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# Global Banking, Financial Spillovers, and Macroprudential Policy Coordination

Pierre-Richard Agénor* Luiz A. Pereira da Silva**

**Abstract**

The gains from international macroprudential policy coordination are studied in a two-region, core-periphery macroeconomic 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 region. Macroprudential regulation takes the form of a countercyclical tax on bank loans to domestic capital goods producers, which responds to real credit growth and is subject to a cost in terms of welfare. Numerical experiments, based on a parameterized version of the model, show that the welfare gains from macroprudential policy coordination are positive, albeit not large, for the world economy. In addition, these gains tend to increase with the degree of international financial integration. However, depending on the origin of financial shocks, they can also be highly asymmetric across regions.

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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—despite the retrenchment of major global and non-major European banks operations in the immediate aftermath of the Global financial crisis. Studies such as Bruno and Shin (2015), Temesvary et al. (2018), Avdjiev 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

[1] See International Monetary Fund (2016) for a formal empirical analysis and Agénor and Pereira da Silva (2018) for a detailed discussion of the recent evidence on the international spillover effects associated with financial shocks.

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 as they feed back onto their own economies—and internalize the cross-border spillover effects associated with their monetary policy decisions and the possible risks that they create (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 capital flows and promote global financial stability.

The foregoing discussion suggests that the analytical case for macroprudential policy coordination across countries rests fundamentally on the fact that financial risks represent negative externalities that tend to increase with the magnitude of spillovers and spillbacks, and the degree to which business and financial cycles are unsynchronized across countries. Conversely, effective domestic macroprudential policy that helps to contain systemic risks in one country may help promote financial stability elsewhere by reducing the scope for negative trade and financial spillovers, creating therefore positive externalities. From that perspective, as noted by Engel (2016), coordination is desirable 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 (reviewed by Frankel (2016) for instance) on international monetary policy coordination, research on this issue remains very limited. Among the few contributions available, based explicitly on a game-theoretic approach, are Agénor et al. (2018*b*), Agénor et al. (2018*c*), and Chen and Phelan (2017). Agénor et al. (2018*b*) 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

[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 (2018) provide a more detailed discussion.

banks in the periphery.[4] A global benevolent policymaker chooses the constrained efficient allocation in order to maximize the expected present value of the population-weighted sum of household utilities in the cooperative case, or own domestic households' utility in the non-cooperative (Nash) equilibrium, subject to a cost associated with the use of distortionary policy instruments. Their results show that the global 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. At the same time, however, the distribution of gains across countries tends to be highly asymmetric, implying therefore that coordination may not be Pareto-improving.

For their part, Agénor et al. (2018*c*) focus on the case of a currency union where investment in each member country is financed by credit from national banks only, subject to collateral-based frictions. Monetary policy is conducted by a common central bank, whereas macroprudential policy can be conducted either by national regulators or a common, union-wide regulator. In either case macroprudential policy (in the form of a simple, implementable countercyclical rule) aims to smooth credit fluctuations in order to maximize welfare. Thus, their focus is on the properties of two alternative, institutional mandates to achieve financial stability: delegation of macroprudential policy to individual member countries (the noncooperative Nash equilibrium or decentralized regime) and delegation to a common regulator (the cooperative equilibrium or centralized regime), with the common central bank retaining full control of monetary policy in both cases. Their results show that in response to asymmetric real and financial shocks cooperation does generate positive gains relative to the noncooperative outcome at the level of the union but coordination does not necessarily benefit all members. Finally, Chen and Phelan (2017), 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 regu-

[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 *both* countries. Other contributions include Kamber and Thoenissen (2013), Alpenda and Aysun (2014), and Cuadra and Nuguer (2018). However, none of them considers the issue of cross-border policy coordination.

lation 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, therefore 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. Periphery banks 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, tends to reduce incentives 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 recent studies as generating significant reverse spillovers, also referred to as spillbacks, on advanced economies. Our focus is on credit spread shocks occurring in both regions.

Numerical experiments show that the welfare gains from macroprudential policy coordination—a regime under which a benevolent regulator internalizes the consequences of policy interdependence—are positive, albeit not large (of the order of 0.2-0.9 percent of steady-state consumption, depending on the origin of the financial shock), for the world economy. In addition, consistent with the evidence alluded to earlier, these gains increase with the degree of international financial integration. However, depending on the origin of shocks, they can also be asymmetric across regions. This result is consistent with those reported in Agénor et al. (2018*b*, 2018*c*), albeit in a very different setting. Although our analysis considered only a single (but representative) financial shock, the fact that gains are not large and that coordination is not necessarily Pareto-improving raises a general question about incentives for countries to remain voluntarily in a cooperative agreement.

The remainder of the paper proceeds as follows. Section 2 describes the model. In the spirit of 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 cost of borrowing.[5] 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 illustrate the functioning of the model, the impulse response functions associated with asymmetric and symmetric financial shocks are described in Section 5. The gains from coordinating macroprudential policies across borders are evaluated in Section 6. Sensitivity analysis is reported in Section 7, in order to examine how the model's structural features affect the gains from coordination. We consider, in particular, the impact of a greater degree of financial integration and the case of a perfectly integrated world housing market, which implies that policy responses to house price shocks occurring in one region may generate a pecuniary externality for other regions—thereby potentially enhancing the scope for coordination to improve welfare. The last section discusses the broad policy implications of the analysis and 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. 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, 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 borrowed. Regions trade in (inter-

[5] See for instance Quint and Rabanal (2014), Levine and Lima (2015), 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.

mediate) goods and government bonds, but markets in cash and credit 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.[6]

### 2.1.1 Households

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

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

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

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

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

The core household's flow budget constraint is

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

[6] In some respects, the model presented here dwells on the class of DSGE models with financial frictions discussed in Agénor (2019, Chapters 4 and 8), in both closed and open economies.

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

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

where $N_t = \int_0^1 N_t^j dj$, $p_t^{CH} = P_t^{CH}/P_t^C$ is the real price of housing (with $P_t^{CH}$ denoting the nominal price), $1+\pi_t^C = P_t^C/P_{t-1}^C$, $b_t^{CC}$ ($z_t^{-1}b_t^{CP}$) real holdings of one-period, non-contingent core (periphery) government bonds, $z_t = E_t P_t^C/P_t^P$, the real exchange rate 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, $w_t$ the economy-wide real wage, $T_t$ real lump-sum taxes, $J_t^I$, $J_t^K$, and $J_t^B$, end-of-period profits 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 $\theta_t^{CP}$ an intermediation premium, which increases with the core household's own stock of periphery bonds:

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

with $\theta_0^B > 0$ denoting a symmetric cost parameter.[8]

The representative household maximizes (1) with respect to sequences $\{C_{t+s}, N_{t+s}, m_{t+s+1}^C, d_{t+s+1}^C, b_{t+s+1}^{CC}, b_{t+s+1}^{CP}, H_{t+s+1}^C\}_{s=0}^{\infty}$, subject to (2)-(5), taking period-$t-1$ variables as well as $w_t$, $T_t$ and real profits as given. The first-order conditions are

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

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

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

[8]For simplicity, intermediation costs are a pure deadweight loss.

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

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

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

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, equation (11) can be approximated by

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

### 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. 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

$$\mathbb{E}_t J_{t+1}^C = q_t^C(1+i_t^{CL})(1-\tau_t^C)l_t^{CK} + (1-q_t^C)\kappa \mathbb{E}_t p_{t+1}^{CH}\bar{H}^C + q_t^{PC}(1+i_t^{CP})l_t^{CP} \tag{14}$$
$$-(1+i_t^{CD})d_t^C - (1+i_t^{CR})l_t^{CB} - \gamma^C\frac{(l_t^{CP})^2}{2} + \Omega_t^C,$$

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, and $q_t^{PC} \in (0,1)$ the repayment probability of periphery banks on their loans, which is determined (as discussed later) by conditions in that region. The first term in (14) is expected repayment when there is no default by domestic firms, whereas the second is the value of collateral seized in case of default, corresponding to a fraction $\kappa \in (0,1)$ of the expected value of the housing stock, which is assumed to be in fixed supply $\bar{H}^C$. We assume that the global bank cannot seize collateral if periphery banks choose to default; these banks therefore have effectively limited liability, so that when they default (which occurs with probability $1-q_t^{PC}$) the global bank gets nothing. Expected repayment (the third term in (14)) is therefore only $q_t^{PC}(1+i_t^{CP})l_t^{CP}$. 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 $\gamma^C > 0$.[9] The last term, $\Omega_t^C$, represents the proceeds of the loan tax; in order we 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, whereas the market for periphery loans is competitive. Thus, it sets the deposit and lending rates, and chooses the amount of lending to periphery banks, so as to maximize expected profits:[10]

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

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

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

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

$$l_t^{CP} = \frac{q_t^{PC}(1+i_t^{CP}) - (1+i_t^{CR})}{\gamma^C}, \tag{18}$$

where $\eta_D, \eta_L > 0$ are gross interest elasticities of the supply of deposits and the demand for loans, respectively. Thus, the wedge between the policy rate and the loan rate depends on both the risk of default and macroprudential regulation. In particular, equation (17) shows that a higher tax on loans raises the lending rate. In addition, equation (18) indicates that the supply of loans to periphery banks is increasing in the expected return on these loans, as measured by $q_t^{PC}(1+i_t^{CP})$.

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:

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

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

[10] One way to view this assumption is to think of a multitude of global banks in the core region being able to collude to set interest rates domestically, but unable to do so with respect to setting the cost of borrowing for periphery banks.

where $\tilde{Y}^C$ is the steady-state level of core final output. Agénor and Pereira da Silva (2017) formally derive an equation similar to (19) as part of the bank's optimization problem, by assuming that monitoring costs are endogenous and that *ex ante* monitoring effort is directly related—as in Allen et al. (2011) and Dell'Ariccia et al. (2014), for instance—to the probability of repayment.[11] The collateral-loan ratio reflects a moral hazard effect, whereas the cyclical position of the economy reflects the fact that (unit) monitoring costs tend to be relatively low in good times.

In Appendix A we relate loans to local firms (the representative CG producer) 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 (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 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 does not intervene in the foreign exchange market and supplies cash, in quantity $m_t^{CS}$, to households and firms. Setting its (constant) stock of foreign reserves to zero, its balance sheet is thus

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

The core central bank supplies liquidity elastically to the global bank at a cost $i_t^{CR}$, which is set on the basis of an inertial Taylor rule:

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

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.[12] We consider a simple implementable rule whereby

[11] As noted by Allen et al., 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.

[12] 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.

changes in the 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 (excessive) credit growth has often been associated with financial crises.[13] 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.[14] Thus, from (17) and (22), borrowing is more costly during episodes of credit booms and this in turn helps to mitigate macroeconomic fluctuations.

### 2.1.4 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[15]

$$b_t^C = G_t - T_t + (\frac{1+i_{t-1}^{CB}}{1+\pi_t^C})b_{t-1}^C - i_{t-1}^{CR}\frac{l_{t-1}^{CB}}{1+\pi_t^C}, \tag{23}$$

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 $G_t$ real expenditure on core final goods, which represents a fraction $\psi^G \in (0,1)$ of final output:

$$G_t = \psi^G Y_t^C. \tag{24}$$

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.

[13] See Taylor (2015) and Aldasoro et al. (2018) for a discussion.

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

[15] Using the balance sheet constraint (20), the last term in (23) can be written as $(1+\pi_t^C)^{-1} i_{t-1}^{CR} m_{t-1}^{CB}$, which corresponds to central bank revenue, rather than seigniorage, 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.

## 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 faced by core households, with the effective rate of return on core government bonds $i_t^C$ defined as, symmetrically to (4),

$$1 + i_t^C = (1 + i_t^{CB})(1 - \theta_t^{PC})\mathbb{E}_t(\frac{E_{t+1}}{E_t}), \tag{25}$$

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

$$\theta_t^{PC} = \frac{\theta_0^B}{2} b_t^{PC}. \tag{26}$$

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

$$b_t^{PC} \simeq \frac{(1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t) - (1 + i_t^{PB})}{\theta_0^B(1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)}. \tag{27}$$

Equations (12) and (27) imply therefore that uncovered interest parity, $1 + i_t^{PB} \simeq (1 + i_t^{CB})\mathbb{E}_t(E_{t+1}/E_t)$, obtains when $\theta_0^B \rightarrow 0$. Thus, as discussed later, the impact of increased financial integration on the gains from coordination can be assessed by lowering $\theta_0^B$.

### 2.2.2 Commercial Banks

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

$$l_t^{PK,i} = (1 - \mu)d_t^{P,i} + z_t l_t^{PC,i} + l_t^{PB,i}, \tag{28}$$

where $l_t^{PK,i}$ is loans to periphery firms, $d_t^{P,i}$ deposits (determined analogously to (9)), $\mu \in (0, 1)$ the required reserve ratio on these deposits, $z_t l_t^{PC,i}$ borrowing from the global bank (with $l_t^{PC,i}$ measured in foreign-currency terms), at the rate $i_t^{CP,i}$, 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.

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:

$$i_t^{PD,i} = (1-\mu) i_t^{PR}. \tag{29}$$

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

$$l_t^{PK,i} = (\frac{1+i_t^{PL,i}}{1+i_t^{PL}})^{-\zeta_L} l_t^{PK}, \tag{30}$$

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

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

$$\mathbb{E}_t J_{t+1}^{B,i} = q_t^{P,i}(1+i_t^{PL,i})(1-\tau_t^P) l_t^{PK,i} + (1-q_t^{P,i})\left(\kappa^i p_{t+1}^{PH} \bar{H}^P\right) - (1+i_t^{PD,i}) d_t^{P,i} + \mu d_t^{P,i}$$
$$-(1+i_t^{PR}) l_t^{PB,i} - q_t^{PC}(1+i_t^{CP}) \mathbb{E}_t(\frac{E_{t+1}}{E_t}) z_t l_t^{PC,i} - \gamma^P z_t \frac{(l_t^{PC,i})^2}{2} + \Omega_t^{P,i},$$

where $i_t^{PR}$ 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 of periphery CG producers. As before, the first two terms represent expected income (net of taxes) from lending, the third interest paid on deposits, the fourth reserve requirements held at the central bank and returned to bank $i$ at the end of the period, the fifth repayment on loans from the central bank, and the sixth 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 $0.5\gamma^P z_t (l_t^{PC,i})^2$, where $\gamma^P > 0$. The last term $\Omega_t^{P,i}$ represents the revenue of the loan tax, which again is transferred back in lump-sum fashion to bank $i$.

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

$$1 + i_t^{PL,i}, z_t l_t^{PC,i} = \arg\max \mathbb{E}_t J_{t+1}^{B,i}. \tag{31}$$

Solving (31) subject to (28) and (30), and taking repayment probabilities as given yields, in a symmetric equilibrium,

$$i_t^{PL} = (\frac{\zeta_L}{\zeta_L - 1}) \frac{(1+i_t^{PR})}{(1-\tau_t^P) q_t^P} - 1, \tag{32}$$

$$l_t^{PC} = \frac{1}{\gamma^P}\left\{(1+i_t^{PR}) - q_t^{PC}(1+i_t^{CP})\mathbb{E}_t(\frac{E_{t+1}}{E_t})\right\}. \tag{33}$$

Equation (32) shows once again that a tighter macroprudential response raises the cost of loans, whereas equation (33) indicates that a higher cost of borrowing from the global bank (adjusted for expected depreciation) reduces the demand for foreign loans—and vice versa for an increase in the marginal cost of borrowing domestically. As before, borrowing from the central bank is determined residually from (28).

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:

$$q_t^P = (\frac{\kappa \mathbb{E}_t p_{t+1}^{PH} \bar{H}^P}{l_t^{PK}})^{\psi_1^P}(\frac{Y_t^P}{\tilde{Y}^P})^{\psi_2^P}, \quad \psi_1^P, \psi_2^P > 0 \tag{34}$$

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

As noted earlier, the global bank cannot effectively secure collateral against its loans to periphery banks. Yet these banks can suffer from lender-enforced penalties, or a reputational cost, which creates an incentive to repay. We assume, in line with the standard literature on foreign borrowing and sovereign default risk, that the repayment probability on core loans is negatively related (due to banks' opaqueness) to the economy-wide debt-to-output ratio:

$$q_t^{PC} = q_0^{PC}(\frac{z_t l_t^{PC}/Y_t^P}{\tilde{z}\tilde{l}^{PC}/\tilde{Y}^P})^{-\psi_Q}, \tag{35}$$

where $\psi_Q > 0$.

### 2.2.3 Central Bank and Regulator

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

$$l_t^{PB} = m_t^{PS}, \tag{36}$$

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):

$$\frac{1+i_t^{PR}}{1+\tilde{\imath}^{PR}} = (\frac{1+i_{t-1}^{PR}}{1+\tilde{\imath}^{PR}})^{\chi^P}\left\{(\frac{1+\pi_t^P}{1+\pi_T^P})^{\varepsilon_1^P}(\frac{Y_t^P}{\tilde{Y}^P})^{\varepsilon_2^P}\right\}^{1-\chi^P}, \tag{37}$$

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):[16]

$$\frac{1+\tau_t^P}{1+\tilde{\tau}^P} = (\frac{1+\tau_{t-1}^P}{1+\tilde{\tau}^P})^{\chi_1^P} \left\{ (\frac{l_t^{PK}}{l_{t-1}^{PK}})^{\chi_2^P} \right\}^{1-\chi_1^P}, \tag{38}$$

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

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

The production structure and the main real and financial flows between agents (abstracting from the government) 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.

Assuming for simplicity that loans to firms are made exclusively in the form of cash, the equilibrium condition of the currency market in the core region is given by

$$m_t^{CS} = m_t^C + l_t^{CK}, \tag{39}$$

Equilibrium in the market for periphery loans requires equating (18) and (33), that is, $l_t^{CP} = l_t^{PC}$, which can be solved for the equilibrium loan rate. Alternatively, rewriting (18) as

$$1 + i_t^{CP} = \frac{(1+i_t^{CR}) + \gamma^C l_t^{PC}}{q_t^{PC}}, \tag{40}$$

shows that an increase in the amount borrowed by periphery banks, as given by (33), raises the cost at which they borrow from the global bank both directly and indirectly, through a reduction in the repayment probability on periphery loans, as implied by

[16] Alternative macroprudential instruments for the periphery could be the required reserve ratio, as in Agénor et al. (2018*a*) for instance, or a direct tax on foreign borrowing, as in Agénor and Jia (2015). 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.

(35). Thus, in the model $1/q_t^{PC}$ plays the same role as the country risk premium externality in the literature on sovereign debt and foreign borrowing.[17]

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

$$H_t^C = \bar{H}^C, \tag{41}$$

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

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

$$nb_t^{CC} + (1-n)b_t^{PC} = 0, \qquad (1-n)b_t^{PP} + nb_t^{CP} = 0. \tag{42}$$

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

$$nCA_t^C + (1-n)E_t^{-1}CA_t^P = 0, \tag{43}$$

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

$$CA_t^C = P_t^{CC}Y_t^{CP} - P_t^{PC}Y_t^{PC} \tag{44}$$
$$+i_{t-1}^{PB}E_{t-1}^{-1}P_{t-1}^{P}b_{t-1}^{CP} + i_{t-1}^{CP}P_{t-1}^{C}l_{t-1}^{PC} - i_{t-1}^{CB}P_{t-1}^{C}b_{t-1}^{PC},$$

where $P_t^{CC}$ is the price of core intermediate goods sold on the periphery market (that is, the price of core exports), $Y_t^{CP}$ are core exports of intermediate goods, which correspond also to the periphery's imports of these goods, $P_t^{PC} = E_t^{-1}P_t^{PP}$ the price of periphery intermediate goods sold in the core region (equal, under local currency pricing, to the price of periphery intermediate goods adjusted for the exchange rate), and $Y_t^{PC}$ core imports of intermediates, which correspond also to the periphery's exports. The third term in (44) 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

[17] See for instance Chung and Turnovsky (2010) for a rigorous derivation of a positively-sloped supply curve of foreign debt. If it had been assumed that the global bank also has monopoly power in setting the interest rate on its loans to periphery banks, and that $\gamma_C = 0$, the solution of the bank's optimization problem would have yielded an expression similar to (40) up to a multiplicative constant. The debt effect would therefore still operate through $q_t^{PC}$.

given by (minus) the net change in foreign assets:[18]

$$CA_t^C = (E_t^{-1}P_t^P b_t^{CP} - E_{t-1}^{-1}P_{t-1}^P b_{t-1}^{CP}) + (P_t^C l_t^{PC} - P_{t-1}^C l_{t-1}^{PC}) - (P_t^C b_t^{PC} - P_{t-1}^C b_{t-1}^{PC}). \quad (45)$$

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$a$) for a small open economy, so we refer to those papers for a more detailed discussion.[19]

# 4 Parameterization

To assess the properties of the model and evaluate the gains from coordination we parameterize it for two groups of countries, corresponding to the core and periphery, respectively: *major advanced economies* (MAEs) and *systemically important middle-income countries* (SMICs). As defined in Agénor and Pereira da Silva (2018), MAEs consist of the United States, the euro area, and Japan, whereas SMICs consist of Brazil, China, India, Indonesia, Mexico, Russia, South Africa, and Turkey. As identified by the International Monetary Fund (2016), these groups of countries represent those who have exerted the largest financial spillovers and spillbacks to each other in recent years.

Our benchmark parameterization uses 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 (2019, 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 $\Lambda$ 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

[18] Combining conditions (44) and (45) gives the foreign exchange market equilibrium condition, which is solved for the exchange rate.

[19] In particular we assume, as in Benigno and Woodford (2005) for instance, that policymakers have no access to lump-sum subsidies to correct the short- and long-run distortions created by monopolistic competition and financial frictions. In that sense, the nonstochastic steady state is inefficient.

parameter for leisure, $\eta_N$, is set at 16, to ensure that in the steady state households in both regions devote one third of their time endowment to market activity—a fairly common benchmark 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 $\psi_N$ is equal to 3), in line with the empirical evidence.

The parameter for composite monetary assets, $\eta_x$, 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, $\eta_H$, we use the same value as in Notarpietro and Siviero (2015), 0.1. The share parameter in the index of money holdings, $\nu$, which corresponds to the relative share of cash in narrow money, is set at 0.2 to capture the predominant use of deposits in transactions in both regions. The cost parameter related to core (periphery) bond holdings by core (periphery) households, $\theta_0^B$, is set initially at 0.8. This value is consistent with a relatively low degree of capital mobility. Sensitivity analysis is performed later on.

The distribution parameter between core and periphery intermediate goods in the production of the final good (or, equivalently, the degree of home bias), $\Lambda_I$, 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, $\eta_I$, is set at 6, which implies that these goods are substitutes in the production of the final good. This value is close to the one used by Bergin et al. (2007). The elasticities of substitution between core intermediate goods among themselves, $\theta^{CC}$, and imported periphery goods among themselves, $\theta^{PP}$, are both set equal to 10. Quint and Rabanal (2014), for instance, use the same value. This implies a steady-state mark-up of 20 percent. The share of capital in output of intermediate goods, $\alpha$, is set at a fairly standard value, 0.35, for both regions. The adjustment cost parameter for prices of domestic intermediate goods, $\phi_I$, is also set uniformly at 74.5 to capture a relatively high degree of nominal price stickiness. This value is close to the average value initially estimated by Ireland (2001, Table 3) and implies a Calvo-type probability of not adjusting prices of approximately 0.71 percent per period, or equivalently an average period of price fixity of about 3.5 quarters. These figures are consistent with the point estimates of Quint and Rabanal (2014, Table 2) and Christoffel and Schabert

(2015, Table 2) for advanced economies, and Agénor et al. (2018$a$) for middle-income countries. The capital depreciation rate, $\delta_K$, is set at a quarterly rate of 0.01 for the core and 0.025 for the periphery, which are within the span of values typically used in the literature. The adjustment cost incurred by the CG producer for transforming investment into capital, $\Theta_K$, is set at 14, in order to match the fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as output in most countries (see Hnatkovska and Koehler-Geib (2018) for instance).

Regarding the global bank and periphery banks, the collateral-loan ratio, $\kappa$, is set at 0.4 for MAEs and at 0.2 for SMICs, to capture the relatively higher costs associated with recovery of collateral and more generally debt enforcement procedures in the latter group of countries, as documented by Djankov et al. (2008). For both regions, the elasticity of the repayment probability with respect to the effective collateral-loan ratio is set initially at $\psi_1^C = 0.05$ for MAEs and $\psi_1^P = 0.1$ for SMICs, whereas the elasticity with respect to deviations in output from its steady state is set initially at $\psi_2^C = 0.1$ for the core and, consistent with Agénor et al. (2018$a$), $\psi_2^P = 0.2$ for the periphery. The cost parameters $\gamma^C$ and $\gamma^P$ are set at 0.05 and 0.1, respectively, in order to generate sensible values for initial interest rates. The elasticities $\eta_D$, $\eta_L$ and $\zeta_L$ are set equal to 2.5, 25 and 25, respectively. This gives a mark-down of the policy rate relative to the policy rate of about 58 basis points in the core region, and a mark-up of the loan rate over the policy rate (given repayment probabilities of 0.966 in the core and 0.936 in the periphery) of about 464 basis points in the core and 823 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.[20] The parameter $\psi^Q$, which measures the sensitivity of the repayment probability on loans by the global bank to periphery banks, is set at 0.3.

The degree of persistence in the core central bank's policy response, $\chi$, is set at 0.7, whereas the responses of the policy rate to inflation and output deviations, $\varepsilon_1$ and $\varepsilon_2$, are set at 1.7 and 0.1, respectively, as in Coenen et al. (2009). For the periphery central bank, the corresponding values are $\chi = 0.8$, $\varepsilon_1 = 2.0$, and $\varepsilon_2 = 0.4$, based on the evidence for upper middle-income countries reported by Federico et al. (2014). In particular, the weight on output fluctuations in SMICs is significantly higher than

[20] The difference in the magnitudes of the parameter $\eta_D$, on the one hand, and $\eta_L$ and $\zeta_L$, 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.

in MAEs, a well-documented fact in the literature. The required reserve ratio, $\mu$, is set at 0.3, consistent with the evidence for some Latin American countries like Brazil (Agénor et Pereira da Silva (2017)).

The share of noninterest government spending in final output, $\psi^G$, is set at 0.2 for the core (as in Coenen et al. (2009), again, and Alpanda and Aysan (2014)) and 0.25 for the periphery, as in Agénor et al. (2018$a$). 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 relatively high for both regions (22.6 and 18.9 percent for the core and the periphery, respectively), 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 countercyclical tax rates on loans, $\tau^C$ and $\tau^P$, are set at 0 initially in both regions.

# 5 Asymmetric Credit Spread Shocks

To characterize the properties of the model in terms of the cross-border transmission of financial shocks, we consider asymmetric credit spread shocks occurring in both regions when there is no countercyclical macroprudential policy ($\chi_2^C = \chi_2^P = 0$).[21] To do so we introduce a multiplicative shock to the loan rate in equations (17) and (32), $\epsilon_t^j$, which reflects a shock to the elasticity of the demand for loans. Moreover, $\epsilon_t^j$ is assumed to follow a first-order autoregressive process of the form $\epsilon_t^j = (\epsilon_{t-1}^j)^{\rho^j} \exp(\xi_t^j)$, where $\rho^j \in (0,1)$ and $\xi_t^j \sim \mathbf{N}(0, \sigma_{\xi^j})$, with $j = C, P$. The autocorrelation coefficients $\rho^j$ are set at the same value, 0.85, which implies a fairly high degree of persistence.

The continuous line in Figure 2 shows the results for a one percentage point negative shock in the core region. The direct impact of the shock is a reduction in the loan rate and an increase in investment in that region. This leads to a gradual increase in the capital stock and an expansion in aggregate demand, which translate into higher marginal production costs and inflation. In response to the increase in cyclical output and inflation the central bank raises its policy rate, which leads to a higher deposit rate and a shift toward deposits. To induce a reduction in the demand for cash, its

[21] 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 shocks.

opportunity cost, the nominal bond rate, must increase. Given our calibration, this increase dominates the rise in (one-period ahead) inflation, so that the (expected) real bond rate increases, thereby leading through intertemporal substitution to a reduction in current consumption by core households. Gross complementarity between consumption and leisure implies that labor supply increases, but because labor demand rises as well, wages tend to increase, thereby raising further marginal costs and inflation. The increase in the bond rate and the drop in current consumption also combine to reduce the demand for housing, which in turn translates into a fall in house prices—and thus a reduction in collateral values, which is large enough to induce a reduction in the repayment probability, despite the positive effect associated with the increase in cyclical output. This drop in the repayment probability mitigates, but does not reverse, the initial fall in the loan rate and the increase in investment.

The increase in the bond rate in the core region is such 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 impact increase in the marginal cost of borrowing from the central bank induces the core bank to cut lending to periphery banks. From the perspective of the periphery, the net effect is thus a capital outflow and an initial depreciation of the nominal and real exchange rates. On the one hand, this makes imported intermediate goods from the core more expensive; on the other, it makes exports from the periphery cheaper. The second effect dominates from the perspective of the periphery and this translates into a current account surplus for that region and a deficit for the core.

The increase in the domestic-currency price of imported inputs associated with the exchange rate depreciation translates into higher inflation in the periphery, which leads to an increase in the policy rate there as well. As a result, however, the loan rate increases now, and consequently investment falls. At the same time, the increase in (expected) inflation is larger than the increase in the nominal bond rate—which occurs through the same mechanism described earlier, related to the shift toward deposits—implying a fall in the real bond rate, which weakens incentives to save and induces an increase now in current consumption. This tends to increase housing demand and real house prices which, through higher collateral values and a higher repayment probability, tend to mitigate the rise in the loan rate and the drop in investment. However, the net effect on aggregate demand is negative and output of final goods falls.

The continuous line in Figure 3 shows the results for a one percentage point negative credit spread shock in the periphery. The results are largely opposite to those described earlier: the expansion in investment and output occurs initially in the periphery, but is transmitted through an inflow of capital and a real appreciation of the periphery's currency to the core region. This time, lending by the global bank increases and serves in part to finance the investment boom that occurs in the periphery. The positive correlation between the policy rate in the periphery and borrowing by periphery banks is consistent with the empirical evidence provided by Avdjiev et al. (2018) on lending in global funding currencies.

In sum, the results show that a credit spread shock in one region is transmitted to the other through portfolio, trade and exchange rate channels, as well as changes in lending by the core global bank to periphery banks. In addition, there is no much co-movement across regions with respect to real and financial variables, except for inflation and portfolio flows. An interesting aspect of our results is that an expansion in the core does not translate into more lending to the periphery; the key reason is that the policy rate in the core (the marginal cost of borrowing for the global bank) rises in response to higher output and inflation and this tends to reduce the supply of loans. Of course, these outcomes are specific to the type of shocks considered. But given that cross-border transmission creates more volatility, in both regions, the issue is whether cooperation between regulators can promote stability and generate welfare gains, compared to a policy setting where they act independently, based on their own strategic interests.

# 6 Gains from Coordination

In the absence of international coordination, each region's regulator sets its instrument taking as given the reaction function of the other regulator. In doing so, each regulator $j = C, P$ seeks to maximize its own country's welfare only, 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. (2017), in the context of monetary policy, and Angelini et al. (2014), with respect to macroprudential policy:[22]

$$W_t^j = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u(C_{t+s}, N_{t+s}) - \varkappa_W \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\tau_{t+s}^j - \tau_{t+s-1}^j)^2, \tag{46}$$

where $\varkappa_W \geq 0$ is a parameter that measures the welfare cost (assumed quadratic) associated with the use of the macroprudential instrument and $u()$ the truncated period utility function given by $u(C_t, N_t) = (1-\varsigma^{-1})^{-1} C_t^{1-\varsigma^{-1}} - \eta_N (1+\psi_N)^{-1} N_t^{1+\psi_N}$.[23]

Thus, under independent policies, the central bank in each region takes as given the behavior of the other regulator and determines the optimal value of the response parameter $\chi_2^j$ in the rules (22) and (38), denoted $\chi_2^{j,N}$, so that, for $j = C, P$,

$$\chi_2^{j,N} = \arg\max \mathcal{W}_t^j, \tag{47}$$

where $\mathcal{W}_t^j$ is the second-order approximation to the objective function $W_t^j$ defined in (46).

In contrast, under coordination, regulators—or a benevolent global policymaker working on their behalf—jointly determine the optimal response parameters, denoted $\chi_2^{C,O}$ and $\chi_2^{P,O}$, so as to maximize a weighted sum of each region's welfare, again defined as in (46):

$$\chi_2^{C,O}, \chi_2^{P,O} = \arg\max [n\mathcal{W}_t^C + (1-n)\mathcal{W}_t^P], \tag{48}$$

where the persistence parameter $\chi_1$ in (22) and (38) is assumed to remain the same under both regimes. Thus, higher welfare 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.

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

[23] The common practice of ignoring real money balances when evaluating welfare is usually justified by assuming that the value set for the preference parameter for liquidity services is small, that is, $\eta_x \to 0$; see Obstfeld and Rogoff (2002) for instance. This is the case here, for both regions. However, as noted in Agénor et al. (2018*c*), this practice can be rationalized at a deeper level by noting that there is a well-established *functional equivalence* between using money as an argument of the utility function, and either entering it into liquidity costs or in a shopping time technology (see Feenstra (1986) and Croushore (1993)). Given this equivalence, accounting for money in the utility function, as in done in (1), is mainly a matter of convenience, rather than a reflection of a firm belief that it provides proper micro-foundations for why money is used. Ignoring it is therefore a sensible approach when evaluating welfare.

To assess the gains from coordination, we compare the two regimes—the Nash equilibrium, under which regions pursue independent policies and set unilaterally the tax rate on loans (or more accurately, the response parameter $\chi_2^j$ in the own tax rule), and the cooperative regime, under which the regions set together a common policy, with differentiated tax rates for each of them, so as to maximize their weighted 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 (38), each regulator has full knowledge of the other regulator's reaction function; their best responses reflect therefore this knowledge.[24]

In line with Lucas (1990) and the subsequent literature, we evaluate welfare gains in terms of compensating variations in consumption. Abstracting from the cost of instrument manipulation (so that $\varkappa_W = 0$), the welfare gain at the level of each region is thus obtained by solving for $\beta^i$, the fraction of the (expected) consumption stream that would make households equally well off, in each period, under noncooperation as under cooperation:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \mathcal{W}[(1+\beta^j) C_{t+s}^{j,N}, N_{t+s}^{j,N}] = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \mathcal{W}(C_{t+s}^{j,O}, N_{t+s}^{j,O}), \tag{49}$$

where $\{C_{t+s}^{j,N}\}_{s=0}^{\infty}$ and $\{N_{t+s}^{j,N}\}_{s=0}^{\infty}$ are solution paths under the Nash equilibrium, based once again on the maximized value of each region's welfare (that is, at the optimal own response parameter $\chi_2^{j,N}$), and $\{C_{t+s}^{j,O}\}_{s=0}^{\infty}$ and $\{N_{t+s}^{j,O}\}_{s=0}^{\infty}$ solution paths under coordination, based on the maximization of the weighted sum of each region's welfare. Thus, a positive value of $\beta^j$ indicates that households in region $i$ prefer the coordination regime—they would need additional consumption under noncooperation to be indifferent between the two regimes.

Similarly, the welfare gain for the world as a whole is calculated by solving for $\beta$ in

[24] Coenen et al. (2009), Banerjee et al. (2016), and Agénor et al. (2018*b*) 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.

the expression

$$\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ n\mathcal{W}[(1+\beta)C_{t+s}^{C,N}, N_{t+s}^{C,N}] + (1-n)\mathcal{W}[(1+\beta)C_{t+s}^{P,N}, N_{t+s}^{P,N}] \right\} \tag{50}$$

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

where again $\beta \geq 0$ indicates a welfare gain under coordination. As discussed in Appendix C, (49) and (50) are evaluated using second-order approximations to both the household's (truncated) period utility function and the model, conditional on the initial steady state being the deterministic steady state. The relative weight of each region is initially set at $n = 0.5$, to capture the case where although their economic weight may differ, political equality prevails when it comes to evaluating world welfare.

The upper part of Table 3 show the results for the asymmetric core and periphery shocks discussed earlier, as well as for the joint shock, for the benchmark set of parameters. In all cases, the adjustment cost parameter $\varkappa_W$ is set uniformly to a very low value of 0.01.[25] The degree of persistence in the regulatory policy rules, $\chi_1$, is set to 0.8.[26] A grid step of 0.01 is used to search for the optimal response parameters $\chi_2^C$ and $\chi_2^P$ in (22) and (38). This is sufficient for our purpose. Compensatory variations, both with and without adjustment for the cost of instrument use, are reported for both individual regions and the world. Figures 4, 5 and 6 show relative welfare levels (normalized by the level of welfare when there is no countercyclical response, that is, when $\chi_2^C = \chi_2^P = 0$) for both regions and the world, for the core, periphery, and joint shocks, respectively. The value of (relative) welfare at the Nash and cooperative solutions in these figures can therefore be interpreted as the gain from activism. The dotted (red) lines in Figures 2 and 3 show the impulse response functions under coordination. Finally, Table 4 shows the asymptotic standard deviations of a range of macroeconomic variables under the three policy regimes—no countercyclical policies, noncooperation, and coordination, for both types of shocks and for the joint shock.

[25] With a countercyclical tax on loans, the gain from activism increases monotonically with the degree of aggressiveness of the rule, in that case, the gain from coordination is zero. A positive value of $\varkappa_W$ is thus necessary to avoid a corner solution whereby it is optimal to fully stabilize credit fluctuations. At the same time, a value of 0.01 is sufficient to ensure determinate results. See Agénor (2019, Chapter 5) for a more detailed discussion.

[26] Using an alternative value of 0.1 for $\chi_1$ did not affect qualitatively the results. To simplify matters, therefore, the persistence parameter is kept constant throughout.

The results show first that welfare in the region where an asymmetric shock originates, as well as in both regions when there is a joint shock, 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, social welfare increases. However, as the policy becomes more aggressive, its cost increases as well. This eventually dominates the initial gains, entailing therefore a marginal reduction in social welfare. Thus, there exists an optimal value for the response parameters $\chi_2^j$ to credit growth, both under Nash and under coordination.

Second, in response to an asymmetric shock in each regulator's own region, it is optimal under the Nash regime for the regulator in the other region *not* to react. This is also the case under coordination for the periphery shock. By contrast, when the shock occurs in the core region, coordination involves a more aggressive response by *both* regulators. Intuitively, under coordination regulators internalize the effects of credit fluctuations (occurring through spillovers to the periphery and spillbacks to the core) in both regions by pursuing a more aggressive policy and this generates a superior outcome for the world as a whole. Thus, coordination does not involve *burden sharing*, a situation where the region where the shock occurs (say, the core) reacts less, whereas the other (say, the periphery) reacts more. Nevertheless, there is still a net benefit for the world economy. When the shock occurs simultaneously in both regions, coordination entails naturally a reaction by both regulators—in both cases by more than under the Nash equilibrium.

Third, the more aggressive the response under coordination by the region where the shock originates means also that the cost of instrument manipulation is higher—so much so that, in fact, compensating variations that account for the cost of instrument manipulation are actually negative for the core for both asymmetric and joint shocks. This loss with respect to the Nash equilibrium means that the gains from coordination are highly asymmetric, particularly so when the shock occurs in the core region. Put differently, policy coordination is not Pareto improving—at least with respect to the type of financial shocks considered here. To the extent that credit spread shocks are representative of those that tend to occur in practice, our results highlight a potential challenge in terms of generating incentives for countries to engage in a formal arrangement to cooperate in setting their macroprudential policy instruments.

Fourth, the results indicate that the gains from coordination depend on whether the cost of instrument manipulation is accounted for or not when evaluating welfare.[27] For instance, with a core shock only, the compensating variation is 0.2 percent in the first scenario (the standard case where welfare is based solely on the discounted present value of the household utility) and 4.4 percent in the second. This difference is quite large, despite the fact that $\varkappa_W$, at 0.01, is fairly small. In addition, when the instrument adjustment cost is accounted for, the gain is not large. Again, in the case of a core shock only, a household with an annual consumption stream of \$50,000 would need to receive compensation of about \$100 to be indifferent between cooperation and noncooperation. This gain is even lower when the shock originates in the periphery. *Prima facie,* these relatively small gains create concerns regarding the ability to provide incentives for countries to join and remain voluntarily in a cooperative agreement. At the same time, however, it is important to keep in mind that in the real world, there could be a variety of financial shocks occurring simultaneously; the gain from coordination could be larger as a result. This is indeed the case when the shock occurs simultaneously in the two regions.

Finally, the results displayed in Table 4 show that while the reduction in volatility is quite large between the last two regimes and the first (no countercyclical regulation) when the shock occurs in the core region, this reduction is much smaller for the periphery shock and for both regions. In fact, for a number of variables there are no discernible differences between outcomes under noncooperation and coordination. These results are consistent with those reported in Table 3, and discussed earlier, regarding the small welfare gain associated with coordination in response to a financial shock occurring in the periphery.

# 7 Sensitivity Analysis

To assess the robustness of the previous analysis, we perform sensitivity analysis with respect to four features of the model: the degree of international financial integration (as measured by the size of intermediation costs on world capital markets), the cost of instrument manipulation, the relative weight of each region in evaluating global

[27] Recall that, to solve for the optimal response parameters, a small cost of instrument volatility is accounted for to eliminate the case where it is optimal to fully stabilize credit.

welfare, and the case where the housing market is perfectly integrated across regions.[28] In all of these cases we focus on the welfare gain from coordination (as measured by adjusted compensating variations), rather than the transmission mechanism.

## 7.1 Financial Integration

First, consider the case where the cost parameter associated with financial intermediation on world capital markets, $\theta_0^B$, falls from its benchmark value of 0.8 to 0.6. 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 rest of the world, implying therefore larger spillovers 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 lower part of Table 3. They show that when the financial shock originates in the core region, both regulators react (when they do at all) slightly less aggressively, both under Nash and under coordination. The same occurs for the regulator in the periphery, when the shock occurs in that region, again both under Nash and under coordination. But while the welfare gain (including the instrument adjustment cost) is smaller for the core region in the first case, the policy loss is smaller for the periphery in both cases. Welfare for the world economy falls in the case of a core shock and increases in the case of a periphery shock. Thus, with greater financial integration, coordination is more beneficial to the periphery and the world as a whole when financial shocks originate in that region. This larger gain for the world economy is consistent with the recent evidence, reviewed by Agénor and Pereira da Silva (2018), which suggests that greater financial interconnectedness in the world economy has increased the potential benefits of macroprudential policy coordination—although these benefits, once again, appear to be asymmetric across regions.

[28] We also considered the case where the macroprudential instrument in rules (22) and (38) are based on the credit-to-output ratio, rather than credit growth. Results were qualitatively similar to those reported in the previous section.

## 7.2 Instrument Cost and Welfare Weights

As noted earlier, the gains from coordination depend on whether the cost of instrument manipulation, as measured by $\varkappa_W$, is accounted for or not when evaluating welfare.[29] The results shown in Table 3 are based on a very low value of $\varkappa_W$; the upper part of Table 5 displays those obtained with a higher value of $\varkappa_W = 0.05$.

The first point to note is that, with a higher cost, the optimal values for the response parameters $\chi_2^j$ are lower, under both under Nash and coordination. This negative correlation, which is also verified for higher values of $\varkappa_W$, is simply the consequence of policymakers internalizing the effect of their policy choices on their objectives. As a result, the stabilization effect is now weaker; this is clearly illustrated by the dashed (blue) lines in Figures 2 and 3, which show again the impulse response functions under coordination.

The second point is that when compensating variations do not account for the instrument adjustment cost, the core benefits less from coordination when the shock occurs there (either individually or jointly) and benefits slightly more when it occurs in the periphery. At the same time, for the world economy, the gain is uniformly lower under coordination, regardless of where the shock occurs and whether the occur simultaneously or not. The third point is that when compensating variations account for the cost of instrument manipulation, the core region benefits a bit more from coordination when the shock occurs in the periphery alone or in both regions, but the gain for the world economy is weaker. 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—inclusive or not of instrument adjustment costs—both at the level of the individual parties and the world economy as a whole.

Alternatively, keeping $\varkappa_W$ at 0.01, consider the case where instead of equal weights in the global welfare function, based on political considerations (one country, one vote), 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, up from 12.8 percent during 2000-09. Thus, we set the size of the core region to $n = 1 - 0.812 = 0.818$. The results associated with the same experiments as before are shown in the lower part

[29] Again, if the cost parameter $\varkappa_W$ is zero, full stabilization ($\chi_2^j \to \infty$) is optimal under both regimes and there is no gain from coordination.

of Table 5. With respect to the optimal response parameters, the most noticeable result relates to the response of the regulator in the periphery under coordination, when the shock occurs in the core region; this response is now much higher. For the core region, the gain (based on the compensating variation inclusive of the instrument adjustment cost) is now significantly higher regardless of the origin of the shock. For the periphery, the reverse holds. Nevertheless, given the higher weight of the core now, the gain for the world economy increases in all cases. For instance, if the shocks occur in both regions at the same time, a household with an annual consumption stream of \$50,000 would need now to receive compensation of about \$470 to be indifferent between cooperation and noncooperation. Yet, because the periphery is now worse off, the enforcement problems highlighted earlier are magnified.

### 7.3 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 growing evidence that house price fluctuations have become highly synchronized across countries, as documented by Hirata et al. (2013), Cesa-Bianchi (2013), Jordà et al. (2018), and most importantly in a comprehensive study 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 (41) for the core region and the equivalent for the periphery, by the single equilibrium condition:

$$nH_t^C + (1-n)H_t^P = \theta^H \bar{H}^C + (1-\theta^H)\bar{H}^P, \tag{51}$$

where $\theta^H \in (0,1)$ is the share of the global housing stock held in the core region, together with the equilibrium price condition:

$$p_t^{PH} = z_t p_t^{CH}, \tag{52}$$

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.[30]

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.[31] 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.

Consider for instance, as before, a negative credit spread shock in the core region. As discussed earlier, this translates into a fall in house prices in that region, due to a reduction in the demand for housing services there. This also lowers the value of collateral that core firms can pledge to the global bank, which in turns tends to increase the loan rate (or, more precisely, mitigate its initial fall), thereby dampening the expansion in investment and output.

With an integrated housing market, and because the depreciation of the real exchange rate documented earlier is not large, house prices in the periphery *fall* as well, instead of increasing as before. Thus, the model now generates co-movement in house prices across countries, in line with the evidence on price synchronicity reported earlier. As a result of that drop, the loan rate in the periphery rises further, investment falls by more on impact, and so does output. This implies also that the policy and bond rates increase by less than in the case of separate housing markets, thereby dampening capital outflows. Put differently, given the shock that we consider, an integrated housing market does generate stronger spillover effects from the core to the periphery, although not necessarily stronger spillbacks from the periphery to the core. Nevertheless, to the extent that these fluctuations lead to higher volatility in consumption and employment, thereby reducing welfare, the regulator in the periphery has an incentive to intervene to stabilize lending. At the same time, however, under non-cooperation, the regulator in each region sets the tax on loans solely on the basis of the behavior of

[30] 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 bearing on the results. Note also that $\theta^H$ is calibrated to ensure that condition (52) holds in the steady state, with $p^{PH}$ solved for from (51). The value obtained is $\theta^H = 0.684$.

[31] Cesa-Bianchi et al. (2018) also consider 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.

the credit-to-output ratio in its *own* jurisdiction; the regulator in the region where the shock occurs (the core) does not internalize the fact that it amplifies fluctuations in the periphery. Thus, a globally integrated housing market may generate a cross-border pecuniary externality, which can be internalized under coordination.

Nevertheless, numerical results show that this additional channel is relatively weak in our model: although housing prices in the periphery do fall now instead of increasing, the repayment probability falls by more, and the lending rate rises by more, than in the benchmark case of segmented housing markets, Figure 7 shows 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 32), 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.[32] However, it is very 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. In our view, 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 ensure that countries do not renege on a commitment to coordinate their macroprudential policies. Such incentives relate to side payment mechanisms and the perceived *ex post*

[32] In particular, it is still optimal for the periphery not to react under coordination. Related results are obtained for the periphery shock, which are not reported to save space.

cost of reneging on a cooperative agreement. Second, our analysis was limited to a narrow (albeit representative) set of financial shocks 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 instruments 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 existing models, although leadership can be thought of as within-period commitment by one player, which clearly makes the leader better off (de Paoli and Paustian (2017)). However, it is in general 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), 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 can be large enough to make macroprudential policy coordination a preferable strategy.

Finally, there is now significant evidence that macroprudential policies are subject to leakages across countries and can generate significant credit spillover effects of their own, as a result of global banks shifting targeted 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 (firms or households) but also through lending locally to foreign branches, as well as through a "rebooking" of

[33] See for instance Canzoneri and Henderson (1989) for an early analytical example, and Coenen et al. (2009) and Bodenstein et al. (2014) in the context of two-country DSGE models.

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 macroprudential 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.

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

[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 (2018) for a discussion.

## Appendix A
## Production Side and Real Equilibrium Conditions

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

**Final Good Production**

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

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

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.[36] Cost minimization yields the capital-labor ratio and the unit real marginal cost, $mc_t^C$, as

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

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

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

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

where $\Lambda^s \lambda_{t+s}$ measures the marginal utility value to the representative core 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

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

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

Under symmetry, the price adjustment equation (A13) becomes

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

[36] For simplicity, we abstract from the cost channel, despite its importance—especially for for middle-income countries. See Agénor (2019, Chapter 1) for a discussion.

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

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

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

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

Subject to (A18) and $l_t^{CF} = I_t^C$ 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 by Agénor et al. (2014, 2018), the solution to this

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

problem yields[38]

$$\mathbb{E}_t r^{CK}_{t+1} \simeq q^C_t (1+i^{CL}_t)\mathbb{E}_t \left\{ [1+\Theta_K(\frac{K^C_{t+1}}{K^C_t}-1)](\frac{1+i^{CB}_t}{1+\pi^C_{t+1}}) \right\} \tag{A19}$$

$$-\mathbb{E}_t \left[ q^C_{t+1}(1+i^{CL}_{t+1}) \left\{ 1-\delta_K + \frac{\Theta_K}{2}[(\frac{K^C_{t+2}}{K^C_{t+1}})^2 - 1] \right\} \right].$$

**Goods market equilibrium**

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

$$Y^{CI}_t = Y^{CC}_t + Y^{CP}_t, \qquad Y^{PI}_t = Y^{PP}_t + Y^{PC}_t. \tag{A20}$$

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

$$Y^C_t = C_t + G_t + I^C_t + \frac{\phi_I}{2}(\frac{P^{CC}_t}{P^{CC}_{t-1}} - 1)^2(\frac{P^{CC}_t}{P^C_t})Y^{CI}_t, \tag{A21}$$

and analogously for the periphery.

Finally, note that the current account for the periphery at current local prices (the analogue of (44)) can be written as

$$CA^P_t = P^{PP}_t Y^{PC}_t - P^{CP}_t Y^{CP}_t \tag{A22}$$

$$-i^{CP}_{t-1}E_{t-1}P^C_{t-1}l^{PC}_{t-1} - i^{PB}_{t-1}P^P_{t-1}b^{CP}_{t-1} + i^C_{t-1}E_{t-1}P^C_{t-1}b^{PC}_{t-1},$$

where $P^{CP}_t = E_t P^{CC}_t$ 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), $Y^{CP}_t$ periphery imports of intermediates, which correspond also to the core's exports, $P^{PP}_t$ is the price of periphery intermediate goods sold on the core market (that is, the price of periphery exports), and $Y^{PC}_t$ are periphery exports of intermediate goods, which correspond also to the core's imports. The third term in (A22) 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, $CA^P_t$ can also be written as, similar to (45),

$$CA^P_t = E_t P^C_t b^{PC}_t - E_{t-1}P^C_{t-1}b^{PC}_{t-1} \tag{A23}$$

$$-(E_t P^C_t l^{PC}_t - E_{t-1}P^C_{t-1}l^{PC}_{t-1}) - (P^P_t b^{CP}_t - P^P_{t-1}b^{CP}_{t-1}).$$

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

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Table 1
Benchmark Parameterization: Key Parameter Values

| Parameter | Description | MAEs | SMICs |
|---|---|---|---|
| Households | | | |
| $\Lambda$ | Discount factor | 0.98 | 0.95 |
| $\varsigma$ | Elasticity of intertemporal substitution | 0.5 | 0.5 |
| $\eta_N$ | Preference parameter for leisure | 16.0 | 16.0 |
| $\psi_N$ | Inverse of Frisch elasticity of labor supply | 3.0 | 3.0 |
| $\eta_x$ | Preference parameter for money holdings | 0.01 | 0.01 |
| $\eta_H$ | Preference parameter for housing | 0.1 | 0.1 |
| $\nu$ | Share parameter in index of money holdings | 0.2 | 0.2 |
| $\theta_0^B$ | Cost parameter, intermediation on world capital markets | 0.8 | 0.8 |
| Producers | | | |
| $\Lambda_I$ | Share of own-region IG goods in final output | 0.6 | 0.8 |
| $\eta_I$ | Elasticity of substitution, baskets of intermediate goods | 6.0 | 6.0 |
| $\theta^{CC}, \theta^{PP}$ | Elasticity of own-region demand, intermediate goods | 10.0 | 10.0 |
| $\alpha$ | Share of capital, intermediate goods production | 0.35 | 0.35 |
| $\phi_I$ | Adjustment cost parameter, intermediate goods prices | 74.5 | 74.5 |
| $\delta_K$ | Depreciation rate of capital | 0.01 | 0.025 |
| $\Theta_K$ | Adjustment cost parameter, investment | 14 | 14 |
| Banks | | | |
| $\kappa$ | Effective collateral-loan ratio | 0.4 | 0.2 |
| $\psi_1$ | Elasticity of repayment probability, collateral | 0.05 | 0.1 |
| $\psi_2$ | Elasticity of repayment probability, cyclical output | 0.1 | 0.2 |
| $\eta_D$ | Elasticity of deposit supply by households | 2.5 | – |
| $\eta_L, \zeta_L$ | Elasticity of loan demand by capital producers | 25 | 25 |
| $\gamma^C$ | Cost parameter, loan supply by global bank | 0.05 | – |
| $\gamma^P$ | Cost parameter, demand for global bank loans | – | 0.1 |
| $\psi_Q$ | Sensitivity of repayment prob., global bank loans | – | 0.3 |
| Central bank | | | |
| $\mu$ | Required reserve ratio | – | 0.3 |
| $\chi$ | Degree of interest rate smoothing | 0.7 | 0.8 |
| $\varepsilon_1$ | Response of policy rate to inflation deviations | 1.7 | 2.0 |
| $\varepsilon_2$ | Response of policy rate to output deviations | 0.1 | 0.4 |
| $\varphi^R$ | Degree of exchange rate smoothing | – | 0.0 |
| $\chi_1$ | Persistence parameter, tax on loans rule | 0.1 | 0.1 |
| Government | | | |
| $\psi^G$ | Share of government spending in final output | 0.2 | 0.25 |
| Shocks | | | |
| $\rho^Q$ | Persistence parameter, credit spread shock | 0.57 | 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 | 0.226 | – |
| $Y^{PC}/Y^{PI}$ | Share of exports in production of intermediate goods, periphery | – | 0.189 |
| $C^j$ | Private consumption | 0.548 | 0.616 |
| $I^j, l^{jF}$ | Investment, loans to IG firms | 0.251 | 0.134 |
| $r^{jK}$ | Rental rate of capital | 0.031 | 0.083 |
| $l^{PC}$ | Loans from global bank to periphery banks | 0.215 | – |
| $q^{jF}$ | Repayment probability, loans to IG firms | 0.966 | 0.936 |
| $q^{PC}$ | Repayment probability, global bank loans to periphery banks | 0.936 | – |
| $i^{jB}, i^{jR}$ | Government bond rate, central bank refinance rate | 0.020 | 0.053 |
| $i^{jD}$ | Bank deposit rate | 0.015 | 0.037 |
| $i^{jL}$ | Loan rate, loans to intermediate goods firms | 0.046 | 0.135 |
| $i^{CP}$ | Loan rate, global bank loans to periphery banks | 0.101 | – |
| $\tau^j$ | Countercyclical tax rate on loans to domestic producers | 0.0 | 0.0 |
| $R^{Pcb}$ | Official reserves, periphery central bank | – | 0.07 |

Table 3
Optimal Policy Responses and Gains from Coordination:
Benchmark Case and Greater Financial Integration, $n = 0.5$, $\varkappa_W = 0.01$[1]

| | Core Shock | Periph. Shock | Joint Shock |
|---|---|---|---|
| | | Benchmark case | |
| Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$ | 6.65, 0.00 | 0.00, 7.20 | 6.90, 7.10 |
| Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$ | 6.71, 0.60 | 0.00, 7.30 | 7.00, 7.30 |
| Compensating variation | | | |
| Core | 0.0452 | 0.0344 | 0.0613 |
| Periphery | −0.0748 | 0.0608 | 0.1246 |
| World | 0.0437 | 0.0602 | 0.0897 |
| Compensating variation (incl. inst. cost) | | | |
| Core | 0.0028 | 0.0344 | 0.0039 |
| Periphery | −0.0759 | −0.0004 | −0.0014 |
| World | 0.0018 | 0.0004 | 0.0015 |
| | | Greater international financial integration | |
| Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$ | 6.60, 0.00 | 0.00, 7.10 | 6.90, 7.00 |
| Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$ | 6.69, 0.50 | 0.00, 7.20 | 7.00, 7.30 |
| Compensating variation | | | |
| Core | 0.0597 | 0.0344 | 0.0639 |
| Periphery | −0.0349 | 0.0611 | 0.1960 |
| World | 0.0584 | 0.0604 | 0.1217 |
| Compensating variation (incl. inst. cost) | | | |
| Core | 0.0019 | 0.0344 | 0.0062 |
| Periphery | −0.0358 | −0.0001 | −0.0027 |
| World | 0.0014 | 0.0009 | 0.0021 |

[1]Compensating variations, with and without the cost of instrument volatility, are calculated using the formulas provided in the text. Greater international financial integration corresponds to a reduction in $\theta_0^B$ from 0.8 to 0.6.

Table 4
Asymptotic Standard Deviations of Key Variables
under Alternative Policy Regimes, Benchmark Parameters, $n = 0.5$, $\varkappa_W = 0.01$[1]
(All numbers should be multiplied by $10^{-3}$)

| | No CC policies | | | Nash equilibrium | | | Coordination | | |
|---|---|---|---|---|---|---|---|---|---|
| | C-Shock | P-Shock | J-Shock | C-Shock | P-Shock | J-Shock | C-Shock | P-Shock | J-Shock |
| *Core* | | | | | | | | | |
| Final output | 4.020 | 0.286 | 4.313 | 1.024 | 0.035 | 1.029 | 1.017 | 0.035 | 1.019 |
| Employment | 1.230 | 0.221 | 1.261 | 0.405 | 0.027 | 0.404 | 0.403 | 0.027 | 0.400 |
| Consumption | 1.619 | 0.357 | 1.900 | 0.212 | 0.034 | 0.236 | 0.210 | 0.033 | 0.233 |
| Investment | 3.897 | 0.217 | 3.904 | 0.930 | 0.028 | 0.920 | 0.924 | 0.027 | 0.911 |
| Inflation | 1.716 | 0.301 | 1.750 | 0.317 | 0.039 | 0.315 | 0.315 | 0.039 | 0.311 |
| Refinance rate | 3.239 | 0.535 | 3.290 | 0.642 | 0.068 | 0.635 | 0.638 | 0.067 | 0.628 |
| Loan rate | 13.357 | 0.418 | 13.308 | 2.669 | 0.058 | 2.644 | 2.650 | 0.057 | 2.616 |
| House prices | 10.519 | 2.322 | 12.356 | 1.379 | 0.220 | 1.537 | 1.366 | 0.217 | 1.516 |
| Repayment prob. | 1.054 | 0.132 | 1.062 | 0.207 | 0.013 | 0.205 | 0.206 | 0.013 | 0.203 |
| Loan-output ratio | 3.365 | 0.232 | 3.351 | 0.781 | 0.027 | 0.771 | 0.776 | 0.026 | 0.763 |
| *Periphery* | | | | | | | | | |
| Final output | 0.290 | 3.342 | 3.406 | 0.030 | 0.721 | 0.722 | 0.033 | 0.714 | 0.708 |
| Employment | 0.146 | 1.144 | 1.168 | 0.036 | 0.322 | 0.325 | 0.036 | 0.319 | 0.320 |
| Consumption | 0.202 | 1.698 | 1.760 | 0.023 | 0.215 | 0.219 | 0.023 | 0.212 | 0.214 |
| Investment | 0.177 | 3.636 | 3.627 | 0.015 | 0.726 | 0.722 | 0.012 | 0.719 | 0.708 |
| Inflation | 0.400 | 0.612 | 0.744 | 0.036 | 0.159 | 0.165 | 0.036 | 0.157 | 0.162 |
| Refinance rate | 0.781 | 1.491 | 1.700 | 0.072 | 0.587 | 0.591 | 0.073 | 0.582 | 0.580 |
| Loan rate | 0.675 | 14.426 | 14.391 | 0.064 | 2.480 | 2.469 | 0.057 | 2.454 | 2.418 |
| House prices | 0.525 | 4.415 | 4.577 | 0.059 | 0.558 | 0.570 | 0.060 | 0.552 | 0.556 |
| Repayment prob. | 0.154 | 2.394 | 2.396 | 0.014 | 0.403 | 0.401 | 0.013 | 0.398 | 0.392 |
| Loan-output ratio | 0.161 | 3.253 | 3.244 | 0.014 | 0.635 | 0.632 | 0.011 | 0.629 | 0.619 |

[1]'No CC policies' means no countercyclical policies. C-Shock refers to the loan rate shock in the core region, P-Shock to the loan rate shock in the periphery, and J-Shock to the joint shock.

Table 5
Optimal Policy Responses and Gains from Coordination:
Higher instrument cost, $\varkappa_W = 0.05$, Unequal Weights in Global Welfare, $n = 0.818$[1]

| | Core Shock | Periph Shock | Joint Shock |
|---|---|---|---|
| | Higher instrument cost, $\varkappa_W = 0.05$ | | |
| Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$ | 1.96, 0.00 | 0.00, 2.11 | 2.10, 2.18 |
| Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$ | 1.99, 0.25 | 0.00, 2.15 | 2.14, 2.29 |
| Compensating variation | | | |
| Core | 0.0333 | 0.0371 | 0.0385 |
| Periphery | 0.0016 | 0.0422 | 0.1064 |
| World | 0.0329 | 0.0421 | 0.0679 |
| Compensating variation (incl. inst. cost) | | | |
| Core | 0.0006 | 0.0371 | 0.0056 |
| Periphery | 0.0001 | −0.0005 | −0.0039 |
| World | 0.0006 | 0.0005 | 0.0013 |
| | Unequal weights, $n = 0.818$ | | |
| Nash: Optimal $\chi_2^{C,N}, \chi_2^{P,N}$ | 6.65, 0.00 | 0.00, 7.20 | 6.90, 7.10 |
| Coordination: Optimal $\chi_2^{C,O}, \chi_2^{P,O}$ | 6.66, 1.80 | 0.00, 7.60 | 6.90, 8.30 |
| Compensating variation | | | |
| Core | 0.0104 | 0.1439 | 0.0230 |
| Periphery | −0.2332 | 0.2806 | 1.3201 |
| World | 0.0095 | 0.2654 | 0.1239 |
| Compensating variation (incl. inst. cost) | | | |
| Core | 0.0042 | 0.1439 | 0.0229 |
| Periphery | −0.2376 | −0.0070 | −0.0560 |
| World | 0.0034 | 0.0064 | 0.0094 |

[1]Compensating variations, with and without the cost of instrument volatility, are calculated using the formulas provided in the text.

# Figure 1
# Model Structure

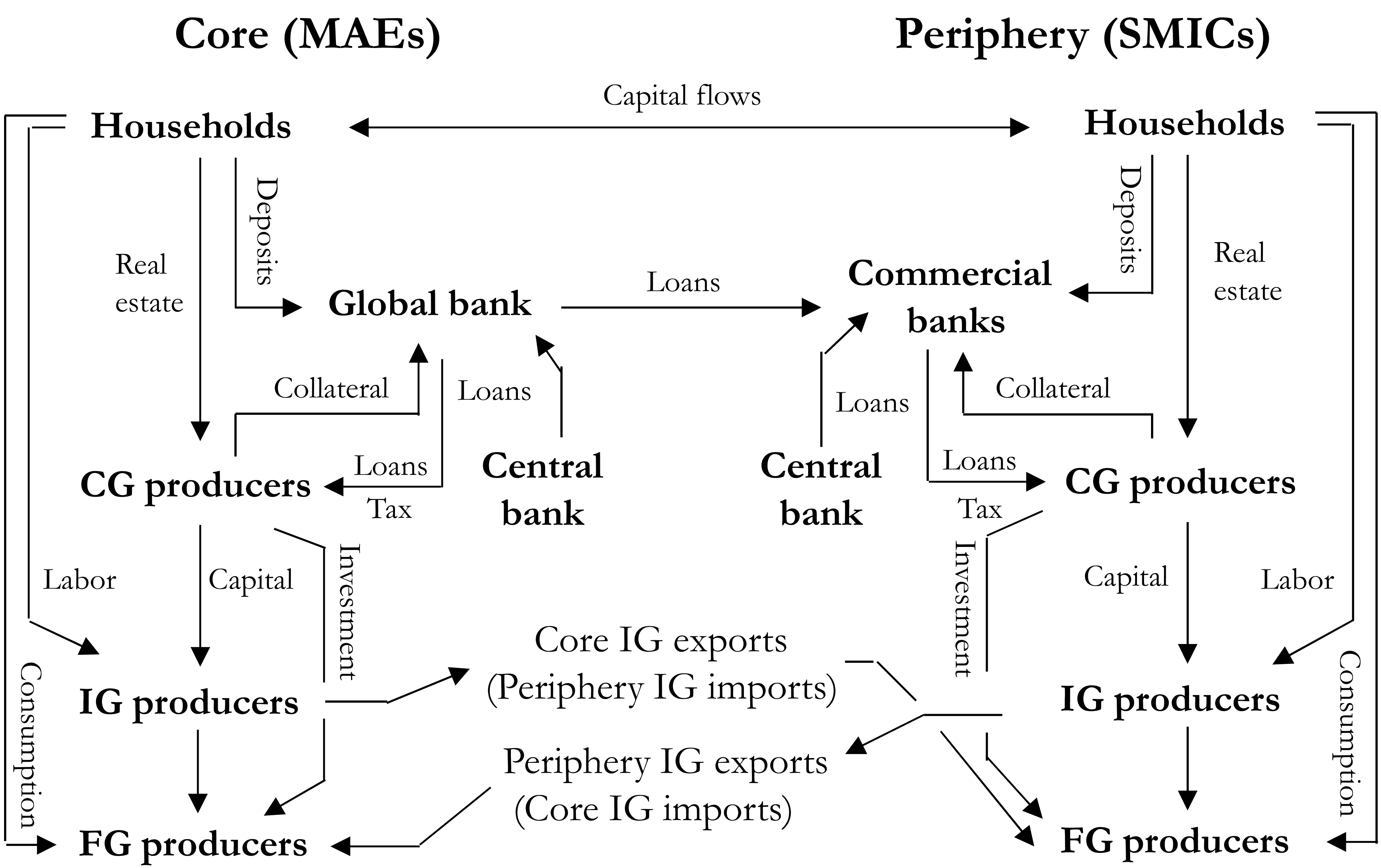
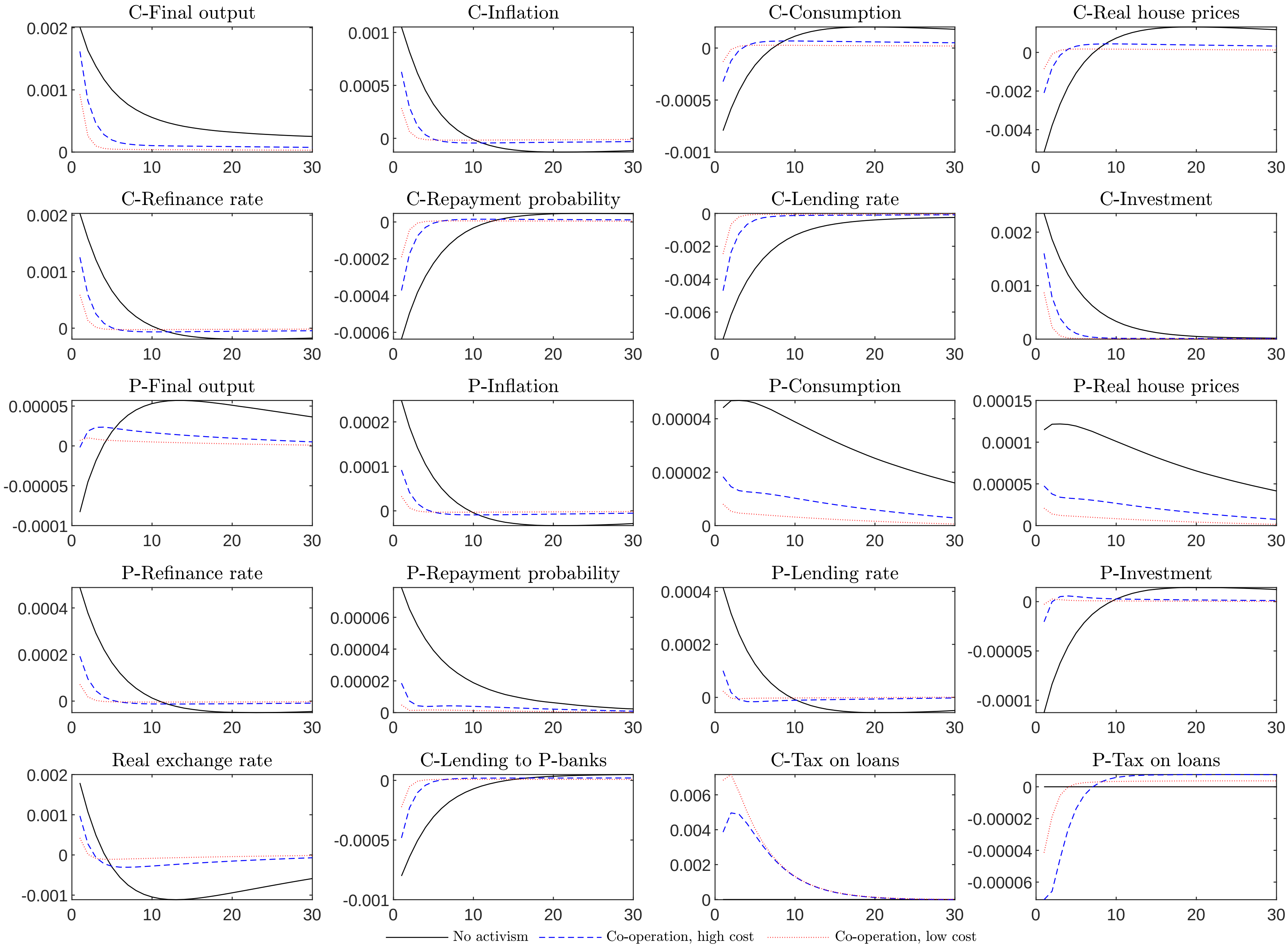
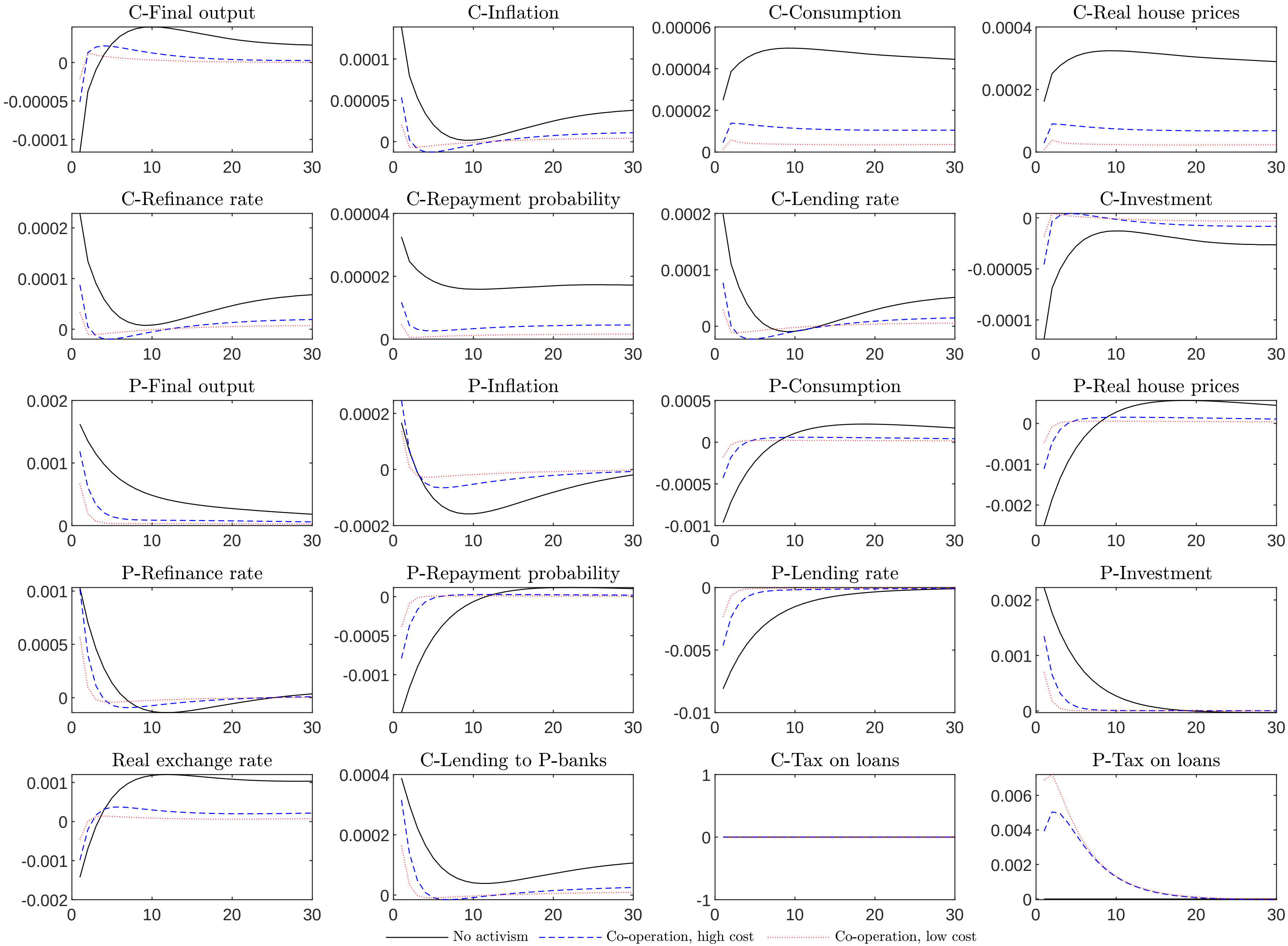


**Figure 2**
**Core Region: Transitory Negative Credit Spread Shock**



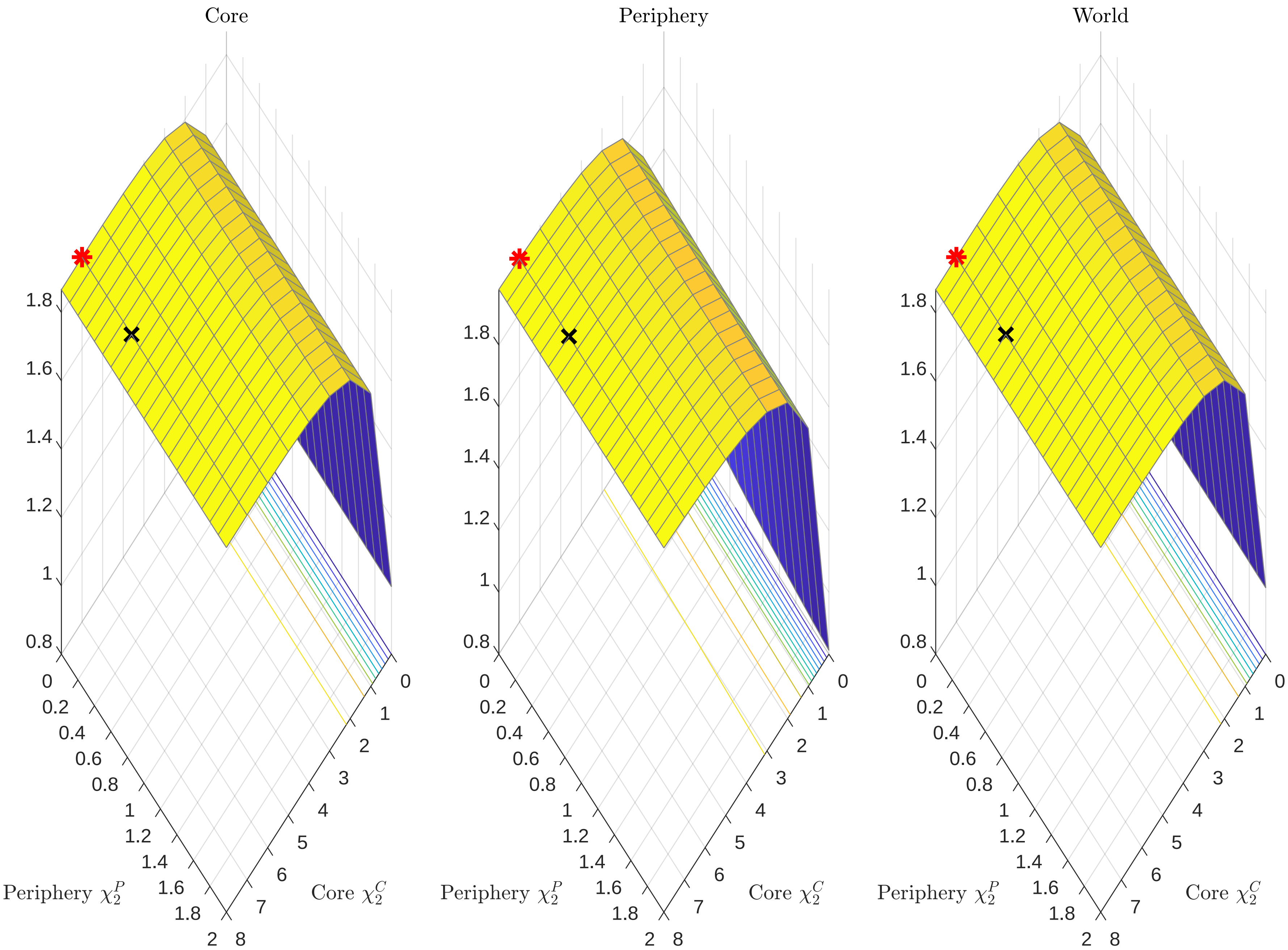

Note: Consumption, investment, output, real house prices, bank foreign borrowing, the real exchange rate, and core lending to periphery banks are percentage deviations from their steady-state values. The lending rate, the refinance rate, the repayment probability and the inflation rate are absolute deviations from their steady-state values. High instrument cost corresponds to 0.05, and low cost to 0.01.

**Figure 3**
**Periphery Region: Transitory Negative Credit Spread Shock**




See Note to Figure 2.

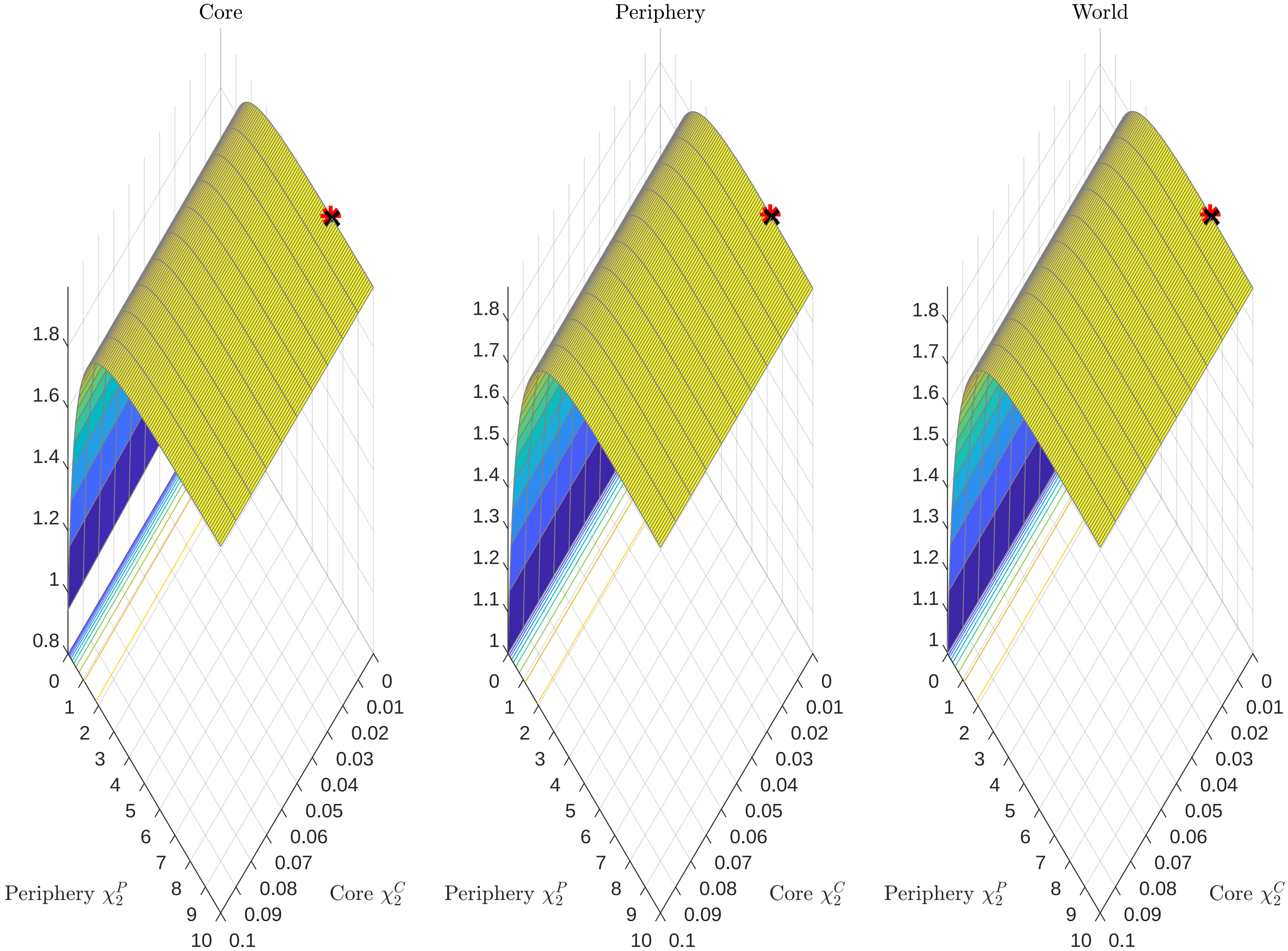
**Figure 4**
**Core Region Shock: Normalized Welfare and Optimal Policy Response**




Note: The red circle corresponds to the Nash equilibrium and the black cross to the equilibrium under coordination.

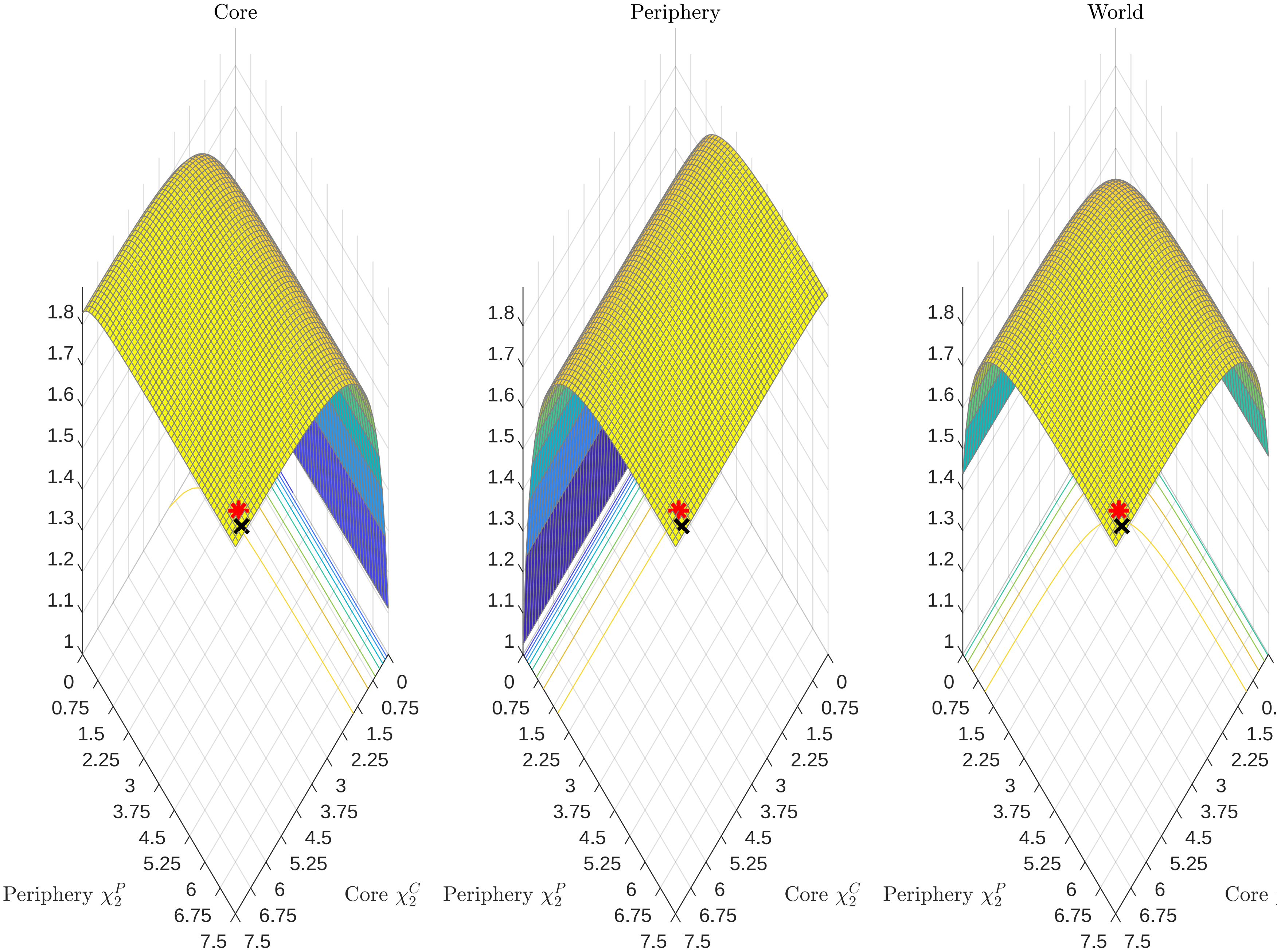
**Figure 5**

**Periphery Region Shock: Normalized Welfare and Optimal Policy Response**



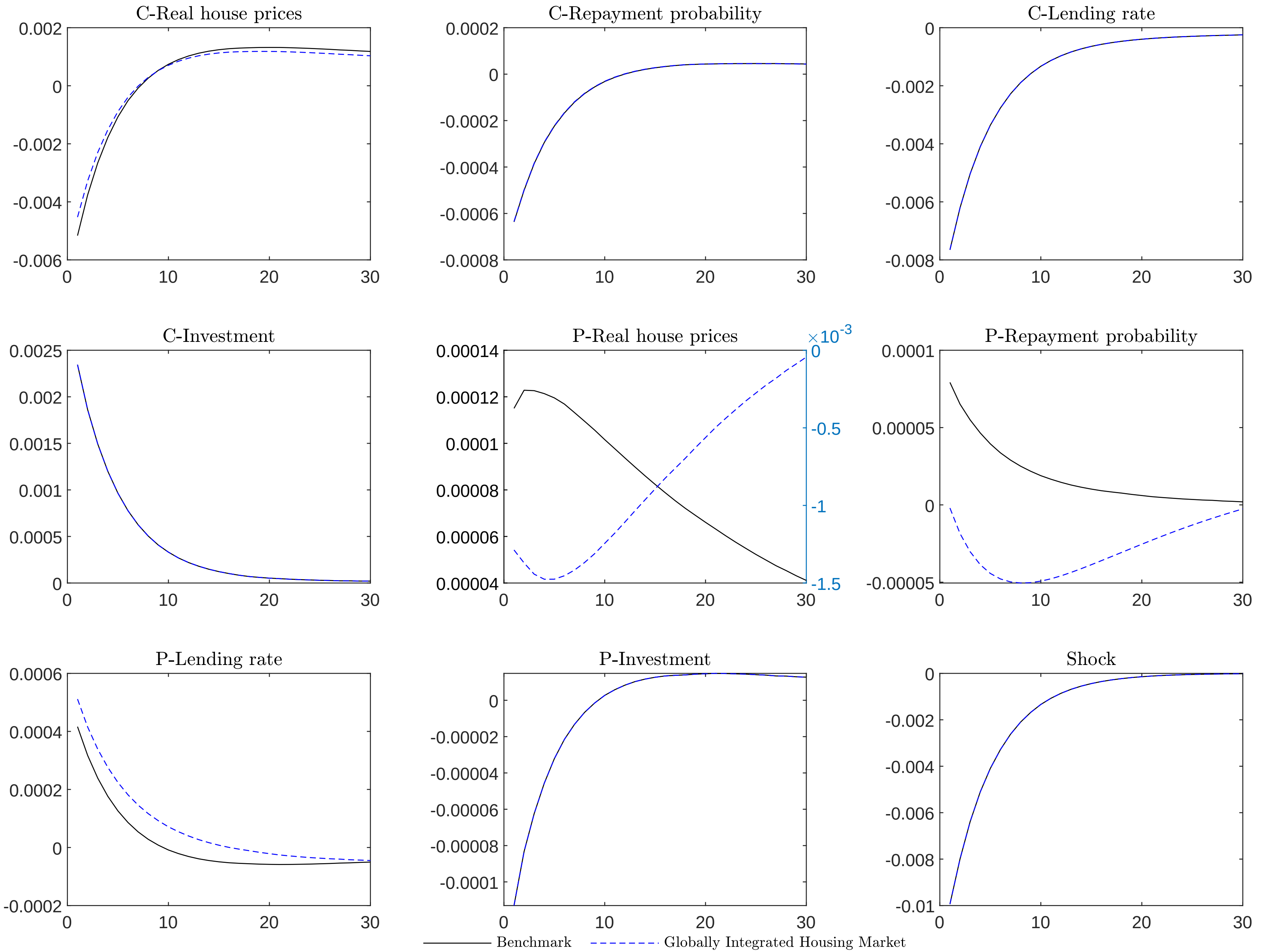

Note: The red circle corresponds to the Nash equilibrium and the black cross to the equilibrium under coordination.

**Figure 6**
**Joint Credit Spread Shock: Normalized Welfare and Optimal Policy Response**




Note: The red circle corresponds to the Nash equilibrium and the black cross to the equilibrium under coordination.

**Figure 7**
**Core Region Shock: Segmented (Benchmark) and Globally Integrated Housing Market**




See Note to Figure 2.

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