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Global Banking, Financial Spillovers, and Macroprudential Policy Coordination

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Abstract

The transmission of financial shocks and the gains from international macroprudential policy coordination are studied in a two-region, core-periphery model with imperfect financial integration and cross-border banking. Financial frictions occur at two levels: between firms and banks in each region, and between periphery banks and a global bank in the core. Numerical experiments show that the model replicates the stylized facts associated with global banking shocks, with respect to output, credit, house prices, and real exchange rate fluctuations in recipient countries, as documented in the empirical literature. Welfare gains from macroprudential policy coordination are positive—and significant, provided that the cost of instrument manipulation is not too large—if the degree of international financial integration, which raises the scope for spillback effects from the periphery to the core, is sufficiently high.

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1 Introduction

There is growing evidence that international financial spillovers have become a two-way street—they occur not only from the major advanced economies to the rest of the world, as in decades past, but also, and increasingly, from a group of large middle-income countries to advanced economies.[1] Indeed, these countries are now more interconnected financially than ever before. As documented by Cerutti and Zhou (2017), McCauley et al. (2017), and World Bank (2018), this process has been partly the result of banking globalization, which has taken the form of growing networks of foreign branches and subsidiaries centered on global parent banks located in advanced economies—despite the retrenchment (especially of non-major European banks) observed in the immediate aftermath of the global financial crisis. Studies such as Bruno and Shin (2015), Temesvary et al. (2018), Avdjiev et al. (2018), Cesa-Bianchi et al. (2018), and Buch et al. (2019), have found robust evidence that changes in monetary policy in the United States—in large part due to the role of the US dollar as a global funding currency—have a strong impact on cross-border lending by US banks, consistent with the existence of an international bank lending channel. Similar results have been established by Gräb and Żochowski (2017) in the case of euro area banks, in response to monetary policy accommodation by the European Central Bank.

The fact that cross-border spillovers operate in both directions and have become more significant does not *prima facie* create a case for greater coordination of policies across countries. Indeed, spillovers (financial or otherwise) do not necessarily reduce global welfare, and coordination is not always needed to improve welfare. In a global recession, for instance, uncoordinated expansionary fiscal policies in a core group of countries with small budget deficits and low public debt ratios can benefit all countries. But because financial markets are prone to amplification effects, and because business and financial cycles remain imperfectly synchronized across countries—even when they share a common currency, as in the euro area—this new environment creates the potential for shocks in one jurisdiction to be magnified and transmitted to others through short-term capital flows, with the possibility that these flows may exacerbate financial instability in both source and recipient countries.

These risks have led policymakers in some large middle-income countries to issue pleas for policymakers in major advanced economies to go beyond their institutional mandate—which normally requires them to take account of the external impact of their policies only insofar

[1] See International Monetary Fund (2016) for a formal empirical analysis and Agénor and Pereira da Silva (2021) for a detailed discussion of the recent evidence on the international spillover effects associated with financial shocks.

as they feed back onto their own economies—and internalize the cross-border spillover effects associated with their monetary policy decisions and their possible adverse consequences (see Mishra and Rajan (2016)).[2] Some observers have gone further and have argued in favour of greater coordination of macroprudential policies (both in their structural and countercyclical components) across countries, to mitigate the adverse effects of cross-border capital flows and promote global financial stability.

The foregoing discussion suggests that the analytical case for macroprudential policy coordination across countries rests fundamentally on whether financial risks represent negative externalities that tend to increase with the magnitude of spillovers and spillbacks, and the extent to which business and financial cycles are synchronized across countries. Conversely, independent national macroprudential policies that help to contain systemic risks in one's own country may help to promote financial stability elsewhere by reducing the scope for negative trade and financial spillovers, therefore creating positive externalities and making the need to cooperate less compelling. Thus, as noted by Engel (2016), coordination is desirable mainly when it enables countries to improve their policy trade-offs.[3] At the same time, to make an *empirical* case for international coordination of macroprudential policies it must be shown that there are potentially significant gains for participating countries, and the world economy as a whole, from doing so. Indeed, these gains must be sufficiently large quantitatively to mitigate incentives to renege and ensure that countries remain voluntarily in a cooperative agreement.

Yet, even though much can be learned from the early literature on international monetary policy coordination—reviewed by Frankel (2016), for instance—research on this issue remains very limited. Among the few contributions available, based explicitly on a game-theoretic approach, are Agénor et al. (2021) and Chen and Phelan (2020). Agénor et al. (2021) study the effects of coordinated and non-coordinated macroprudential policies in a model with financial frictions as in Gertler and Karadi (2011) and where global banks in a core region lend domestically and to banks in the periphery.[4] Their results show that the global

[2] The popular press has echoed these calls to some degree; see, for instance, the article "Rate rises affect global markets—and may feed back to America," in *The Economist*, June 14th 2018.

[3] Other arguments in favor of international macroprudential policy coordination have also been based on other considerations, such as pecuniary externalities; see for instance Bengui (2014) and Jeanne (2014). Agénor and Pereira da Silva (2021) provide a more detailed discussion.

[4] A number of papers on international financial spillovers assume the existence of global banks. In Kollmann et al. (2011) and Kollmann (2013), for instance, there is a single bank in the world economy which collects deposits from households and lends to entrepreneurs in *all* countries. Other studies include Kamber and Thoenissen (2013), Alpenda and Aysun (2014), and Cuadra and Nuguer (2018). However, none of these contributions considers the issue of cross-border policy coordination.

welfare gain from coordination can be relatively large (of the order of 1-2 percent of steady-state consumption), essentially because it mitigates significantly the cross-border spillovers of country-specific shocks. Chen and Phelan (2020), dwelling on the continuous-time framework developed by Brunnermeier and Sannikov (2015), formulate a symmetric two-country model in which countries have limited ability to issue state-contingent contracts in international markets. As a result, the relative share of global wealth held by each country affects its own level of output. Because of market incompleteness, national macroprudential regulation of each country's borrowing position (in the form of restrictions on capital flows) can improve national welfare. But tight regulation in one country creates incentives for the other one to reciprocate to avoid being relatively poorer on average. Coordination, by eliminating these incentives, generates gains for both countries.

Adopting also a game-theoretic approach, this paper contributes to the literature by focusing on a two-region, core-periphery dynamic stochastic general equilibrium model with imperfect financial integration and a global bank in the core region lending to banks in the periphery. As in some of the contributions alluded to earlier, our analysis considers two levels of financial frictions: between firms and banks in each region, and between periphery banks and the global bank. In contrast with the open-economy literature in the Kiyotaki-Moore tradition, financial intermediaries in the periphery are not constrained on how much they can borrow from the global bank but they must pay a premium that increases with the amount borrowed. A higher premium, in turn, mitigates the incentive to borrow. The model is parameterized for two groups of countries, the major advanced economies and a group of large (systemically important) middle-income countries, which have been identified in some recent studies, reviewed in Agénor and Pereira da Silva (2021), as generating significant reverse spillovers (also referred to as spillbacks) on advanced economies.

To assess the gains from coordination—a regime under which a benevolent regulator internalizes the consequences of policy interdependence—we focus on policy responses to a global lending shock. In an important contribution, Aldasoro et al. (2020) provided robust evidence on the causal effects of cross-border bank lending shocks on a sample of 22 emerging markets. Using a new identification procedure (based on exploiting the heterogeneity in the size distribution of confidential bilateral bank lending flows) they found that an increase in cross-border bank credit leads to a loosening of domestic financial conditions (in the form of a drop in domestic interest rates), an increase in domestic lending, an expansion in investment and domestic output, a real and nominal exchange rate appreciation, and higher house prices.[5] These “stylized facts” are replicated for the first time in our core-periphery model, with the cross-border bank lending shock taking the form of a transitory reduction in the cost of borrowing from the global bank. We view the ability of the model to reproduce these facts as an essential first step to address the issue at stake. In addition, by its very nature—the model solves simultaneously, rather than recursively, for the global equilibrium—it also captures the spillback effects associated with that shock. Both features make the model an attractive setting for evaluating the benefits (or lack thereof) of international macroprudential policy coordination.

Regulators in both regions are endowed with a narrow institutional mandate, which consists of promoting financial stability. This is consistent with the evidence on these mandates, especially since the Global financial crisis (see Calvo et al. (2019)). To do so they have at their disposal a simple implementable macroprudential rule. To assess the gains from coordination we use a two-stage approach, as in Agénor and Flamini (2019). In a first stage, the optimal parameters of the policy rule are solved for using a loss function approach, consistent with a narrow mandate defined in terms of an operational target for financial stability—mitigating credit fluctuations. In a second stage, the performance of the rule is evaluated in terms of household welfare. Thus, compared to the standard welfare maximization approach, our two-stage procedure brings together both the positive and the normative aspects of policy evaluation.

Our experiments show that the welfare gains from macroprudential policy coordination are positive—and significant, provided that the cost of instrument manipulation is not too large—for all parties and the world economy when the degree of financial integration, as measured by transactions costs in global capital markets, is sufficiently strong. The key reason is that greater integration increases the magnitude not only of spillovers but of spillbacks as well, which enhance the potential benefits of coordination for the particular shock that we consider. Otherwise, only the periphery gets to benefit, implying that cooperation is not Pareto-improving. Our paper is the first to provide a rigorous foundation for this claim. In addition, coordination does not necessarily involve *burden sharing*—a less aggressive policy response from the regulator in the region where the shock occurs, coupled with a stronger response in the other region—and gains can be substantially different across regions. Although our analysis considered only a single (albeit important) financial shock, the fact that

[5] Cesa-Bianchi et al. (2018) also found that an expansion in credit by global banks leads to increases in loans, house prices, and consumption in the rest of the world, as well as a real appreciation. However, as discussed by Aldasoro et al. (2020), the variable used in that study to instrument international banking claims may generate biases in estimating causal effects.

coordination may not be Pareto-improving raises the issue of what type of incentives must be put in place for countries to enter and remain voluntarily in a cooperative agreement in the area of macroprudential policy.

The remainder of the paper proceeds as follows. Section 2 describes the model. In line with a number of recent contributions, and to enhance analytical tractability, macroprudential regulation is introduced as a time-varying tax on bank loans. Such a tax can be viewed as a *generic* specification consistent with the price-based channel through which two major instruments of macroprudential policy, capital requirements and dynamic provisions, operate in terms of their impact on the market cost of borrowing.[6] A simple implementable macroprudential rule, linking the tax on loans to deviations in the credit-to-output ratio, is defined. The equilibrium and some key features of the steady state are briefly discussed in Section 3, and a benchmark parameterization is presented in Section 4. To characterize the properties of the model, the impulse response functions associated with a positive global lending shock (in the form of a temporary reduction in the cost of borrowing from the global bank) are described in Section 5. The gains from coordinating macroprudential policies across regions are evaluated in Section 6, whereas sensitivity analysis is reported in Section 7. The last section discusses some potentially fruitful extensions.

2 The World Economy

The world economy consists of two regions, called core and periphery, of normalized economic size $n \in (0, 1)$ and $1 - n$, respectively. Population size in both parts of the world is normalized to unity. The nominal exchange rate between the two regions is fully flexible. 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, and a central bank, which also operates as the macroprudential regulator. A single global bank operates in the core economy, whereas a continuum of commercial banks operate in the periphery. In line with the *original sin* argument (Eichengreen et al. (2005)), banks in the periphery cannot borrow in their own currency. They are also unable to fully hedge against foreign exchange risk. In addition, the cost at which banks in the periphery borrow from the global bank is increasing in the amount

[6] See, for instance, Quint and Rabanal (2014), Levine and Lima (2015), Agénor and Pereira da Silva (2017), and Kiley and Sim (2017). Such a tax can also be implemented via time-varying reserve requirements, as argued by Kashyap and Stein (2012). A related specification is proposed by de Paoli and Paustian (2017), who model macroprudential policy directly as a tax (or subsidy) on firms' borrowing costs, which they incur to pay wages prior to the sale of output.

borrowed. Regions trade in intermediate goods and government bonds, whereas cash and credit markets are segmented. In particular, firms in either region cannot directly lend or borrow internationally.

2.1 Core Economy

In what follows we describe the behavior of households, the global bank, the central bank, and the government in the core economy. Because households and the government behave essentially in the same way in both regions, we subsequently describe only the behavior of banks and the central bank in the periphery. The structure of production is also the same in both regions, and details for these sectors are provided in Appendix A.

2.1.1 Households

The objective of the representative household in the core economy is to maximize[7]

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

where C_t^C is consumption of the core final good, $N_t^{C,j}$ the number of hours provided to IG producer $j \in (0,1)$, x_t^C a composite index of real monetary assets, H_t^C the stock of housing, $\Lambda \in (0,1)$ a discount factor, $\varsigma > 0$ the intertemporal elasticity of substitution in consumption, ψ_N the inverse of the Frisch elasticity of labor supply, $\mathbb{E}_t$ the expectation operator conditional on information available 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.

In standard fashion, money generates utility because it facilitates transactions. The composite monetary asset consists of real cash balances, m_t^C, and real bank deposits, d_t^C, both measured in terms of the price of core final output, P_t^C:[8]

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

The core household's flow budget constraint is

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

[7] Superscripts C and P are used (as first acronym) throughout to identify core and periphery, respectively. However, to further simplify notations, they are omitted when there is no risk of confusion.

[8] As discussed later, deposits represent a source of funding for banks, whereas the equilibrium condition of the currency market is used to solve for the equilibrium bond rate.

$$= w_t^C N_t^C - T_t^C - C_t^C + \frac{m_{t-1}^C}{1+\pi_t^C} + (\frac{1+i_{t-1}^{CD}}{1+\pi_t^C})d_{t-1}^C + (\frac{1+i_{t-1}^{CB}}{1+\pi_t^C})b_{t-1}^{CC}$$
$$+(1+i_{t-1}^P)z_t^{-1}b_{t-1}^{CP} + J_t^{CI} + J_t^{CK} + J_t^{CB},$$

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, noncontingent core (periphery) government bonds, $z_t = E_t P_t^C/P_t^P$, the real exchange rate 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 region'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} profits (if any) of the IG producer, the CG producer, and the global bank, respectively. For simplicity, housing does not depreciate.

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

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

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

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

with $\theta_0^B > 0$ denoting a symmetric cost parameter. Because households internalize the impact of their portfolio decisions on the intermediation costs that they face on world capital markets, this specification captures in a simple way the assumption (consistent with the evidence) of imperfect capital mobility across regions.[9]

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

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

[9] See Agénor and Montiel (2015, Chapter 13) for a discussion of the evidence and Gabaix and Maggiori (2015) for a specification based on a micro-founded model of the foreign exchange market.

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

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

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

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

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

together with appropriate transversality conditions. These results are standard, with the exception of the last two which define core household demand for housing services and periphery bonds. Ignoring covariance terms, and after some manipulations, equation (11) can be approximated by[10]

$$b_t^{CP} \simeq \frac{(1+i_t^{PB})\mathbb{E}_t(E_t/E_{t+1}) - (1+i_t^{CB})}{\theta_0^B (1+i_t^{PB})\mathbb{E}_t(E_t/E_{t+1})}. \tag{12}$$

2.1.2 Global Bank

The balance sheet of the global bank is given by

$$l_t^{CK} + l_t^{CP} = d_t^C + l_t^{CB}, \tag{13}$$

where l_t^{CK} is lending to core CG producers, l_t^{CP} lending to periphery banks, and l_t^{CB} borrowing from the core central bank.[11]

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

$$\mathbb{E}_t J_{t+1}^{CB} = q_t^C (1+i_t^{CL})(1-\tau_t^C) l_t^{CK} + (1-q_t^C)\kappa \mathbb{E}_t p_{t+1}^{CH} H_t^C + (1+i_t^{CP}) l_t^{CP} \tag{14}$$

$$-(1+i_t^{CD}) d_t^C - (1+i_t^{CR}) l_t^{CB} - \gamma^C \frac{(l_t^{CP})^2}{2} + \Omega_t^C,$$

where i_t^{CR} is the marginal cost of borrowing from the central bank, i_t^{CP} the interest rate on loans to periphery banks, $\tau_t^C \in (0,1)$ the tax rate on the gross value of domestic loans imposed for macroprudential reasons, $q_t^C \in (0,1)$ the repayment probability of core firms on their loans. The first term in (14) is expected repayment when there is no default by domestic

[10] See Agénor et al. (2018) for a detailed derivation and discussion of equations (11) and (12).

[11] Note that periphery households cannot hold deposits with the global bank.

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, $(1+i_t^{CP})l_t^{CP}$, measures repayment on periphery loans. The fourth term is repayment to depositors and the fifth repayment to the central bank, neither of which is state contingent. The global bank also incurs a convex cost that increases with the amount of international lending to periphery banks, as measured by $0.5\gamma^C(l_t^{CP})^2$, where $\gamma^C > 0$. This cost can be viewed as reflecting operational expenses incurred when gathering information and screening borrowers in the context of cross-border transactions. The last term, Ω_t^C, represents the proceeds of the loan tax; in order to abstract from the fiscal effects of macroprudential policy, we assume that these proceeds are rebated to each bank in lump-sum fashion.

The bank has monopoly power in the deposit and domestic credit markets. It sets the deposit and lending rates, together with the amount of lending to periphery banks, so as to maximize expected profits:

$$1+i_t^{CD}, 1+i_t^{CL}, l_t^{PC} = \arg\max \mathbb{E}_t J_{t+1}^C. \tag{15}$$

Solving (15) subject to (13), taking the repayment probabilities as given, yields

$$1+i_t^{CD} = \frac{1+i_t^{CR}}{1+\eta_D^{-1}}, \tag{16}$$

$$1+i_t^{CL} = \frac{(1+i_t^{CR})}{(1+\eta_L^{-1})(1-\tau_t^C)q_t^C}, \tag{17}$$

$$l_t^{CP} = \frac{(i_t^{CP} - i_t^{CR})}{\gamma^C}, \tag{18}$$

where $\eta_D > 0$ and $\eta_L < 0$ are gross interest elasticities of the supply of deposits and the demand for loans, respectively. Equation (17) shows that the wedge between the policy rate and the loan rate depends on both the risk of default and the macroprudential tax rate. In addition, equation (18) indicates that the supply of loans to periphery banks is increasing in the differential between the return on these loans and the marginal cost of borrowing, as measured by $i_t^{CP} - i_t^{CR}$.

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:

$$q_t^C = \left(\frac{\kappa \mathbb{E}_t p_{t+1}^{CH} H_t^C / \tilde{p}^{CH} \tilde{H}^C}{l_t^{CK} / \tilde{l}^{CK}}\right)^{\psi_1^C} \left(\frac{Y_t^C}{\tilde{Y}^C}\right)^{\psi_2^C}, \quad \psi_1^C, \psi_2^C > 0 \tag{19}$$

where Y_t^C is the level of core final output and variables with a tilde represent steady-state values. Agénor and Pereira da Silva (2017) formally derive an equation similar to (19) as part of the bank's optimization problem, by assuming that *ex ante* monitoring effort is directly related to the probability of repayment—a common assumption in the theoretical literature on banking, as in Allen et al. (2011) and Dell'Ariccia et al. (2014), for instance—and that unit monitoring costs are countercyclical.[12] The collateral-loan ratio reflects a moral hazard or *skin in the game* effect, whereas the cyclical position of the economy reflects the fact that (unit) monitoring costs tend to be relatively low in good times.

In Appendix A loans contracted by CG producers are related to investment. Thus, given (17), the supply of these loans is perfectly elastic. In addition, because the supply of deposits is determined by households (given in (16)), and that the supply of loans to periphery banks is set in (18) on the basis of the net return to lending, borrowing from the core central bank is determined residually from (13).

2.1.3 Central Bank

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

$$l_t^{CB} = m_t^{Cs}. \tag{20}$$

The supply of liquidity to the global bank is perfectly elastic at the prevailing rate i_t^{CR}, which is set on the basis of an inertial Taylor rule:

$$\frac{1+i_t^{CR}}{1+\tilde{\imath}^{CR}} = (\frac{1+i_{t-1}^{CR}}{1+\tilde{\imath}^{CR}})^{\chi^C} \left\{ (\frac{1+\pi_t^C}{1+\pi_T^C})^{\varepsilon_1^C} (\frac{Y_t^C}{\tilde{Y}^C})^{\varepsilon_2^C} \right\}^{1-\chi^C}, \tag{21}$$

where $\tilde{\imath}^{CR}$ is the steady-state value of the refinance rate, $\pi_T^C \geq 0$ the inflation target, $\chi^C \in (0,1)$, and $\varepsilon_1^C, \varepsilon_2^C > 0$.

As noted earlier, macroprudential regulation takes the form of a time-varying tax on bank loans to domestic firms.[13] We consider a simple implementable rule whereby changes in the macroprudential tax rate are related to an operational target for systemic risk, the credit growth rate. The focus on that variable is consistent with the evidence which suggests that fast credit expansions often lead to excessive leverage (by both lenders and borrowers),

[12] As noted by Allen et al. (2011), this one-to-one relationship can be interpreted as meaning that the lender observes information about a borrower and then uses it to help improve the borrower's performance. The important point is that greater monitoring is desirable from the borrower's perspective. See Agénor (2020, chapter 4) for a thorough discussion.

[13] Because the goal of the regulator in the core region is financial stability at home only, and the base of the tax is credit to domestic firms only, we naturally assume that the rule is specified in terms of that variable as well, thereby excluding credit to periphery banks.

making the economy more vulnerable to negative shocks and fueling financial instability.[14] It also reflects the assumption that inefficient credit fluctuations are not directly observable, which implies that in practice regulators can only adopt policies that are based on noisy indicators of financial risks. Specifically,

$$\frac{1+\tau_t^C}{1+\tilde{\tau}^C} = (\frac{1+\tau_{t-1}^C}{1+\tilde{\tau}^C})^{\chi_1} \left\{ (\frac{l_t^{CK}}{l_{t-1}^{CK}})^{\chi_2^C} \right\}^{1-\chi_1}, \tag{22}$$

where $\chi_1 \in (0,1)$ is a persistence parameter and $\chi_2^C > 0$ is the response parameter to the credit growth rate.[15] Thus, from (17) and (22), borrowing is more costly during episodes of credit booms and this in turn helps to mitigate aggregate fluctuations.

2.2 Periphery

2.2.1 Households

Periphery households have the same utility function as core households. They also face a resource allocation problem similar to the one core households are confronted with, in which the effective rate of return on core government bonds, i_t^C, is defined as, symmetrically to (4),

$$1+i_t^C = (1+i_t^{CB})(1-\theta_t^{PC})\mathbb{E}_t(\frac{E_{t+1}}{E_t}), \tag{23}$$

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

$$\theta_t^{PC} = \frac{\theta_0^B}{2} b_t^{PC}. \tag{24}$$

The solution is therefore analogous to (6)-(11). In particular, periphery demand for core government bonds can be approximated by

$$b_t^{PC} \simeq \frac{(1+i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t) - (1+i_t^{PB})}{\theta_0^B(1+i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)}. \tag{25}$$

Equation (25) implies therefore that uncovered interest parity, $1+i_t^{PB} \simeq (1+i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)$, obtains when $\theta_0^B \to 0$. A similar result can be established from (11). Thus, as discussed later, the impact of increased financial integration on the gains from coordination can be assessed by lowering θ_0^B.

[14] See Taylor (2015) and Aldasoro et al. (2018) for a discussion. Some contributions, such as Krishnamurthy and Muir (2017), have documented the fact that low credit spreads tend also to precede episodes of financial instability.

[15] As is clear from (22), the response parameters do not affect the steady-state level of the macroprudential tax rate, only its cyclical properties.

2.2.2 Commercial Banks

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

$$l_t^{PK,i} = (1-\mu)d_t^{P,i} + z_t l_t^{PC,i} + l_t^{PB,i}, \tag{26}$$

where $l_t^{PK,i}$ is loans to periphery firms, $d_t^{P,i}$ household 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 $i_t^{CP,i}$, 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.[16]

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

$$i_t^{PD,i} = (1-\mu)i_t^{PR}. \tag{27}$$

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

$$l_t^{PK,i} = (\frac{1+i_t^{PL,i}}{1+i_t^{PL}})^{-\zeta_L} l_t^{PK}, \tag{28}$$

where $i_t^{PL,i}$ is the interest 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

$$\mathbb{E}_t J_{t+1}^{PB,i} = q_t^{P,i}(1+i_t^{PL,i})(1-\tau_t^P)l_t^{PK,i} + (1-q_t^{P,i})\left(\kappa^i p_{t+1}^{PH} H_t^{P,i}\right) - (1+i_t^{PD,i})d_t^{P,i} + \mu d_t^{P,i} \tag{29}$$

$$-(1+i_t^{PR})l_t^{PB,i} - (1+i_t^{CP})\mathbb{E}_t(\frac{E_{t+1}}{E_t})z_t l_t^{PC,i} - \gamma^P z_t \frac{(l_t^{PC,i})^2}{2} + \Omega_t^{P,i},$$

where $\kappa^i \in (0,1)$, i_t^{PR} is the marginal cost of borrowing from the central bank, $\tau_t^P \in (0,1)$ the macroprudential tax rate, and $q_t^P \in (0,1)$ the repayment probability on loans to periphery CG producers. As before, the first two terms represent expected income (net of taxes) from

[16] In practice, banks in large MICs do have some access to forward markets for foreign exchange, and prudential requirements often impose on a permanent basis some degree of hedging of their foreign-currency liabilities. However, in most cases these markets remain underdeveloped. Accounting for partial hedging of foreign exchange rate risk would not change the main thrust of our results.

lending, with $p^{PH}_{t+1}H^{P,i}_t$ representing the expected value of housing collateral, 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 expected repayment to the global bank (given limited liability). In addition, periphery banks incur a convex cost that increases with the amount of borrowing abroad, as measured by $0.5\gamma^P z_t(l^{PC,i}_t)^2$, where $\gamma^P > 0$. This assumption helps to capture in a simple way imperfect substitutability between domestic and foreign borrowing. The last term $\Omega^{P,i}_t$ represents the revenue of the macroprudential tax levied on bank i, which again is transferred back in lump-sum fashion to that bank.

Each bank maximizes profits with respect to their loan rate and their demand for foreign loans:

$$1 + i^{PL,i}_t, z_t l^{PC,i}_t = \arg\max \mathbb{E}_t J^{PB,i}_{t+1}. \tag{30}$$

Solving (30) subject to (26) and (28), and taking repayment probabilities as given, yields, in a symmetric equilibrium,

$$1 + i^{PL}_t = (\frac{\zeta_L}{\zeta_L - 1})\frac{(1 + i^{PR}_t)}{(1 - \tau^P_t)q^P_t}, \tag{31}$$

$$l^{PC}_t = \frac{1}{\gamma^P}\left\{(1 + i^{PR}_t) - (1 + i^{CP}_t)\mathbb{E}_t(\frac{E_{t+1}}{E_t})\right\}. \tag{32}$$

Equation (31) shows once again that a tighter macroprudential response raises the cost of loans, whereas equation (32) indicates that a higher cost of borrowing from the global bank (adjusted for expected depreciation) reduces the demand for foreign loans. As before, borrowing from the central bank is determined residually from (26).

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

$$q^{P,i}_t = (\frac{\kappa^i \mathbb{E}_t p^{PH}_{t+1} H^{P,i}_t/\tilde{p}^{PH}}{l^{PK,i}_t/\tilde{l}^{PK}})^{\psi^P_1}(\frac{Y^P_t}{\tilde{Y}^P})^{\psi^P_2}, \quad \psi^P_1, \psi^P_2 > 0 \tag{33}$$

where Y^P_t is the periphery's final output and $\tilde{Y}^P$ its steady-state value. As noted earlier, this specification can be derived as part of banks' optimization problem by assuming a one-to-one relationship between the probability of repayment and monitoring effort, as well as endogenous monitoring costs.

2.2.3 Central Bank and Regulator

Analogously to (20), the balance sheet of the periphery central bank is given by

$$l^{PB}_t = m^{Ps}_t, \tag{34}$$

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 (21):

$$\frac{1+i_t^{PR}}{1+\tilde{\imath}^{PR}} = (\frac{1+i_{t-1}^{PR}}{1+\tilde{\imath}^{PR}})^{\chi^P} \left\{ (\frac{1+\pi_t^P}{1+\pi_T^P})^{\varepsilon_1^P} (\frac{Y_t^P}{\tilde{Y}^P})^{\varepsilon_2^P} \right\}^{1-\chi^P}, \tag{35}$$

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

The tax on loans is also set according to a rule similar to (22):[17]

$$\frac{1+\tau_t^P}{1+\tilde{\tau}^P} = (\frac{1+\tau_{t-1}^P}{1+\tilde{\tau}^P})^{\chi_1^P} \left\{ (\frac{l_t^{PK}}{l_{t-1}^{PK}})^{\chi_2^P} \right\}^{1-\chi_1^P}, \tag{36}$$

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

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 equilibrium condition of the market for cash is solved for the bond rate. The equilibrium in the market for periphery loans requires equating (18) and (32), that is, $l_t^{CP} = l_t^{PC}$, which is solved for the equilibrium loan rate. The equilibrium condition of the housing market is solved, using (10), to determine the dynamics of real house prices. In equilibrium, net trade in government bonds (or, equivalently, the world net supply of bonds) must be zero. Analogously, in a two-region world, current account surpluses and deficits must be zero, so $nCA_t^C + (1-n)E_t^{-1}CA_t^P = 0$, where CA_t^j is the region j's current account, defined also in Appendix A.

The steady-state solution of the model, assuming a zero target inflation rate, is briefly described in Appendix B. Several of its key features are fundamentally similar to those described in Agénor et al. (2014, 2018) for a small open economy, so we refer to those papers for a more detailed discussion.[18]

[17] Alternative macroprudential instruments for the periphery could be the required reserve ratio, as in Agénor et al. (2018) for instance, or a direct tax on foreign borrowing, as in Agénor and Jia (2020). Both instruments have been used repeatedly in middle-income countries over the years. However, for symmetry with the core region we assume that the instrument used is also a (generic) tax on loans.

[18] In particular we assume, as in Benigno and Woodford (2005), for instance, that policymakers have

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 (2021), 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. As identified by the International Monetary Fund (2016), these groups of countries represent those that have exerted the largest financial spillovers and spillbacks to each other in recent years.

Our benchmark parameterization is based on 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. In addition, for some of the parameters that are deemed critical from the perspective of this study, sensitivity analysis is reported later on.

The discount factor Λ is set at 0.98 for MAEs and 0.95 for SMICs, which gives a steady-state annualized interest rate (real and nominal, given zero inflation in the steady state) of about 2.0 percent in the first case and 5.3 percent in the second. Thus, consistent with the evidence, real interest rates are significantly higher in SMICs. The intertemporal elasticity of substitution is uniformly set at 0.5, in line with the empirical evidence discussed by Braun and Nakajima (2012) and Thimme (2017). The preference parameter for leisure, η_N, is set at 25, which implies that in the steady state households in both regions devote about two-fifths of their time endowment to market activity—a slightly higher value than in other contributions in the literature (see Christoffel and Schabert (2015) and Boz et al. (2015), for instance). The Frisch elasticity of labor supply is set at 0.33 for both regions (implying that ψ_N is equal to 3), in line with the empirical evidence.

The parameter for composite monetary assets, η_x, is set at a low value, 0.01, to capture the common assumption in the literature that their weight in household preferences is negligible (see, for instance, Coenen et al. (2009) and Christoffel and Schabert (2015)). For the housing preference parameter, η_H, we use the same value as in Notarpietro and Siviero (2015), 0.1. The share parameter in the index of money holdings, ν, which corresponds to the relative

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.

share of cash in narrow money, is set at 0.2 to capture the predominant use of deposits in transactions in both regions. The cost parameter related to core (periphery) bond holdings by core (periphery) households, θ_0^B, is set initially at 0.2. This value is consistent with a relatively low degree of capital mobility. Sensitivity analysis is performed later on.

The distribution parameter between home and imported intermediate goods in the production of the final good (or, equivalently, the degree of home bias), Λ_I, is set at 0.8 for MAEs and 0.6 for SMICs, to reflect the fact that the latter group is relatively more open than the former. The elasticity of substitution between baskets of domestic and imported composite intermediate goods used in the production of the final good, η_I, is set at 2.5, which implies that these goods are substitutes in the production of the final good. The elasticities of substitution between core intermediate goods among themselves, θ^{CC}, and imported periphery goods among themselves, θ^{PP}, are both set equal to 10. Quint and Rabanal (2014), in particular, use the same value. This implies a steady-state mark-up of 11 percent. The share of capital in output of intermediate goods, α, is set at a fairly standard value, 0.35, for both regions. The adjustment cost parameter for prices of domestic intermediate goods, ϕ_I, is also set uniformly at 74.5 to capture a relatively high degree of nominal price stickiness. This value is close to the average value initially estimated by Ireland (2001, Table 3) and implies a Calvo-type probability of not adjusting prices of approximately 0.71 percent per period, or equivalently an average period of price fixity of about 3.5 quarters. These figures are consistent with the point estimates of Quint and Rabanal (2014, Table 2) and Christoffel and Schabert (2015, Table 2) for advanced economies, and Agénor et al. (2018) for middle-income countries. The capital depreciation rate, δ_K, is set at a quarterly rate of 0.01 percent for the core and 0.025 percent for the periphery, which is within the span of values typically used in the literature. The adjustment cost incurred by the CG producer for transforming investment into capital, Θ_K, is set at 14, in order to match the fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as output in most countries (see Hnatkovska and Koehler-Geib (2018), for instance).

Regarding the global bank and periphery banks, the collateral-loan ratio, κ, is set at 0.4 for MAEs and at 0.2 for SMICs, to capture the relatively higher costs associated with recovery of collateral and, more generally, weaknesses in 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 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 $\psi_2^C = 0.1$ for the core and, consistent with Agénor et al. (2018), $\psi_2^P = 0.2$ for the periphery. The cost parameters γ^C and γ^P are set at 0.05 and 0.1, respectively, in order to generate sensible values for initial interest rates. The elasticities η_D, η_L and ζ_L are set equal to 2.5, 4.5 and 4.5, respectively. This gives a mark-down of the deposit rate relative to the policy rate of about 100 basis points in the core region, 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 260 basis points in the core and 420 basis points in the periphery. The latter results are in line with the evidence for MAEs and SMICs, which suggests significantly higher default rates and higher lending spreads for the latter group of countries.[19]

The degree of persistence in the core central bank's policy response, χ, is set at 0.7, whereas the responses of the policy rate to inflation and output deviations, ε_1 and ε_2, are set at 1.7 and 0.1, respectively, as in Coenen et al. (2009). For the periphery central bank, the corresponding values are $\chi = 0.0$, $\varepsilon_1 = 2.0$, and $\varepsilon_2 = 0.4$, based on the evidence for emerging markets reported by Coulibaly (2012). In particular, the weight on output fluctuations in SMICs is significantly higher than in MAEs, a well-documented fact in the literature. The required reserve ratio, μ, is set at 0.3, consistent with the evidence for some large Latin American countries like Brazil and Colombia (see Agénor and Pereira da Silva (2017)).

The share of noninterest government spending in final output, ψ^G, is set at 0.2 for the core (as in Coenen et al. (2009), again, and Alpanda and Aysan (2014)) and 0.25 for the periphery, as in Agénor et al. (2018). These values are consistent with actual data 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 the shares of (intermediate good) exports are of the order of 10 percent for both regions, and that the amount of loans from the global bank to the periphery banks is relatively large in proportion of the region's output. The macroprudential tax rates, τ^C and τ^P, are set at 0 initially in both regions.

[19] The difference in the magnitudes of the parameter η_D, on the one hand, and η_L and ζ_L, on the other, is due to the fact that the markup applies to the *net* interest rate in the first case and to the gross rate in the second.

5 Global Lending Shock

To characterize the properties of the model, we consider a global lending shock taking the form of a temporary reduction in the cost of borrowing from the global bank, i_t^{CP}, asymmetric credit spread shocks occurring in both regions when there is no countercyclical macroprudential policy, that is, $\chi_2^C = \chi_2^P = 0$ in (22) and (36).[20] Specifically, given that $l_t^{CP} = l_t^{PC}$, we use (32) to solve for lending by the global bank and rewrite (18) to solve for the cost of borrowing from the global bank, so that $i_t^{CP} = (\gamma^C l_t^{CP} + i_t^{CR})\epsilon_t^C$. The multiplicative shock, ϵ_t^C, can be broadly interpreted as reflecting exogenous changes in risk perception by lenders, which induce them to expand credit to periphery banks. Moreover, ϵ_t^C is assumed to follow a first-order autoregressive process of the form $\epsilon_t^C = (\epsilon_{t-1}^C)^{\rho^C} \exp(\xi_t^C)$, where $\rho^C \in (0,1)$ and $\xi_t^C \sim \mathbf{N}(0, \sigma_{\xi^C})$. We set $\rho^C = 0.57$. This implies therefore a relatively high degree of persistence.

The results for a one percentage point reduction in the cost of borrowing from the global bank are shown by the continuous line in Figure 2. The lower cost of foreign loans induces periphery banks to borrow more, which translates into a capital inflow. In turn, the capital inflow leads to an exchange rate appreciation, which lowers inflation and thus the refinance rate in the periphery. As a result, the loan rate also falls, thereby stimulating investment and raising aggregate demand. The increase in cyclical output leads to a higher repayment probability, which further reduces the loan rate. At the same time, the drop in the refinance rate—which is mitigated by the output expansion—leads to a reduction in both the deposit rate and the demand for deposits, which is accommodated in part by an increase in money demand. To maintain equilibrium in the money market, the nominal bond rate (the opportunity cost of holding cash) must fall. Given our calibration this drop exceeds the fall in (one-period ahead) inflation, implying that the (expected) real bond rate also falls—thereby reducing incentives to save and inducing households to increase consumption today.

The increase in household spending is also associated with higher demand for housing services, which tends to raise their price. In turn, higher house prices raise the value of collateral and induce a further increase in the repayment probability and downward pressure on the loan rate, which amplifies the increase in investment. These effects persist over several quarters, before the economy returns to its initial equilibrium position.

Fluctuations in the periphery are transmitted back to the core through trade and financial

[20] We consider only a financial shock, given the large body of evidence in the recent literature which suggests that macroprudential policy is effective mainly when it responds to financial disturbances.

channels. While the real exchange rate appreciation reduces the domestic cost of imported intermediates in the periphery, thereby increasing their demand and reducing the demand for domestic intermediates, it also has an adverse effect on periphery exports of these goods.[21] The opposite occurs in the core; the demand for home intermediates increases, which raises the demand for capital, its expected rate of return, and investment. In turn, this raises core output and inflation, which leads to higher interest rates. However, the increase in the nominal bond rate is smaller than the increase in (one-period ahead) inflation and, as a result, the (expected) real bond rate falls. Current consumption therefore increases in the core, and so do the demand for housing services and house prices. The ensuing increase in collateral values, together with the expansion in output, combine to generate an increase in the repayment probability, which mitigates the initial hike in the loan rate. The increase in the bond rate in the core region, coupled with the reduction in that rate in the periphery, implies that the demand for periphery bonds by core households falls, whereas the demand for core bonds by periphery households increases. At the same time, the increase in the marginal cost of borrowing from the core central bank mitigates the interest rate on loans by the global bank to periphery banks. Nevertheless, the net effect is, from the perspective of the periphery, a capital inflow and an initial appreciation.

The results corresponding to a higher cost parameter in the profit function of periphery banks, parameter γ^P in (29), are shown as the dotted lines in Figure 2. The results are largely similar to those described earlier. In particular, the increase in lending by the global bank generates an investment boom in the periphery. The key difference is qualitative; lending by the global bank to periphery banks is now lower, as expected. A higher cost parameter in the profit function of the global bank, parameter γ^C in (14), generates a similar result and is not reported for clarity.

In sum, the impulse response functions associated with a global lending shock replicate all the causal effects associated with an increase in cross-border lending on domestic macroeconomic and financial variables identified by Aldasoro et al. (2020) and summarized in the introduction.[22] The effects on house prices is also consistent with the evidence, provided by Banti and Phylaktis (2019), of a positive link between global lending shocks and global house prices. The positive correlation between the policy rate in the periphery and borrowing by periphery banks is consistent as well with the empirical evidence provided by Avdjiev et al.

[21] Consequently, the periphery's current account deteriorates whereas the core's current account improves.

[22] In addition, we also document a positive effect on domestic consumption—which is consistent with the results of Cesa-Bianchi et al. (2018).

(2018) on lending in global funding currencies.

Moreover, our experiments show that movements in all major macroeconomic variables (except inflation, and thus interest rates) are positively correlated across countries.[23] The fact that the model is able to reproduce, and be consistent with, well-documented facts regarding cross-border effects of global lending shocks, while at the same time accounting for spillback effects to the core, makes it a natural starting point for assessing the gains from international macroprudential policy coordination. Indeed, the question now, given that these shocks can create significant fluctuations in both regions, is whether cooperation between regulators can promote stability and generate significant gains, compared to a setting where they act solely on the basis of their own strategic interests.

6 Gains from Coordination

As noted earlier, regulators in both regions are assigned an institutional mandate by society—to promote financial stability. Specifically, each regulator $j = C, P$ seeks to minimize a policy loss function in terms of its own credit-to-output ratio, adjusted for the cost of changing its macroprudential instrument, in similar fashion to Rudebusch and Svensson (1999), Taylor and Williams (2010), and Debortoli et al. (2019), in the context of monetary policy, and Angelini et al. (2014), with respect to macroprudential policy:[24]

$$\mathcal{L}_t^j = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s [(\frac{l_t^{jK}/\tilde{l}^{jK}}{Y_t^j./\tilde{Y}^j})^2 + \varkappa_W \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\tau_{t+s}^j - \tau_{t+s-1}^j)^2, \quad (37)$$

where $\varkappa_W \geq 0$ is a parameter that measures the cost (assumed quadratic) associated with the use of the macroprudential instrument.

In the absence of international coordination, or under independent (Nash) policies, the regulator in each region sets its instrument taking as given the behavior of the other regulator and determines the optimal value of the response parameter χ_2^j in the rules (22) and (36), denoted $\chi_2^{j,N}$, so that, for $j = C, P$,

$$\chi_2^{j,N} = \arg\min \mathcal{L}_t^j. \quad (38)$$

In contrast, under coordination, national regulators—or a benevolent global policymaker working on their behalf—jointly determine the optimal response parameters, denoted $\chi_2^{C,O}$

[23]This result is consistent with studies such as Abbate et al. (2016), for instance, who found that U.S. financial shocks generate positive co-movement in output across countries.

[24]Most of these contributions are based on a loss function minimization approach, but the idea that policymakers face a cost in adjusting policy instruments is fairly general and naturally applies also when maximizing welfare.

and $\chi_2^{P,O}$, so as to maximize a weighted sum of each region's welfare, again defined as in (37):

$$\chi_2^{C,O}, \chi_2^{P,O} = \arg\min[n\mathcal{L}_t^C + (1-n)\mathcal{L}_t^P], \tag{39}$$

where the persistence parameter χ_1 in (22) and (36) is assumed to remain the same under both regimes. Thus, a lower policy loss for each region taken individually in the coordination regime relative to the uncooperative regime is a sufficient, but not necessary, condition to generate a net gain for the world as a whole; this also depends on the magnitude of the relative gain (or loss) for each region and the relative weight of each of them, as measured by n, in the common welfare function.

Policies are computed under commitment, that is, under the assumption that regulators (individually and jointly) have the ability to deliver on past promises—no matter what the current situation is today. As in de Paoli and Paustian (2017), for instance, under non-cooperation we solve for the closed-loop or feedback equilibrium. Given the pre-determined nature of the feedback rules (22) and (36), each regulator has full knowledge of the other regulator's reaction function; their best responses reflect therefore this knowledge.[25]

While the optimal policy response parameters are determined by minimizing a loss function (consistent with the institutional mandate that society bestows on regulators) the social benefit of the optimal policy is evaluated in terms of household welfare, by using a second-order approximation of the discounted present value of utility under both regimes, $\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u^N(C_{t+s}^{j,N}, N_{t+s}^{j,N})$ under independent policymaking, and

$$\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ n \cdot u^C(C_{t+s}^{C,O}, N_{t+s}^{C,O}) + (1-n)u^P(C_{t+s}^{P,O}, N_{t+s}^{P,O}) \right\},$$

under coordination.[26] The gains from coordination are then assessed by calculating the relative welfare gain associated with the cooperative regime, relative to the Nash equilibrium. The relative weight of each region is initially set at $n = 0.5$, that is, equal weight.

The upper part of Table 3 show the results for the benchmark set of parameters. Initially, the adjustment cost parameter $\varkappa_W$ is set uniformly to a low value of 0.02.[27] The degree of

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

[26] As discussed in Appendix C, these expressions are evaluated using second-order approximations to both the household's period utility function and the model, conditional on the initial steady state being the deterministic steady state.

[27] A positive value of $\varkappa_W$ is necessary to avoid a corner solution in which it is optimal to fully stabilize credit fluctuations. At the same time, a value of 0.02 is sufficient to ensure determinate results. See Agénor (2020, chapter 5) for a more detailed discussion of the role of instrument manipulation costs.

persistence in the regulatory policy rules, χ_1, is set to 0.1.[28] A grid step of 0.1 is used to search for the optimal response parameters χ_2^C and χ_2^P in (22) and (36), in the interval $(-15, +15)$. This is sufficient for our purpose. Welfare results are reported for both individual regions and the world.

The results show first that an optimal policy exists because the relationship between welfare and the macroprudential tool has an inverted U-shape form, both under Nash and under coordination. The intuition is as follows. Initially, as countercyclical regulatory policy is implemented, volatility falls at first, because it stabilizes credit, investment and aggregate demand. As a result, welfare increases. However, as the policy becomes more aggressive, its cost increases as well. This cost eventually dominates the initial gains, entailing therefore a reduction in welfare. Thus, there exists an optimal value for the response parameters, χ_2^j, under activism.

Second, coordination involves a less aggressive response in *both* regions. The reason is that under coordination regulators internalize the effects of credit fluctuations (occurring through spillovers to the periphery and spillbacks to the core) in both regions. Thus, coordination does not involve *burden sharing*, a situation where the region that is directly affected by the shock (the periphery) reacts less, whereas the other (the core) reacts more.

Third, when considered at the level of individual regions, the gains from coordination are asymmetric. Indeed, while the periphery gains from coordination, the core loses from it. This asymmetry means that policy coordination is not always Pareto improving—at least with respect to the financial shock considered here. However, as also discussed later, this depends critically on the degree of financial integration.

7 Sensitivity Analysis

To assess the robustness of the previous analysis, we perform sensitivity analysis with respect to several features of the model and its parameterization: the degree of international financial integration (as measured by the size of intermediation costs on world capital markets), the degree to which economies of scope prevail in banking, the cost of instrument manipulation, the relative weight of each region in evaluating global welfare, and the case where the housing market is perfectly integrated across regions.[29]

[28] Using an alternative value of 0.8 for χ_1 did not affect qualitatively the results. To simplify matters, therefore, the persistence parameter is kept constant throughout.

[29] We also performed sensitivity analysis with respect to a number of structural parameters, includoing γ^C, Λ_I^C, and so on. The results did not differ much (if at all) from those obtained in the benchmark case

7.1 Financial Integration

First, consider the case where the cost parameter associated with financial intermediation on world capital markets, θ_0^B, falls from its benchmark value of 0.2 to 0.1. As a result of greater financial integration, changes in interest rates become more closely correlated across jurisdictions. This implies that shocks in one region are transmitted to a greater extent to the other, implying therefore larger spillovers or spillbacks, and potentially larger gains from international coordination, given that this regime allows regulators, acting together, to internalize cross-border effects.

The results are displayed in the first column of Table 3. They show that while the regulator in the periphery reacts less aggressively under coordination, the regulator in the core reacts as much as it can under both regimes. Thus, there is no *burden sharing*, as defined earlier. More importantly, coordination is Pareto improving; both parties, and thus the world economy, benefit this time, in contrast to the benchmark case. The fundamental reason is that greater integration amplifies not only spillovers but also spillbacks, and in so doing enhances the potential benefits of coordinated countercyclical policy responses for the shock that we consider. At the same time, coordination is more beneficial to the periphery and the world than it is for the core. These results are consistent with the recent evidence, reviewed by Agénor and Pereira da Silva (2021), which suggests that greater financial interconnectedness in the world economy has increased the potential benefits of international macroprudential policy coordination—although the magnitude of these benefits may not be the same for all parties to the agreement.

7.2 Costly Banking and Spillovers

In the basic model presented earlier, the key mechanism through which a global banking shock creates an expansion in the periphery is because of a *policy channel*: the real appreciation associated with the bank capital inflow puts downward pressure on inflation in the periphery, which in turn leads to a reduction in the refinance rate in that region, through the Taylor rule.[30] In turn, the reduction in the marginal cost of borrowing from the central bank induces a fall in the loan rate and an expansion in activity there, which benefits the core, through trade and financial channels.

and are therefore omitted to save space.

[30] The magnitude of the policy channel in the model could be made stronger by assuming, in line with the evidence on augmented Taylor rules discussed by Agénor and Pereira da Silva (2019, chapter 4), that the central bank in the periphery responds directly to the initial appreciation by lowering the refinance rate.

To account for a more direct bank-based transmission channel, suppose that banking activity in the periphery is costly. But while managing deposits and central bank borrowing entails negligible costs, those associated with managing domestic loans and foreign borrowing are not. Specifically, suppose that there is cost complementarity between managing loans and foreign borrowing. To capture this case, we can replace the term $-0.5\gamma z_t(l_t^{PC,i})^2$ in the profit function (29) by a nonseparable cost function in l_t^{PK} and $z_t l_t^{PC}$, $\Gamma(l_t^{PK}, z_t l_t^{PC})$, which for tractability is defined as a Diewert cost function:

$$\Gamma(l_t^{PK}, l_t^{PC}) = \gamma_{PK} l_t^{PK} + \gamma_{PC} l_t^{PC} - 2\gamma\sqrt{l_t^{PK} z_t l_t^{PC}}, \tag{40}$$

where $\gamma_{PK}, \gamma_{PC} \geq 0$ and $\gamma > 0$. Solving again the bank's optimization problem, it can be shown that, the first-order conditions (31) and (32) are now replaced by

$$1 + i_t^{PL} = \frac{\zeta^L}{(\zeta^L - 1)(1 - \tau_t^P)q_t^P}\left\{1 + i_t^{PR} + \gamma_{PK} - \gamma(\frac{z_t l_t^{PC}}{l_t^{PK}})^{0.5}\right\}, \tag{41}$$

$$\frac{z_t l_t^{PC}}{l_t^{PK}} = [\frac{\gamma}{(1 + i_t^{CP})\mathbb{E}_t(\frac{E_{t+1}}{E_t}) + \gamma_{PC} - (1 + i_t^{PR})}]^2. \tag{42}$$

From these equations, it is easy to see how the bank-based channel operates. From (42), a negative shock to the interest rate on global bank loans raises (all else equal) the ratio of these loans to domestic loans. In turn, from (41), an increase in that ratio tends (by reducing marginal management costs) to lower the loan rate—independently of any change in the refinance rate.

Figure 3 displays the impulse response functions when equations (31) and (32) are replaced by (41) and (41), and for $\gamma_{PK} = \gamma_{PC} = 0.0$, as well as two values of γ, 0.1 and 0.5. Qualitatively, the effects are the same as in Figure 2; in addition, the results show that for a higher value of γ (that is, for a higher degree of cost complementarity between foreign borrowing and domestic loans) the magnitude of the expansionary effect on investment and output is amplified, as expected, due to a larger initial reduction in the loan rate. However, because the countercyclical policy response is stronger under *both* independent policymaking and cooperation, the benefits of coordination are not significantly different from those obtained when only the policy channel is present.

7.3 Instrument Cost and the Size of Regions

The benchmark results discussed earlier consider a cost of $\varkappa_W = 0.02$. The second and third columns of Table 3 display those obtained with higher values of $\varkappa_W = 0.03$ and $\varkappa_W = 0.05$.

The first point to note is that, with a higher cost, the optimal values for the response parameters χ_2^j are lower, under both under Nash and coordination. This negative correlation, which is also verified for higher values of $\varkappa_W$, is the consequence of policymakers internalizing the effect of their policy choices on their objective function (37); the policy instruments are strategic complements. As a result, the stabilization effect is now weaker. The second point is that, the higher the cost, the more similar policies under the two regimes are. As a result, the gain from coordination, while positive for all parties at first, becomes negligible for higher values of the cost parameter. Overall, a higher cost of instrument manipulation does have an adverse effect on the magnitude of the welfare gain associated with international macroprudential policy coordination—both at the level of the individual parties and the world economy as a whole. Nevertheless, as shown in Table 3, the key result obtained earlier continues to hold: with greater financial integration, coordination is Pareto-improving.

Alternatively, consider the case where instead of equal weights in the global policy loss function, weights are based on economic strength. Specifically, suppose that n is calculated on the basis of the total GDP of the two regions. World Bank data indicate that SMICs accounted for a share of 18.2 percent over the period 2010-17. Thus, we set the size of the core region to $n = 1 - 0.182 = 0.818$. The results are shown in the lower part of Table 3. With respect to the optimal response parameters, there are no noticeable differences with the benchmark case, regardless of the instrument cost. But with respect to the welfare gain of coordination, the core region and the world as a whole continue to be adversely affected—and significantly more so, regardless of the instrument cost. At the same time, the gain for the periphery is higher than in the benchmark case. Thus, the enforcement challenges highlighted earlier with respect to cooperative arguments become even more severe.

7.4 Globally Integrated Housing Market

Finally, we consider the case where the housing market is globally integrated. In this setting, housing services can now be traded across regions, even though dwellings themselves are immovable assets. This is consistent with the growing evidence which suggests that house price fluctuations have become highly synchronized across countries, as documented by Hirata et al. (2013), Cesa-Bianchi (2013), Jordà et al. (2018), Banti and Phylaktis (2019), and most importantly by the International Monetary Fund (2018, chapter 3), which considers a large sample of high- and middle-income economies.

A simple way to account for a globally integrated housing market in our model consists of treating households as *global property owners* and replacing the region-specific housing market equilibrium conditions, equation (A26) for the core region and the equivalent for the periphery, by the single equilibrium condition:

$$nH_t^C + (1-n)H_t^P = n\bar{H}^C + (1-n)\bar{H}^P, \tag{43}$$

together with the equilibrium price condition:

$$p_t^{PH} = z_t p_t^{CH}, \tag{44}$$

where for simplicity we abstract from region-specific real estate transactions costs and other regulations, such as restrictions on land use or foreign buyers, limits on loan-to-value ratios, and so on.[31]

A globally integrated housing market may transmit and amplify shocks by increasing the exposure of local markets to global financial conditions. In our model, more specifically, it implies that house price changes in one region are now transmitted directly through collateral effects to the other region.[32] The question is whether, in a setting where regulators operate on the basis of a simple domestic credit-output policy rule to maximize welfare, this additional channel creates room for coordinated policy responses to be Pareto-improving.

As discussed earlier, a global lending shock translates into an increase in both consumption and house prices in the periphery. This raises the value of collateral that intermediate-good producers in that region can pledge to local banks, which in turns tends to lower the loan rate (or, more precisely, amplify its initial fall), thereby magnifying the expansion in investment and output.

With an integrated housing market, the increase in house prices in the periphery, combined with the real exchange rate depreciation (from the perspective of the core region) documented earlier translates into an increase in house prices in the core as well, thereby amplifying, again through the collateral channel, increases in investment and output in that region. Put differently, an integrated housing market helps to generates a stronger positive co-movement in house prices across regions, and greater spillback effects from the periphery to the core. However, to the extent that these fluctuations lead to higher volatility, the regulator in the core has stronger incentives to intervene to stabilize lending. At the same time,

[31] To the extent that these costs are proportional to prices and do not change in response to the financial shocks considered here, abstracting from them has no significant bearing on the results.

[32] Cesa-Bianchi et al. (2018) also considered the case where house price increases, and associated movements in exchange rates, contribute to cross-border spillovers through changes in collateral values. Their mechanism, however, differs substantially from the one considered in this paper.

however, under non-cooperation, the regulator in each region sets the macroprudential tax rate solely on the basis of the behavior of the credit-to-output ratio in its own jurisdiction; neither one of them internalizes the fact that it may benefit the other. Thus, a globally integrated housing market may generate a cross-border pecuniary externality, which can be internalized under coordination.

Nevertheless, numerical experiments showed that this additional channel is relatively weak in our model, compared to the benchmark case of segmented housing markets. The reason is that the impact on investment is muted. This is largely due to the fact that the arbitrage condition with respect to the rate of return on capital (see Appendix A, equation (A19)) involves the *expected* loan rate. In turn, as can be inferred from (17) and 31), the expected loan rate depends only on changes in monetary and regulatory policy instruments. As a result, an assessment of the gains from coordination leads to results that are not discernibly different from those reported in the upper part of Table 3. However, it is certainly possible that, in a more general model with housing collateral and a globally integrated housing market, the cross-border pecuniary externality discussed earlier could be the source of significant gains from international macroprudential policy coordination. This is an important issue for future research.

8 Concluding Remarks

The purpose of this paper was to study the extent to which international coordination of macroprudential policy (in the form of a countercyclical tax on bank loans) can generate welfare gains, in a two-region, core-periphery model with a global bank, imperfect financial integration, and financial frictions occurring at both the national levels (between firms and banks in each region) and international level (between periphery banks and the global bank in the core region). Our key results were summarized in the introduction.

Our contribution can be extended in a number of directions. First, a key issue that our analysis raised relates to the need to identify what type of incentives can be used to ensure that countries do not renege on a commitment to coordinate their macroprudential policies. Such incentives relate fundamentally to side payment mechanisms and the perceived *ex post* cost of reneging on a cooperative agreement, but their practical design (including the role of a benevolent global institution) is a matter of debate. Second, our analysis was limited to a single, albeit important, financial shock, and a particular type of financial frictions. In the real world, of course, there are a number of alternative sources of shocks and financial frictions; it is possible that accounting for a *combination* of financial frictions could make the gains from coordination significantly larger. Third, as is well known from game theory, the choice of policy instrument can matter significantly in a non-cooperative game.[33] Our focus has been on a tax on bank loans as a generic macroprudential instrument, which captures the typical cost effect associated with price-based macroprudential tools (such as capital requirements). However, there is a range of other, quantity-based tools (such as loan-to-value or debt-to-income ratios), whose effects operate through different channels; it is possible that the welfare effects of these instruments may differ substantially under non-cooperation. Fourth, the coordination issue could be cast in the context of leadership games, which would involve one regulator leading the decision-making process. Given that these games involve within-period timing, they are difficult to model fully in standard models. As noted by de Paoli and Paustian (2017), leadership can be thought of as within-period commitment by one player, which clearly makes the leader better off. However, in general it is not the case that a leadership setup improves welfare compared to the case where both players move simultaneously. Similarly, rather than one-shot games, one could focus on modeling repeated games between regulators. From the experimental literature reviewed by Dal Bó and Fréchette (2018), for instance, one can surmise that as long as these games are sufficiently robust to strategic uncertainty—that is, uncertainty regarding the behavior of regulators in an interactive setting—reputational gains may be large enough to make coordination a preferable strategy.

Finally, there is significant evidence that macroprudential policies are subject to leakages across countries and can generate spillover effects of their own, as a result of global banks shifting activities across countries in response to changes in prudential regulation where they are based—essentially outside the scope of the instrument's application and enforcement. These spillover effects can operate not only through direct lending to foreign-country borrowers but also through lending locally to foreign branches, as well as through a "rebooking" of loans—whereby credit is originated by subsidiaries, but then booked on the balance sheet of the parent institution.[34] If increased lending induced by cross-border regulatory arbitrage by foreign banks contributes to a credit boom or asset price pressures in the recipient economies, depending on the stage of their financial cycles a counterbalancing macropruden-

[33] See for instance Canzoneri and Henderson (1989) for an early analytical example, and Coenen et al. (2009) in the context of a two-country DSGE model.

[34] See Reinhardt and Riddiough (2014), Avdjiev et al. (2017), Kang et al. (2017), and Cerutti and Zhou (2018). Buch and Goldberg (2017) provided a broad review of the evidence on the impact of cross-border lending by foreign banks on domestic credit.

tial response by regulators there may also be called for to mitigate systemic financial risks.[35] If delays in policy responses can magnify these risks, or if manipulating policy instruments is costly, *ex ante* coordination may improve global welfare. The model presented in this paper could be extended to account for these effects, possibly by considering economies of scope between domestic and foreign lending by global banks.[36]

[35] The need to mitigate incentives for cross-border regulatory arbitrage is precisely what underlies Basel III's *Principle of jurisdictional reciprocity* in the setting of countercyclical capital buffers. See Agénor and Pereira da Silva (2021) for a discussion.

[36] This issue is addressed in ongoing work (Agénor et al. (2021)), in a model that focuses on responses to an expansionary monetary policy shock in the core.

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Table 1
Benchmark Parameterization: Key Parameter Values

Parameter	Description	MAEs	SMICs
Households			
Λ	Discount factor	0.98	0.95
ς	Elasticity of intertemporal substitution	0.5	0.5
η_N	Preference parameter for leisure	25.0	25.0
ψ_N	Inverse of Frisch elasticity of labor supply	3.0	3.0
η_x	Preference parameter for money holdings	0.01	0.01
η_H	Preference parameter for housing	0.1	0.1
ν	Share parameter in index of money holdings	0.2	0.2
θ_0^B	Cost parameter, intermediation on world capital markets	0.2	0.2
Producers			
Λ_I	Share of own-region IG goods in final output	0.6	0.8
η_I	Elasticity of substitution, baskets of intermediate goods	4.5	4.5
θ^{CC}, θ^{PP}	Elasticity of own-region demand, intermediate goods	10.0	10.0
α	Share of capital, intermediate goods production	0.35	0.35
ϕ_I	Adjustment cost parameter, intermediate goods prices	74.5	74.5
δ_K	Depreciation rate of capital	0.01	0.025
Θ_K	Adjustment cost parameter, investment	14	14
Banks			
κ	Effective collateral-loan ratio	0.4	0.2
ψ_1	Elasticity of repayment probability, collateral	0.05	0.1
ψ_2	Elasticity of repayment probability, cyclical output	0.1	0.2
η_D	Elasticity of deposit supply by households	2.5	–
η_L, ζ_L	Elasticity of loan demand by capital producers	4.5	4.5
γ^C	Cost parameter, loan supply by global bank	0.2	–
γ^P	Cost parameter, demand for global bank loans	–	0.05
Central bank			
μ	Required reserve ratio	–	0.3
χ	Degree of interest rate smoothing	0.7	0.0
ε_1	Response of policy rate to inflation deviations	1.7	2.0
ε_2	Response of policy rate to output deviations	0.1	0.4
χ_1	Persistence parameter, tax on loans rule	0.1	0.1
Government			
ψ^G	Share of government spending in final output	0.2	0.25
Shocks			
ρ^C	Persistence parameter, global lending shock	0.57	–

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

Variable	Description	MAEs	SMICs
Y^{CP}/Y^{CI}	Share of exports in production of intermediate goods, core	0.098	–
Y^{PC}/Y^{PI}	Share of exports in production of intermediate goods, periphery	–	0.094
C^{j}	Private consumption	0.650	0.650
I^{j}, l^{jF}	Investment, loans to IG firms	0.150	0.100
r^{jK}	Rental rate of capital	0.031	0.083
l^{PC}	Loans from global bank to periphery banks	0.253	–
q^{jF}	Repayment probability, loans to IG firms	0.960	0.936
i^{jB}, i^{jR}	Government bond rate, central bank refinance rate	0.020	0.053
i^{jD}	Bank deposit rate	0.010	0.037
i^{jL}	Loan rate, loans to CG producers	0.046	0.095
i^{CP}	Loan rate, global bank loans to periphery banks	0.040	–
τ^{j}	Countercyclical tax rate on loans to domestic producers	0.0	0.0

Table 3
Optimal Policy Responses and Gains from Coordination:
Benchmark Case and Sensitivity Analysis[1]

	$\kappa = 0.02$	$\kappa = 0.03$	$\kappa = 0.05$
Benchmark case			
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$9.2, 0.6$	$6.0, 0.4$	$3.4, 0.2$
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$8.6, 0.5$	$5.6, 0.4$	$3.3, 0.2$
Relative welfare gain			
Core	-0.0025	0.0001	0.0000
Periphery	0.0162	0.0008	0.0005
World	-0.0015	0.0002	0.0000
Greater financial integration, $\theta_0^B = 0.1$			
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$15.0, 0.5$	$15.0, 0.4$	$8.2, 0.2$
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$15.0, 0.4$	$13.6, 0.3$	$7.8, 0.2$
Relative welfare gain			
Core	0.0182	0.0181	0.0008
Periphery	0.0420	0.0433	0.0008
World	0.0212	0.0212	0.0008
Unequal size, $n = 0.818$			
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$9.2, 0.6$	$6.0, 0.4$	$3.4, 0.2$
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$9.0, 0.4$	$5.9, 0.3$	$3.4, 0.1$
Relative welfare gain			
Core	-0.0058	-0.0039	-0.0064
Periphery	0.0339	0.0220	0.0324
World	-0.0053	-0.0036	-0.0060
Greater integration, $\theta_0^B = 0.1$, unequal size, $n = 0.818$			
Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$	$15.0, 0.5$	$15.0, 0.4$	$8.2, 0.2$
Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$	$15.0, 0.2$	$13.3, 0.1$	$7.5, 0.0$
Relative welfare gain			
Core	0.0509	0.0493	0.0309
Periphery	0.1230	0.1281	0.0964
World	0.0531	0.0517	0.0328

[1]Calculations of the optimal response parameters and the welfare gains are explained in the text. Initial values of n and θ_0^B are 0.5, 0.2, respectively.

Figure 1
Model Structure: Financial Flows

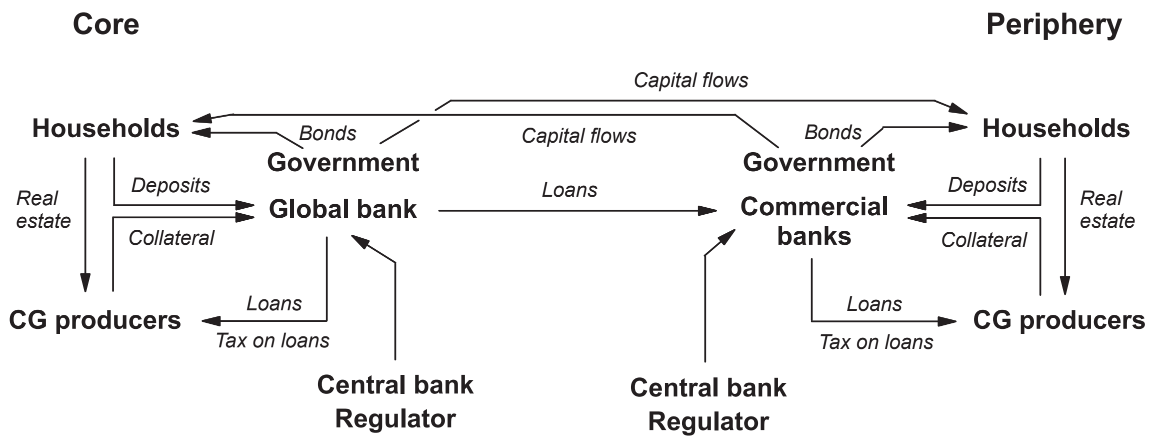
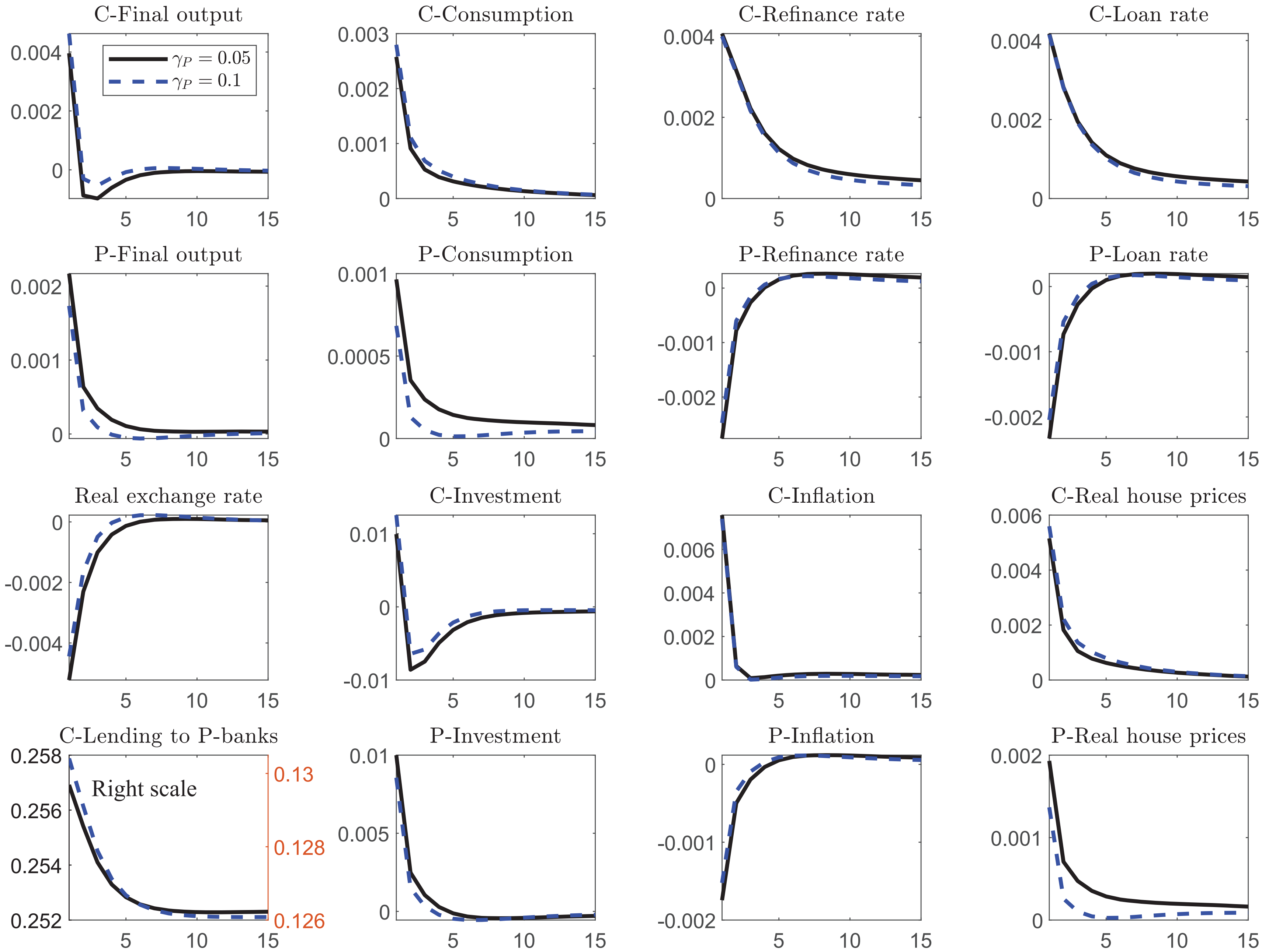
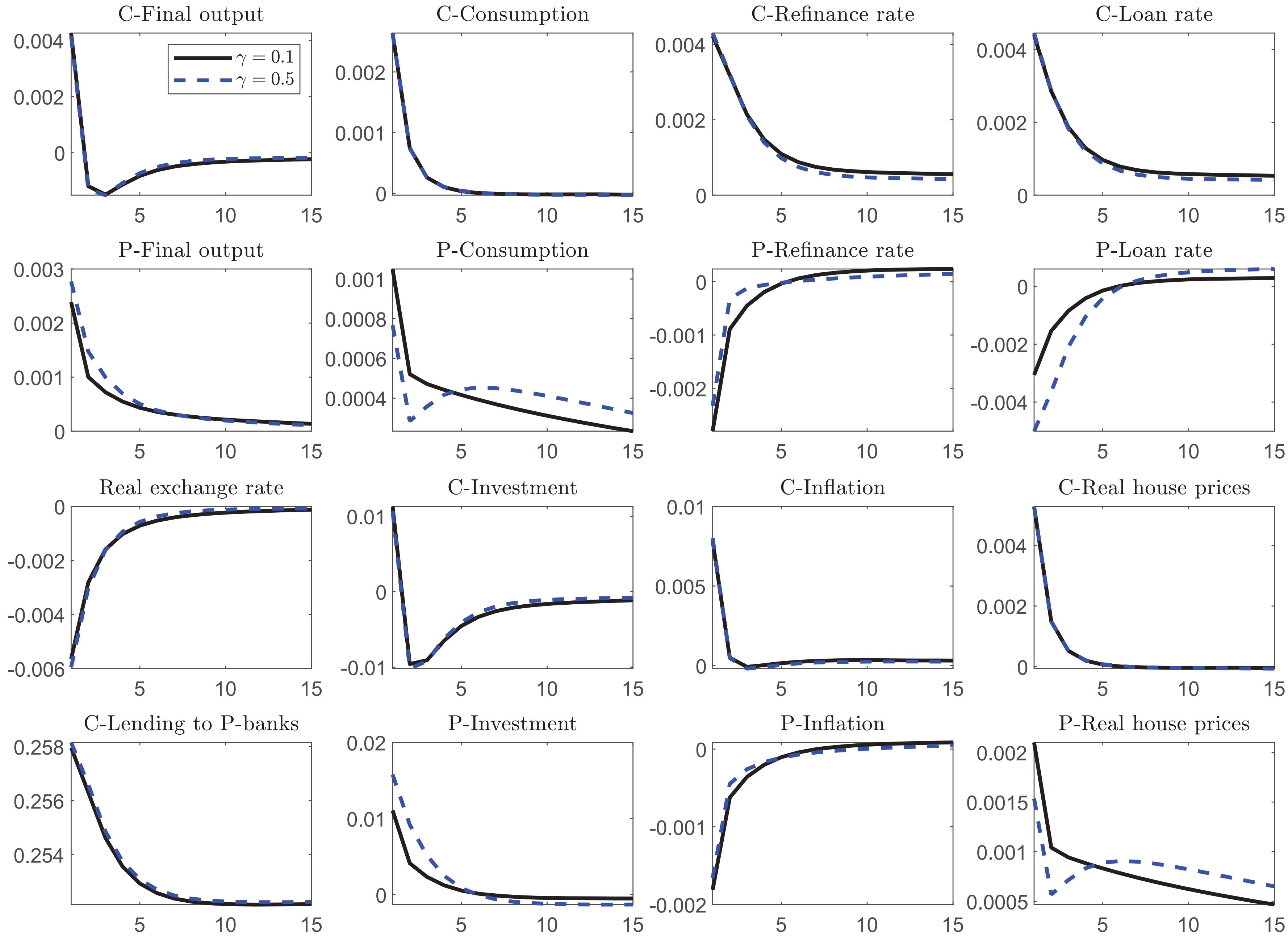


Figure 2
Positive Global Banking Shock



Notes: Consumption, investment, output, real house prices, the real exchange rate, and core lending to periphery banks are percentage deviations from their steady-state values. The loan rate, the refinance rate, and the inflation rate are absolute deviations from their steady-state values. Low cost corresponds to 0.05, and high cost to 0.1.

Figure 3
Positive Global Banking Shock: Economies of Scope



Note: See Notes to Figure 2.

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}:

$$Y_t^C = [\Lambda_I (Y_t^{CC})^{(\eta_I - 1)/\eta_I} + (1 - \Lambda_I)(Y_t^{PC})^{(\eta_I - 1)/\eta_I}]^{\eta_I/(\eta_I - 1)}, \tag{A1}$$

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

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

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

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

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

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

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

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

$$Y_t^{CC} = \Lambda_I^{\eta_I} (\frac{P_t^{CC}}{P_t^C})^{-\eta_I} Y_t^C, \quad Y_t^{PC} = (1 - \Lambda_I)^{\eta_I} (\frac{P_t^{PC}}{P_t^C})^{-\eta_I} Y_t^C, \tag{A5}$$

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

$$P_t^C = [\Lambda_I^{\eta_I} (P_t^{CC})^{1-\eta_I} + (1 - \Lambda_I)^{\eta_I} (P_t^{PC})^{1-\eta_I}]^{1/(1-\eta_I)}, \tag{A6}$$

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

$$P_{jt}^{PC} = E_t^{-1} P_{jt}^{PP}, \tag{A7}$$

where P_{jt}^{PP} is the foreign-currency price of foreign intermediates, set in the periphery. 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 region output of intermediate good j, Y_{jt}^{CI}, is sold on a monopolistically competitive market and is produced by combining labor, N_{jt}^C, and beginning-of-period capital, K_{jt}^C:

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

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

Capital is rented from a randomly matched CG producer at the rate r_t^{CK} and paid for after the sale of output.[37] Cost minimization yields the capital-labor ratio and the unit real marginal cost, mc_t^C, as

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

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

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

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

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

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

where $\phi_I \geq 0$.

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

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

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

Under symmetry, the price adjustment equation (A13) becomes

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

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

[37] For simplicity, we abstract from the cost channel, despite its importance—especially for for middle-income countries. See Agénor (2020, Chapter 1) for a discussion.

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:[38]

$$P_t^{CP} = E_t P_t^{CC}. \tag{A15}$$

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:

$$Y_{jt}^{CI} = Y_{jt}^{CC} + Y_{jt}^{CP}, \tag{A16}$$

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:

$$Y_{jt}^{PI} = Y_{jt}^{PP} + Y_{jt}^{PC}, \tag{A17}$$

with Y_{jt}^{PC} (core region 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:

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

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, H_t^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 $q_t^C \in (0,1)$. Expected repayment is thus $q_t^C(1 + i_t^{CL}) l_t^{CK} + (1 - q_t^C)\kappa \mathbb{E}_t p_{t+1}^{PH} H_t^C$, where $\kappa \in (0,1)$ is the share of the housing stock that can be effectively pledged as collateral.

Subject to (A18) and $l_t^{CK} = I_t^C$ 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 in Agénor et al. (2020, Chapter 4), the solution to this problem yields[39]

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

[38] 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.

[39] 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.

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

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[40]

$$b_t^C = G_t^C - T_t^C + (\frac{1+i_{t-1}^{CB}}{1+\pi_t^C})b_{t-1}^C - i_{t-1}^{CR}\frac{l_{t-1}^{CB}}{1+\pi_t^C}, \tag{A20}$$

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

$$G_t^C = \psi^G Y_t^C. \tag{A21}$$

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.

For the periphery, 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 (A20), with now $b_t^P = b_t^{PP} + b_t^{CP}$ and interest payments of $(1+\pi_t^P)^{-1}(1+i_{t-1}^{PB})b_{t-1}^P$.

Equilibrium Conditions

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:

$$Y_t^{CI} = Y_t^{CC} + Y_t^{CP}, \qquad Y_t^{PI} = Y_t^{PP} + Y_t^{PC}. \tag{A22}$$

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

$$Y_t^C = C_t^C + G_t^C + I_t^C + \frac{\phi_I}{2}(\frac{P_t^{CC}}{P_{t-1}^{CC}}-1)^2(\frac{P_t^{CC}}{P_t^C})Y_t^{CI}, \tag{A23}$$

and analogously for the periphery.

Government bonds are in zero net supply. The counterpart to bank loans is cash, which is used instantaneously to buy investment goods at the beginning of the period. The equilibrium condition of the market for cash in the core region is thus

$$m_t^{Cs} = m_t^C, \tag{A24}$$

which can be solved for the equilibrium bond rate.

[40] Using the central bank balance sheet constraint (20), the last term in (A20) can be written as $(1+\pi_t^C)^{-1}i_{t-1}^{CR}m_{t-1}^{Cs}$, which corresponds to central bank revenue, rather than seigniorage, consistent with the distinction made by Buiter (2007). 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, as noted in the text, transferred to the government.

Equilibrium in the market for periphery loans requires equating (18) and (32), that is, $l_t^{CP} = l_t^{PC}$, which can be solved for the equilibrium loan rate. Alternatively, rewriting (18) as

$$1 + i_t^{CP} = (1 + i_t^{CR}) + \gamma^C l_t^{PC}, \tag{A25}$$

shows that an increase in the amount borrowed by periphery banks, as given by (32), raises the cost at which they borrow from the global bank.

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

$$H_t^C = \bar{H}^C, \tag{A26}$$

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

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

$$nb_t^{CC} + (1-n)b_t^{PC} = 0, \qquad (1-n)b_t^{PP} + nb_t^{CP} = 0. \tag{A27}$$

Analogously, in a two-region world, current account surpluses and deficits must be zero:

$$nCA_t^C + (1-n)E_t^{-1}CA_t^P = 0, \tag{A28}$$

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

$$\begin{aligned} CA_t^C = {} & P_t^{CC} Y_t^{CP} - P_t^{PC} Y_t^{PC} \\ & + i_{t-1}^P E_{t-1}^{-1} P_{t-1}^P b_{t-1}^{CP} + i_{t-1}^{CP} P_{t-1}^C l_{t-1}^{PC} - i_{t-1}^C P_{t-1}^C b_{t-1}^{PC}. \end{aligned} \tag{A29}$$

In this expression, P_t^{CC} is the price of core intermediate goods sold to 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 to the core (equal, under local currency pricing, to the price of periphery intermediate goods adjusted for the nominal exchange rate), and Y_t^{PC} core imports of intermediate goods, which correspond also to the periphery's exports. The third term in (A29) 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:[41]

$$CA_t^C = (E_t^{-1} P_t^P b_t^{CP} - E_{t-1}^{-1} P_{t-1}^P b_{t-1}^{CP}) + (P_t^C l_t^{PC} - P_{t-1}^C l_{t-1}^{PC}) - (P_t^C b_t^{PC} - P_{t-1}^C b_{t-1}^{PC}). \tag{A30}$$

Finally, note that the current account for the periphery at current local prices (the analogue of (A29)) can be written as

$$\begin{aligned} CA_t^P = {} & P_t^{PP} Y_t^{PC} - P_t^{CP} Y_t^{CP} \\ & - i_{t-1}^{CP} E_{t-1} P_{t-1}^C l_{t-1}^{PC} - i_{t-1}^{PB} P_{t-1}^P b_{t-1}^{CP} + i_{t-1}^C E_{t-1} P_{t-1}^C b_{t-1}^{PC}, \end{aligned} \tag{A31}$$

where $P_t^{CP} = E_t P_t^{CC}$ is the price of core goods sold in the periphery region (equal to, under local currency pricing, the price of core intermediate goods adjusted for the exchange rate),

[41] Combining conditions (A29) and (A30) gives the foreign exchange market equilibrium condition, which is solved 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 (A31) 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 (A30),

$$CA_t^P = E_t P_t^C b_t^{PC} - E_{t-1} P_{t-1}^C b_{t-1}^{PC} \tag{A32}$$

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

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