	0.025	Depreciation rate of capital
Θ_K	14	Adjustment cost parameter, investment
Commercial Banks		
κ	0.6	Effective share, collateral-loan ratio
φ_1	0.05	Elasticity of repayment probability, collateral
φ_2	0.2	Elasticity of repayment probability, cyclical output
ζ_L	4.5	Elasticity of substitution between differentiated loans
Common central bank		
χ	0.8	Degree of interest rate smoothing
ε_1	1.6	Response of base policy rate to inflation deviations
ε_2	0.04	Response of base policy rate to output deviations
χ_1	0.8	Persistence parameter, macroprudential tax rule
μ	0.02	Required reserve ratio
Government		
ψ	0.18	Share of government spending in domestic output sales
Shocks		
ρ^L	0.8	Persistence parameter, financial shock
ρ^R	0	Persistence parameter, refinance rate shock

Table 2
Initial Steady-State Values: Key Variables[1]
(In proportion of output or in percent)

Variable	Description	Value
C	Private consumption	0.713
G	Government spending	0.18
Y^{HF}/Y^{H}	Exports as a share of final output (percent)	0.12
N	Employment (percent of total time)	0.325
I, l	Investment, loans to intermediate goods firms	0.107
K/Y	Capital-output ratio	4.28
r^K	Rental rate of capital (percent)	0.036
q	Repayment probability, loans to intermediate goods firms	0.975
i^B, i^R	Government bond rate, central bank refinance rate (percent)	0.010
i^D	Bank deposit rate (percent)	0.009
i^L	Loan rate, capital goods producers (percent)	0.047
τ^H	Tax rate on loans to capital goods producers (percent)	0.0

[1]Country index j is omitted given that the countries are symmetric.

Table 3
Optimal Policy Responses and Gains from Coordination
Home and Global Financial Shocks, Benchmark Case and Asymmetric Country Size[1]

	$\varkappa_W = 0.1$		$\varkappa_W = 0.4$	
	Home	Global	Home	Global
Benchmark case				
Decentralized regime: $\chi_2^{H,N}, \chi_2^{F,N}$	1.0, 0.7	1.0, 1.0	0.3, 1.4	0.3, 0.3
Centralized regime: Separate $\chi_2^{H,O}, \chi_2^{F,O}$	1.1, 0.4	1.1, 1.1	0.4, 0.9	0.4, 0.4
Centralized regime: Uniform $\chi_2^{H,C} = \chi_2^{F,C}$	1.1	1.1	0.4	0.4
Gain from centralization: Separate instruments				
Home	0.000	0.001	0.000	0.006
Foreign	0.107	0.001	0.181	0.006
Union	0.001	0.001	0.006	0.006
Gain from centralization: Uniform instrument				
Home	0.000	0.001	0.000	0.006
Foreign	0.107	0.001	0.178	0.006
Union	0.001	0.001	0.005	0.006
Asymmetric country size				
Decentralized regime: $\chi_2^{H,N}, \chi_2^{F,N}$	1.0, 5.4	1.0, 1.0	0.4, 10.0	0.4, 0.3
Centralized regime: Separate $\chi_2^{H,O}, \chi_2^{F,O}$	1.1, 1.7	1.1, 1.1	0.4, 10.0	0.4, 0.4
Centralized regime: Uniform $\chi_2^{H,C} = \chi_2^{F,C}$	1.1	1.1	0.4	0.4
Gain from centralization: Separate instruments				
Home	0.000	0.001	0.000	0.005
Foreign	0.107	0.002	0.000	−0.001
Union	0.001	0.001	0.000	0.003
Gain from centralization: Uniform instrument				
Home	0.000	0.001	0.000	0.005
Foreign	0.105	0.002	−0.025	−0.001
Union	0.001	0.001	−0.001	0.003

[1]'Home' refers to a financial shock in the home country only and 'Global' to a financial shock of the same size in both countries. Gains from centralization are relative welfare gains inclusive of the cost of instrument manipulation, and are calculated using the formulas provided in the text. Asymmetric country size involves setting the weight of the home country to 1.5, both in calculating average cyclical output and inflation, and in setting the policy interest rate, as well as in solving for the optimal policy responses.

Table 4
Asymptotic Standard Deviations of Key Variables under Alternative Policy Regimes
Asymmetric Financial Shock[1]

	No macropru. policies	Nash equilibrium	Coordination Single ins.	Coordination Separate ins.	Ramsey policy
Home country					
Final output	0.1909	0.1443	0.1342	0.1342	0.0005
Employment	0.2234	0.1780	0.1673	0.1673	0.0005
Investment	0.1441	0.1110	0.1037	0.1037	0.0004
Consumption	0.0451	0.0304	0.0273	0.0274	0.0001
Inflation	0.0210	0.0141	0.0128	0.0128	0.0001
Loan rate	1.6521	1.2420	1.1527	1.1527	0.0023
Tax rate on loans	−−	0.4864	0.5892	0.5891	2.1504
Real house prices	0.2128	0.1436	0.1291	0.1293	0.0002
Repayment probability	0.1011	0.0769	0.0715	0.0716	0.0001
Loan-to-output ratio	0.3765	0.2906	0.2713	0.2713	0.0007
Foreign country					
Final output	0.0218	0.0156	0.0133	0.0138	0.0002
Employment	0.0445	0.0297	0.0273	0.0271	0.0001
Investment	0.0032	0.0013	0.0012	0.0011	0.0001
Consumption	0.0173	0.0117	0.0104	0.0105	0.0001
Inflation	0.0154	0.0103	0.0092	0.0093	0.0000
Loan rate	0.0397	0.0551	0.0369	0.0452	0.0009
Tax rate on loans	−−	0.0306	0.0149	0.0232	0.0013
Real house prices	0.0818	0.0554	0.0490	0.0495	0.0001
Repayment probability	0.0195	0.0125	0.0114	0.0113	0.0001
Loan-to-output ratio	0.3765	0.2906	0.2713	0.2713	0.0007
Union					
Refinance rate	0.0209	0.0138	0.0124	0.0124	0.0000
Inflation (equal weights)	0.0172	0.0115	0.0103	0.0104	0.0000
Output (equal weights)	0.1022	0.0764	0.0706	0.0707	0.0002

[1]'No Macropru. policies' indicates countercyclical macroprudential policies, 'ins.' refers to instrument. Results correspond to the case where $\varkappa_W = 0.4$.

Table 5
Optimal Policy Responses and Gains from Coordination
Home and Foreign Financial Shocks, Asymmetric Country Size and Structure[1]

	$\varkappa_W = 0.1$		$\varkappa_W = 0.4$	
	Home	Foreign	Home	Foreign
Unequal refinance rate weighting, $\upsilon = 1.5$				
Decentralized regime: $\chi_2^{H,N}, \chi_2^{F,N}$	$1.6, -0.2$	$0.4, 0.9$	$0.5, -0.2$	$1.0, 0.3$
Centralized regime: Separate $\chi_2^{H,O}, \chi_2^{F,O}$	$1.7, -0.2$	$0.2, 1.2$	$0.6, -0.2$	$0.6, 0.4$
Centralized regime: Uniform $\chi_2^{H,C} = \chi_2^{F,C}$	1.7	1.2	0.6	0.4
Gain from centralization: Separate instruments				
Home	0.000	0.240	−0.003	0.143
Foreign	0.082	−0.034	0.156	−0.025
Union	0.001	0.027	0.000	0.024
Gain from centralization: Uniform instrument				
Home	−0.002	0.239	−0.004	0.142
Foreign	0.008	−0.034	0.117	−0.025
Union	−0.002	0.027	−0.002	0.024
Equal refinance rate weighting, $\upsilon = 1$				
Decentralized regime: $\chi_2^{H,N}, \chi_2^{F,N}$	$1.7, -0.3$	$0.2, 0.9$	$0.6, -0.3$	$0.3, 0.3$
Centralized regime: Separate $\chi_2^{H,O}, \chi_2^{F,O}$	$1.7, -0.3$	$0.5, 1.1$	$0.6, -0.1$	$0.5, 0.4$
Centralized regime: Uniform $\chi_2^{H,C} = \chi_2^{F,C}$	1.7	1.1	0.6	0.4
Gain from centralization: Separate instruments				
Home	0.001	0.170	0.001	0.143
Foreign	−0.013	−0.018	−0.013	−0.027
Union	0.000	0.011	0.001	0.009
Gain from centralization: Uniform instrument				
Home	0.000	0.167	0.001	0.143
Foreign	−0.129	−0.018	−0.091	−0.027
Union	−0.002	0.011	−0.001	0.009

[1]See Notes to Table 3. 'Home' and 'Foreign' refer to a financial shock in the home country only and the foreign country only, respectively. See text for a description of the structural differences between the home (core) country and the foreign (periphery) country.

Table 6
Optimal Policy Responses and Gains from Coordination
Global Supply and Demand shocks, Symmetric and Asymmetric Country Size and Structure[1]

	Demand shock		Supply shock	
	Sym	Asym	Sym	Asym
Decentralized regime: $\chi_2^{H,N}, \chi_2^{F,N}$	$-0.3, -0.3$	$-0.3, -0.3$	$2.3, 2.3$	$5.8, 1.9$
Centralized regime: Separate $\chi_2^{H,O}, \chi_2^{F,O}$	$-0.3, -0.3$	$-0.3, -0.3$	$2.3, 2.3$	$5.9, 1.1$
Centralized regime: Uniform $\chi_2^{H,C} = \chi_2^{F,C}$	-0.3	-0.3	2.3	3.6
Gain from centralization: Separate instruments				
Home	0.000	0.000	0.000	0.001
Foreign	0.000	0.000	0.000	-0.001
Union	0.000	0.000	0.000	0.000
Gain from centralization: Uniform instrument				
Home	0.000	0.000	0.000	-0.001
Foreign	0.000	0.000	0.000	-0.002
Union	0.000	0.000	0.000	-0.001

[1]See Notes to Table 3. 'Sym' and 'Asym' refer to the cases of symmetric and asymmetrice countries, both in size and structure, respectively. See text for a description of the structural differences, under asymmetry, between the home (core) country and the foreign (periphery) country. Results correspond to the case where $\varkappa_W = 0.4$.

Figure 1
Model Structure: Home Country

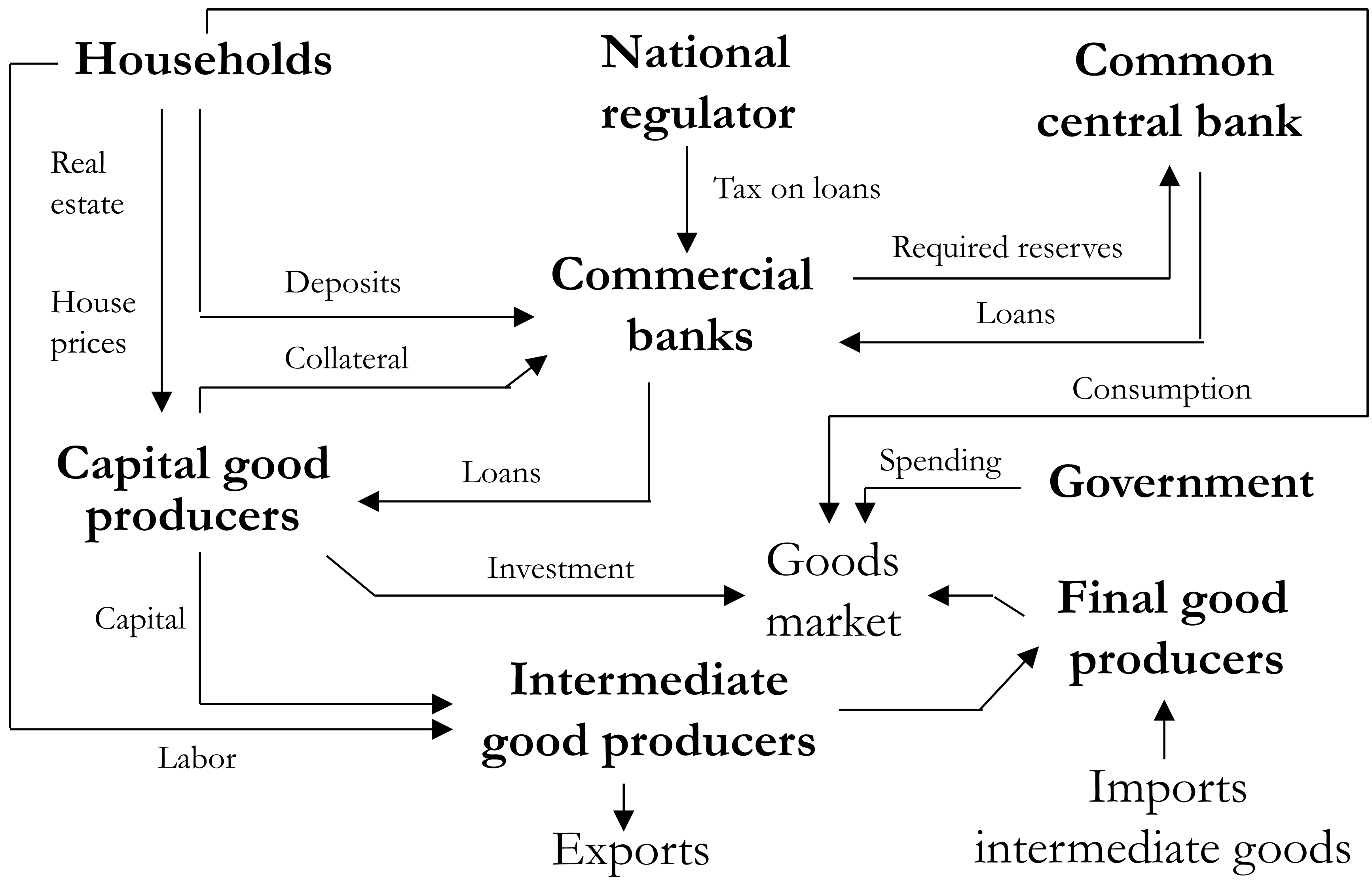
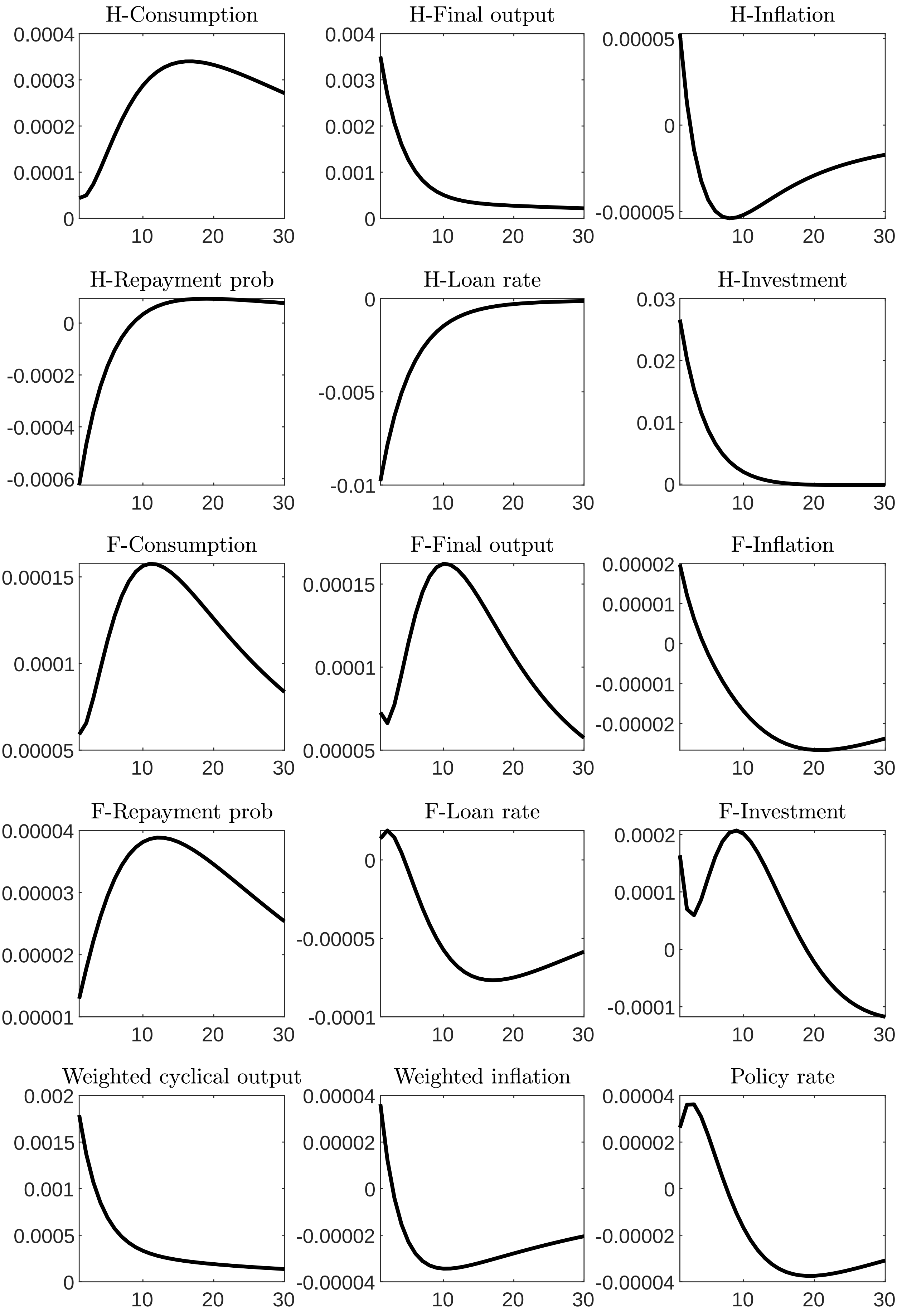
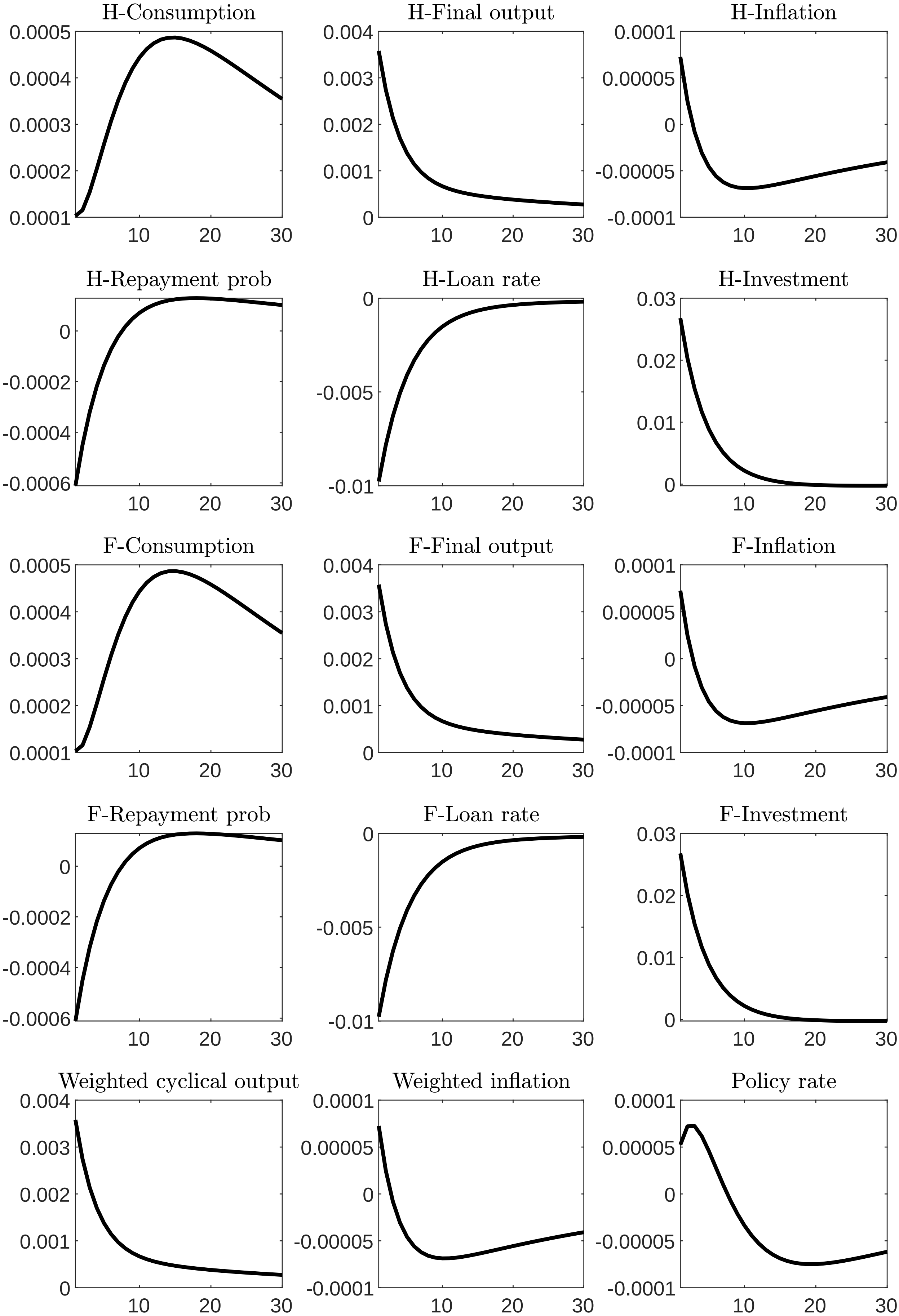


Figure 2
Negative Credit Spread Shock, Home Country



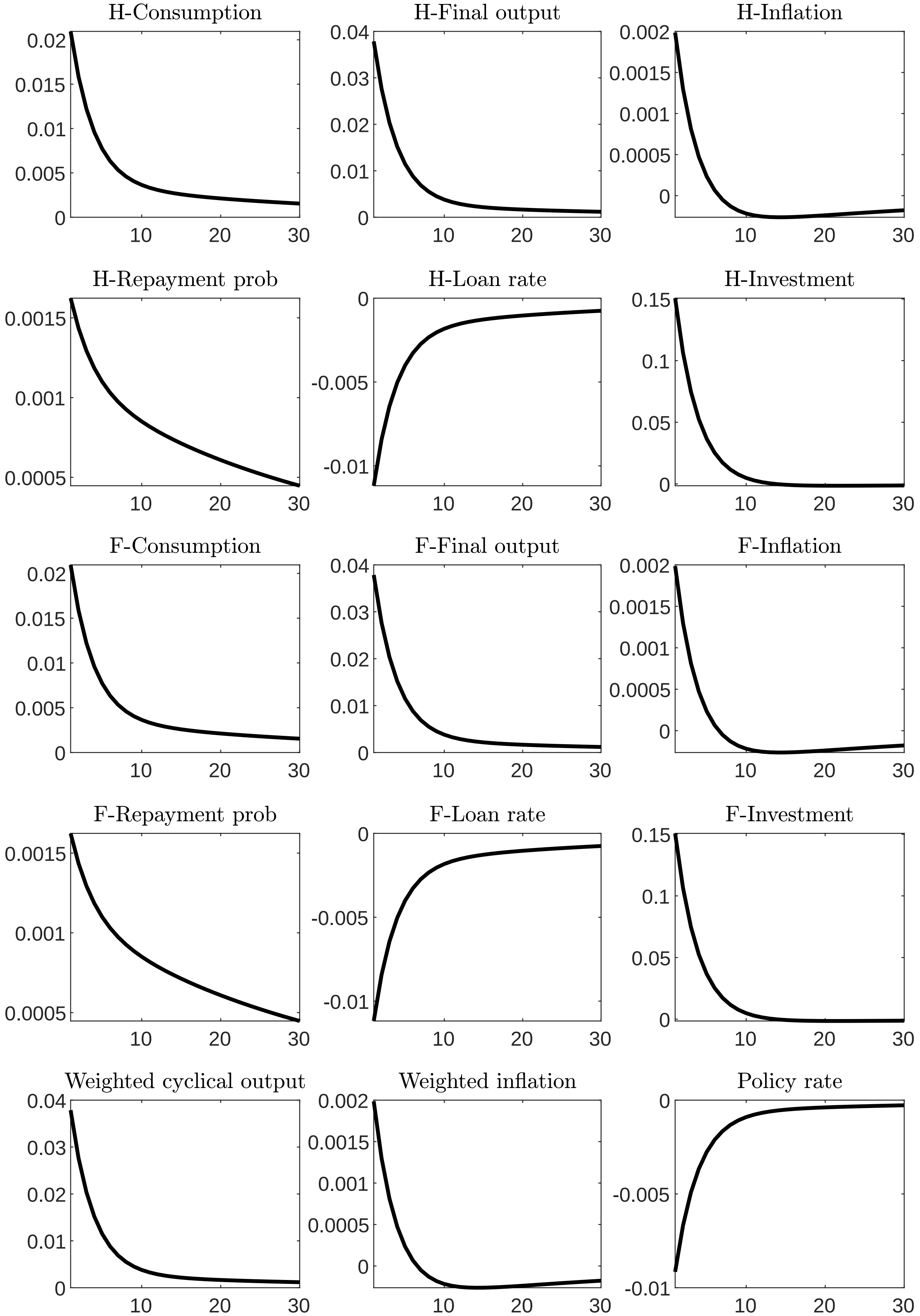
Notes: H (F) referes to the home country. Responses of consumption, investment, final output, and real house prices, are expressed as percent deviations from their steady-state values. Responses of the loan rate, the policy rate, the repayment probability, and the inflation rate are expressed as absolute deviations (or percentage points) from their steady-state values.

Figure 3
Negative Credit Spread Shock, Symmetric across Countries



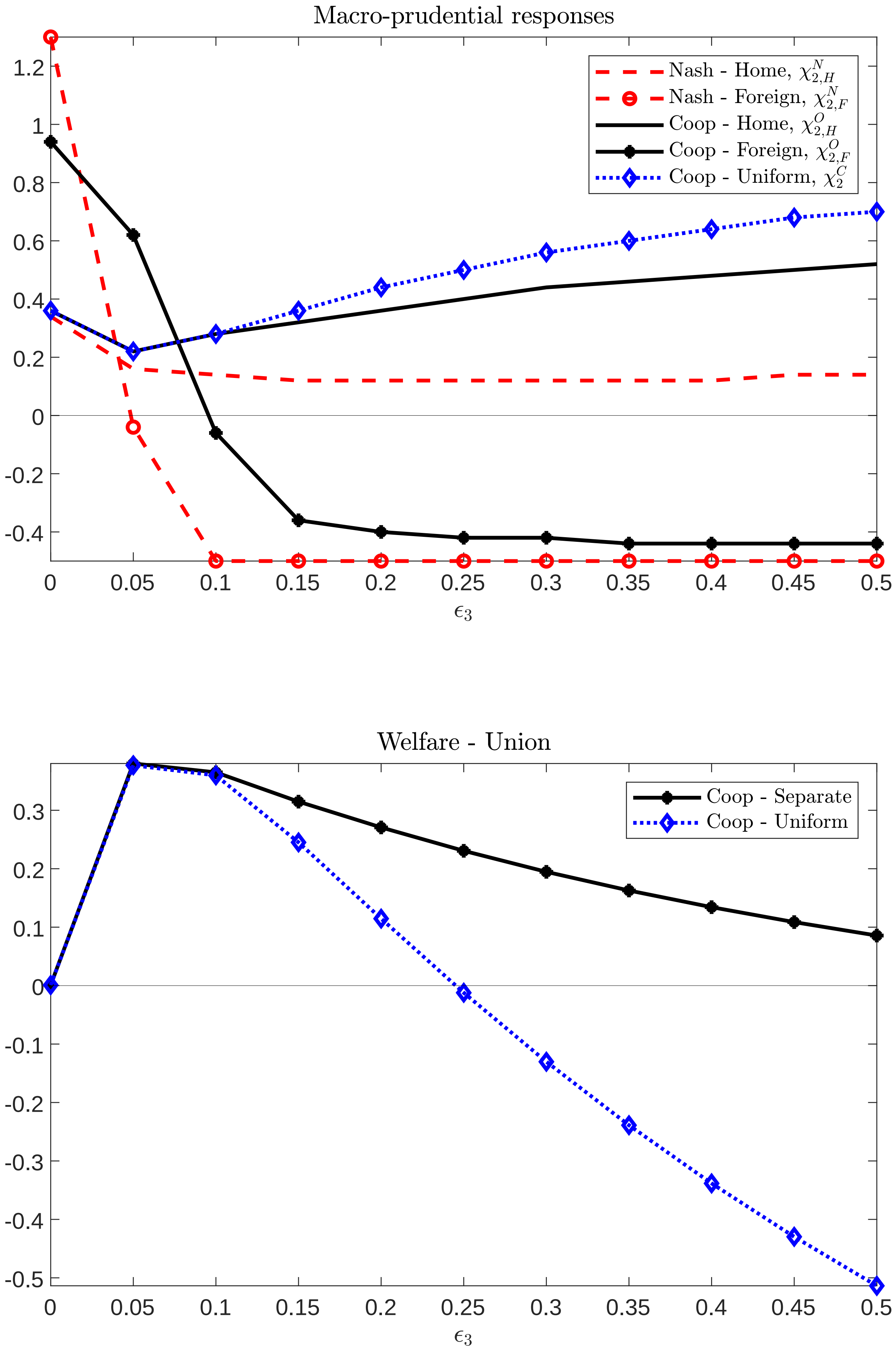
Note: See Notes to Figure 2.

Figure 4
Temporary Reduction in Refinance Rate, Common Central Bank



Note: See Notes to Figure 2.

Figure 5
Negative Credit Spread Shock: Optimal Macroprudential Policy Responses and Union-wide Welfare under Alternative Regimes and *Leaning against the Wind*



Note: For convenience, welfare (inclusive of the instrument manipulation cost) is normalized to zero when the central bank does not respond to credit fluctuations.