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Cross-Border Regulatory Spillovers and Macroprudential Policy Coordination

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Abstract

A core-periphery model with financial frictions, imperfect financial integration, and cross-border banking is used to assess the magnitude of regulatory spillovers and the gains from international macroprudential policy coordination. A core global bank lends to its affiliates in the periphery and banks in both regions are subject to risk-sensitive capital regulation. Following an expansionary monetary policy in the core, a countercyclical response in capital requirements induces the global bank to engage in regulatory arbitrage. The magnitude of the resulting cross-border capital flows depends on the degree of economies of scope in lending. Welfare gains associated with countercyclical capital buffers are calculated for three policy regimes: independent policies (Nash), coordination, and reciprocity—a regime in which capital ratios set in the core are imposed on branches operating in the periphery. If regulators set policies on the basis of a narrow financial stability mandate, and these policies are evaluated in terms of household welfare, reciprocity may perform better than Nash, and as well as coordination for all parties, when regulatory leakages are strong.

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Appendix A is available online, whereas Appendices B to D are available upon request.

1 Introduction

In recent years there has been greater recognition that, in a world where financial institutions and markets are highly interconnected, differences in national macroprudential policies can be an important source of international spillovers. Through cross-border regulatory arbitrage, these differences may lead to large swings in capital flows, which in turn may magnify the transmission of financial shocks across regions and exacerbate financial risks in recipient countries. In response to a tightening of capital requirements at home, for instance, domestic banks with a regional or global presence may respond by increasing lending abroad, through direct loans to either foreign-country borrowers (firms or households) or their foreign affiliates.[1] Houston et al. (2012), Aiyar et al. (2014), Bremus and Fratzscher (2015), Reinhardt and Riddiough (2015), Avdjiev et al. (2017), Beirne and Friedrich (2017), Damar and Mordel (2017), Forbes et al. (2017), Hills et al. (2017), Cerutti and Zhou (2018), Franch et al. (2019), Tripathy (2020) and Claessens et al. (2021) have all provided evidence that banks with a global outreach often engage in regulatory arbitrage, by transferring funds to (or, in some cases, from) markets with weaker regulations—creating, in effect, an international credit channel.[2] Damar and Mordel (2017), for instance, found that tighter regulatory requirements at home push Canadian banks to lend more abroad. For their part, Cerutti and Zhou (2018) found that while tighter macroprudential policies in lender countries reduce direct cross-border, bank-related capital outflows, they also tend to be associated with larger outflows through local affiliates.

Increased lending induced by cross-border regulatory arbitrage may contribute to a credit boom or asset price pressures in recipient countries.[3] But whether a counterbalancing macroprudential response by regulators in those countries is also called for to mitigate financial risks depends on the stage of their financial cycles. At the

[1] Of course, regulatory arbitrage may also occur at the domestic level—as occurred prior to the global financial crisis—if banks choose to sell or securitize those assets for which the regulatory capital charge is higher than the one the regulator would impose, while keeping on the books poorer quality assets for which the regulatory capital charge is relatively low. Although our focus is on cross-border arbitrage, this issue is further discussed in our concluding remarks.

[2] Cross-border arbitrage may also operate through increased lending to foreign branches or through a "rebooking" of loans, whereby loans are originated by subsidiaries but then booked on the balance sheet of the parent institution. See Reinhardt and Riddiough (2015) and Fillat et al. (2018) for a discussion of how different forms of banking organization may affect the transmission of financial shocks across countries.

[3] Buch and Goldberg (2017) and World Bank (2018) provide a broad review of the evidence on the impact of cross-border lending by foreign banks on domestic credit.

same time, aggregate fluctuations and policy responses in recipient countries may generate significant spillback effects, through both trade and financial channels, which in turn may hamper the achievement of the initial objectives set out by regulators in source countries. The implication is that when global financial institutions can evade policy actions taken by regulators in their jurisdiction, financial cycles are not well synchronized across economies, and reverse spillovers are potentially significant, the combination of national macroprudential policies may be sub-optimal from the perspective of the world economy—even when each country's national macroprudential policy, taking everyone else's as given, is optimal. If policy decisions can magnify risks for all parties when taken independently, *ex ante* coordination may improve global welfare. The potential benefit of coordinated action is indeed one of the rationales underlying Basel III's *Principle of reciprocity*, which applies to countercyclical capital buffers (see Basel Committee on Banking Supervision (2011)).[4] In the same vein, automatic reciprocation of countercyclical capital buffers is required in the European Union since 2016. In effect, the fundamental rationale for reciprocity is that greater coordination of macroprudential policies across countries may help to maintain, or promote, global financial stability.

Despite the importance of this issue from a policy perspective, theoretical contributions aimed at modeling cross-border regulatory leakages and at quantifying the gains from international macroprudential coordination (involving reciprocity or not) remain scant.[5] Acharya (2003) provided an early discussion of the role of regulatory arbitrage as a motive for international bank flows. His focus was on how effective can convergence in international capital adequacy standards be. His key argument is that unless it is accompanied by convergence in other aspects of financial regulation, such as bank closure policies, coordination in setting regulatory standards would not necessarily eliminate regulatory arbitrage. In a more recent contribution, Bengui and Bianchi (2018) developed a small open-economy model in which macroprudential regulation can only be enforced on a subset of agents—which, in their setting, can be loosely

[4] Designed to overcome the problems associated with global banks bypassing national regulations on capital requirements, the Principle stipulates that when the countercyclical capital buffer embedded in Basel III is activated in any given country, *all* countries are expected to apply the same buffer on exposures to that country from banks in their jurisdiction. See Agénor and Pereira da Silva (2018) for a discussion.

[5] See Agénor and Pereira da Silva (2019) and Agénor et al. (2021), as well as the references therein, for some recent contributions on internatiobal macroprudential regulation. Rubio (2020) discussed regulatory reciprocity but in a model that focuses on loan-to-value ratios.

interpreted as traditional banks. As a result, a macroprudential policy aimed at inducing regulated agents to internalize the pecuniary externality created by frictions in financial markets, while contributing to a safer environment, may have the unintended consequence of encouraging borrowing by unregulated agents, which can be interpreted in their setting as shadow banks.[6] These within-country spillovers undermine the effectiveness of macroprudential policy and may increase exposure to financial crises. At the same time, and in contrast to what is often argued in policy circles, the presence of leakages does not necessarily call for weaker intervention.[7] Nevertheless, while useful for bringing to the fore some aspects of the link between regulatory arbitrage and capital flows, neither contribution addresses the issue of whether the coordination of countercyclical macroprudential policies across countries, in the form of either a hypothetical joint optimization process or a formal reciprocal regulatory agreement, has a significant quantitative effect on national welfare while at the same time being Pareto improving for the world economy.

This paper contributes to filling this gap by developing a two-region, core-periphery DSGE model with financial frictions to study two issues. First, we characterize the cross-border leakages when regulators in the core region tighten their macroprudential stance in response to an expansionary monetary shock in that region. Second, we evaluate the potential benefits of macroprudential policy coordination and reciprocity agreements (pertaining to countercyclical capital buffers, consistent with Basel III's Principle alluded to earlier) in the presence of regulatory arbitrage. To do so, we use two approaches: first, the standard, utility-based welfare approach, and second, a two-staged approach, which involves solving first for the optimal policy based on a loss function, consistent with an institutional mandate focused on financial stability, and then measuring the benefits of that policy in terms of household welfare.

Specifically, the paper extends the core-periphery model developed in Agénor and Pereira da Silva (2019), which features imperfect financial integration and global banking.[8] These extensions relate, first, to the assumption that banks in the periphery are

[6]These results are consistent with those in the literature focusing on interactions between prudential regulation of banks and the growth of shadow banking in closed economies. See, for instance, Meeks et al. (2017), Begenau and Landvoigt (2020), and Gebauer and Mazelis (2020).

[7]Indeed, in their model, while a small macroprudential tax on regulated agents is always strictly welfare-improving for all agents, a larger intervention remains effective at reducing vulnerability to financial crises.

[8]Other quantitative two-country models with cross-border banking include Kollman et al. (2011), Ueda (2012), Kollman (2013), Cuadra and Nuguer (2018), Darracq Pariès et al. (2019), Agénor et

all considered to be affiliates set up by the global bank and loans between them occur through an internal capital market. Second, banks in both regions are subject to a risk-sensitive capital regulatory regime. We define (outward) leakage in macroprudential policies as a situation where, in response to changes in countercyclical capital requirements in the core, which affect lending there, the global bank shifts lending from its jurisdiction to lending to its affiliates abroad. Regulatory arbitrage therefore contributes to financial spillovers (and potential spillbacks) across jurisdictions.

Using a parameterized version of the model, an expansionary monetary policy in the core—a key driver of the global financial cycle, as documented, for instance, by Miranda-Agrippino and Rey (2020)—is used to illustrate how lending costs, countercyclical capital buffers (which respond to credit fluctuations), and regulatory arbitrage affect cross-border bank capital flows. Welfare gains are calculated for three policy regimes: independent policies (Nash), coordination, and reciprocity—a regime where, in line with the Basel III Accord, capital ratios set in the core region are also imposed on affiliates of the global bank operating in the periphery. A novelty of our analysis therefore is to treat reciprocity—a regime which, in a sense, involves partial cooperation—as an independent policy regime, whose performance can be compared with the standard cases of cooperation and noncooperation. The gains from coordination are evaluated using the two approaches alluded to earlier: a standard, utility-based welfare approach, and a two-stage approach.

Our main results can be summarized as follows. Following an expansionary monetary policy in the core, a countercyclical response in capital requirements induces the global bank to engage in regulatory arbitrage. The magnitude of the resulting cross-border capital flows is shown to depend on the degree of economies of scope in lending by the global bank. Thus, the model provides a structural interpretation of the empirical evidence on the growing importance of regulatory arbitrage. At the same time, because the equilibrium of the world economy is solved for simultaneously, simulations of the model help also to capture the spillback effects associated with fluctuations in the periphery—making it therefore particular suitable to study the potential benefits of cooperative regimes, in terms of either reciprocity or coordination. From that perspective, we also find that under the standard welfare approach, the periphery is always

al. (2021), and Johnson (2021). Although some of these models considered the cross-border spillover effects of capital requirements, none of them asssesses the gains from international policy coordination in this type of instrument.

worse off under reciprocity. However, under the two-stage approach, where regulators set policies on the basis of a narrow financial stability mandate and these policies are evaluated in terms of household welfare, reciprocity may perform better than Nash, and as well as coordination for all parties if cross-border regulatory leakages are strong. Yet, the gains for the core and the world economy are invariably not large, despite the reciprocating jurisdiction (the periphery) being better off. Thus, despite being narrowly defined, reciprocity agreements may face significant obstacles in practice, in the absence of adequate incentives (penalties or side-payment mechanisms) to ensure voluntary participation. Our results may also help to explain why, as discussed in Agénor and Pereira da Silva (2021), reciprocity has been only rarely activated in the real world.

The remainder of the paper proceeds as follows. Section 2 presents the model. The financial frictions that are accounted for allow us to capture three key features and implications of the regulatory regime. First, as a result of monopoly banking (in the core) and monopolistic banking (in the periphery), the rate at which firms must borrow to finance investment can be written as a markup over a weighted average of the cost of central bank liquidity and the cost of issuing bank capital. Second, the probability of loan repayment, which also affects the cost of borrowing and is itself linked to changes in collateral values, as well as cyclical output, has a direct impact on the risk weight used to calculate required capital ratios. Third, although capital is costly, it also generates a pecuniary benefit; consequently, it is optimal for banks to hold capital in excess of the required level.[9] The model's equilibrium and its steady-state solution are briefly characterized in Section 3, and its parameterization is discussed in Section 4. Section 5 illustrates the functioning of the model by considering an expansionary financial shock in the core (a temporary cut in the monetary policy rate), with and without the activation of countercyclical capital buffers in that region. The focus on this shock is consistent with the evidence (discussed further later on) that has identified spillovers from monetary policy in advanced economies as a key driver of the global bank lending channel. The gains from coordination, relative to independent (Nash) policies and reciprocity are assessed in Section 6. The last section discusses the broad policy implications of the analysis and identifies some potentially fruitful extensions.

[9] See Agénor and Jackson (2019) for a more detailed discussion of our modeling of capital requirements and how it relates to the literature.

2 The Model

The world economy consists of two regions, core and periphery, of size $n \in (0,1)$ and $1-n$, respectively. Each region is populated by a representative household, a continuum of monopolistic (IG) firms producing intermediate goods, a representative final good (FG) producer, a representative capital good (CG) producer, a government, a central bank, and a regulator. IG firms produce intermediates using labor and physical capital, and set prices in monopolistic fashion. The CG producer borrows from local banks to invest and transform final goods into physical capital, which is rented to IG firms. Trade between the two regions involves only intermediate goods.[10] A single global bank operates in the core economy. It owns a continuum of affiliates in the periphery, which operate as independent commercial banks. Regions trade in government bonds, but markets for cash and credit are segmented. In particular, firms in either region cannot directly lend or borrow internationally. The exchange rate between the two regions is fully flexible.

Banks in both regions issue debt-like instruments to satisfy a risk-sensitive capital regulatory regime. They pay interest on household deposits and the liquidity that they borrow from the central bank, as well as interest on the debt that they issue. At the end of each period, banks close their books and start afresh at the beginning of the next. Thus, bank debt is redeemed at the end of each period, all its profits are distributed, and new debt is issued at the beginning of the following period. As a result, there is no intrinsic distinction between issuing equity or debt from the perspective of banks.[11] Banks also hold excess capital, depending on the cost of issuing debt relative to the marginal cost of funding, that is, the cost of borrowing from the central bank. For simplicity, they do not hold government bonds.

2.1 Core Economy

In what follows we describe the behavior of households, the global bank and the regulatory capital regime, the central bank, and the regulator in the core economy. Because

[10] This specification, consistent with the McCallum-Nelson approach, is used in a number of contributions involving multi-country models. See Cuadra and Nuguer (2018) and Dogan (2019), for instance.

[11] Thus, capital consists solely of "tier 2" capital, in Basel III terminology. A broader interpretation of bank debt in this model would be to view it as consisting of convertible bonds, which in practice have been used by banks quite extensively to satisfy capital requirements.

households behave essentially in the same way in both regions, we subsequently describe only the behavior of banks, the central bank and the regulator in the periphery. The structure of production is also the same in both regions, and details for these sectors, as well as the government, are relegated to Appendix A.[12]

2.1.1 Households

The objective of the representative household in the core economy is to maximize[13]

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

where C_t^C is consumption of the final good, $N_t^{C,j}$ the number of hours provided to IG producer j, x_t^C a composite index of real monetary assets, H_t^C the stock of housing, $\Lambda \in (0,1)$ a discount factor, $\varsigma > 0$ the intertemporal elasticity of substitution in consumption, ψ_N the inverse of the Frisch elasticity of labor supply, $\mathbb{E}_t$ the expectation operator conditional on the state of nature at the beginning of date t, and $\eta_N, \eta_x, \eta_H > 0$ are preference parameters. Households derive utility from housing services, which are proportional to their stock of dwellings.

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

$$x_t^C = (m_t^C)^{\nu} (d_t^C)^{1-\nu}. \qquad \nu \in (0,1) \quad (2)$$

The core household's flow budget constraint is

$$m_t^C + d_t^C + b_t^{CC} + z_t^{-1} b_t^{CP} + p_t^{CH} \Delta H_t^C + V_t^C \quad (3)$$

$$= w_t^C N_t^C - T_t^C - C_t^C + \frac{m_{t-1}^C}{1+\pi_t^C} + (\frac{1+i_{t-1}^{CD}}{1+\pi_t^C}) d_{t-1}^C + (\frac{1+i_{t-1}^{CB}}{1+\pi_t^C}) b_{t-1}^{CC}$$

$$+(1+i_{t-1}^P) z_t^{-1} b_{t-1}^{CP} + J_t^{CI} + J_t^{CK} + J_t^{CB} + (\frac{1+i_{t-1}^{CV}}{1+\pi_t^C}) V_{t-1}^C - \Theta_V^C \frac{(V_t^C)^2}{2},$$

where $N_t^C = \int_0^1 N_t^{C,j} dj$, $p_t^{CH} = P_t^{CH}/P_t^C$ is the real price of housing (with P_t^{CH} denoting the nominal price), $1+\pi_t^C = P_t^C/P_{t-1}^C$, b_t^{CC} ($z_t^{-1} b_t^{CP}$) real holdings of one-period, non-contingent core (periphery) government bonds, $z_t = E_t P_t^C/P_t^P$, the real exchange rate

[12] In some respects, the model presented here dwells on the class of DSGE models with financial frictions discussed in Agénor (2020, Chapters 4 and 8), in both closed and open economies.

[13] Superscripts C and P are used (as first acronym) throughout the paper to identify core and periphery, respectively.

measured from the perspective of the periphery, with P_t^P the price of the periphery's final good and E_t the nominal exchange rate (expressed in terms of units of periphery currency per unit of core currency, so that an increase in E_t is a depreciation), i_t^{CD} the interest rate on bank deposits, i_t^{CB} the interest rate on core government bonds, i_t^P the premium-adjusted (or *effective*) interest rate on periphery government bonds measured in the core's currency, w_t^C the economy-wide real wage, T_t^C real lump-sum taxes, J_t^{CI}, J_t^{CK}, and J_t^{CB}, end-of-period profits (if any) of the IG producer, the CG producer, and the global bank, respectively.[14] V_t^C represents real holdings of bank capital (one-period debt), and i_t^{CV} the nominal interest rate on bank debt. The last term, $0.5\Theta_V^C(V_t^C)^2$, represents transactions costs that households incur when adjusting their stock of bank capital, with $\Theta_V^C > 0$ the adjustment cost parameter.[15] For simplicity, housing does not depreciate.

Core households face intermediation costs when acquiring periphery bonds. The effective rate of return on these bonds is given by

$$1 + i_t^P = (1 + i_t^{PB})(1 - \theta_t^{CP})\mathbb{E}_t(\frac{E_t}{E_{t+1}}), \tag{4}$$

where i_t^{PB} is the (unadjusted) periphery bond rate and θ_t^{CP} an intermediation premium, which increases with the core household's own stock of periphery bonds:

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

with $\theta_0^B > 0$ denoting a symmetric cost parameter. This specification captures in a simple way the assumption of imperfect capital mobility across regions.[16]

The representative household maximizes (1) with respect to sequences $\{C_{t+s}^C$, N_{t+s}^C, m_{t+s+1}^C, d_{t+s+1}^C, b_{t+s+1}^{CC}, b_{t+s+1}^{CP}, H_{t+s+1}^C, $V_{t+s+1}^C\}_{s=0}^{\infty}$, subject to (2)-(5), and taking the path of core interest rates, the periphery bond rate, as well as prices and inflation, and all lump-sum transfers and taxes, as given. The first-order conditions are

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

[14] Profits of the global bank consist of net income earned both in the core and in the periphery, given that banks there are affiliates owned by the parent institution. However, to avoid complicating the interpretation of capital flows across regions, we assume that periphery households own shares in the global bank, and that these shares entitle them to receive all the profits made by periphery banks.

[15] The presence of adjustment costs can be viewed as reflecting asymmetric information. As in Markovic (2006), for instance, the adjustment cost is taken to be a deadweight loss for society.

[16] This assumption is well supported by the evidence for developing countries; see Agénor and Montiel (2015, Chapter 11) for a discussion. For simplicity, intermediation costs do not benefit anybody in the economy; they are taken to be a pure deadweight loss.

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

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

$$d_t^C = \frac{\eta_x (1-\nu)(C_t^C)^{1/\varsigma}(1+i_t^{CB})}{i_t^{CB} - i_t^{CD}}, \tag{9}$$

$$\frac{p_t^{CH}}{(C_t^C)^{1/\varsigma}} - \frac{\eta_H}{H_t^C} - \Lambda \mathbb{E}_t[\frac{p_{t+1}^{CH}}{(C_{t+1}^C)^{1/\varsigma}}] = 0, \tag{10}$$

$$\frac{z_t^{-1}}{(C_t^C)^{1/\varsigma}} - (1+i_t^{PB})\Lambda \mathbb{E}_t[\frac{z_{t+1}^{-1}}{(C_{t+1}^C)^{1/\varsigma}}(1-\theta_0^B b_t^{CP})] = 0, \tag{11}$$

$$V_t^C = \frac{i_t^{CV} - i_t^{CB}}{\Theta_V^C (1+i_t^{CB})}, \tag{12}$$

together with appropriate transversality conditions. These results are standard, with the exception of the last three which define core household demand for housing services and periphery bonds, and demand for bank capital, respectively. In particular, equation (12) shows that the demand for bank capital is positively (negatively) related to the nominal rate of return on bank debt (government bonds). Without adjustment costs ($\Theta_V^C = 0$) it boils down to $i_t^{CV} = i_t^{CB}$, which indicates that households are indifferent between holding bank capital and domestic government bonds.

Ignoring covariance terms, equation (11) can be approximated by

$$b_t^{CP} \simeq \frac{(1+i_t^{PB})\mathbb{E}_t(E_t/E_{t+1}) - (1+i_t^{CB})}{\theta_0^B (1+i_t^{PB})\mathbb{E}_t(E_t/E_{t+1})}. \tag{13}$$

2.1.2 Global Bank

The balance sheet of the global bank is given by

$$l_t^{CK} + l_t^{PC} = V_t^C + d_t^C + l_t^{CB}, \tag{14}$$

where l_t^{CK} is lending to core CG producers, l_t^{PC} lending to its affiliates in the periphery, l_t^{CB} borrowing from the core central bank, and

$$V_t^C = V_t^{CR} + V_t^{CE}, \tag{15}$$

with V_t^C denoting total capital, V_t^{CR} required capital, and V_t^{CE} excess capital.[17]

[17] Banks do not accumulate capital through retained earnings, in contrast to some contributions in the literature. Barnea and Kim (2014) considered a more general setting in which capital is financed through both channels.

The global bank is subject to risk-based capital requirements; it must hold an amount of capital that covers an endogenous percentage of its risky loans to domestic producers. Loans to its affiliates in the periphery are made through an internal capital market and are not subject to capital regulation. Thus, with σ_t^{CK} denoting the risk weight on domestic investment loans, capital requirements are given by

$$V_t^{CR} = \rho_t^C \sigma_t^{CK} l_t^{CK}, \tag{16}$$

where $\rho_t^C \in (0,1)$ is the capital adequacy ratio, defined later. The risk weight is inversely related to the repayment probability of core firms on their loans, $q_t^C \in (0,1)$:

$$\sigma_t^{CK} = (\frac{q_t^C}{\tilde{q}^C})^{-\phi_q^C}, \tag{17}$$

where $\phi_q^C \geq 0$ and $\tilde{q}^C$ is the steady-state value of q_t^C. Thus, if weights are insensitive to default risk (as in a Basel I-type regime), $\phi_q^C = 0$ and $\sigma_t^{CK} = 1$.

The global bank's expected real profits at the end of period t (or beginning of $t+1$), $\mathbb{E}_t J_{t+1}^{CB}$, are defined as

$$\mathbb{E}_t J_{t+1}^{CB} = q_t^C (1 + i_t^{CL}) l_t^{CK} + (1 - q_t^C) \kappa \mathbb{E}_t p_{t+1}^{CH} H_t^C \tag{18}$$

$$+ (1 + i_t^{CP}) l_t^{PC} - (1 + i_t^{CD}) d_t^C - (1 + i_t^{CR}) l_t^{CB} - (1 + i_t^{CV}) V_t^C$$

$$-\gamma_V^C V_t^C + \frac{\gamma_{VV}^C (V_t^{CE})^{1-\phi_E^C}}{1 - \phi_E^C} - \Gamma(l_t^{CK}, l_t^{PC}),$$

where i_t^{CR} is the marginal cost of borrowing from the central bank and i_t^{CP} the interest rate on lending to affiliates in the periphery. The first term in (18) is expected repayment when there is no default by domestic firms, whereas the second is the value of collateral seized in case of default, corresponding to a fraction $\kappa \in (0,1)$ of the expected value of the housing stock, $\mathbb{E}_t p_{t+1}^{CH} H_t^C$. The third term is income from lending to affiliates. The fourth term is repayment to depositors and the fifth repayment to the central bank, neither of which is state contingent.

The sixth term, $(1 + i_t^{CV}) V_t^C$, represents the gross value of bank debt redeemed at the end of the period. The linear term, $\gamma_V^C V_t^C$, captures the cost associated with issuing debt, which includes the cost of underwriting and so on. The term $\gamma_{VV}^C (1 - \phi_E^C)^{-1} (V_t^{CE})^{1-\phi_E^C}$, where $\gamma_{VV}^C \geq 0$ and $\phi_E^C \in (0,1)$, captures the view that maintaining a positive level of excess capital generates a pecuniary benefit—it represents a signal that the bank's financial position is strong, and reduces the intensity of regulatory scrutiny (or the degree of intrusiveness in the bank's operations), which in turn reduces the cost associated with providing the information required by the supervision authority.[18] The restriction $\phi_E^C < 1$ ensures that holding excess capital entails decreasing marginal benefits.

The term $\Gamma(l_t^{CK}, l_t^{PC})$ measures the nonseparable cost of managing the two types of bank loans and is defined as

$$\Gamma(l_t^{CK}, l_t^{PC}) = \gamma_K l_t^{CK} + \gamma_L l_t^{PC} + 2\gamma\sqrt{l_t^{CK} l_t^{PC}}, \tag{19}$$

where $\gamma_K, \gamma_L > 0$ and $\gamma < 0$. Thus, there are *economies of scope* (or cost complementarity); lending more domestically reduces the cost of lending abroad, and vice versa.[19]

The global bank sets the domestic deposit and loan rates, the cost of borrowing by affiliates, and the amount of excess capital, so as to maximize expected profits (18), subject to the balance sheet and capital requirement constraints (14)-(16), the cost function (19), and taking the value of collateral, the refinance rate i_t^{CR}, the repayment probability q_t^C, the capital ratio ρ_t^C, the cost of bank capital i_t^{CV}, the risk weight σ_t^{CK}, and the gross return to lending abroad, $(1 + i_t^{CP})l_t^{PC}$, as given:[20]

$$1 + i_t^{CD}, 1 + i_t^{CL}, 1 + i_t^{CP}, V_t^{CE} = \arg\max \mathbb{E}_t J_{t+1}^{CB}.$$

As shown in Appendix B, the solution to this problem gives

$$1 + i_t^{CD} = \frac{\eta_D}{1 + \eta_D}(1 + i_t^{CR}), \tag{20}$$

$$1+i_t^{CL} = \frac{\eta_L}{(1 + \eta_L)q_t^C} \left\{(1 - \rho_t^C \sigma_t^{CK})(1 + i_t^{CR}) + \rho_t^C \sigma_t^{CK}(1 + i_t^{CV} + \gamma_V^C) + \gamma_K + \gamma(\frac{l_t^{PC}}{l_t^{CK}})^{0.5}\right\}, \tag{21}$$

[18] See Agénor and Jackson (2019) for a more detailed discussion.

[19] There is broad evidence of (cost) economies of scope in banking, especially in advanced economies (see Humphrey (2019) and Beccalli and Rossi (2020)), as they relate to bank loans and deposits. However, as far as we know, no study has focused specifically on efficiency in the joint production of domestic and foreign loans. We therefore consider sensitivity analysis with respect to the magnitude of γ.

[20] Under Basel's internal ratings-based (IRB) approach, banks are allowed in principle to use their own estimated risk parameters (subject to minimum values) for the purpose of calculating regulatory capital. This could be captured by assuming that the global bank internalizes the fact that changes in the repayment probability affects the risk weight σ_t^{CK}, as implied by (14). However, use of the IRB approach requires approval by the regulator, which we assume is given only *ex post* to mitigate moral hazard on the part of the bank. We capture this by assuming that the bank takes the risk weight as given when setting the loan rate to maximize expected profits. In practice, the threat of pecuniary penalties could also induce banks to be truthful *ex ante* about their risk exposures.

$$1 + i_t^{CP} = \frac{\eta_P}{1+\eta_P} \left\{ 1 + i_t^{CR} + \gamma_L + \gamma(\frac{l_t^{CK}}{l_t^{PC}})^{0.5} \right\}, \tag{22}$$

$$V_t^{CE} = (\frac{\gamma_{VV}^C}{i_t^{CV} + \gamma_V^C - i_t^{CR}})^{1/\phi_E^C}, \tag{23}$$

where η_D, η_L and η_P are gross interest elasticities of the supply of deposits, the demand for domestic loans, and the demand for foreign loans, respectively.

Equation (20) defines the deposit rate as a mark-down over the refinance rate. Equation (21) shows that the loan rate depends negatively on the repayment probability and positively on a weighted average of the marginal cost of borrowing from the central bank (at the gross rate $1+i_t^{CR}$) and the cost of raising bank capital, which accounts for both the gross rate of return to be paid to investors, $1 + i_t^{CV}$, and the (linear) cost of issuing debt, γ_V^C. Weights on each component of funding costs are measured in terms of the ratio of required capital to loans, $1 - \rho_t^C \sigma_t^{CK}$ and $\rho_t^C \sigma_t^{CK}$, respectively. Thus, a higher marginal cost of raising capital implies a higher loan rate. And assuming that raising funds through bank capital is more costly than borrowing from the central bank ($i_t^{CV} + \gamma_V^C > i_t^{CR}$), all else equal an increase in the capital adequacy ratio, ρ_t^C, or the risk weight, σ_t^{CK}, also increases the loan rate. In addition, because of cost complementarity ($\gamma < 0$), an increase in the foreign-domestic loan ratio lowers the marginal cost of producing loans and reduces the cost of lending.

Equation (22) shows that the interest rate on loans to periphery banks is a markup over the marginal cost of lending, which consists of the cost of borrowing from the central bank (the refinance rate) augmented by the marginal cost of issuing and managing loans to periphery banks, given by the derivative of the cost function (19) with respect to l_t^{PC}. Because $\gamma < 0$, an increase in the relative share of lending at home reduces the marginal cost of producing foreign loans and lowers the cost of borrowing for periphery banks.

Equation (23) shows that an increase in the cost of issuing debt, i_t^{CV} or γ_V^C, reduces excess capital, whereas an increase in the marginal benefit, γ_{VV}^C, raises it. With $\gamma_{VV}^C = 0$, holding capital beyond what is required brings no benefit, so $V_t^E = 0$ for all t. Finally, from (15), (16), and (23), it can be inferred that an increase in required capital (that is, an increase in ρ_t), all else equal, raises the cost of issuing bank debt (that is, i_t^{CV}). In turn, this has a negative effect on the desired level of excess capital. Thus, the two components of bank capital are *substitutes*—a result that has significant implications for assessing the impact of regulation.

The repayment probability on loans to local firms depends positively on the expected value of collateral relative to the volume of loans, and the cyclical position of the economy:

$$q_t^C = (\frac{\kappa \mathbb{E}_t p_{t+1}^{CH} / \tilde{p}^{CH}}{l_t^{CK} / \tilde{l}^{CK}})^{\psi_1^C} (\frac{Y_t^C}{\tilde{Y}^C})^{\psi_2^C}, \quad \psi_1^C, \psi_2^C > 0 \tag{24}$$

where $\tilde{Y}^C$ is the steady-state level of core final output. Agénor and Pereira da Silva (2017) formally derive an equation similar to (24) as part of the bank's optimization problem, by assuming that monitoring costs are endogenous and that *ex ante* monitoring effort is directly related—as in Allen et al. (2011) and Dell'Ariccia et al. (2014), for instance—to the probability of repayment.[21] The collateral-loan ratio reflects a moral hazard effect, whereas the cyclical position of the economy reflects the fact that (unit) monitoring costs tend to fall in good times.

In Appendix A we relate loans to local firms (the representative CG producer) to investment. Thus, given (21), the supply of these loans is perfectly elastic. In addition, because the supply of deposits is determined by households (given (20)), and that the supply of loans abroad is determined by periphery banks (as discussed next), borrowing from the core central bank is determined residually from the balance sheet constraint (14).

2.1.3 Central Bank and Regulator

The central bank operates a standing facility, through which its supply of (uncollateralized) loans to the global bank, l_t^{CB}, is perfectly elastic at the prevailing policy rate, i_t^{CR}. It supplies cash, in quantity m_t^{Cs}, to households and firms. Its balance sheet is thus

$$l_t^{CB} = m_t^{Cs}. \tag{25}$$

In turn, the policy rate is set on the basis of an inertial Taylor rule:

$$\frac{1 + i_t^{CR}}{1 + \tilde{\imath}^{CR}} = (\frac{1 + i_{t-1}^{CR}}{1 + \tilde{\imath}^{CR}})^{\chi^C} \left\{ (\frac{1 + \pi_t^C}{1 + \pi_T^C})^{\varepsilon_1^C} (\frac{Y_t^C}{\tilde{Y}^C})^{\varepsilon_2^C} \right\}^{1-\chi^C} \epsilon_t, \tag{26}$$

where $\chi^C \in (0, 1)$, $\varepsilon_1^C > 1$, $\varepsilon_2^C > 0$, $\tilde{\imath}^{CR}$ is the steady-state value of the refinance rate, $\pi_T^C \geq 0$ the inflation target, and ϵ_t a stochastic shock which follows a first-order

[21] As noted by Allen et al. (2011), this one-to-one relationship can be interpreted as resulting from the lender observing information about a borrower and then using it to help improve the borrower's performance. The important point is that greater monitoring is desirable from the borrower's perspective.

autoregressive process, $\epsilon_t = (\epsilon_{t-1})^{\rho_\epsilon} \exp(\xi_t)$, where $\rho_\epsilon \in (0,1)$ and $\xi_t \sim \mathbf{N}(0, \sigma_\xi)$ is a serially uncorrelated random shock with zero mean.

The overall capital ratio, ρ_t^C, can be decomposed into a deterministic component, ρ^{CD}, and a cyclical component, ρ_t^{CC}:

$$\rho_t^C = \rho^{CD} + \rho_t^{CC}. \tag{27}$$

Thus, the component ρ^{CD} can be viewed as the minimum capital adequacy ratio imposed under the Basel arrangements, whereas the component ρ_t^{CC} can be viewed as the discretionary component, that is, the countercyclical capital buffer, which in our base specification is adjusted in response to credit growth:

$$\frac{1+\rho_t^{CC}}{1+\tilde{\rho}^{CC}} = \left(\frac{1+\rho_{t-1}^{CC}}{1+\tilde{\rho}^{CC}}\right)^{\chi_1^C} \left\{\left(\frac{l_t^K}{l_{t-1}^K}\right)^{\chi_2^C}\right\}^{1-\chi_1^C}, \tag{28}$$

where $\chi_1^C \in (0,1)$ and $\chi_2^C > 0$. Thus, the macroprudential policy rule is designed to directly counter the easing of lending conditions that induces borrowers to take on more debt when, all else equal, house prices and collateral values increase. The focus on credit growth is consistent with the large body of evidence suggesting that excessive credit expansion has often been associated with financial instability and financial crises, in developed and developing countries alike.[22]

2.2 Periphery

As for the core, we consider in turn the behavior of households, commercial banks, and the central bank and regulator.

2.2.1 Households

Periphery households have the same utility function, and a similar budget constraint, as core households. They therefore face a resource allocation problem similar to the one faced by core households, with the effective rate of return on core government bonds i_t^C defined as, symmetrically to (4),

$$1 + i_t^C = (1 + i_t^{CB})(1 - \theta_t^{PC})\mathbb{E}_t\left(\frac{E_{t+1}}{E_t}\right), \tag{29}$$

[22] See Agénor and Montiel (2015), Taylor (2015), and Aldasoro et al. (2018) for a discussion. There is also recent evidence that the *quality* (or degree of riskiness) of credit allocation helps to predict episodes of financial instability. See, for instance, Brandão-Marques et al. (2019).

where θ_t^{PC} is the intermediation premium faced by periphery households, defined analogously to (5):

$$\theta_t^{PC} = \frac{\theta_0^B}{2} b_t^{PC}. \tag{30}$$

The solution is therefore analogous to (6)-(12). In particular, periphery demand for bank capital is given by

$$V_t^P = \frac{i_t^{PV} - i_t^{PB}}{\Theta_V^P (1 + i_t^{PB})}, \qquad \Theta_V^P > 0 \tag{31}$$

whereas demand for core government bonds can be approximated by

$$b_t^{PC} \simeq \frac{(1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t) - (1 + i_t^{PB})}{\theta_0^B (1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)}. \tag{32}$$

Equations (13) and (32) imply that uncovered interest parity, $1 + i_t^{PB} \simeq (1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)$, obtains when $\theta_0^B \to 0$. Thus, as discussed later, the impact of increased financial integration on the gains from coordination can be assessed by lowering θ_0^B.

2.2.2 Commercial Banks

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

$$l_t^{PK,i} = (1 - \mu) d_t^{P,i} + V_t^{P,i} + z_t l_t^{PC,i} + l_t^{PB,i}, \tag{33}$$

where $l_t^{PK,i}$ is loans to periphery firms, $d_t^{P,i}$ deposits (determined analogously to (9)), $\mu \in (0, 1)$ the required reserve ratio on these deposits, $z_t l_t^{PC,i}$ borrowing from the global bank (with $l_t^{PC,i}$ measured in foreign-currency terms), at the rate $i_t^{CP,i}$, $V_t^{P,i}$ total capital, and $l_t^{PB,i}$ borrowing from the periphery central bank. Thus, due to the absence of hedging instruments, periphery banks are exposed to exchange rate risk; fluctuations in the real exchange rate generate balance sheet effects.[23]

We consider first the case where foreign affiliates of the global bank are subsidiaries, which are legally subject to regulation by the host jurisdiction. Thus, the regulator in the periphery determines how much capital local banks must hold based on its

[23] Alternatively, it could be assumed (as is the case in practice) that banks have some access to forward markets or that prudential requirements impose some degree of hedging of their foreign-currency liabilities. Accounting for partial hedging of foreign exchange rate risk would not change the main thrust of our results.

own requirements. Total bank capital and the risk-based regulatory regime are thus characterized by equations similar to (15)-(17):

$$V_t^{P,i} = V_t^{PR,i} + V_t^{PE,i},$$

$$V_t^{PR,i} = \rho_t^P \sigma_t^P l_t^{PK,i} = \rho_t^P (\frac{q_t^{P,i}}{\tilde{q}^{P,i}})^{-\phi_q^P} l_t^{PK,i}, \tag{34}$$

where ρ_t^P is the capital adequacy ratio and $\phi_q^P \geq 0$.

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:

$$i_t^{PD,i} = (1 - \mu) i_t^{PR}. \tag{35}$$

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

$$l_t^{PK,i} = (\frac{1 + i_t^{PL,i}}{1 + i_t^{PL}})^{-\zeta_L} l_t^{PK}, \tag{36}$$

where $i_t^{PL,i}$ is the rate on the loan extended by bank i, $l_t^{PK} = [\int_0^1 (l_t^{PK,i})^{(\zeta_L - 1)/\zeta_L} di]^{\zeta_L/(\zeta_L - 1)}$ the amount borrowed by the representative CG producer (set equal to the level of investment, as shown in Appendix A), with $\zeta_L > 1$ denoting the elasticity of substitution between differentiated loans, and $1 + i_t^{PL} = [\int_0^1 (1 + i_t^{PL,i})^{1-\zeta_L} di]^{1/(1-\zeta_L)}$ the aggregate loan rate.

Expected profits of bank i at the end of period t are given by

$$\begin{aligned} \mathbb{E}_t J_{t+1}^{PB,i} = {} & q_t^{P,i}(1 + i_t^{PL,i}) l_t^{PK,i} + (1 - q_t^{P,i}) \left(\kappa^i \mathbb{E}_t p_{t+1}^{PH} H_t^P\right) - (1 + i_t^{PD,i}) d_t^{P,i} + \mu d_t^{P,i} \\ & -(1 + i_t^{PR}) l_t^{PB,i} - (1 + i_t^{CP}) \mathbb{E}_t (\frac{E_{t+1}}{E_t}) z_t l_t^{PC,i} - \gamma_P z_t \frac{(l_t^{PC,i})^2}{2} \\ & -(1 + i_t^{V,i}) V_t^{P,i} - \gamma_V^P V_t^{P,i} + \frac{\gamma_{VV}^P}{1 - \phi_E^P} (V_t^{PE,i})^{1-\phi_E^P}, \end{aligned} \tag{37}$$

where $\gamma_{VV}^P, \gamma_V^P > 0$, $\phi_E^P \in (0, 1)$, i_t^{PR} is the marginal cost of borrowing from the central bank (the refinance rate), and $q_t^P \in (0, 1)$ the repayment probability of periphery CG producers. As before, the first two terms represent expected income (with $\mathbb{E}_t p_{t+1}^{PH} H_t^P$ the expected value of housing collateral) from lending, the third interest paid on deposits, the fourth reserve requirements held at the central bank and returned to bank i at the end of the period, the fifth repayment on loans from the central bank, and the sixth repayment to the global bank. In addition, periphery banks incur a convex cost that increases with the amount of borrowing received from the global bank, as measured by $0.5\gamma_P z_t (l_t^{PC,i})^2$, where $\gamma_P > 0$. This assumption helps to capture in a simple way imperfect substitutability between domestic and foreign borrowing. The last three terms relate to the cost of servicing bank capital and the benefit that excess capital provides, analogously to (18).

Each bank maximizes profits with respect to their loan rate, excess capital, and their demand for foreign loans, subject again to taking other interest rates, the repayment probability, the capital ratio, and the risk weight as given:

$$1 + i_t^{PL,i}, V_t^{PE}, z_t l_t^{PC,i} = \arg\max \mathbb{E}_t J_{t+1}^{PB,i}. \tag{38}$$

As shown in Appendix B, solving (38) subject to (33) and (36) yields, in a symmetric equilibrium,

$$1 + i_t^{PL} = \frac{\zeta^L}{(\zeta^L - 1)q_t^P}[(1 - \rho_t^P \sigma_t^P)(1 + i_t^{PR}) + \rho_t^P \sigma_t^P (1 + i_t^{PV} + \gamma_V^P)], \tag{39}$$

$$l_t^{PC} = \frac{1}{\gamma_P}\left\{(1 + i_t^{PR}) - (1 + i_t^{CP})\mathbb{E}_t(\frac{E_{t+1}}{E_t})\right\}, \tag{40}$$

$$V_t^{PE} = (\frac{\gamma_{VV}^P}{i_t^{PV} + \gamma_V^P - i_t^{PR}})^{1/\phi_E^P}. \tag{41}$$

Equation (39) shows once again that a tighter macroprudential response raises the cost of loans, whereas equation (40) indicates that a higher cost of borrowing from the global bank (adjusted for expected depreciation) reduces the demand for foreign loans—and vice versa for an increase in the marginal cost of borrowing domestically. Equation (41) takes the same form as (23). As before, borrowing from the central bank is determined residually from (33).

The repayment probability, as in (24), depends positively on the expected value of collateral relative to the volume of loans, and the cyclical position of the economy:

$$q_t^P = (\frac{\kappa \mathbb{E}_t p_{t+1}^{PH}/\tilde{p}^{PH}}{l_t^{PK}/\tilde{l}^{PK}})^{\psi_1^P} (\frac{Y_t^P}{\tilde{Y}^P})^{\psi_2^P}, \quad \psi_1^P, \psi_2^P > 0 \tag{42}$$

where Y_t^P is the periphery's final output and $\tilde{Y}^P$ its steady-state value.

2.2.3 Central Bank and Regulator

As noted earlier, the exchange rate between the two regions is fully flexible. Thus, analogously to (25), the balance sheet of the periphery central bank is given by

$$l_t^{PB} = m_t^{Ps}. \tag{43}$$

The periphery central bank also operates a standing facility. Its supply of liquidity to local banks is perfectly elastic at the rate i_t^{PR}, which is set through a Taylor rule similar to (26):

$$\frac{1+i_t^{PR}}{1+\tilde{\imath}^{PR}} = (\frac{1+i_{t-1}^{PR}}{1+\tilde{\imath}^{PR}})^{\chi^P} \left\{ (\frac{1+\pi_t^P}{1+\pi_T^P})^{\varepsilon_1^P} (\frac{Y_t^P}{\tilde{Y}^P})^{\varepsilon_2^P} \right\}^{1-\chi^P}, \tag{44}$$

where $\pi_T^P \geq 0$ is the inflation target, $\chi^P \in (0,1)$ and $\varepsilon_1^P, \varepsilon_2^P > 0$.

As in (27) and (28), the regulator sets both a deterministic component, ρ^{CD}, and a cyclical component, ρ_t^{PC}, of the capital ratio:

$$\rho_t^P = \rho^{PD} + \rho_t^{PC}, \tag{45}$$

with the latter defined in the base specification as

$$\frac{1+\rho_t^{PC}}{1+\tilde{\rho}^{PC}} = (\frac{1+\rho_{t-1}^{PC}}{1+\tilde{\rho}^{PC}})^{\chi_1^P} \left\{ (\frac{l_t^{PK}}{l_{t-1}^{PK}})^{\chi_2^P} \right\}^{1-\chi_1^P}, \tag{46}$$

where $\chi_1^P \in (0,1)$ and $\chi_2^P > 0$.

2.3 Regulatory Reciprocity

Suppose now that affiliates of the global bank, rather than being subsidiaries, are branches that in general are not subject to regulation in the host jurisdiction. Instead, a reciprocity agreement is in place, requiring the regulator in the periphery to impose to local banks the same capital adequacy ratio as applied in the core. In our setting, the goal of the agreement is fundamentally to prevent the global bank, through its internal capital market, to engage in regulatory arbitrage by expanding its lending operations abroad when faced with higher capital requirements (aimed at mitigating credit growth and risks to financial stability) at home.

Thus, instead of (34), under reciprocity we have

$$V_t^{PR} = \rho_t^C \sigma_t^P l_t^{PK}, \tag{47}$$

where σ_t^P remains as defined earlier. Equations (39) now become

$$1+i_t^{PL}=\frac{\zeta^L}{(\zeta^L-1)q_t^P}[(1-\rho_t^C\sigma_t^P)(1+i_t^{PR})+\rho_t^C\sigma_t^P(1+i_t^{PV}+\gamma_V^P)], \tag{48}$$

with equations (40) and (41) remaining the same, whereas (45) and (46) no longer apply.

The main financial flows between agents and regions are summarized in Figure 1.

3 Equilibrium and Steady State

As shown in Appendix A, in a symmetric equilibrium all IG firms in both regions produce the same output, prices are the same across firms, and total output of core and periphery 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 counterpart to loans to capital producers is cash, which is used instantaneously to buy investment goods at the beginning of the period. The equilibrium condition of the money market in the core is thus given by

$$m_t^C=m_t^{Cs}, \tag{49}$$

where m_t^C and m_t^{Cs} are determined by (8) and (25), respectively.

Given that the global bank sets the interest rate on loans to the periphery banks (see 23)), market equilibrium requires the actual supply of loans to be determined by (40).

From (15), (16), the equilibrium condition of the market for bank capital is

$$V_t^C=\rho_t^C\sigma_t^{CK}l_t^{CK}+V_t^{CE}, \tag{50}$$

which, using the demand functions (12) and (23), can be used to solve for the rate of return on bank capital, i_t^{CV}.

The supply of housing is fixed at $\bar{H}^C$. The equilibrium condition of the housing market is therefore

$$H_t^C=\bar{H}^C, \tag{51}$$

which can be solved, using (10), to determine the dynamics of house prices. A similar condition holds for the periphery.

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

$$nb_t^{CC} + (1-n)b_t^{PC} = 0, \qquad (1-n)b_t^{PP} + nb_t^{CP} = 0. \tag{52}$$

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

$$nCA_t^C + (1-n)E_t^{-1}CA_t^P = 0, \tag{53}$$

with the core's current account (at current local prices) defined in conventional manner as

$$CA_t^C = P_t^{CC}Y_t^{CP} - P_t^{PC}Y_t^{PC} \tag{54}$$

$$+i_{t-1}^{CP}P_{t-1}^{C}l_{t-1}^{PC} + i_{t-1}^{PB}E_{t-1}^{-1}P_{t-1}^{P}b_{t-1}^{CP} - i_{t-1}^{CB}P_{t-1}^{C}b_{t-1}^{PC},$$

where P_t^{CC} is the price of core intermediate goods sold in the periphery (that is, the price of core exports), Y_t^{CP} are core exports of intermediate goods, which correspond also to the periphery's imports of these goods, $P_t^{PC} = E_t^{-1}P_t^{PP}$ the price of periphery intermediate goods sold in the core (equal, under local currency pricing, to the price of periphery intermediate goods adjusted for the exchange rate), and Y_t^{PC} core imports of intermediates, which correspond also to the periphery's exports. The third term in (54) is the interest income from loans to the periphery by the global bank, and the fourth (fifth) term interest income (payment) on holdings of periphery (core) bonds by core (periphery) households. By definition, the current account is also given by (minus) the net change in foreign assets:[24]

$$CA_t^C = (E_t^{-1}P_t^P b_t^{CP} - E_{t-1}^{-1}P_{t-1}^P b_{t-1}^{CP}) + (P_t^C l_t^{PC} - P_{t-1}^C l_{t-1}^{PC}) - (P_t^C b_t^{PC} - P_{t-1}^C b_{t-1}^{PC}). \tag{55}$$

The steady-state solution of the model, assuming a zero target inflation rate, is briefly described in Appendix C. Several of its key features are fundamentally similar to those described in Agénor and Pereira da Silva (2019), so we refer to that paper for a more detailed discussion.[25]

[24] Combining conditions (54) and (55) gives the foreign exchange market equilibrium condition, which is solved for the exchange rate.

[25] In particular, we assume (as in a number of contributions) that policymakers have no access to lump-sum subsidies to correct the short- and long-run distortions created by monopolistic competition and financial frictions. The nonstochastic steady state is thus inefficient.

4 Parameterization

To assess the properties of the model and evaluate the gains from coordination we parameterize it for two groups of countries, corresponding to the core and periphery, respectively: *major advanced economies* (MAEs) and *systemically-important middle-income countries* (SMICs). As defined in Agénor and Pereira da Silva (2018), MAEs consist of the United States, the euro area, and Japan, whereas SMICs consist of Brazil, China, India, Indonesia, Mexico, Russia, South Africa, and Turkey. This classification is based in part on the results of a study by the International Monetary Fund (2016), in which these groups of countries represent those that have exerted the largest financial spillovers and spillbacks to each other in recent years. Based on the calculations reported in Agénor and Pereira da Silva (2018), which dwell on GDP measures for the two regions, the relative size of the core is set at $n = 0.818$. Thus, SMICs account for about one-fifth of the combined output of the two regions.

Our benchmark parameterization dwells to a significant extent on the standard values used in the literature on small open-economy and two-country models. In addition, a number of asymmetries across regions are imposed. In particular, we account for the fact that, as documented elsewhere (see Agénor (2020, Chapter 1)), financial frictions are more pervasive in middle-income countries.

The discount factor Λ is set at 0.95 for both regions, a standard value in the literature. The intertemporal elasticity of substitution is uniformly set at 0.5, in line with the empirical evidence reviewed in Agénor and Montiel (2015) and Thimme (2017). The preference parameter for leisure, η_N, is set at 25 for both regions, to ensure that in the steady state households devote two-fifths of their time endowment to market activity—a slighly higher value that the benchmark often used in the literature (see Christoffel and Schabert (2015) and Boz et al. (2015), for instance). The Frisch elasticity of labor supply is set at 0.715 for both regions (implying that ψ_N is equal to 1.4), in line again with the empirical evidence (see Dogan (2019), 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 money generates little direct utility (see, for instance, Obstfeld and Rogoff (1996, p. 684) and Coenen et al. (2009)). For the housing preference parameter, η_H, we use the same value as in Notarpietro and Siviero (2015), 0.1. 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 the predominant use of deposits in transactions in both regions. The cost parameter related to core (periphery) bond holdings by core (periphery) households, θ_0^B, is set at 0.2. This value is consistent with a moderate degree of capital mobility. The cost parameter associated with holdings of bank debt, Θ_V, is calibrated at 2.64 for the core and 1.83 for the periphery, to ensure that (given other parameters and steady-state values) the cost of issuing capital is higher than the marginal cost at which banks can borrow from the central bank (the refinance rate) in their respective region.

The distribution parameter between core and periphery intermediate goods in the production of the final good (or, equivalently, the degree of home bias), Λ_Y^C, is set at 0.6 for MAEs and 0.8 for SMICs, to reflect the fact that the former group is relatively more open than the latter. The elasticity of substitution between baskets of domestic and imported composite intermediate goods used in the production of the final good, η_Y, is set at 1.5, the value estimated by Dogan (2019), for instance, for Mexico and the United States, which implies that these goods are substitutes in the production of the final good. The elasticities of substitution between core intermediate goods among themselves, θ^{CC}, and imported periphery goods among themselves, θ^{PP}, are both set equal to 10. Quint and Rabanal (2014), for instance, use the same value. This implies a steady-state mark-up of 11 percent. The share of capital in output of intermediate goods, α, is set at a fairly standard value, 0.35, for both regions. The adjustment cost parameter for prices of domestic intermediate goods, ϕ_I, is also set uniformly 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 advanced economies, and Agénor et al. (2018) for middle-income countries. The capital depreciation rate, δ_K, is set at the same quarterly rate of 0.015 for both regions, a common value used in the literature. The adjustment cost incurred by the CG producer for transforming investment into capital, Θ_K, is set at 14, in order to match the well-established fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as output in most countries (see Hnatkovska and Koehler-Geib (2018), for instance).

Regarding the global bank and periphery banks, the collateral-loan ratio, κ, is set at 0.4 for MAEs and at 0.2 for SMICs, to capture the relatively higher costs associated with recovery of collateral and more generally debt enforcement procedures in the latter group of countries, as documented by Djankov et al. (2008). The elasticity of the repayment probability with respect to the effective collateral-loan ratio is set initially at $\psi_1^C = 0.05$ for MAEs and $\psi_1^P = 0.1$ for SMICs, whereas the elasticity with respect to deviations in output from its steady state is set initially at $\psi_2^C = 0.9$ for the core and, consistent with Agénor et al. (2018), $\psi_2^P = 0.9$ for the periphery. The cost parameter γ_P is set at 0.1 for the core and 0.15 for the periphery, in order to generate sensible values for initial interest rates. The elasticities η_D, η_L and ζ_L are set equal to 2.5, 4.5 and 4.5, respectively. This gives a mark-down of the deposit rate relative to the policy rate of about 100 basis points in the core, and a mark-up of the loan rate over the policy rate (given repayment probabilities of 0.96 in the core and 0.936 in the periphery) of about 264 basis points in the core and 423 basis points in the periphery. The latter results are in line with the evidence for MAEs and SMICs, which suggests higher default rates and higher lending spreads for the latter group of countries. The parameters for the cost function for producing loans by the global bank, γ_L and γ_K, are set at the same low value of 0.1, as in Agénor and Jackson (2019), whereas the parameter γ, which measures the strength of economies of scope in lending, is set at -0.1.

The degree of persistence in the core central bank's policy response, χ, is set at 0.8, whereas the responses of the policy rate to inflation and output deviations, ε_1 and ε_2, are set at 1.7 and 0.1, respectively, as in Coenen et al. (2009). For the periphery central bank, the corresponding values are $\chi = 0.0$, $\varepsilon_1 = 1.1$, and $\varepsilon_2 = 1.0$, based on the evidence for middle-income countries which suggests stronger concerns with output stability in these countries. The required reserve ratio, μ, is set at 0.2, consistent with the evidence for some of the larger countries in Latin America (see Federico et al. (2014)). Given the high degree of inertia already embedded in the core Taylor rule, we set ρ_ϵ, the persistence parameter of the core policy rate shock, to 0.0.

Regarding the regulatory regime, the elasticity of the risk weight with respect to the repayment probability is set at the same low value for both regions, $\phi_q = 0.05$, consistent with Covas and Fujita (2010). The cost parameter γ_V is set at 0.01. The capital adequacy ratio, ρ, is set at 0.08, which corresponds to the floor value set under the current Basel regime. As noted earlier, the steady-state value of the risk weight is equal to unity. By implication, the steady-state required capital-risky loan ratio is also 8 percent. The benefit parameter γ_{VV} is set at 0.001, to ensure that the steady-state excess capital-loan ratio is about 4 percent, in line with the evidence reported by Fonseca et al. (2010). Finally, the parameters ϕ_E^C and ϕ_E^P, which measure the marginal benefit of excess capital in the core and the periphery, respectively, are set at 0.5 and 0.45, in line with Agénor et al. (2014).

The share of noninterest government spending in final output, ψ^G, is set at 0.2 for the core, as in Coenen et al. (2009) and Alpanda and Aysan (2014), and 0.22 for the periphery, as in Agénor et al. (2018). These values are consistent with recent averages for MAEs and SMICs and close to those used in a number of other contributions.

Parameter values are summarized in Table 1, whereas initial steady-state values for some key variables are shown in Table 2. In particular, they indicate that consumption accounts for about 65 percent of final output in both regions, and that investment represents 15 and 13 percent for the core and the periphery, respectively. The shares of (intermediate good) exports are relatively high for both regions (24.4 and 17.4 percent for the core and the periphery, respectively). Loans from the global bank to its affiliates in the periphery amount to 0.084 percent of the region's output, consistent with a strong presence of foreign banks there. As noted earlier, the required and excess capital ratios account for 8 and 4 percent, respectively, of investment loans. Thus, the total capital-risk weighted assets ratio is 12 percent, consistent with the evidence. Finally, the countercyclical capital ratios are set at 0 initially in both regions.

5 Core Expansionary Shock

To illustrate the properties of the model, we consider an expansionary monetary policy shock in the core. As noted in the introduction, monetary policy spillovers from advanced economies have been identified in a number of recent empirical studies as one of the key drivers of the global financial cycle and international capital flows—including bank-related flows. These studies include Bruno and Shin (2015), Avdjiev et al. (2018), Correa et al. (2018), Temesvary et al. (2018), Buch et al. (2019), Gajewski et al. (2019), Habib and Venditti (2019), Albrizio et al. (2020), Brauning and Ivashina (2020), Miranda-Agrippino and Rey (2020), and Cesa-Bianchi and Sokol

(2022). Albrizio et al. (2020), for instance, found robust evidence that an increase (reduction) in funding costs following an exogenous monetary tightening (loosening) in the United States leads to a statistically and economically significant decline (increase) in cross-border bank lending. Others, including Hills et al. (2019), Morais et al. (2019), Tillmann et al. (2019), Alper et al. (2020), and Ca' Zorzi et al. (2020), have documented statistically significant effect of these flows on recipient countries. Morais et al. (2019), in particular, found that expansionary monetary policies in both Europe and the United States have a positive impact on credit growth in Mexico through increased lending by foreign banks, whereas Ca' Zorzi et al. (2020) found that monetary policy shocks in the United States have a significantly larger impact on credit spreads and borrowing costs in the rest of the world than comparable shocks occurring in the euro area. Alper et al. (2020) documented similar results for Turkey.[26]

More specifically, our analysis proceeds in two steps. First, we assess the extent to which regulatory arbitrage, and its impact on cross-border bank capital flows, is a consequence of changes in relative rates of return initiated by a drop in the policy interest rate in the core, without at first considering any countercyclical regulatory response—a case which we refer to as no activism. Second, we perform the same assessment when the regulator in the core alone responds to credit fluctuations at home through changes in countercyclical capital buffers, using rule (28).

5.1 Constant Capital Ratios

Figure 2 illustrates the results of a transitory reduction of 1 percentage point in the refinance rate in the core, as defined in (26), with two values of the parameter measuring the degree of economies of scope, $\gamma = -0.1$ and $\gamma = -0.2$, both under no activism.

In both cases, the drop in the marginal cost of borrowing from the central bank lowers the loan rate in the core and leads to an expansion in investment, thereby raising aggregate demand and prices in that region. Because the global bank borrows more from the core central bank—credit to domestic producers goes up, and the lower refinance rate reduces the deposit rate, and thus the amount of household deposits available to fund domestic lending operations—liquidity increases at the initial level of foreign lending. To maintain equilibrium of the money market, the nominal bond

[26] Some studies have focused on the spillover effects of US Quantitative easing. See, for instance, Kolasa and Wesolowski (2020) and Bhattarai et al. (2021).

rate must fall. This, combined with an increase in inflation, leads to an unambiguous reduction in the expected real bond rate, which in turn induces agents (through intertemporal substitution) to spend more today. The increase in consumption is associated with a higher demand for housing services, which raises their real price. Higher house prices raise collateral values, but because the increase in investment (and thus domestic loans by the global bank) is relatively larger, the collateral-loan ratio actually falls, thereby *reducing* the repayment probability—despite the increase in cyclical output, which operates in the opposite direction. This mitigates somewhat the initial drop in the loan rate and the investment boom.

Required bank capital increases in the core, both because investment loans (risky assets) expand and because the risk weight rises, due to the reduction in the repayment probability. Given that capital adequacy ratios (in both regions) remain constant in this experiment, the increase in the risk weight—and thus the cost of issuing debt to meet capital requirements—mitigates the drop in the loan rate. At the same time, because the differential between the marginal cost of issuing capital, $i_t^{CV} + \gamma_V^C$, and the refinance rate, i_t^{CR}, falls, excess capital (as can be inferred from (23)) increases. As illustrated in Figure 2, the leverage ratio (the ratio of loans to total bank capital) unambiguously increases as well. As implied by (12), the spread between the rate of return on that debt and the bond rate, $i_t^{CV} - i_t^{CB}$, or equivalently the excess return on bank debt, must also increase for households to alter the composition of their portfolios and hold a greater amount of bank-issued debt.

Cross-border spillovers associated with the expansionary policy shock in the core occur through several channels: a portfolio channel, a monetary policy channel, a regulatory arbitrage channel—even when there is no countercyclical regulatory response *per se* in the core—and a trade channel.[27] The reduction in asset returns in the core induces periphery households to reduce their holdings of core government bonds. At the same time, lending to periphery banks rises (see Figure 2). The increase in investment and credit at home tends to lower the global bank's marginal operating costs, which mitigates—as can be inferred from (21) and (22)—the initial drop in the interest rate on domestic loans and reduces the interest rate on loans to foreign affiliates. As a result, the demand for loans by periphery banks increases. Thus, there is a capital

[27] In what follows, and given the focus of this paper, we do not discuss in detail the trade channel, which operates (in standard fashion) through the impact of the real exchange rate on the composition of output (namely, the distribution of sales on the domestic market and exports) and the trade balance.

inflow to the periphery, which translates into a nominal and real appreciation.

In turn, the appreciation puts downward pressure on inflation in the periphery. The periphery's central bank response is to reduce its policy rate, which in turn leads to a reduction in the loan rate and an expansion in investment and aggregate demand. The bond rate falls also (through the same mechanism as described earlier, with respect to the equilibrium of the money market) and this induces households to shift consumption to the present, raising real house prices in the process. Once again, the collateral-loan ratio falls and (despite higher cyclical output) so does the repayment probability—thereby mitigating the initial drop in the loan rate and the expansion in credit. Consequently, as in the core the risk weight rises, and this contributes (together with the increase in loans) to higher bank capital. However, there is no substitution between required and excess capital, as the differential between the marginal cost of issuing bank debt and the refinance rate now falls. Thus, the net effect of the shock on total bank capital is again positive. All other effects are, qualitatively, similar to those discussed earlier for the core.

The dotted lines in Figure 2 show what happens when the cost parameter that captures the cost complementarity effect is stronger, that is, $\gamma = -0.2$ instead of -0.1. Qualitatively, the results are the same. Quantitatively, however, they differ substantially for the periphery. In particular, lending by the global bank increases substantially, and so do investment and the leverage ratio in that region. There is a positive correlation between the strength of the complementary effect (as measured by $|\gamma|$) and the spillover effects of global lending.

The thrust of the foregoing discussion is that, even though capital requirement ratios are constant in both regions in this experiment, there may be some degree of regulatory arbitrage because risk weights are endogenous and affect loan rates. Indeed, a risk-based regulatory regime operating in the region where financial shocks occur may generate incentives for cross-border bank capital flows—even in the absence of a countercyclical regulatory response. However, this happens only because domestic and foreign loans by the global bank are imperfect substitutes, as a result of economies of scope.

5.2 Endogenous Core Capital Buffers

Consider now the case where the countercyclical capital rule (28) is operated by the core regulator. To illustrate the results, we set $\chi_1^C = 0.1$ (which implies a relatively low degree of persistence) and $\chi_2^C = 50$. The results are reported in Figure 3.

While the magnitudes of some effects differ, qualitatively they are generally close to those obtained under no activism. Notable differences relate, not surprisingly, to changes in required, excess, and total bank capital, and thus the leverage ratio, which now moves in the opposite direction. Intuitively, as credit initially expands in the core, the regulator in that region raises the countercyclical capital ratio, therefore mitigating the drop in the loan rate and the lending boom. In fact, the policy response is strong enough to generate an increase in the domestic cost of borrowing. Total bank capital is also higher compared to no activism, despite a strong substitution effect between its components.

From the perspective of cross-border arbitrage, the key issue is how lending by the global bank to periphery banks evolves under activism. Such lending rises again, but by more than before, when the core regulator intervenes. The policy mitigates the drop in the loan rate and the investment boom, in both regions. But although the increase in domestic lending is weaker (which therefore dampens the reduction in marginal operating costs, compared to no activism), the refinance rate in the core drops by more as a result of the smaller increase in cyclical output. The result therefore is a larger drop in the interest rate on loans to periphery banks, and therefore higher lending to these banks and a larger capital inflow in that region. However, because inflation in the core is also lower under activism, the net effect on the real exchange rate is a weaker appreciation.

These results (both with constant and endogenous capital ratios) illustrate fairly well how countercyclical regulatory responses, implemented in a core jurisdiction where financial shocks occur, can contribute to international regulatory arbitrage by inducing cross-border bank capital flows. At the same time, they show that the magnitude of these flows to the periphery depends on the extent to which the core global bank benefits from economies of scope in its lending operations at home and abroad.

More generally, these results help to provide a rationale for the evidence which suggests that tighter capital requirements in advanced economies—in this case, in response to a credit expansion and perceived risks to financial stability induced by an expansionary monetary policy—contribute to financial spillovers across countries. Hills et al. (2017), for instance, found that large UK banks increased their lending abroad when faced with tighter capital restrictions at home. Zochowski et al. (2019) also found that foreign affiliates of euro-area banks increased lending following the tightening of sector-specific capital buffers in the countries where their parent banks reside.[28]

6 Optimal Policy and Gains from Coordination

We now consider the gains from international macroprudential policy coordination, using two approaches. The first is based on the standard utility-based welfare approach. The second proceeds in two steps: first, the regulator minimizes a policy loss function motivated by a financial stability objective, consistent with an institutional mandate. This therefore reflects a positive dimension. Second, the benefits of the policy are evaluated in terms of their impact on household welfare, reflecting consequently a normative dimension. This two-stage approach is useful because it helps to reconcile the fact that real-world mandates bestowed by society upon regulators, especially after the global financial crisis that unfolded between mid-2007 and late 2008, are overwhelmingly specified in terms of financial stability (and often in terms of a specific credit-based operational target), with the economist's concern with the welfare implications of these narrow mandates.

6.1 Standard Welfare Approach

In the standard approach, we assume that the objective function that the regulator in each region $j = C, P$ seeks to maximize depends on the present discounted value of household utility adjusted by the cost of adjusting countercyclical capital buffers:

$$W_t^j = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u^j(C_{t+s}^j, N_{t+s}^j, x_{t+s}^j) - \varkappa_W \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\rho_{t+s}^{jC} - \rho_{t+s-1}^{jC})^2, \qquad (56)$$

[28] In a previous version of this paper, we considered the case where spillovers may take the form of a *fall* in lending by global banks to periphery banks. Berrospide et al. (2017) found that tighter prudential regulation in the United States reduced foreign lending by global US banks. These results are consistent with those of Aiyar et al. (2014), who found that tighter capital requirements for large UK banks led to a reduction in these banks' cross-border lending. However, our focus is only on lending to banks.

where $\varkappa_W \geq 0$ is a parameter that measures the cost (assumed quadratic) associated with changes in countercyclical capital buffers and $u^j()$ the period utility function defined in (1).[29]

We consider three policy regimes. Under the *independent regime* (or Nash), each regulator sets its capital buffer so as to maximize its own region's objective function only, taking as given the reaction function of the other regulator. Formally, under independent policies, the regulator in region $j = C, P$ determines the optimal value of the response parameter χ_2^j in the rules (28) and (47), denoted $\chi_2^{j,N}$, so that

$$\chi_2^{C,N} = \arg\max W_t^C\big|_{\chi_2^P = \chi_2^{P,N}}, \quad \chi_2^{P,N} = \arg\max W_t^P\big|_{\chi_2^C = \chi_2^{C,N}}, \tag{57}$$

Under the *reciprocity regime*, the regulator in the core sets the response parameter χ_2^C in the rule (28) so as to maximize its own objective function only, denoted $\chi_2^{C,R}$, whereas the regulator in the periphery imposes the same optimal value of the countercyclical capital buffer in its jurisdiction; thus,

$$\chi_2^{C,R} = \arg\max W_t^C \text{ and } \rho_t^{PC} = \rho_t^{CC}, \forall t. \tag{58}$$

Under the *coordination regime*, regulators—or a benevolent global policymaker working on their behalf—jointly determine the optimal response parameters, denoted $\chi_2^{C,O}$ and $\chi_2^{P,O}$, so as to maximize a weighted sum of each region's objective function:

$$\chi_2^{C,O}, \chi_2^{P,O} = \arg\max[nW_t^C + (1-n)W_t^P]. \tag{59}$$

Thus, higher welfare for each region taken individually in the coordination regime, relative to either the independent or the reciprocity regimes, is a sufficient, but not necessary, condition to generate a net gain for the world as a whole; this also depends on the magnitude of the relative gain (or loss) for each region and the relative weight of each of them, as measured by n, in the common objective function.

To assess the gains from coordination, compared to the two other regimes, policies are computed 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. As in de Paoli and Paustian (2017), for instance, un-

[29] See Appendix D for a discussion. Debortoli et al. (2019), for instance, also accounted for the cost of adjusting policy instruments.

der non-cooperation we solve for the closed-loop or feedback equilibrium.[30] Given the pre-determined nature of the feedback rules (28) and (47), each regulator has full knowledge of the other regulator's reaction function; their best responses reflect therefore this knowledge.

Numerically, welfare gains are evaluated using second-order approximations to both the household's period utility function and the model, conditional on the initial steady state being the deterministic steady state, and by calculating the percentage change in the objective function, defined as the value of that function under coordination divided by its value under either Nash or reciprocity, minus unity (see Appendix D). The same procedure is used to assess the gain from reciprocity relative to Nash.

6.2 Two-Stage Welfare Approach

In the alternative approach described earlier, the loss function that the regulator in each region $j = C, P$ seeks to minimize in the first stage depends on the present discounted value of deviations in the credit-to-output ratio, augmented by the cost of adjusting countercyclical capital buffers:

$$\mathcal{L}_t^j = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s [(\frac{l_t^{jK}/\tilde{l}^{jK}}{Y_t^j/\tilde{Y}^j})^2 + \varkappa_W \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\rho_{t+s}^{jC} - \rho_{t+s-1}^{jC})^2, \tag{60}$$

with now (57), (58), and (59) involving minimization of the objective function $\mathcal{L}_t^j$. Other aspects of the calculation of the optimal response parameters remain the same as before. In the second stage, the solutions obtained with the first stage are used to calculate household welfare under alternative regimes, using again a second-order approximation of the utility function and the model.

6.3 Results

Table 3 shows the results for the standard and two-stage welfare approaches for two values of the parameter γ, which measures (as discussed earlier) the strength of cross-border leakages, -0.1 and -0.2. The results shown correspond to the benchmark set of parameters displayed in Table 1, and with a relative weight of each region initially

[30] Coenen et al. (2009), Banerjee et al. (2016), and Agénor et al. (2020) solved instead for the open-loop (Ramsey) optimal policy with commitment. In such conditions, each regulator chooses an instrument *path* at the beginning of time—as opposed to a *reaction function* under a closed-loop equilibrium—taking as given the whole future path of the other regulator's instrument.

set at its benchmark value, $n = 0.818$. The adjustment cost parameter $\varkappa_W$ is set uniformly to a low value of 0.1.[31] To simplify matters, and to facilitate comparisons, the degree of persistence in the regulatory policy rules, χ_1^j, is kept at 0.1 throughout.[32] Under both approaches, a grid step of 0.001 points is used to search for the optimal response parameters χ_2^j in (28) and (47). Relative welfare changes are reported for both individual regions and the world.

The first result is that coordination involves a more aggressive response of the regulator in the periphery. Intuitively, under coordination regulators internalize the effects of credit fluctuations (occurring through spillovers to the periphery and spillbacks to the core) in both regions by pursuing a more aggressive policy, and this generates a superior outcome for the world as a whole. Thus, coordination involves some degree of *burden sharing*, a situation where the regulator in the core reacts either less or about the same, but the regulator in the periphery reacts significantly more. Consequently, *relative to Nash*, under the standard welfare approach (upper part of Table 3) the periphery experiences a substantial welfare loss under coordination, whereas the core gains. Thus, the benefits of coordination, relative to independent policymaking, are asymmetric. Nevertheless, even though coordination is not Pareto improving, it generates a slight benefit for the world economy as a whole.

The second result is that, under a standard welfare approach, the gains from coordination, *relative to reciprocity*, are also positive for the core, whereas they are negative (and large) for the periphery. Intuitively, full cooperation benefits the core more than reciprocity (which, again, can be viewed as a form of partial coordination), because it induces the periphery regulator to react more aggressively; as a result, spillback effects to the core are substantially mitigated. For the periphery, reacting more under coordination, relative to reciprocity, is welfare-reducing because of the cost associated with instrument manipulation. But while the periphery loses significantly from coordination, the core gains; and given the relative weight of the periphery in the combined objective function (only one-fifth that of the core) the world as a whole does slightly better under coordination. Fourth, similar results hold when comparing reciprocity

[31] This low value of $\varkappa_W$ is sufficient to illustrate our basic results; a higher value is considered later on. Note also that, in this model, when $\varkappa_W = 0$ it is optimal to fully stabilize credit, that is, $\chi_2^j \to \infty$ for $j = C, P$.

[32] Using higher uniform values affect the values of χ_2^j across the board but do not affect the results qualitatively.

and Nash; reciprocity benefits the core and the world economy as a whole, but the periphery is worse off compared to when it acts independently. At the same time, the loss for the periphery is lower under reciprocity (compared to Nash) because it uses the countercyclical capital buffer less aggressively than under coordination.

The third, and perhaps most important result is that, under a two-stage welfare approach, policy responses are now much less aggressive (see bottom part of Table 3). As a result, the cost of instrument manipulation is smaller. The regulator in the periphery reacts less under coordination than under reciprocity. Moreover, and importantly, reciprocity may now perform better than Nash, and as well as coordination, for all parties if cross-border regulatory leakages are strong. In fact, these benefits tend to increase with the strength of cross-border leakages, as measured by the absolute value of γ.

To assess the robustness of these results, we conducted sensitivity analysis with respect to a number of key parameters (including the degree of financial integration), the cost of instrument manipulation, and the relative size of each region under coordination, as measured by n. While the countercyclical response parameters, and the magnitude of the gains across regimes, did vary, the key results highlighted earlier remained essentially the same. Consider, for instance, the case where $n = 0.5$, to capture a situation where although the economic weight of the two regions may differ, the principle of "one country, one vote" applies in setting policy under coordination.[33] Regarding the optimal response parameters, outcomes under Nash and reciprocity are identical to those reported Table 3 for the benchmark case. The reason, of course, is that n only affects coordination, not reciprocity or Nash; thus, a change in n does not affect our key result relative to the benefit of reciprocity relative to Nash—only the gains relative to coordination. Under coordination, given the larger weight now attached to the periphery's objective function, the regulator there reacts less. As a result, compared to Nash the loss for the periphery is lower than in the benchmark case. As before, the core is better off (particularly so when $\gamma = -0.2$), and so is the world economy. In addition, compared to reciprocity, coordination generates results that are similar to those reported in Table 3: the periphery still loses significantly from coordination (given that it reacts more aggressively under that regime), whereas the

[33] In this scenario, and to facilitate comparisons with the other experiments, n is changed only in calculating the global objective function, not in solving for the global current account balance condition given in Appendix A.

core and the world economy benefit from it.

7 Concluding Remarks

This paper developed a two-region, core-periphery model with financial frictions, a risk-sensitive capital regulatory regime, imperfect financial integration, and cross-border banking to assess the gains from international macroprudential policy coordination. In the model, a core global bank lends to its branches in the periphery. The model was parameterized and used to examine first the cross-border effects of an expansionary monetary policy shock in the core, with and without independent regulatory responses, and to study the role of regulatory arbitrage. The model was then used to assess the gains from coordination relative to the case where regulators act independently, and the gains from reciprocity, where only the core optimizes with respect to its objective function and the periphery applies to the core's foreign affiliates in its jurisdiction the same countercyclical capital adequacy ratio as the one chosen by the core.

The main results of our analysis were summarized in the introduction. To conclude, it is worth pointing some potentially fruitful extensions of our analysis. First, a key assumption of the model is that *all* banks in the periphery are foreign affiliates. This helped to simplify significantly the model and made it easier to understand the channels through which (outward) regulatory arbitrage is transmitted across countries. However, as a result we were unable to capture the substitution effects that may occur between domestic and foreign lenders *within* the periphery, and their indirect impact on cross-border bank capital flows induced by regulatory changes occurring in the core—the key experiment that we focused on in the paper. A model with both domestic and foreign banks operating in the periphery would also be necessary to assess another type of cross-border leakages—the possibility that tighter regulation in the periphery on domestic banks may induce foreign branches (which are not subject to local prudential rules) to extend more credit to local borrowers, thereby hampering the achievement of the policy's intended goal. There is evidence that this type of (inward) leakages have been quite significant as well (Buch and Goldberg (2017)). In such conditions, the gain from reciprocity could be even more significant under a financial stability mandate. It is therefore possible that our results provide only a lower bound on the potential benefits (both in terms of welfare and financial stability) that a broad application of regulatory reciprocity may generate for the world economy.[34]

Second, future research should also consider the possibility of leakages from regulated banks to non-regulated (shadow) financial intermediaries *within* jurisdictions. As noted in the introduction, imposing prudential restrictions on regulated banks may contribute (in addition to encouraging international spillovers) to the growth of shadow banking at home. If borrowers, when faced with higher costs from regulated banks, can switch to non-bank financing, tighter capital buffers (triggered or not by a reciprocity agreement) may fail in achieving their objective to smooth the credit cycle. To prevent leakages may require broadening the scope of regulation or relying on other regulatory instruments, such as prudential capital controls on shadow banks (see, for instance, Johnson (2021)). To address these issues, a model that accounts for three types of lenders—domestic regulated banks, domestic shadow banks, and foreign banks—would be necessary.

A third issue that would be worth considering is how knowledge gains, through information sharing, could improve the decision process that underlies macroprudential policy coordination across countries. These gains may be particularly significant when, as noted by Engel (2016) in the context of monetary policy, model uncertainty generates disagreements among policymakers acting independently.[35] Greater information sharing may in turn promote convergence of views and improve consensus around policy choices, possibly increasing in the process the gains from coordination.

[34] However, it should also be noted that in practice, to mitigate the risk that an increase in credit by foreign banks may substitute for a contraction in loans by domestic banks, a growing number of recipient countries have opted to restrict entry by foreign banks in the form of branches, which obviates the need to invoke reciprocity with the jurisdiction where the parent bank is registered. Indeed, as documented by the World Bank (2018, Figure O.7), since the global financial crisis over a third of developing countries have placed restrictions on creating branches.

[35] In practice, to promote coordination (and communication) among financial regulators, establishing concrete, commonly-accepted measures of global financial stability risks is necessary. This creates a role for multilateral financial institutions. See Adrian et al. (2019) for a discussion of a two-pronged approach that relates financial stability risks to macro-financial imbalances.

Appendix A
Production Side and Real Equilibrium Conditions

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 core country, results for the periphery are similar.

Final Good Production

To produce the core final good, Y_t^C, a basket of domestically-produced differentiated intermediate goods sold domestically, Y_t^{CC}, is combined with a basket of imported intermediate goods produced abroad (that is, foreign exports), Y_t^{PC}:

$$Y_t^C = [\Lambda_Y^C (Y_t^{CC})^{(\eta_Y - 1)/\eta_Y} + (1 - \Lambda_Y^C)(Y_t^{PC})^{(\eta_Y - 1)/\eta_Y}]^{\eta_Y/(\eta_Y - 1)}, \qquad \text{(A1)}$$

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

$$Y_t^i = \left\{ \int_0^1 [Y_{jt}^i]^{(\theta^i - 1)/\theta^i} dj \right\}^{\theta^i/(\theta^i - 1)}. \quad i = CC, PC \qquad \text{(A2)}$$

In this expression, $\theta^i > 1$ is the elasticity of substitution between intermediate core goods among themselves ($i = CC$), and imported goods among themselves ($i = PC$), 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 functions for each variety j of intermediate goods:

$$Y_{jt}^i = (\frac{P_{jt}^i}{P_t^i})^{-\theta^i} Y_t^i, \quad i = CC, PC \qquad \text{(A3)}$$

where P_{jt}^{CC} (P_{jt}^{PC}) is the domestic price of core (periphery) intermediate good j, and P_t^{CC} and P_t^{PC} are price indices, which are given by

$$P_t^i = \left\{ \int_0^1 (P_{jt}^i)^{1-\theta^i} dj \right\}^{1/(1-\theta^i)}. \quad i = CC, PC \qquad \text{(A4)}$$

Demand functions for baskets of core and periphery goods by the core final good producers are

$$Y_t^{CC} = (\Lambda_Y^C)^{\eta_Y} (\frac{P_t^{CC}}{P_t^C})^{-\eta_Y} Y_t^C, \quad Y_t^{PC} = (1 - \Lambda_Y^C)^{\eta_Y} (\frac{P_t^{PC}}{P_t^C})^{-\eta_Y} Y_t^C, \qquad \text{(A5)}$$

where P_t^C is the price of core final output, given by

$$P_t^C = [(\Lambda_Y^C)^{\eta_Y} (P_t^{CC})^{1-\eta_Y} + (1 - \Lambda_Y^C)^{\eta_Y} (P_t^{PC})^{1-\eta_Y}]^{1/(1-\eta_Y)}, \qquad \text{(A6)}$$

with an analogous expression for the price of final output in the periphery, P_t^P.

Under the assumption of producer currency pricing (PCP), and assuming no transportation costs between regions and no rigidities, the law of one price implies that the price of imported periphery good j in the core economy is given by

$$P_{jt}^{PC} = E_t^{-1} P_{jt}^{PP}, \qquad \text{(A7)}$$

where P_{jt}^{PP} is the foreign-currency price of foreign intermediates, set in the periphery. There is therefore full exchange rate pass-through. However, because of home bias in production, P_t^C and P_t^P in general differ from each other; their ratio defines the real exchange rate.

Production of Intermediate Goods

Core output of intermediate good j, Y_{jt}^{CI}, is sold on a monopolistically competitive market and is produced by combining labor, N_{jt}^C, and beginning-of-period capital, K_{jt}^C:

$$Y_{jt}^{CI} = (N_{jt}^C)^{1-\alpha}(K_{jt}^C)^{\alpha}, \tag{A8}$$

where $\alpha \in (0,1)$.

Capital is rented from a randomly matched CG producer at the rate r_t^{CK} and paid for after the sale of output.[36] Cost minimization yields the capital-labor ratio and the unit real marginal cost, mc_t^C, as

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

$$mc_t^C = \frac{\left(w_t^C\right)^{1-\alpha}\left(r_t^{CK}\right)^{\alpha}}{\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}}. \tag{A10}$$

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

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

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

$$J_{jt}^{CI} = (\frac{P_{jt}^{CC}}{P_t^{CC}})Y_{jt}^{CI} - mc_t^C Y_{jt}^{CI} - \frac{\phi_I}{2}(\frac{P_{jt}^{CC}}{P_{jt-1}^{CC}} - 1)^2 Y_t^{CI}, \tag{A12}$$

where $\phi_I \geq 0$.

Using (A12) after substituting for (A3), the first-order condition for problem (A11) takes the standard form

$$(1-\theta^{CC})(\frac{P_{jt}^{CC}}{P_t^{CC}})^{-\theta^{CC}}\frac{1}{P_t^{CC}} + \theta^{CC}(\frac{P_{jt}^{CC}}{P_t^{CC}})^{-\theta^{CC}-1}\frac{mc_t^C}{P_t^{CC}} \tag{A13}$$

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

[36] For simplicity, we abstract from the cost channel, despite its importance—especially for middle-income countries. See Agénor (2020, chapter 4) for a formal discussion.

Under symmetry, the price adjustment equation (A13) becomes

$$mc_t^C = \frac{\theta^{CC}-1}{\theta^{CC}} + \frac{\phi_I}{\theta^{CC}}[\pi_t^{CC}(1+\pi_t^{CC})] - \frac{\phi_I}{\theta^{CC}}\mathbb{E}_t\left\{\rho_{t,t+1}\pi_{t+1}^{CC}(1+\pi_{t+1}^{CC})\frac{Y_{t+1}^{CC}}{Y_t^{CC}}\right\}, \quad \text{(A14)}$$

where $\rho_{t,t+1} = \Lambda\lambda_t/\lambda_{t+1}$.

Under PCP, the law of one price implies once again that the price of core intermediate goods sold on the periphery market (that is, the price of core exports in the periphery), P_t^{CP}, is equal to the core price adjusted for the exchange rate:[37]

$$P_t^{CP} = E_t P_t^{CC}. \quad \text{(A15)}$$

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

$$Y_{jt}^{CI} = Y_{jt}^{CC} + Y_{jt}^{CP}, \quad \text{(A16)}$$

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

$$Y_{jt}^{PI} = Y_{jt}^{PP} + Y_{jt}^{PC}, \quad \text{(A17)}$$

with Y_{jt}^{PC} (core imports) given by (A3).

Note that we also have in value terms $P_t^{CI}Y_t^{CI} = P_t^{CC}Y_t^{CC} + P_t^{CP}Y_t^{CP}$, where P_t^{CI} is the implicit output price of intermediate goods. Given (A15) and (A16), this expression gives $P_t^{CI} = P_t^{CC}(Y_t^{CC} + E_tY_t^{CP})/(Y_{jt}^{CC} + Y_{jt}^{CP})$.

Capital Good Production

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

$$K_{t+1}^C = I_t^C + \left\{1 - \delta_K - \frac{\Theta_K}{2}(\frac{K_{t+1}^C - K_t^C}{K_t^C})^2\right\} K_t^C, \quad \text{(A18)}$$

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 $l_t^{CK} = I_t^C$. The household makes its exogenous housing stock, $\bar{A}^C$, available without any direct charge to the CG producer, who uses it as collateral against which it borrows from the bank. Repayment is uncertain and occurs with probability $q_t^{CF} \in (0,1)$. Expected repayment is thus $q_t^{CF}(1+i_t^{CL})l_t^{CK} + (1-q_t^{CF})\kappa\mathbb{E}_t p_{t+1}^{PH}\bar{H}^P$,

[37] Defining the terms of trade for the core region as the price of imports relative to the price of exports (both in own currency) as $\tau_t = P_t^{PC}/P_t^{CC}$ yields $P_t^{PC} = \tau_t P_t^{CC}$. Substituting this result in (A6) yields $P_t^C = P_t^{CC}[\Lambda_I^\eta + (1-\Lambda_I)^\eta \tau_t^{1-\eta}]^{1/(1-\eta)}$. A related definition holds for P_t^P. By log-linearizing these two equations, it can be shown that deviations in the real exchange rate, defined in the text as $z_t = E_tP_t^C/P_t^P$, are proportional to deviations in the terms of trade between the two countries.

where $\kappa \in (0,1)$ is the share of the housing stock that can be effectively pledged as collateral.

Subject to (A18), the CG producer chooses the level of capital K_{t+1}^C so as to maximize the value of the discounted stream of dividend payments to the matched household. As shown by Agénor et al. (2014, 2018), the solution to this problem yields[38]

$$\mathbb{E}_t r_{t+1}^{CK} \simeq q_t^C(1+i_t^{CL})\mathbb{E}_t\left\{[1+\Theta_K(\frac{K_{t+1}^C}{K_t^C}-1)](\frac{1+i_t^{CB}}{1+\pi_{t+1}^C})\right\} \tag{A19}$$

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

For the periphery, the amount borrowed by the representative CG producer is a Dixit-Stiglitz basket of differentiated loans, each supplied by a bank i, with an elasticity of substitution $\zeta^L > 1$:

$$l_t^{PK} = [\int_0^1 (l_t^{PK,i})^{(\zeta^L-1)/\zeta} di]^{\zeta^L/(\zeta^L-1)}.$$

The demand for type-i loan, $l_t^{PK,i}$, is thus given by the downward-sloping curve

$$l_t^{PK,i} = (\frac{1+i_t^{PL,i}}{1+i_t^{PL}})^{-\zeta^L} l_t^{PK}, \tag{A20}$$

where $i_t^{PL,i}$ is the rate on the loan extended by bank i and $1+i_t^{PL} = [\int_0^1 (1+i_t^{PL,i})^{1-\zeta^L} di]^{1/(1-\zeta^L)}$ is the aggregate loan rate.

Government

Income received by the central bank on its lending to the global bank is transferred to the government, whereas (as noted earlier) revenue from the macroprudential tax is returned lump-sum to the global bank. The core government budget constraint is thus given by[39]

$$b_t^C = G_t^C - T_t^C + (\frac{1+i_{t-1}^{CB}}{1+\pi_t^C})b_{t-1}^C - i_{t-1}^{CR}\frac{l_{t-1}^{CB}}{1+\pi_t^C}, \tag{A21}$$

where $b_t^C = b_t^{CC} + b_t^{PC}$ is the real stock of riskless one-period bonds held by core (b_t^{PC}) and periphery (b_t^{PC}) households, and G_t^C real expenditure on core final goods, which represents a fraction $\psi^G \in (0,1)$ of final output:

$$G_t^C = \psi^G Y_t^C. \tag{A22}$$

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

[38] The derivation of equation (A19) ignores covariance terms for simplicity. It boils down to the standard arbitrage condition $\mathbb{E}_t r_{t+1}^{CK} \simeq i_t^{CB} - \mathbb{E}_t\pi_{t+1}^C + \delta_K$ in the absence of bank borrowing and adjustment costs.

[39] Using the balance sheet constraint (25), the last term in (A21) can be written as $(1+\pi_t^C)^{-1} i_{t-1}^{CR} m_{t-1}^{CB}$, which corresponds to central bank revenue, rather than seigniorage. It represents the interest earned by investing the resources obtained through the issuance of base money, in the form of loans to the global bank. This revenue is transferred to the government.

Interest income received by the central bank is once again transferred to the government. The periphery government budget constraint takes therefore the same form as (A21), with now $b_t^P = b_t^{PP} + b_t^{CP}$ and interest payments of $(1+\pi_t^P)^{-1}(1+i_{t-1}^{PB})b_{t-1}^P$.

Goods market equilibrium

In a symmetric equilibrium, all IG firms, produce the same output and prices are the same across firms. Thus, the market-clearing conditions (A16) and (A17) for good j also imply that total output of core and periphery intermediate goods be equal to world demand for those goods:

$$Y_t^{CI} = Y_t^{CC} + Y_t^{CP}, \quad Y_t^{PI} = Y_t^{PP} + Y_t^{PC}. \tag{A23}$$

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

$$Y_t^C = C_t^C + G_t^C + I_t^C + \frac{\phi_I}{2}(\frac{P_t^{CC}}{P_{t-1}^{CC}} - 1)^2(\frac{P_t^{CC}}{P_t^C})Y_t^{CI}, \tag{A24}$$

and analogously for the periphery.

Current Account

The current account for the periphery at current local prices (the analogue of (54)) can be written as

$$CA_t^P = P_t^{PP}Y_t^{PC} - P_t^{CP}Y_t^{CP} \tag{A25}$$
$$-i_{t-1}^{CP}E_{t-1}P_{t-1}^C l_{t-1}^{PC} - i_{t-1}^{PB}P_{t-1}^P b_{t-1}^{CP} + i_{t-1}^C E_{t-1}P_{t-1}^C b_{t-1}^{PC},$$

where $P_t^{CP} = E_t P_t^{CC}$ is the price of core goods sold in the periphery (equal to, under local currency pricing, the price of core intermediate goods adjusted for the exchange rate), Y_t^{CP} periphery imports of intermediates, which correspond also to the core's exports, P_t^{PP} is the price of periphery intermediate goods sold on the core market (that is, the price of periphery exports), and Y_t^{PC} are periphery exports of intermediate goods, which correspond also to the core's imports. The third term in (A25) is the interest payment on loans to the periphery by the global bank, and the fourth (fifth) term interest payment (income) on holdings of periphery (core) bonds by (periphery) core households.

In terms of changes in foreign assets, CA_t^P can also be written as, similar to (55),

$$CA_t^P = E_t P_t^C b_t^{PC} - E_{t-1}P_{t-1}^C b_{t-1}^{PC} \tag{A26}$$
$$-(E_t P_t^C l_t^{PC} - E_{t-1}P_{t-1}^C l_{t-1}^{PC}) - (P_t^P b_t^{CP} - P_{t-1}^P b_{t-1}^{CP}).$$

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Table 1
Benchmark Parameterization: Key Parameter Values

Parameter	Description	MAEs	SMICs
Households			
Λ	Discount factor	0.95	0.95
ς	Elasticity of intertemporal substitution	0.5	0.5
η_N	Preference parameter for leisure	25.0	25.0
ψ_N	Inverse of Frisch elasticity of labor supply	1.4	1.4
η_x	Preference parameter for money holdings	0.001	0.001
η_H	Preference parameter for housing	0.1	0.1
ν	Share parameter in index of money holdings	0.2	0.2
θ_0^B	Cost parameter, interm. on world capital markets	0.2	0.2
Θ_V^j	Cost parameter, holdings of bank capital	2.64	1.83
Producers			
Λ_Y^j	Share of own-region IG goods in final output	0.8	0.6
η_Y	Elasticity of substitution, baskets of interm. goods	1.5	1.5
θ^{jj}	Elasticity of own-region demand, intermediate goods	10.0	10.0
α	Share of capital, intermediate goods production	0.35	0.35
ϕ_I	Adjustment cost parameter, intermediate goods prices	74.5	74.5
δ_K	Depreciation rate of capital	0.015	0.015
Θ_K	Capital adjustment cost parameter, investment	14	14
Banks			
κ^j	Effective collateral-loan ratio	0.4	0.2
ψ_1^j	Elasticity of repayment probability, coll.-loan ratio	0.05	0.1
ψ_2^j	Elasticity of repayment probability, cyclical output	0.9	0.9
η_D	Elasticity of deposit supply by households	2.5	–
η_L, ζ_L	Elasticity of loan demand by capital producers	4.5	4.5
η_P	Elasticity of demand for global bank loans by periphery	–	4.5
γ_K	Cost parameter, core cost function	0.1	–
γ_L	Cost parameter, core cost function	0.1	–
γ	Cost parameter, core joint cost function	−0.1	–
γ_V^j	Cost parameter, bank excess capital holdings	0.01	0.01
γ_{VV}^j	Cost parameter, bank excess capital holdings	0.001	0.001
ϕ_E^j	Sensitivity parameter, marg. benefit of excess capital	0.5	0.45
γ_P	Cost parameter, demand for global bank loans	–	0.15
ϕ_q^j	Sensitivity of risk weight to repayment probability	0.05	0.05
Policymakers			
μ^j	Required reserve ratio	–	0.2
χ^j	Degree of interest rate smoothing	0.8	0.0
ε_1^j	Response of policy rate to inflation deviations	1.7	2.0
ε_2^j	Response of policy rate to output deviations	0.1	1.0
ψ^G	Share of government spending in final output	0.2	0.22
Shock			
ρ_ϵ	Persistence parameter, core policy rate shock	0.0	–

Table 2
Initial Steady-State Values: Key Variables
(In proportion of each region's final output or in percent; $j = C, P$)

Variable	Description	MAEs	SMICs
Real variables			
Y^{CP}/Y^{CI}	Share of exports in production of intermediate goods, core	0.244	–
Y^{PC}/Y^{PI}	Share of exports in production of interm. goods, periphery	–	0.174
C^j	Private consumption	0.65	0.65
I^j, l^{jK}	Investment, loans to IG firms	0.15	0.13
r^{jK}	Rental rate of capital (percent)	0.068	0.069
Financial variables			
l^{PC}	Loans from global bank to periphery banks	0.084	–
q^j	Repayment probability, loans to IG firms (percent)	0.96	0.936
i^{jB}, i^{jR}	Gov. bond rate, central bank refinance rate (percent)	0.053	0.053
i^{jD}	Bank deposit rate (percent)	0.042	0.042
i^{jL}	Loan rate, loans to intermediate goods firms (percent)	0.046	0.095
i^{CP}	Loan rate, global bank loans to periphery banks (percent)	0.04	–
i^{jV}	Rate of return, bank capital (percent)	0.103	0.083
σ^{jK}	Risk rate, required capital (percent)	1.0	1.0
V^{jR}/l^{jK}	Required bank capital (in proportion of loans)	0.08	0.08
V^{jE}/l^{jK}	Excess bank capital (in proportion of loans)	0.04	0.04
V^j/l^{jK}	Total bank capital (in proportion of loans)	0.12	0.12
ρ^{jC}	Countercyclical capital ratio	0.0	0.0

Table 3
Optimal Policy Responses and Gains from Coordination
Alternative Welfare Approaches[1]

	$\gamma = -0.1$	$\gamma = -0.2$
Standard Welfare Approach		
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$0.022, 0.008$	$0.025, 0.006$
Reciprocity: Optimal χ_2^{C} ($\rho_t^{PC} = \rho_t^{CC}$)	0.023	0.027
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$0.022, 0.049$	$0.025, 0.051$
Gain from coordination, rel. to Nash		
Core	0.0001	0.0004
Periphery	−0.0310	−0.1048
World	0.0001	0.0002
Gain from coordination, rel. to reciprocity		
Core	0.0001	0.0002
Periphery	−0.0268	−0.0804
World	0.0000	0.0001
Gain from reciprocity, rel. to Nash		
Core	0.0001	0.0002
Periphery	−0.0041	−0.0225
World	0.0000	0.0001
Two-Stage Welfare Approach		
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$0.010, 0.006$	$0.010, 0.006$
Reciprocity: Optimal χ_2^{C} ($\rho_t^{PC} = \rho_t^{CC}$)	0.010	0.010
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$0.010, 0.007$	$0.010, 0.010$
Gain from coordination, rel. to Nash		
Core	0.0000	0.0000
Periphery	0.0003	0.0025
World	0.0000	0.0000
Gain from coordination, rel. to reciprocity		
Core	0.0000	0.0000
Periphery	0.0009	0.0000
World	0.0000	0.0000
Gain from reciprocity, rel. to Nash		
Core	0.0000	0.0000
Periphery	0.0012	0.0025
World	0.0000	0.0000

[1]The gains from coordination (with respect to both noncooperation and reciprocity) are calculated using the procedure discussed in the text. The instrument cost is $\varkappa_W = 0.1$.

Figure 1

Core-Periphery Model with Capital Regulation

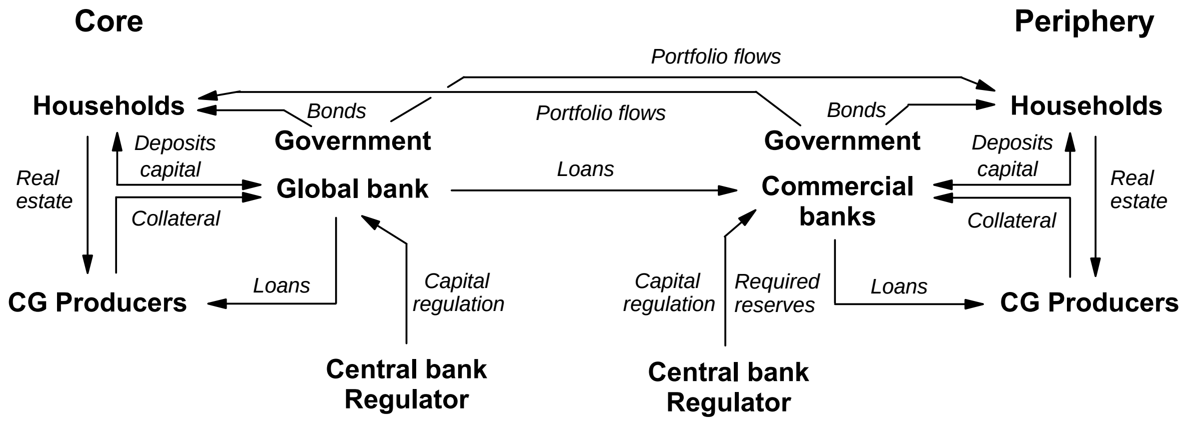
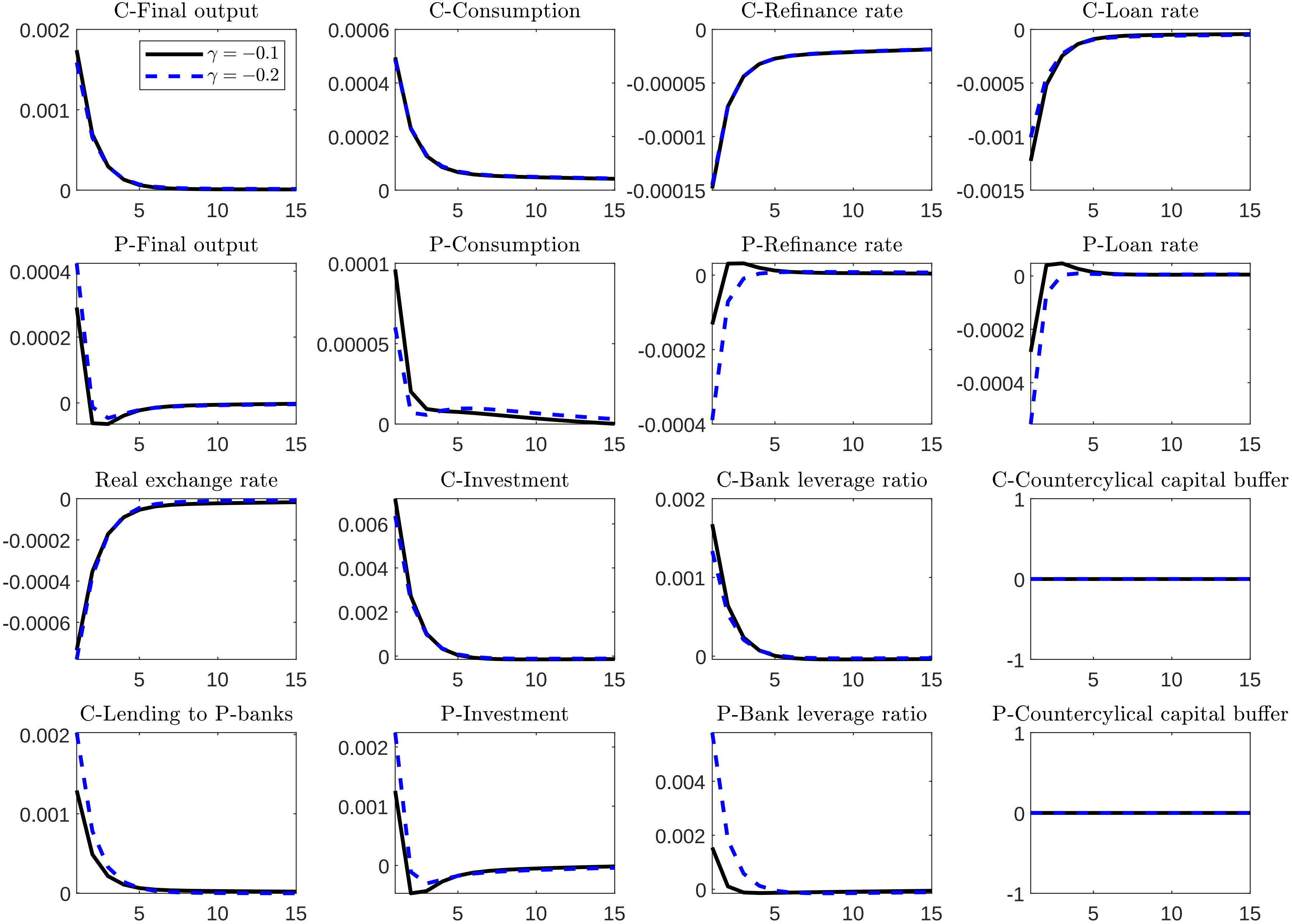
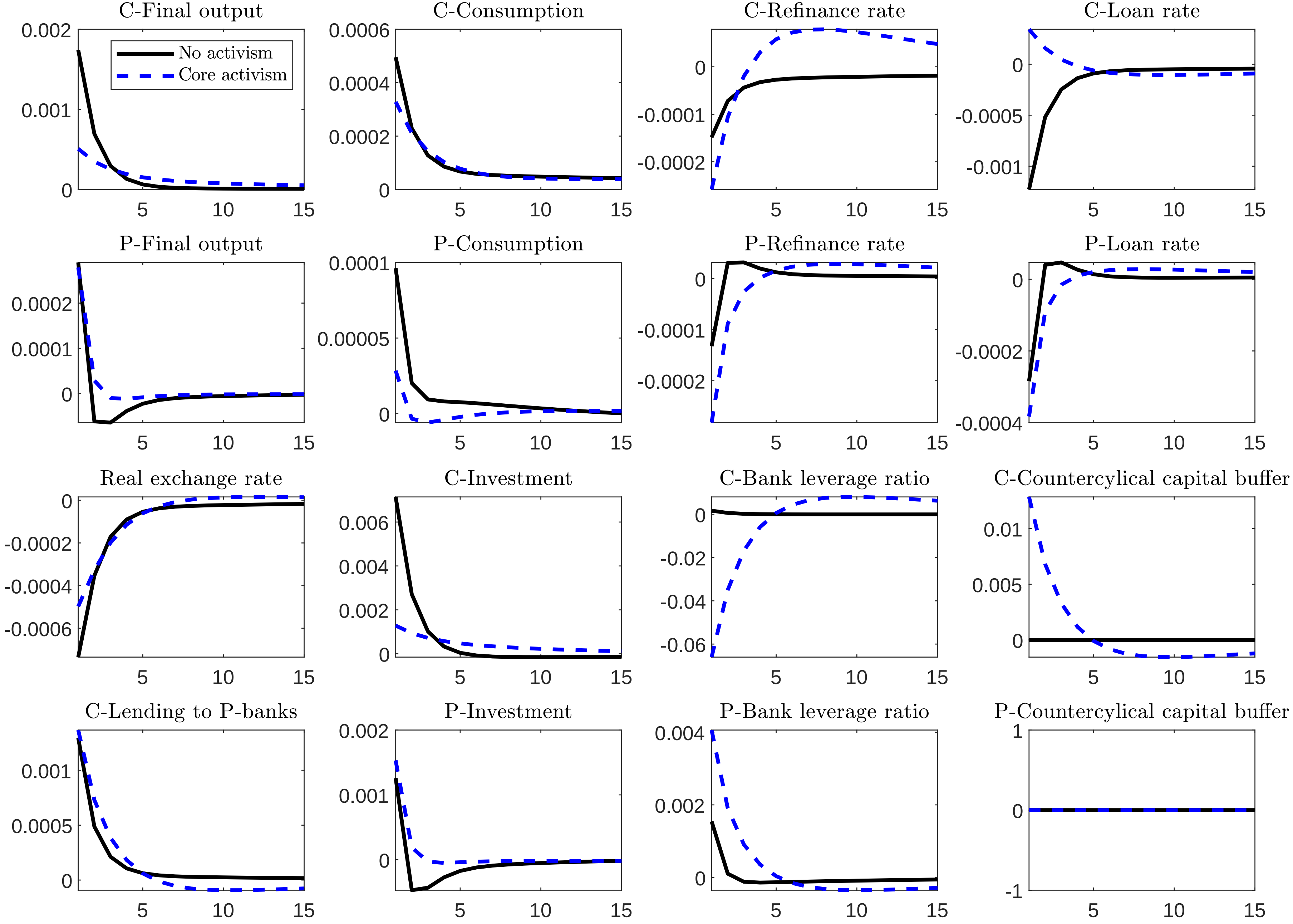


Figure 2
Transitory Negative Shock to Core Refinance Rate
(Deviations from steady state)



Notes: The responses of consumption, investment, final output, real house prices, required and excess bank capital, and the nominal and real exchange rates are expressed as percent deviations from their steady-state values. The responses of the loan rate, the refinance rate, the excess return on bank debt, the repayment probability, the inflation rate, the risk weight, and the countercyclical capital ratio are expressed as absolute deviations (or percentage points) from their steady-state values.

Figure 3
Transitory Negative Shock to Core Refinance Rate, with Core Prudential Response
(Deviations from steady state)



Notes: See notes to Figure 2. "Core response" refers to the endogenous response by the core regulator through its countercyclical capital buffer rule.

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