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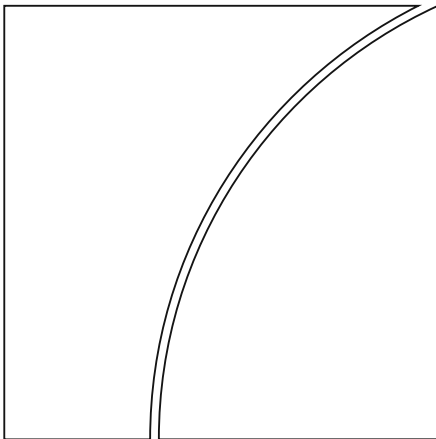
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## Cross-border regulatory spillovers and macroprudential policy coordination

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# Cross-Border Regulatory Spillovers and Macroprudential Policy Coordination

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## Abstract

We develop a core-periphery model with financial frictions and cross-border banking to assess the magnitude of regulatory spillovers and the gains from 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 in that region induces the global bank to increase cross-border lending. We calculate welfare gains associated with countercyclical capital buffers under a range of policy regimes, including independent policymaking, full coordination, and reciprocity—a regime in which capital ratios set in the core are imposed on the global bank’s affiliates abroad. One of our key results is that, even when regulatory spillovers are strong, reciprocity can make all parties better off if regulators attach a sufficient weight to financial stability considerations. With a standard, utility-based welfare criterion, reciprocity may also perform better than independent policymaking when regulatory spillovers are weak.

**JEL Classification Numbers:** E58, F42, F62

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\*University of Manchester; \*\*University of Liverpool; and \*\*\*Bank for International Settlements (at the time the paper was written). We are grateful to several colleagues and an anonymous reviewer for helpful discussions and comments on a previous draft. However, the views expressed in this paper are our own and do not necessarily reflect those of the BIS. Appendices B to F are available upon request. A shorter version of this paper is published in the *Journal of Monetary Economics*.

# 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.<sup>1</sup> 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), Tripathy (2020), and Franch 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.<sup>2</sup> 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.<sup>3</sup> 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

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<sup>1</sup>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.

<sup>2</sup>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.

<sup>3</sup>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)).<sup>4</sup> In the same vein, a framework of voluntary reciprocity of macroprudential policy measures, including countercyclical capital buffers, was put in place in the European Union in late 2015 (see Cantone et al. (2019) and European Systemic Risk Board (2022)). In effect, the fundamental rationale for reciprocity, broadly defined, is that greater coordination of macroprudential policies across countries may help to maintain, or promote, global financial stability.

From a theoretical perspective, it is important to note that even though cross-border spillovers and spillbacks associated with changes in national regulation may be significant, it does not necessarily follow that they reduce global welfare and that cooperation is *prima facie* welfare improving. Indeed, as argued by Korinek (2016), if capital flows reflect an equilibrium response of optimizing agents (as noted earlier), they are not necessarily a source of Pareto inefficiencies. Korinek’s *first welfare theorem for open economies* spells out the conditions that need to be violated to generate inefficiency and create a scope for cooperation. One of these conditions relates to limitations in the ability to use policy instruments, due, for instance, to manipulation costs, which affect the policymaker’s objective function and create incentives for burden

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<sup>4</sup>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—up to a rate of 2.5 percent—on exposures to that country from banks in their jurisdiction. See Agénor and Pereira da Silva (2022) for a discussion.

sharing.

Contributions aimed at modeling cross-border regulatory leakages and at quantifying the gains from international macroprudential coordination (involving reciprocity or not) remain scant.<sup>5</sup> 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 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.<sup>6</sup> 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.<sup>7</sup> Bahaj and Malherbe (2022) developed a two-country, two-period model in which banks finance loans with a mix of insured deposits and equity capital (for which there is global competition), and changes in bank capital requirements in one country may generate either capital outflows or capital inflows. They also showed that, compared to coordination, reciprocity may generate an excessive policy response in both directions: countries have an incentive to increase countercyclical capital buffers too much in good times (when equity capital is abundant), and reduce them too much in bad times (when equity capital is scarce). Nevertheless, while useful for bringing to the fore some important conceptual

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

<sup>6</sup>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), Gebauer and Mazelis (2020), and Claessens et al. (2021).

<sup>7</sup>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.

aspects of the link between national financial regulation, cross-border regulatory arbitrage, and capital flows, none of these contributions addresses a critical issue from a policy perspective—whether partial coordination, in the form of a reciprocal regulatory agreement on countercyclical macroprudential policies, may generate significant benefits, in terms of welfare or financial stability, not only for individual parties but also for the world economy. Agénor et al. (2021, 2023), for instance, presented relevant two-region, core-periphery DSGE models with financial frictions, but macroprudential policy is modeled as a generic tax and the issue of reciprocity in capital requirements is not discussed. Chen and Phelan (2021) also abstracted from reciprocity arrangements.

This paper contributes to the literature in two related ways. 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) in the presence of regulatory arbitrage. To do so, we use two approaches: first, the standard, utility-based welfare approach, and second, a two-stage approach, which follows Agénor and Flamini (2022) and involves solving first for the optimal policy based on a loss function, consistent with an institutional mandate (delegated by society) focused on financial stability, and then measuring the benefits of that policy in terms of household welfare.

Specifically, we characterize the cross-border spillovers that occur when regulators in the core region tighten their macroprudential stance in response to an expansionary monetary shock in that region. We then evaluate the potential benefits of reciprocity agreements involving countercyclical capital buffers, which respond endogenously to credit fluctuations. The paper extends the model in Agénor et al. (2023) by assuming, first, that banks in the periphery are all affiliates set up by the global bank and loans between them occur through an internal capital market.<sup>8</sup> Second, the model accounts for economies of scope in lending domestically and abroad by the global bank. Third, banks in both regions are subject to a risk-sensitive capital regulatory regime and countercyclical capital buffers react endogenously to credit fluctuations. Fourth,

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<sup>8</sup>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 al. (2021), and Johnson (2021). Although some of these models considered the cross-border spillover effects of capital requirements, none of them assesses the gains from international policy coordination in this type of instrument.

as in Korinek (2016), we account for instrument manipulation costs and study their implications for coordination. Fifth, we conduct our analysis in terms of a general specification of policy preferences, which dwells on Bodenstein et al. (2019) and Agénor and Jackson (2022), and allows us to assess the extent to which institutional mandates matter for assessing policy performance.

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), and De Santis and Zimic (2022)—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 countercyclical capital buffers set in the core region are also imposed on affiliates of the global bank operating in the periphery. An important novelty of our analysis therefore is to treat reciprocity (or *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, which we believe to be particularly relevant for the issue at stake, given the proliferation of narrow financial stability mandates delegated to regulators since the global financial crisis.

Our main results can be summarized as follows. Following an expansionary monetary policy in the core, a countercyclical increase in capital requirements in that region induces the global bank to reallocate more of its loan portfolio towards lending to its affiliates abroad. The magnitude of this regulatory-induced cross-border spillover (or regulatory spillover, for short) depends on the degree of substitutability between domestic and foreign loans, which is captured through a cost parameter related to the degree of economies of scope in lending. If regulatory spillovers are weak, reciprocity performs uniformly better than the core acting alone, regardless of the importance regulators attach to financial stability. However, the stronger spillovers are, the larger must be the weight on financial stability for reciprocity to be Pareto-improving, that is, for the policy response to benefit all parties—and therefore the world at large.<sup>9</sup>

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<sup>9</sup>The focus on Pareto improvements, as in Agénor and Jackson (2022), for instance, provides a stricter policy evaluation criterion than requiring only that cooperation benefits the world as a whole—an outcome that may occur, both in our setting and in general, even if one party is worse off.



With a standard, utility-based welfare criterion, reciprocity may also perform better than Nash if regulatory spillovers are weak or if concerns for financial stability are sufficiently strong. At the same time, even when reciprocity is Pareto-improving, gains relative to the core acting alone are not generally large. This may help to explain why, in practice, as discussed in Agénor and Pereira da Silva (2022), reciprocity agreements are rarely activated.<sup>10</sup> Finally, our analysis shows that, in an asymmetric world in which domestic distortions can exacerbate financial risks associated with capital flows, and regulators are concerned with financial stability, the presence of instrument manipulation costs is a necessary, but not sufficient, condition for coordination to be Pareto-improving. Extensive sensitivity analysis, including a stock treatment of bank capital, show that these results are robust to a wide range of specification and parameter alterations.

How do these results compare to the relevant literature? As noted earlier, partial equilibrium models of international macroprudential policy coordination include, from a banking perspective, Acharya (2003), Dell’Ariccia and Marquez (2006), Kara (2016), and Park and Kim (2018), from a banking perspective, and Bengui (2014) and Jeanne (2014), from a broader macroeconomic perspective. This literature has shed useful light on a number of factors, including heterogeneity in the structure of banking markets, liquidity provision, and cross-border spillovers. However, the partial equilibrium nature of these models also means that they are not well suited to provide a thorough quantitative assessment of the gains associated with macroprudential coordination. In addition, none of these contributions assesses the performance of reciprocity arrangements. To our knowledge, the only paper that relates directly to ours is Rubio (2020). In her model macroprudential regulation takes the form of setting a loan-to-value ratio (a borrower-based instrument), whereas in ours it consists of capital requirements (a lender-based instrument), along the lines of Basel III. More importantly, in addition to considering the case where only the core responds to a shock in its own jurisdiction, reciprocity is defined in terms of both countries responding optimally, using separate instruments. By contrast, in our paper reciprocity (or *partial* coordination) corresponds to the case where the periphery applies the *same* countercyclical response parameter as the core. Thus, what Rubio defines as reciprocity corresponds, in our framework, to

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In that context, the issue of how cooperation agreements should be enforced (a recurrent concern in practice) becomes less relevant—unless the *magnitude* of each party’s gain also matters.

<sup>10</sup>See <https://www.bis.org/bcbs/ccyb/> for a summary of the evidence on reciprocity activations.

*full* cooperation. Thus, her results are not strictly comparable to ours. Nevertheless, we also found, as she did, that full cooperation, compared to the core acting alone, can be Pareto-improving—with the caveat that, in our case, this occurs only if regulators care sufficiently about financial stability.

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—a well-documented fact.<sup>11</sup> 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.

## 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

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<sup>11</sup>See, for instance, World Bank (2020). Agénor and Jackson (2022) provide a more detailed discussion of our modeling of capital requirements and how it relates to the literature.

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.<sup>12</sup> 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. This assumption is consistent with the growing use of hybrid securities, so-called contingent convertible capital instruments, or CoCos, to absorb losses (by converting them into common equity) and satisfy regulatory capital requirements. Under Basel III (and its implementation legislation, such as CRD V in the European Union), CoCos can qualify as either Additional Tier 1 (AT1) or Tier 2 capital.<sup>13</sup> Banks 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 period. Thus, all profits are distributed. 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 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

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<sup>12</sup>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.

<sup>13</sup>Issuance of CoCos by banks has increased substantially since they were first used in 2009, especially in the form of AT1 instruments. See Avdjiev et al. (2020). The possibility that banks accumulate capital through retained earnings, as in some contributions in the literature, is discussed later on.

sectors, as well as the government, are relegated to Appendix A.<sup>14</sup>

### 2.1.1 Households

The objective of the representative household in the core economy is to maximize<sup>15</sup>

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

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,  $\psi_N$  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,  $P_t^C$ :

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

Both deposits cash are accounted for because deposits are a key source of funding for banks, whereas (as discussed later on) the domestic bond rate is solved from the equilibrium condition of the money market.

The core household's flow budget constraint is

$$\begin{aligned} & m_t^C + d_t^C + b_t^{CC} + z_t^{-1} b_t^{CP} + p_t^{CH} \Delta H_t^C + V_t^C \\ &= w_t^C N_t^C - T_t^C - C_t^C + \frac{m_{t-1}^C}{1 + \pi_t^C} + \left( \frac{1 + i_{t-1}^{CD}}{1 + \pi_t^C} \right) d_{t-1}^C + \left( \frac{1 + i_{t-1}^{CB}}{1 + \pi_t^C} \right) b_{t-1}^{CC} \\ &+ (1 + i_{t-1}^P) z_t^{-1} b_{t-1}^{CP} + J_t^{CI} + J_t^{CK} + J_t^{CB} + \left( \frac{1 + i_{t-1}^{CV}}{1 + \pi_t^C} \right) V_{t-1}^C - \Theta_V^C \frac{(V_t^C)^2}{2}, \end{aligned} \quad (3)$$

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

<sup>14</sup>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.

<sup>15</sup>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.<sup>16</sup>  $V_t^C$  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.<sup>17</sup> 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

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

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

$$\theta_t^{CP} = \frac{\theta_0^B}{2} b_t^{CP}, \quad (5)$$

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.<sup>18</sup>

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

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

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<sup>16</sup>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.

<sup>17</sup>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.

<sup>18</sup>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.

$$N_t^C = \left[ \frac{w_t^C (C_t^C)^{-1/\zeta}}{\eta_N} \right]^{1/\psi_N}, \quad (7)$$

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

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

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

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

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

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

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

### 2.1.2 Global Bank

The balance sheet of the global bank is given by

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

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

$$V_t^C = V_t^{CR} + V_t^{CE}, \quad (15)$$

with  $V_t^C$  denoting total capital,  $V_t^{CR}$  required capital, and  $V_t^{CE}$  excess capital.<sup>19</sup>

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<sup>19</sup>Banks do not accumulate capital through retained earnings, in contrast to some contributions in the literature (see Appendix C). Barnea and Kim (2014) considered a more general setting in which capital is built up 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  $\sigma_t^{CK}$  denoting the risk weight on domestic investment loans, capital requirements are given by

$$V_t^{CR} = \rho_t^C \sigma_t^{CK} l_t^{CK}, \quad (16)$$

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,  $q_t^C \in (0, 1)$ :

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

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

$$\begin{aligned} \mathbb{E}_t J_{t+1}^{CB} = & q_t^C (1 + i_t^{CL}) l_t^{CK} + (1 - q_t^C) \kappa \mathbb{E}_t p_{t+1}^{CH} H_t^C \\ & + (1 + i_t^{CP}) l_t^{PC} - (1 + i_t^{CD}) d_t^C - (1 + i_t^{CR}) l_t^{CB} - (1 + i_t^{CV}) V_t^C \\ & - \gamma_V^C V_t^C + \frac{\gamma_{VV}^C (V_t^{CE})^{1-\phi_E^C}}{1 - \phi_E^C} - \Gamma(l_t^{CK}, l_t^{PC}), \end{aligned} \quad (18)$$

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.<sup>20</sup> 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

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

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.<sup>21</sup> This specification provides a simple way to account for imperfect substitutability, from the perspective of the global bank, between the two types of lending.

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  $\rho_t^C$ , the cost of bank capital  $i_t^{CV}$ , the risk weight  $\sigma_t^{CK}$ , and the gross return to lending abroad,  $(1 + i_t^{CP})l_t^{PC}$ , as given:<sup>22</sup>

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

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

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

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

<sup>20</sup>See Agénor and Jackson (2023) for a more detailed discussion.

<sup>21</sup>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  $\gamma$ .

<sup>22</sup>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  $\sigma_t^{CK}$ , 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.



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

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

where  $\eta_D$ ,  $\eta_L$  and  $\eta_P$  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,  $\gamma_V^C$ . 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,  $\rho_t^C$ , or the risk weight,  $\sigma_t^{CK}$ , 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  $\gamma_V^C$ , reduces excess capital, whereas an increase in the marginal benefit,  $\gamma_{VV}^C$ , 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  $\rho_t$ ), 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, required and excess capital holdings 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:

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

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'Araccia et al. (2014), for instance—to the probability of repayment.<sup>23</sup> 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

$$l_t^{CB} = m_t^{Cs}. \quad (25)$$

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

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

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

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<sup>23</sup>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,  $\rho_t^C$ , can be decomposed into a deterministic component,  $\rho^{CD}$ , and a cyclical component,  $\rho_t^{CC}$ :

$$\rho_t^C = \rho^{CD} + \rho_t^{CC}. \quad (27)$$

Thus, the component  $\rho^{CD}$  can be viewed as the minimum capital adequacy ratio imposed under the Basel arrangements, whereas the component  $\rho_t^{CC}$  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:

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

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, as documented by Agénor and Montiel (2015, Chapter 15), Taylor (2015), and Aldasoro et al. (2018).<sup>24</sup> Thus, in a sense, credit growth is an *operational target* for financial stability.

## 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),

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

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<sup>24</sup>There is also some 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  $\theta_t^{PC}$  is the intermediation premium faced by periphery households, defined analogously to (5):

$$\theta_t^{PC} = \frac{\theta_0^B}{2} b_t^{PC}. \quad (30)$$

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

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

whereas demand for core government bonds can be approximated by

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

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  $\theta_0^B \rightarrow 0$ . Thus, as discussed later, the impact of increased financial integration on the gains from coordination can be assessed by lowering  $\theta_0^B$ .

### 2.2.2 Commercial Banks

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

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

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.<sup>25</sup>

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

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<sup>25</sup>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.

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

$$\begin{aligned} V_t^{P,i} &= V_t^{PR,i} + V_t^{PE,i}, \\ V_t^{PR,i} &= \rho_t^P \sigma_t^P l_t^{PK,i} = \rho_t^P \left( \frac{q_t^{P,i}}{\tilde{q}^{P,i}} \right)^{-\phi_q^P} l_t^{PK,i}, \end{aligned} \quad (34)$$

where  $\rho_t^P$  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:

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

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

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

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

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

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:

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

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

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

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

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

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:

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

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

$$l_t^{PB} = m_t^{Ps}. \quad (43)$$

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):

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

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,  $\rho^{CD}$ , and a cyclical component,  $\rho_t^{PC}$ , of the capital ratio:

$$\rho_t^P = \rho^{PD} + \rho_t^{PC}, \quad (45)$$

with the latter defined in the base specification as

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

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, where the banks are incorporated. 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 (imposed initially to mitigate credit growth and risks to financial stability) at home. In doing so, reciprocity alleviates incentives for capital to flow across borders and may therefore also benefit the periphery.

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

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

where  $\sigma_t^P$  remains as defined earlier. Equations (39) now become

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

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

$$m_t^C = m_t^{Cs}, \quad (49)$$

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

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

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

$$H_t^C = \bar{H}^C, \quad (51)$$



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

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

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

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

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

$$CA_t^C = P_t^{CC}Y_t^{CP} - P_t^{PC}Y_t^{PC} + i_{t-1}^{CP}P_{t-1}^C l_{t-1}^{PC} + i_{t-1}^{PB}E_{t-1}^{-1}P_{t-1}^P b_{t-1}^{CP} - i_{t-1}^{CB}P_{t-1}^C b_{t-1}^{PC}, \quad (54)$$

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:<sup>26</sup>

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

The steady-state solution of the model, assuming a zero target inflation rate, is briefly described in Appendix D. Several of its key features are fundamentally similar to those described in Agénor et al. (2019), so we refer to that paper for a more detailed discussion.<sup>27</sup>

<sup>26</sup>Combining conditions (54) and (55) gives the foreign exchange market equilibrium condition, which is solved for the exchange rate.

<sup>27</sup>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 (2022), 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 were identified as 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 (2022), 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  $\Lambda$  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 relative weight of the disutility of working,  $\eta_N$ , 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 slightly higher value than 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  $\psi_N$  is equal to 1.4), in line again with the empirical evidence (see Dogan (2019), for instance).

The parameter for composite monetary assets,  $\eta_x$ , 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,  $\eta_H$ , we use the same value as in Notarpietro and Siviero (2015), 0.1. The share parameter in the index of money holdings,  $\nu$ , 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,  $\theta_0^B$ , 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,  $\Theta_V$ , 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),  $\Lambda_Y^C$ , 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,  $\eta_Y$ , 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,  $\theta^{CC}$ , and imported periphery goods among themselves,  $\theta^{PP}$ , 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,  $\alpha$ , is set at a fairly standard value, 0.35, for both regions. The adjustment cost parameter for prices of domestic intermediate goods,  $\phi_I$ , 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,  $\delta_K$ , 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,  $\Theta_K$ , 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,  $\kappa$ , 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  $\gamma_P$  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  $\eta_D$ ,  $\eta_L$  and  $\zeta_L$  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,  $\gamma_L$  and  $\gamma_K$ , are set at the same low value of 0.1, as in Agénor and Jackson (2022), whereas the parameter  $\gamma$ , which measures the strength of economies of scope in lending, is set at  $-0.1$  initially.

The degree of persistence in the core central bank's policy response,  $\chi$ , is set at 0.8, whereas the responses of the policy rate to inflation and output deviations,  $\varepsilon_1$  and  $\varepsilon_2$ , 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,  $\mu$ , 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  $\rho_\epsilon$ , 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  $\gamma_V$  is set at 0.01. The capital adequacy ratio,  $\rho$ , 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  $\gamma_{VV}$  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  $\phi_E^C$  and  $\phi_E^P$ , 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,  $\psi^G$ , 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 8.4 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).

Monetary policy spillovers from major advanced (core) economies have been identified in a number of studies as one of the key drivers of the global financial cycle and international capital flows. These studies include Bruno and Shin (2015), Temesvary et al. (2018), Buch et al. (2019), Albrizio et al. (2020), Brauning and Ivashina (2020), Miranda-Agrippino and Rey (2020), and Cesa-Bianchi and Sokol (2022). Others, including Morais et al. (2019), and Tillmann et al. (2019), have documented statistically significant effects of these flows on recipient countries.

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.<sup>28</sup>

To illustrate the model's properties, we therefore consider an expansionary monetary policy shock in the core, with and without a regulatory response in that region. 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).

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<sup>28</sup>Some studies have focused on the spillover effects of US Quantitative easing. See, for instance, Kolasa and Wesolowski (2020) and Bhattarai et al. (2021).

## 5.1 Constant Capital Adequacy 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 refinance rate 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 deposits available to fund domestic lending operations—liquidity increases. To maintain money market equilibrium, the nominal bond rate must fall. This, combined with an increase in inflation, leads to an unambiguous reduction in the expected real bond rate, which induces households to spend more today. The increase in consumption is associated with a higher demand for housing, which raises their real price. In turn, higher house prices improve 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 expansion in investment.

Required bank capital increases in the core, both because loans expand and because the risk weight rises, due to the reduction in the repayment probability. Given that capital adequacy ratios in both regions ( $\rho_t^C$  and  $\rho_t^P$ ) remain constant in this experiment, the increase in the risk weight—and thus the cost of issuing bank capital to meet regulatory 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 increases. The leverage ratio—the ratio of loans to unweighted regulatory bank capital,  $l_t^{CK}/(\rho_t^C l_t^{CK} + V_t^{CE})$ , which differs from the inverse of the commonly-defined bank capital ratio,  $V_t^C/(\sigma_t^{CK} l_t^{CK})$ —rises as well.<sup>29</sup> The spread  $i_t^{CV} - i_t^{CB}$ , or equivalently the excess return on bank capital, must also increase for households to alter the composition of their portfolios and hold a greater amount of bank-issued liabilities.

Cross-border spillovers occur through several channels. First, the fall in asset re-

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<sup>29</sup>Note that in the experiment considered both the leverage ratio and the bank capital ratio vary, even though  $\rho_t^C$  and  $\rho_t^P$  are constant, because in the model banks also hold excess capital.

turns in the core induces periphery households to reduce their holdings of core government bonds. Second, through the bank portfolio channel, lending to periphery banks by the global bank rises (see Figure 2). The increase in lending at home lowers the global bank's marginal operating costs, which mitigates the initial drop in the loan rate there and reduces the cost at which it lends to its affiliates. As a result, the demand for loans by periphery banks increases. The capital inflow to the periphery translates into a nominal and real appreciation.

Third, the appreciation puts downward pressure on inflation in the periphery. The central bank's response is to reduce its policy rate, which in turn leads to a drop in the loan rate and an expansion in aggregate demand. The bond rate falls as well (through the same mechanism as described earlier) 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. This mitigates the initial drop in the loan rate and the expansion in credit. Consequently, as in the core, the risk weight rises, which leads (combined with the increase in lending) to higher bank capital. However, there is no substitution between required and excess capital, as the differential between the marginal cost of issuing bank capital 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. Finally, the appreciation also lowers the price of intermediate goods for the periphery, thereby stimulating the region's imports. The opposite occurs for the core. However, because of home bias in production, this substitution effect is muted in both regions.

The dotted lines in Figure 2 show what happens when the 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 for the periphery. In particular, lending by the global bank increases substantially more, 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.



## 5.2 Core Activism

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  $\chi_2^C = 50$ .<sup>30</sup> 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 bank capital, and thus the leverage ratio, and the core loan rate. 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 expansion in lending. 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, and as a result the leverage ratio falls. But although the increase in domestic lending is weaker, the refinance rate drops by more as a result of the smaller increase in cyclical output. The result is a larger drop in the interest rate on loans to periphery banks and therefore, compared to no activism, higher lending to these banks and a larger capital inflow in that region initially. Investment in the periphery also increases by more initially, and so does the leverage ratio. At the same time, as shown in Figure 3, the policy helps to stabilize output and consumption in both regions.

To characterize further the magnitude of regulatory spillovers, we computed conditional mean values of lending by the global bank, for a range of values of  $\gamma$ , under both no activism and core prudential activism. The results are displayed in Figure 4. As expected, the stronger economies of scope are (the larger  $|\gamma|$  is), the larger the increase in lending to the periphery—regardless of whether the core regulator reacts or not. Thus, financial spillovers (in the form of increased global lending) are indeed an equilibrium response to the shock under consideration. In addition, for any given value of  $|\gamma|$ , spillovers through global lending are stronger when the core regulator reacts. In what follows, given our focus on activist policy regimes, we will refer to  $|\gamma|$  as a measure of the strength of regulatory spillovers.

These results (both with constant and endogenous capital ratios) illustrate fairly well how countercyclical regulatory responses, implemented in a core jurisdiction where

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<sup>30</sup>This relatively high value of  $\chi_2^C$  is related to the fact that, in this experiment, there is implicitly no cost to instrument manipulation. This issue is discussed in the next section.

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. Franch et al. (2021) 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.

## 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.

Regulator  $j$ ’s objective function takes the form

$$W_t^j = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ \varkappa_U^j u_{t+s}^j - \varkappa_L^j \left( \frac{l_{t+s}^{jK}}{Y_{t+s}^j} - \frac{\tilde{l}^{jK}}{\tilde{Y}^j} \right)^2 - \varkappa_I^j (\rho_{t+s}^{jC} - \rho_{t+s-1}^{jC})^2 \right\}, \quad (56)$$

where  $u_t^j$  is the period utility function defined in (1),  $\varkappa_U^j = 0$  or  $1$ ,  $\varkappa_L^j \in (0, 1)$  measures the degree of bias towards financial stability in policy preferences, as in Bodenstein et

al. (2019) and Agénor and Jackson (2022), and  $\varkappa_t^j > 0$  is a parameter that captures the cost associated with changes in capital ratios. Thus, the objective function that the regulator seeks to maximize depends not only on household utility but also on financial stability concerns, as measured by fluctuations in the credit-to-output ratio. The standard welfare maximization approach corresponds to  $\varkappa_U^j = 1$  and  $\varkappa_L^j = 0$ . The opposite case,  $\varkappa_U^j = 0$  and  $\varkappa_L^j = 1$ , corresponds to the two-stage welfare maximization approach defined in Agénor and Flamini (2022), in which the objective function is a loss function defined in terms of financial stability only (as a result of an institutional mandate) but with policy performance evaluated in terms of household welfare. In addition to these polar cases, policy performance can be assessed by setting  $\varkappa_U^j = 1$  and varying  $\varkappa_L^j$  between 0 and 1, thereby allowing us to determine how strong the financial stability objective must be—short of being the only, or dominant, objective—for reciprocity to be preferable to other policy regimes.

## 6.1 Alternative Policy Regimes

We consider four alternative policy regimes. Under *core activism only*, the regulator in the core sets its capital buffer so as to maximize its own objective function, whereas the regulator in the periphery does not react. This is the base scenario analyzed also by Rubio (2020). Under *independent policymaking* (or Nash), each regulator determines the optimal value of the response parameter  $\chi_2^j$  in their policy rules, so that  $\chi_2^{C,N} = \arg \max W_t^C |_{\chi_2^P = \chi_2^{P,N}}$  and  $\chi_2^{P,N} = \arg \max W_t^P |_{\chi_2^C = \chi_2^{C,N}}$ . Under *reciprocity*, the regulator in the core sets the response parameter in its policy rule so as to maximize its own objective function only, whereas the regulator in the periphery imposes the same value of the countercyclical capital buffer in its jurisdiction; thus,  $\chi_2^{C,R} = \arg \max W_t^C$  and  $\rho_t^{PC} = \rho_t^{CC}, \forall t$ . Under (full) *coordination*, regulators 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; thus,  $\chi_2^{C,O}, \chi_2^{P,O} = \arg \max [nW_t^C + (1-n)W_t^P]$ , where  $n \in (0, 1)$ .<sup>31</sup>

Policies are computed under commitment and welfare gains are assessed in terms of consumption-equivalent variations. Second-order approximations to both the household utility function and the model, conditional on the deterministic steady state, are

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<sup>31</sup>Given the focus of this paper on reciprocity arrangements, we do not elaborate on the comparison between these regimes and no activism, and between (full) coordination and Nash.

used (see Appendix E). To ensure consistency, the term that captures bias towards financial stability is used to solve for optimal responses, not to compute welfare gains.

## 6.2 Results

Table 3 shows the results for the standard welfare approach ( $\varkappa_L^j = 0$ ) and three values of the bias parameter ( $\varkappa_L^j = 0.2, 0.5, 1.0$ ), and for three values of  $\gamma$ , whose absolute value again measures the strength of regulatory spillovers,  $-0.01$ ,  $-0.1$  and  $-0.2$ . The instrument manipulation cost  $\varkappa_I^j$  is set uniformly to a low value of 0.1.<sup>32</sup> To facilitate comparisons, the degree of persistence in the regulatory policy rules,  $\chi_1^j$ , is kept at 0.1 throughout.<sup>33</sup> A grid step of 0.001 points is used to search for the optimal values of  $\chi_2^j$ .

The first result is that under all regimes, and regardless of the weight attached to financial stability, the core's policy response becomes more aggressive as the strength of regulatory spillovers increases. However, under the standard welfare approach ( $\varkappa_L^j = 0$ , Panel A), the periphery is better off under reciprocity, compared to the core acting alone, only if  $|\gamma|$  is low. As the strength of spillovers (as measured by  $|\gamma|$ ) increases, reciprocity is Pareto-improving—all parties are better off—only if regulators put greater emphasis on financial stability, that is, if  $\varkappa_L^j$  is relatively high (Panel D). This is shown more clearly in Figure 5, which displays combinations of  $\varkappa_L^j$  and  $\gamma$  for which reciprocity is Pareto-improving relative to the core acting alone. When  $\varkappa_L^j = 0$  (as in Panel A) this is the case when  $\gamma = -0.04$ . But as  $|\gamma|$  increases, so must the weight attached to financial stability,  $\varkappa_L^j$ , for welfare gains to be positive for all parties. This is the case, in particular, with equal weights ( $\varkappa_U^j = \varkappa_L^j = 1$ , Panel D). This result also holds when  $\varkappa_U^j = 0$  and  $\varkappa_L^j = 1$ , when only financial stability matters.

The second result is that under the standard welfare approach, the periphery is always worse off under reciprocity compared to Nash. However, as illustrated in Figure 6, if  $|\gamma|$  is not too large (below 0.08) and if financial stability matters sufficiently for the regulator ( $\varkappa_L^j \geq 0.7$ ), reciprocity can be Pareto-improving relative to Nash. Intuitively, even though the core and the world economy may benefit, the loss for the periphery

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<sup>32</sup>Sensitivity analysis is reported in Appendix F. In general, the optimal response parameters vary inversely with the magnitude of the instrument cost. However, what matters here is how they vary *across* policy regimes, for a given cost. The *existence* of a cost is also important, as discussed later on.

<sup>33</sup>Using uniformly higher persistence parameters would affect the values of  $\chi_2^j$  across the board but would not have any impact on the relative rankings of policy regimes.

resulting from partial coordination increases with stronger regulatory spillovers. Thus, if  $|\gamma|$  is too high, there are no Pareto-improving outcomes, regardless of the value of  $\varkappa_L^j$ —including the case where regulators are only concerned with financial stability.

The third result is that the periphery is generally worse off under coordination, relative to reciprocity. The reason is that coordination requires the periphery to react more aggressively as  $|\gamma|$  increases; thus, joint policymaking involves some degree of *burden sharing*, a situation where the regulator in the core reacts either less or the same, but the regulator in the periphery reacts more. As a result, spillback effects to the core are substantially mitigated. But although the core and the world are generally better off, the periphery is worse off because it incurs a higher instrument manipulation cost.

A broader implication of our results is the extent to which instrument costs matter. With no manipulation cost, it is optimal for the core regulator to fully stabilize credit fluctuations at home ( $\chi_2^C \rightarrow \infty$ ); thus, there is no rationale for coordination. This is consistent with Korinek’s (2016) analysis, as alluded to earlier. At the same time, while necessary, a positive instrument cost is not sufficient for coordination to be Pareto-improving.<sup>34</sup> The magnitude of financial frictions (namely, the degree of cost complementarity for the global bank) and the degree to which regulators care about financial stability, also play a crucial role.

### 6.3 Sensitivity Analysis

To assess the robustness of these results, sensitivity analysis was conducted with respect to the specification of the capital regime and a number of key parameters. Experiments involved exogenous excess capital, the cost of instrument manipulation, the relative size of each region ( $n$ ), the degree of trade and financial integration, and a stock specification of bank capital. For lack of space, these results are discussed in detail in Appendix F. While the optimal values of the countercyclical response parameters, and the magnitude of welfare gains across regimes, varied somewhat, the key results highlighted earlier (and the role of parameters  $|\gamma|$  and  $\varkappa_L^j$ ) remained fundamentally the same. This is the case, in particular, when  $n$  is set equal to 0.5, to capture the principle of “one country, one vote” under coordination, or when the degree of financial

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<sup>34</sup>Note also that, in our setting, the use of simple policy rules to maximize the objective function (D29) may constrain the attainable allocations below the Pareto frontier.

integration is increased, by reducing the cost parameter  $\theta_0^B$  from 0.2 to 0.1 and 0.01. A notable new result is that under greater trade integration, and under the standard welfare approach ( $\varkappa_U^j = 1$ ,  $\varkappa_L^j = 0$ ), reciprocity may also be Pareto-improving relative to Nash, if regulatory spillovers are not too strong. Intuitively, tighter trade links between regions enhance the potential for spillovers and spillbacks which, even under partial coordination, benefit all parties.

## 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. Among the most important ones are our characterization of the link between the degree of substitutability between domestic and foreign loans by the global bank (which is captured through a single cost parameter, related to the degree of economies of scope in lending), cross-border regulatory leakages, and capital flows between regions. Equally important, the results show that 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.

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 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 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)). These are actually the type of leakages that Basel III’s Principle of Reciprocity is designed to address.<sup>35</sup> 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.<sup>36</sup>

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 may fail in achieving their objective to smooth the credit cycle. To prevent these 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 is how knowledge gains, through information sharing, could improve

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<sup>35</sup>Indeed, as noted in the introduction, under this principle foreign supervisors must apply (at least) the same additional capital buffers imposed by the host supervisor to their banks’ lending to the host country. Dehaj and Malherbe (2022) provided a theoretical analysis of this regime.

<sup>36</sup>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.

the decision process that underlies policy coordination. These gains may be significant when, as noted by Engel (2016) in the context of monetary policy, model uncertainty generates disagreements among policymakers acting independently.<sup>37</sup> Greater information sharing may in turn promote convergence of views and improve consensus around policy choices, possibly increasing the gains from coordination.

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<sup>37</sup>In practice, to promote 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.



## 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),  $Y_t^{PC}$ :

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

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

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

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:

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

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

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

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

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

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

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

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

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

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,  $K_{jt}^C$ :

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

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.<sup>38</sup> Cost minimization yields the capital-labor ratio and the unit real marginal cost,  $mc_t^C$ , as

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

$$mc_t^C = \frac{(w_t^C)^{1-\alpha} (r_t^{CK})^\alpha}{\alpha^\alpha (1-\alpha)^{1-\alpha}}. \quad (\text{A10})$$

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

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

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

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

where  $\phi_I \geq 0$  is an adjustment cost parameter.

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

$$(1 - \theta^{CC}) \left( \frac{P_{jt}^{CC}}{P_t^{CC}} \right)^{-\theta^{CC}} \frac{1}{P_t^{CC}} + \theta^{CC} \left( \frac{P_{jt}^{CC}}{P_t^{CC}} \right)^{-\theta^{CC}-1} \frac{mc_t^C}{P_t^{CC}} \quad (\text{A13})$$

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

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<sup>38</sup>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.<sup>39</sup>

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

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  $P_t^{CI} = P_t^{CC} (Y_t^{CC} + E_t Y_t^{CP}) / (Y_{jt}^{CC} + Y_{jt}^{CP})$ .

### 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:

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

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  $q_t^{CF} (1 + i_t^{CL}) l_t^{CK} + (1 - q_t^{CF}) \kappa \mathbb{E}_t p_{t+1}^{PH} \bar{H}^P$ ,

<sup>39</sup>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  $z_t = E_t P_t^C / P_t^P$ , 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<sup>40</sup>

$$\begin{aligned} \mathbb{E}_t r_{t+1}^{CK} &\simeq q_t^C (1 + i_t^{CL}) \mathbb{E}_t \left\{ \left[ 1 + \Theta_K \left( \frac{K_{t+1}^C}{K_t^C} - 1 \right) \right] \left( \frac{1 + i_t^{CB}}{1 + \pi_{t+1}^C} \right) \right\} \\ &- \mathbb{E}_t \left[ q_{t+1}^C (1 + i_{t+1}^{CL}) \left\{ 1 - \delta_K + \frac{\Theta_K}{2} \left[ \left( \frac{K_{t+2}^C}{K_{t+1}^C} \right)^2 - 1 \right] \right\} \right]. \end{aligned} \quad (\text{A19})$$

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  $\zeta^L > 1$ :

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

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

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

where  $i_t^{PL,i}$  is the rate on the loan extended by bank  $i$  and  $1 + i_t^{PL} = \left[ \int_0^1 (1 + i_t^{PL,i})^{1 - \zeta^L} di \right]^{1 / (1 - \zeta^L)}$  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<sup>41</sup>

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

where  $b_t^C = b_t^{CC} + b_t^{PC}$  is the real stock of riskless one-period bonds held by core ( $b_t^{CC}$ ) 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:

$$G_t^C = \psi^G Y_t^C. \quad (\text{A22})$$

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.

<sup>40</sup>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.

<sup>41</sup>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:

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

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

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

and analogously for the periphery.

The equilibrium condition of the housing market for the core region is

$$H_t^C = \bar{H}^C, \quad (\text{A25})$$

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

### Current Account

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

$$\begin{aligned} CA_t^P &= P_t^{PP} Y_t^{PC} - P_t^{CP} Y_t^{CP} \\ &\quad - i_{t-1}^{CP} E_{t-1} P_{t-1}^C l_{t-1}^{PC} - i_{t-1}^{PB} P_{t-1}^P b_{t-1}^{CP} + i_{t-1}^C E_{t-1} P_{t-1}^C b_{t-1}^{PC}, \end{aligned} \quad (\text{A26})$$

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 (A26) 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),

$$\begin{aligned} CA_t^P &= E_t P_t^C b_t^{PC} - E_{t-1} P_{t-1}^C b_{t-1}^{PC} \\ &\quad - (E_t P_t^C l_t^{PC} - E_{t-1} P_{t-1}^C l_{t-1}^{PC}) - (P_t^P b_t^{CP} - P_{t-1}^P b_{t-1}^{CP}). \end{aligned} \quad (\text{A27})$$

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Table 1  
Benchmark Parameterization: Key Parameter Values

Parameter	Description	MAEs	SMICs
Households			
$\Lambda$	Discount factor	0.95	0.95
$\varsigma$	Elasticity of intertemporal substitution	0.5	0.5
$\eta_N$	Relative weight of the disutility of working	25.0	25.0
$\psi_N$	Inverse of Frisch elasticity of labor supply	1.4	1.4
$\eta_x$	Preference parameter for money holdings	0.001	0.001
$\eta_H$	Preference parameter for housing	0.1	0.1
$\nu$	Share parameter in index of money holdings	0.2	0.2
$\theta_0^B$	Intermediation cost parameter, world capital markets	0.2	0.2
$\Theta_V^j$	Cost parameter, holdings of bank capital	2.64	1.83
Producers			
$\Lambda_Y^j$	Share of own-region IG goods in final output	0.8	0.6
$\eta_Y$	Elasticity of substitution, baskets of interm. goods	1.5	1.5
$\theta^{jj}$	Elasticity of own-region demand, intermediate goods	10.0	10.0
$\alpha$	Share of capital, intermediate goods production	0.35	0.35
$\phi_I$	Adjustment cost parameter, intermediate goods prices	150.0	150.0
$\delta_K$	Depreciation rate of capital	0.015	0.015
$\Theta_K$	Capital adjustment cost parameter, investment	10	10
Banks			
$\kappa^j$	Effective collateral-loan ratio	0.4	0.2
$\psi_1^j$	Elasticity of repayment probability, coll.-loan ratio	0.05	0.1
$\psi_2^j$	Elasticity of repayment probability, cyclical output	0.9	0.9
$\eta_D$	Elasticity of deposit supply by households	2.5	—
$\eta_L, \zeta_L$	Elasticity of loan demand by capital producers	4.5	4.5
$\eta_P$	Elasticity of demand for global bank loans by periphery	—	4.5
$\gamma_K$	Cost parameter, core cost function	0.1	—
$\gamma_L$	Cost parameter, core cost function	0.1	—
$\gamma$	Cost parameter, core joint cost function	−0.1	—
$\gamma_V^j$	Cost parameter, bank excess capital holdings	0.01	0.01
$\gamma_{VV}^j$	Cost parameter, bank excess capital holdings	0.001	0.001
$\phi_E^j$	Sensitivity parameter, marg. benefit of excess capital	0.5	0.45
$\gamma_P$	Cost parameter, demand for global bank loans	—	0.15
$\phi_q^j$	Sensitivity of risk weight to repayment probability	0.05	0.05
Policymakers			
$\mu^j$	Required reserve ratio	—	0.2
$\chi^j$	Degree of interest rate smoothing	0.8	0.0
$\varepsilon_1^j$	Response of policy rate to inflation deviations	1.7	2.0
$\varepsilon_2^j$	Response of policy rate to output deviations	0.1	1.0
$\psi^G$	Share of government spending in final output	0.2	0.22
Shock			
$\rho_\epsilon$	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
$\sigma^{jK}$	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
$\rho^{jC}$	Countercyclical capital ratio	0.0	0.0

Table 3  
Optimal Policy Responses and Welfare Gains  
under Alternative Policy Regimes<sup>1</sup>

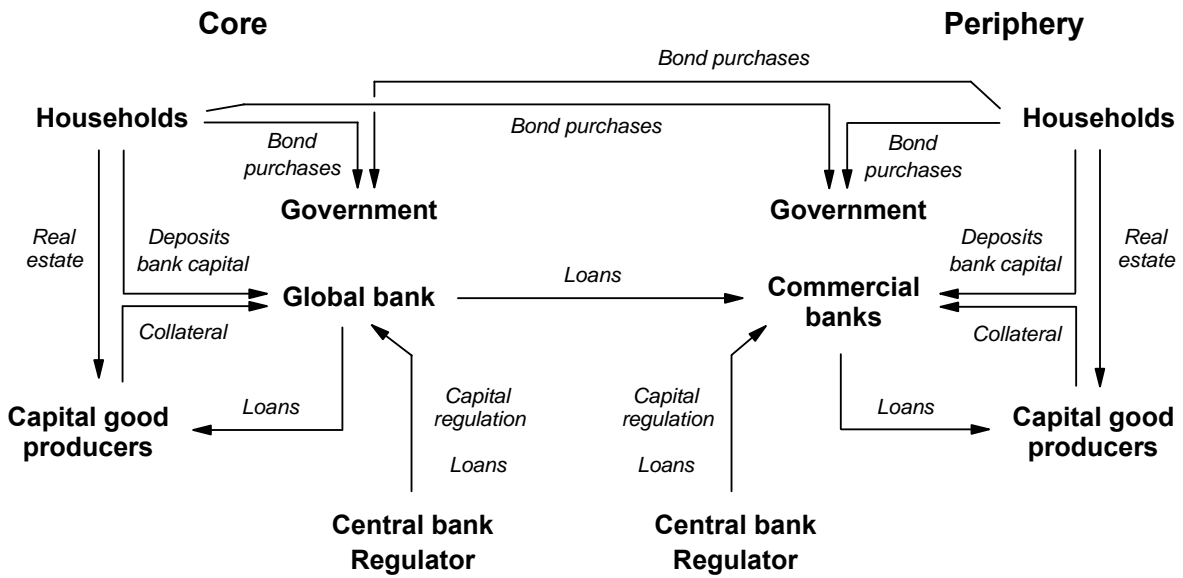
	$\gamma = -0.01$	$\gamma = -0.1$	$\gamma = -0.2$
Panel A			
Standard Welfare Objective, $\varkappa_L^j = 0.0$			
Core activism: Optimal $\chi_2^C$	0.020	0.022	0.025
Reciprocity: Optimal $\chi_2^C$ ( $\rho_t^{PC} = \rho_t^{CC}$ )	0.020	0.023	0.027
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	0.020, 0.014	0.022, 0.008	0.025, 0.006
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	0.020, 0.000	0.022, 0.049	0.025, 0.051
Gain from reciprocity, rel. to core activism			
Core	-0.0008	0.0015	0.0043
Periphery	0.0025	-0.0196	-0.2142
World	-0.0007	0.0014	0.0036
Gain from reciprocity, rel. to Nash			
Core	-0.0002	0.0010	0.0033
Periphery	-0.0004	-0.0282	-0.2303
World	-0.0002	0.0008	0.0025
Gain from coordination, rel. to reciprocity			
Core	0.0008	0.0019	0.0042
Periphery	-0.0025	-0.1729	-0.5424
World	0.0007	0.0006	0.0012
Panel B			
Biased policy preferences, $\varkappa_L^j = 0.2$			
Core activism: Optimal $\chi_2^C$	0.018	0.020	0.022
Reciprocity: Optimal $\chi_2^C$ ( $\rho_t^{PC} = \rho_t^{CC}$ )	0.018	0.020	0.023
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	0.018, 0.013	0.020, 0.008	0.022, 0.006
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	0.018, 0.000	0.020, 0.040	0.022, 0.043
Gain from reciprocity, rel. to core activism			
Core	-0.0007	0.0014	0.0041
Periphery	0.0028	-0.0122	-0.1588
World	-0.0006	0.0013	0.0036
Gain from reciprocity, rel. to Nash			
Core	-0.0002	0.0008	0.0031
Periphery	-0.0001	-0.0210	-0.1772
World	-0.0002	0.0007	0.0025
Gain from coordination, rel. to reciprocity			
Core	0.0007	0.0014	0.0031
Periphery	-0.0028	-0.1122	-0.4479
World	0.0006	0.0006	0.0011

Table 3 (concluded)  
Optimal Policy Responses and Welfare Gains  
under Alternative Policy Regimes<sup>1</sup>

	$\gamma = -0.01$	$\gamma = -0.1$	$\gamma = -0.2$
Panel C			
Biased policy preferences, $\mathcal{X}_L^j = 0.5$			
Core activism: Optimal $\chi_2^C$	0.016	0.016	0.017
Reciprocity: Optimal $\chi_2^C$ ( $\rho_t^{PC} = \rho_t^{CC}$ )	0.016	0.016	0.018
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	0.016, 0.011	0.016, 0.007	0.017, 0.006
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	0.016, 0.000	0.016, 0.028	0.017, 0.030
Gain from reciprocity, rel. to core activism			
Core	-0.0006	0.0011	0.0037
Periphery	0.0029	-0.0006	-0.0729
World	-0.0006	0.0011	0.0035
Gain from reciprocity, rel. to Nash			
Core	-0.0002	0.0006	0.0026
Periphery	0.0001	-0.0094	-0.0953
World	-0.0002	0.0006	0.0024
Gain from coordination, rel. to reciprocity			
Core	0.0006	0.0008	0.0014
Periphery	-0.0029	-0.0465	-0.2492
World	0.0006	0.0005	0.0005
Panel D			
Biased policy preferences, $\mathcal{X}_L^j = 1.0$			
Core activism: Optimal $\chi_2^C$	0.011	0.010	0.010
Reciprocity: Optimal $\chi_2^C$ ( $\rho_t^{PC} = \rho_t^{CC}$ )	0.011	0.010	0.010
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	0.011, 0.008	0.010, 0.006	0.010, 0.006
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	0.011, 0.001	0.010, 0.007	0.010, 0.010
Gain from reciprocity, rel. to core activism			
Core	-0.0004	0.0007	0.0017
Periphery	0.0028	0.0085	0.0141
World	-0.0004	0.0007	0.0017
Gain from reciprocity, rel. to Nash			
Core	-0.0001	0.0003	0.0007
Periphery	0.0004	-0.0001	-0.0126
World	-0.0001	0.0003	0.0006
Gain from coordination, rel. to reciprocity			
Core	0.0004	-0.0002	0.0000
Periphery	-0.0024	0.0005	0.0000
World	0.0003	-0.0002	0.0000

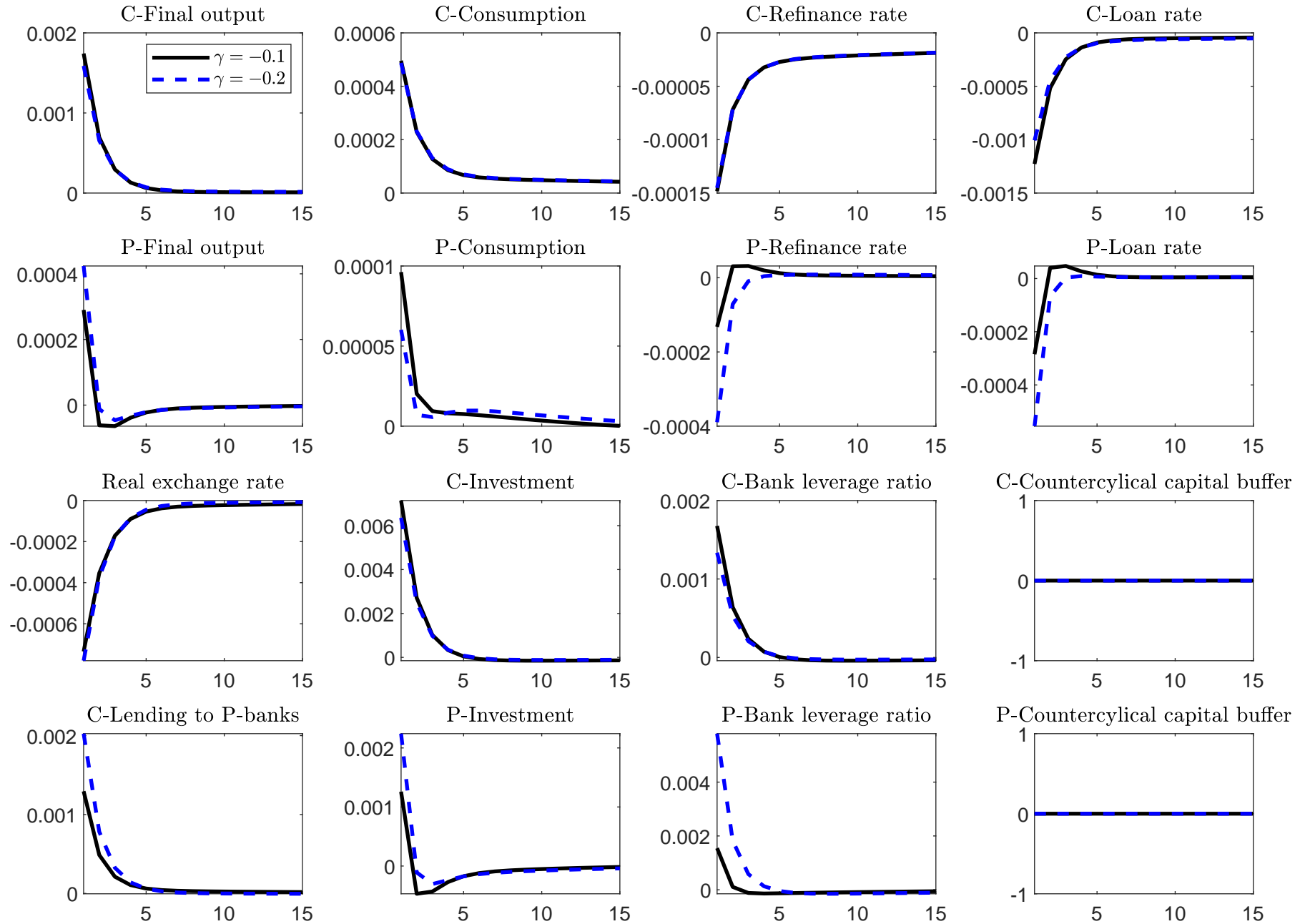
<sup>1</sup>Welfare gains are assessed in terms of consumption-equivalent variations. Specifically, the gain from Regime B relative to Regime A is measured in terms of the fraction of the consumption stream under regime A that would leave households in both regions indifferent between living in a world where Regime B is in place, and a world where Regime A prevails. A positive value implies a welfare improvement. In all panels, the weight  $\mathcal{X}_U^j$  is 1 and the instrument cost is  $\mathcal{X}_I^j = 0.1$ .

Figure 1  
 Core-Periphery Model with Capital Regulation:  
 Main Interactions and Financial Flows





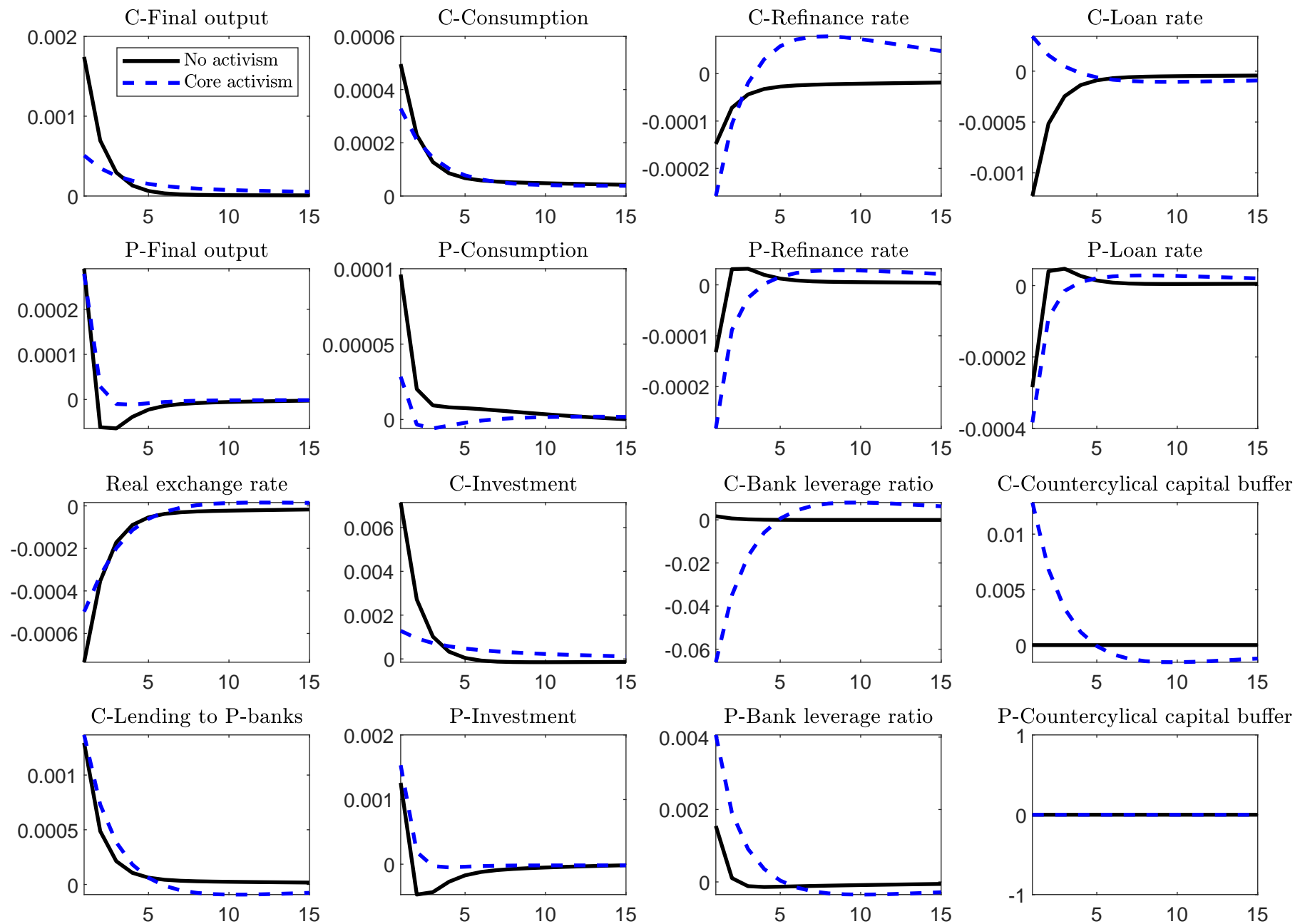
**Figure 2**  
**Transitory Negative Shock to Core Refinance Rate**  
 (Deviations from steady state)



Notes: The responses of consumption, investment, final output, core lending to periphery banks, and the real exchange rate are expressed as percent deviations from their steady-state values. The responses of the loan rate, the refinance rate, the leverage ratio, and the countercyclical capital buffer are expressed as absolute deviations (or percentage points) from their steady-state values.

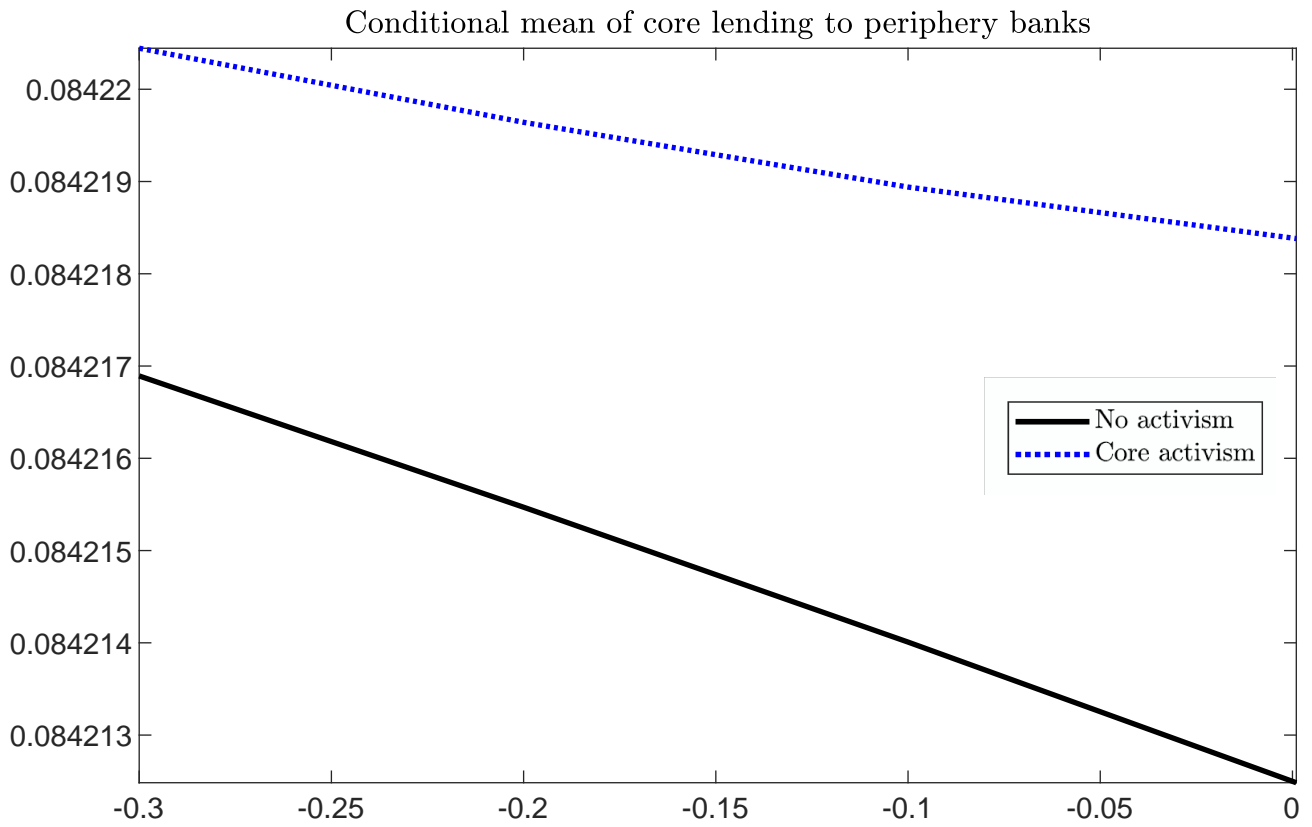
**Figure 3****Transitory Negative Shock to Core Refinance Rate, with Core Prudential Response**

(Deviations from steady state)

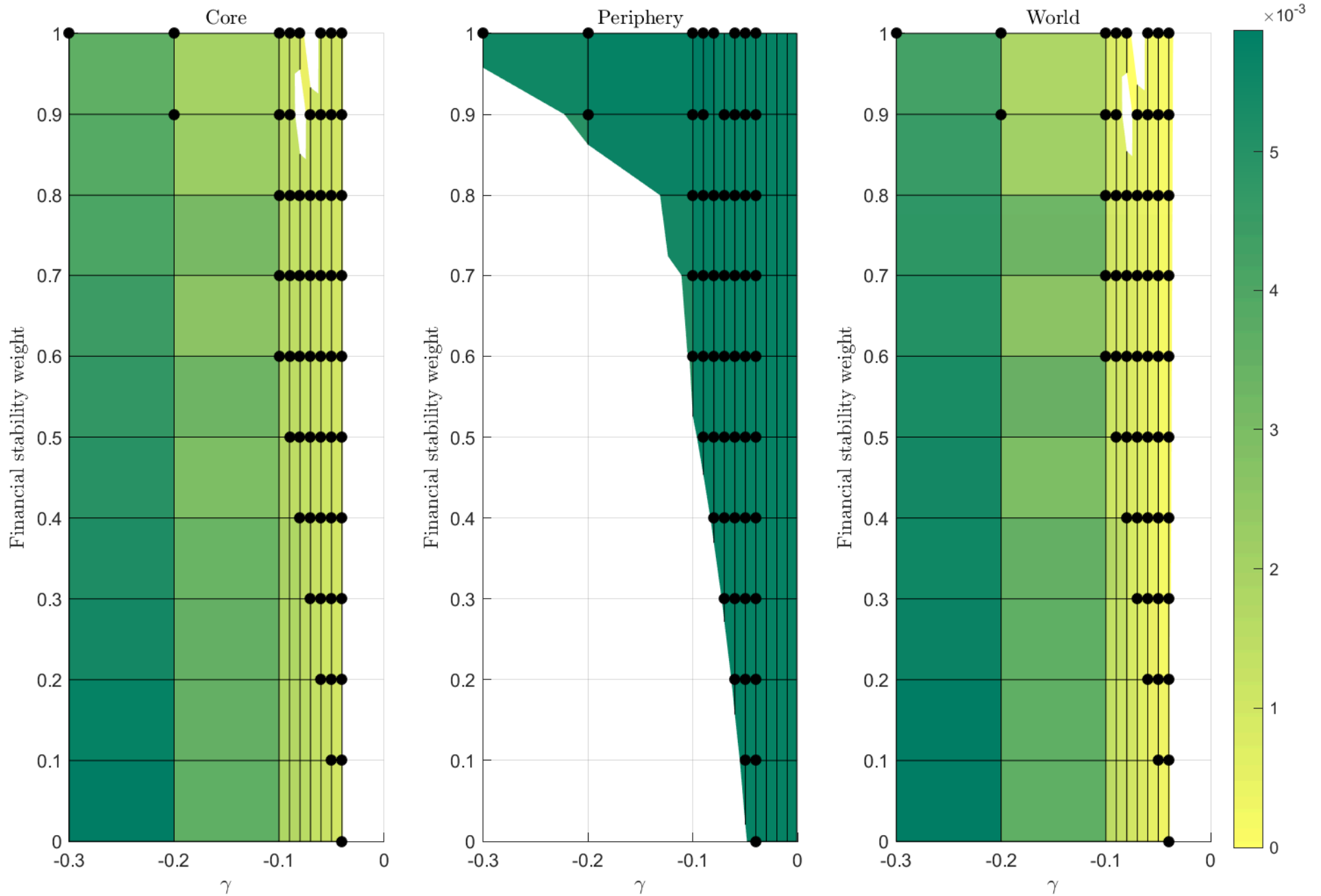


Notes: See notes to Fig. 2. "No activism" corresponds to the continuous line in Fig. 2, whereas "Core activism" refers to the endogenous response by the core regulator only, through its countercyclical capital rule. The response parameter in the rule is set at 50 and persistence at 0.1.

**Figure 4**  
**Degree of Economies of Scope and Magnitude of Regulatory Spillovers**  
(Asymptotic conditional means)

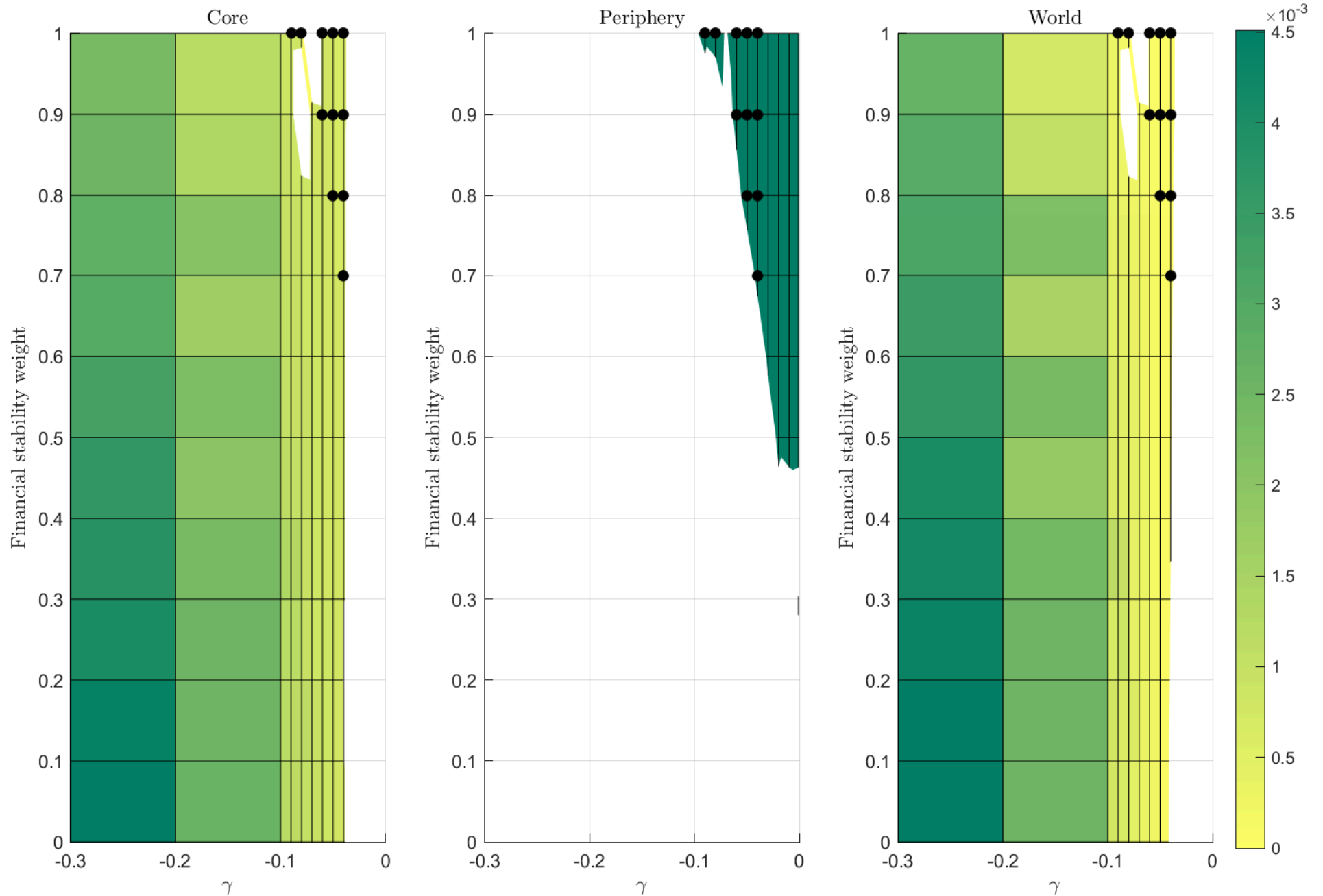


**Figure 5**  
**Welfare Gains of Reciprocity vs. Core Activism Only**  
**as a Function of the Strength of Regulatory Spillovers and Weight of Financial Stability**



Note: Parameter combinations identified by markers are those for which reciprocity makes all parties better off, relative to core activism only. White zones in each panel correspond to combinations which generate welfare losses for the relevant party.

**Figure 6**  
**Welfare Gains of Reciprocity vs. Nash**  
**as a Function of the Strength of Regulatory Spillovers and Weight of Financial Stability**



Note: Parameter combinations identified by markers are those for which reciprocity makes all parties better off, relative to the Nash equilibrium. White zones in each panel correspond to combinations which generate welfare losses for the relevant party.

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