Macroprudential Policy Coordination in Open Economies: A Multicountry Framework*

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Abstract

Motivated by the presence of financial spillovers from advanced economies on emerging markets, and the apparent difficulties of the latter to shield their economies from external shocks, we set up a three-country center-periphery model, with banks and financial agency frictions. The key defining feature of an emerging economy will be the limited capacity of financial intermediation that leads to a financial dependency relation with the center. Each country will have access to a macroprudential instrument that affects its source of inefficiencies and allows it to smooth the credit spread distortions. However, such regulation can be costly and interdependent, opening a potential scope for international policy coordination. Based on this framework, we obtain the optimal instruments and study the welfare features of a variety of policy arrangements that differ by the degree of cooperation. The results suggest that there are significant policy spillovers at the cross-country level, that grow with the financial friction of each economy. Additionally, each policy framework can be effective in mitigating the financial friction while the presence of coordination gains will depend on the flexibility, cost, and effectiveness of the macroprudential instruments.

JEL Codes: F38, F42, E44, G18

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1 Introduction

A global trend towards the liberalization of financial markets have been observed in recent decades. The motivation is clear: resources should flow to their most productive destination. Alas, this comes a the cost of higher volatility in financial markets, global imbalances, and the global financial cycle, which is particularly hurtful for emerging economies (Rey (2013)). Naturally, a policy response aimed to mitigate this cost followed through implementation of new regulations such as the Basel accords and the establishment of institutions such as the financial stability board.

The economic implications of these regulations have been subject of numerous studies, ranging from those concerned with their effectiveness (Hahm et al. (2011) and Akinci and Olmstead-Rumsey (2018)), to the ones on the broader implications of the prudential toolkit, for example the policy leakages and interactions with other sectors (Aiyar et al. (2014) or Aizenman et al. (2017)), policy goals (Coimbra and Rey (2017)), or even countries (Buch and Goldberg (2017)).

The cross-border spillover effect of these policies opens a question about the viability of coordinated regulation arrangements between economies. In fact, some features of these policies may indicate the scope for cooperation welfare gains, for example, these instruments are interdependent, as their effects extend beyond their country of origin and may induce foreign policymakers to change their own toolkit in response, but also their implementation is costly, and may be subject to trade-offs with other policy goals. As a result, nationally oriented policies that fail to internalize these effects may be inneficient.

This question is even more relevant for emerging economies where financial frictions are more prevalent as mentioned by Chang and Velasco (2001) and where their small economy features render them more fragile to the whims of global markets. Could this countries, helpless on their own, react in any way (e.g. cooperatively) to compensate for their fragility and keep pursuing the benefits of financial integration? We try to answer such question by setting a model with multiperipheral features (several emerging economies) but where a financial center imposes strong spillovers on the rest of the world.

Our contribution to the literature consists on studying cooperation from a multiperipheral perspective while still allowing the rest of the world to adjust their toolkit when witnessing cooperative efforts in other regions. To the best of our knowledge, this is novel and still encompasses the usual approaches (center-periphery or periphery-periphery with exogenous center). More concretely, we study a wide menu of policy setups with different degrees of cooperation, as shown in table 1.

Table 1: Policy Setups to Analize

Case	Solutions
Nash	$RPP^i = \max \hat{W}^i, \quad \text{for } i = \{e_1, e_2, c\}$
Coalition 1 (Emergent Economies - EMEs)	$RPP^{e_1,e_2} = \max n_1\hat{W}^{e_1} + n_2\hat{W}^{e_2} \quad \text{vs} \quad RPP^c = \max \hat{W}^c$
Coalition 2 (Center and EME-1)	$RPP^{e_1,c} = \max n_1\hat{W}^{e_1} + (1-n_1-n_2)\hat{W}^c \quad \text{vs} \quad RPP^{e_2} = \max \hat{W}^{e_2}$
Cooperation	$RPP = \max n_1\hat{W}^{e_1} + n_2\hat{W}^{e_2} + (1-n_1-n_2)\hat{W}^c$

Note: The world consists of 3 countries $i = \{e_1, e_2, c\}$ where the sizes are respectively $n_1, n_2, 1-n_1-n_2 > 0$ and $n_1 + n_2 \leq 1/2$.

In Table 1 RPP_i makes reference to the Ramsey Planner Problem of the social planner, consisting on maximizing an objective welfare function subject to the private equilibrium choices of the agents. Notice how the objective function under cooperation corresponds to a weighted welfare of the participating countries.

In our setup they key ingredient justifying policy interventions is the presence of financial frictions. In that spirit, the standard question in the literature (Fujiwara and Teranishi (2017), Banerjee et al. (2016) and Agénor et al. (2017)) is: do financial frictions call for policy cooperation?. Here in addition, we explore whether peripheric countries should cooperate when facing financial frictions and spillovers stemming from a center.

The financial friction we consider takes the form of a costly enforcement agency distortion, in the spirit of Gertler and Karadi (2011), that is more prevalent in the emerging markets. As a result, the interbank lending relationships of emerging economies will be subject to default premium. In that context, we verify the relative convenience our menu of policy setups aimed to mitigate this distortion and smooth the credit spread.

At first, intuition may dictate that the policy stance of a periphery, cooperative or not, is inconsequential for shaping market outcomes given the relative size of the economy, and instead by cooperating, a financial center relinquishes more than what it gains. However, if the peripheric block is no longer very small in relative terms, for example, as a result of several small countries joining policy efforts, there could be a scope for cooperation.

Methodologically we set our model as a large open economy framework along the lines of Banerjee et al. (2016), Agénor et al. (2017), and Aoki et al. (2018). However, it differs from these setups in which we abstract from monetary policy concerns, a simplification that makes easier to extend the environment to that of a multiperipheral financially integrated economy, a feature that in turn, allows us to examine the strategic interactions between macroprudential regulators in different types of economies.

The international policy externalities manifest through two channels, first, the profits of exiting bankers are directly affected by domestic and foreign policy tools and enter the households' budget constraint since these are the banks' owners, second, on the real side the firms fund their input acquisitions with banking loans, whose cost depends on the policy instruments, which affect the investment decisions that shape the output dynamics. In this context, policymakers that act cooperatively will internalize the budget constraints of coalitions' participants which depending on the degree of coordination will lead to different policy prescriptions and equilibrium allocations.

Our results suggest the presence of important international policy spillovers that result from the interaction of two features. First, the cross-border effects stemming from the Center are strong, and second, the local effects of policy are weaker at the Center. As a result, Center based policymakers aiming to implement a given domestic effect are induced to apply stronger policies that ripple substantially to the rest of the world. Both features occur due to the role of the Center as a global creditor. For the former, the Center's policies affect the banking profits in every country, domestically via revenue rates, and globally via changes in the cost of interbank lending. On the other hand, the weaker local effect is explained by adjustments in the demand for funding by borrowers that partially offsets the intended effect on intermediation targeted by the regulators.

We obtain that the policy effects are increasing in the extent of the financial distortions, which is consistent with the conventional wisdom suggesting these policies are more useful in emerging markets (Alam et al. (2019)). Other features that determine these effects are the net foreign asset positions, the price and demand changes in the interbank sector, and lastly the disruption in real production activities, a concern that is ubiquitous in regulation circles and lately in empirical studies (e.g., Richter et al. (2019)).

Regarding international policy coordination we find non-sizable welfare gains from cooperation in our baseline setup. Relatedly, every policy setup (decentralized, semi-cooperative, and cooperative) can mimic the first best and undo the financial distortion. Interestingly, the optimal policies will differ by becoming more conservative as the degree of cooperation increases. The latter implies a property of the cooperative policy setups: they limit the level of interventionism necessary for mitigating the financial frictions.

We confirm these results in additional exercises, where we show that with costly policymaking the coordinated setups can generate substantial gains. Additionally, we show the inclusion of a second periphery yields results analogous to a two-country center-periphery setup if the new periphery is analogous to the first one. However, without symmetric features the peripheral interactions may lead to qualitatively different results.

Related Literature. Our work relates to the literature studying the macroeconomic effect of financial frictions that originate in the financial intermediaries sector. Then it incorporates elements from frameworks that model the banking sector explicitely (e.g., Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Adrian and Shin (2010)) and its cycle amplifying implifications for the rest of the economy.[1]

This study is also concerned with the open economy dimension of the macroprudential policies and the presence of international financial spillovers between emerging and advanced economies. Then, it is related to the global financial cycle literature (Rey (2013), Rey (2016)) and to studies on the stabilizing role of financial regulations for emerging economies (Nuguer (2016), Cuadra and Nuguer (2018)).

Finally, a main theme of our work is that of strategic interactions between regulators in presence of financial frictions. One strand of this literature revises the case of monetary policy cooperation with financial imperfections (e.g., Sutherland (2004), Fujiwara and Teranishi (2017), or Bodenstein et al. (2020)), or study the coordination between monetary and financial regulators (De Paoli and Paustian (2017)). Our work, incorporates some of these features but is only concerned about the international coordination of macroprudential regulators. In that sense, it relates more closely to Davis and Devereux (2019), Korinek (2020), Bengui (2014), Jin and Shen (2020), and Kara (2016). Interestingly, these studies suggest cooperation is advisable from different, and seemingly contradicting perspectives. In some cases because it prevents unnecessary interventionism, or in the latter two studies by preventing sub-optimal levels of regulation. We align with the first group in that we find that one advantage of coordination is that the level of intervenionism is limited.

However, we still differ from these articles in several dimensions, namely, we model the frictions at the banking model explicitely and we analyze a multiperipheral structure, hence allowing for potential retaliative policies from regulators outside the cooperative coalitions. The inclusion of these features, as discussed here and shown in Granados (2021) can be critical in determining whether or not cooperation is a good policy recommendation, and hence allows to reconcile these seemingly opposing results which, partly, constitutes our contribution to the literature.

The rest of the paper is organized as follows: section 2 explains the main model, section 3 describes the cross-border policy spillovers, then in section 4 we set the optimal policy problems. In section 5 we carry out the welfare comparison across policy setups for our baseline, while in the sections 6 and 7 we explore alternative versions of the model. Finally, we discuss the added value of considering a second periphery and conclude.

[1] See Brunnermeier et al. (2013) for a complete literature survey on this topic.

2 The Model

The model considered is based on Banerjee et al. (2016) and Agénor et al. (2017), meaning that it essentially follows the banking sector modelation of Gertler and Karadi (2011) applied to an open economy setup. At the same time it will include a macroprudential policy in the form of a tax to the return on capital such as Agénor et al. (2017) and Aoki et al. (2018), among others. The advantage of such formulation is that the policy instrument will be attached directly to the credit spread of the economy that drives the capital flows at the cross country level. Our formulation will be set in a finite horizon setup and will be amplified with a third economy to consider a more relevant role for the peripheral economic block.

2.1 Economic Environment

In this model the main feature defining whether a country is an emerging market economy is that its financial sector has a limited intermediation capacity, meaning that is unable to issue deposits claims for their households to some extent. Such feature implies that it will have to resort to the international financial banking sector to make up for the difference and being able to meet the funding needs of its firms. This setup is shown in Figure 1 (left), where the pointed red arrows represent financial flows.

Such structure implies that the emerging economies have a financial dependency on the funding stemming from center banks, and in an environment of imperfect information between creditors and debtors, this could imply a double layer of agency frictions in the economy: that between center households and banks and another one between global banks and emerging country banks. However, we assume the friction is more prevalent in countries that are financially underdeveloped at a greater extent, i.e., the distortion is more accentuated in the peripheries.

For simplicity, and mainly because I focus solely on macroprudential policies, the real sector will consist only on one consumption good and there will be no deviations from the law of one price. In addition, preferences are identical between agents, which implies that the parity or purchasing power holds and the real exchange rate will be constant, playing no role in this version of the model.

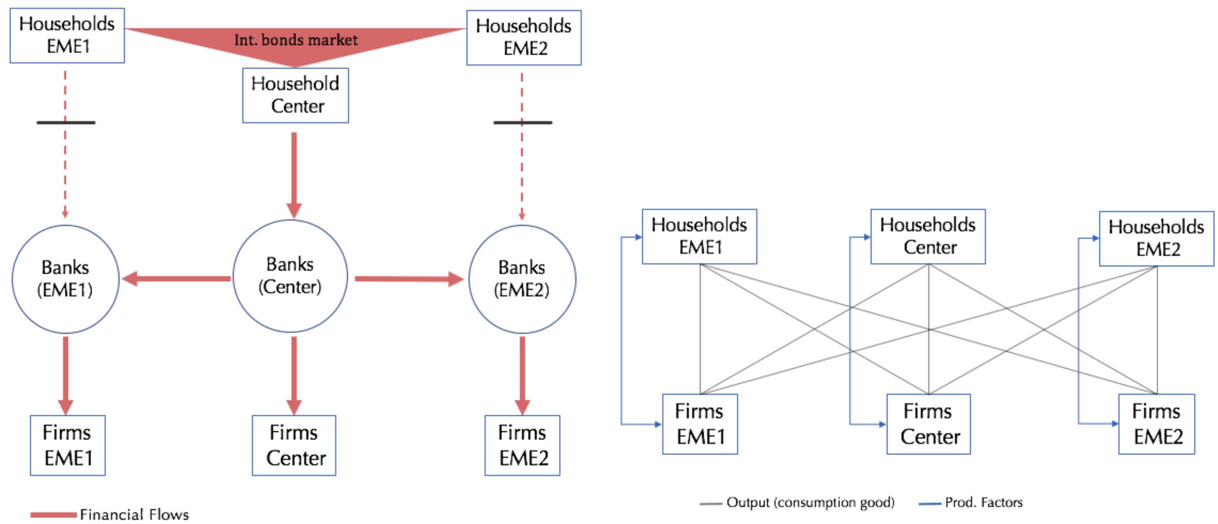

Figure 1: Financial (left) and Real (right) sector flows in the model

Finally, the households will have access to a non-contingent bond, traded internationally in a competitive market. Therefore, despite the lack of local financial capacity in the emerging countries banks, the household savings will not be curtailed. This implies that the resource fluctuations and differences between agents in each country will be driven mostly by wedges in credit spreads at the bank level rather than by constraints at the household level in achieving their intended optimal consumption/savings levels.

2.2 Model Setup

The world consists of three economies that live for two periods $t = 1, 2$. The economies are indexed by $j = a, b, c$, the first two will be emerging or peripheral countries (a and b) and the third one is a developed economy that acts as financial center (c). The relative population sizes of the economies are n_j with $1 - (n_a + n_b) \geq \frac{1}{2}$. There is an international financial market where the households trade in assets. There will be one final consumption good, freely traded and available to all economies.

Each economy has five types of agents: Households, final consumption good producers, capital producers, banks and a government sector.

In terms of notation, throughout the document, superindexes denote the country, while subindexes refer to other features such as the sector of the economy and time periods. Additionally, if a superindex is ommited it normally means that the variable or equation applies to the three countries, which is also taken into account when the equation is numbered (each additional number denotes the expression for one of the economies).

2.3 Investors

For simplicity, the investment decision is separated from the other household decisions and will be subject to adjustment costs. Physical capital is produced in a competitive market by using old capital and investment. The depreciation rate of capital is $1-(1-\delta)\xi_t^j$, where ξ_t^j represents a capital quality shock with expected value of one. The investment will be subject to convex adjustment costs, with the total cost of investing I_1^j being:

$$C(I_1) = I_1 \left(1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2\right)$$

Where $\bar{I}$ represents the benchmark level of reference with respect to which the adjustment cost is defined. The reference level is usually set at the steady state, the previous level of investment or a combination of both. Most importantly, it must be satisfied that $C(0) = 0,\ C''(\cdot) > 0$. For simplicity we pick $\bar{I}$ as I_0, i.e., the predetermined level of capital.

The capital producing firms buy back the old capital stock from the banks at price Q_1^j and produce new capital subject to the adjustment costs.

The investor solves:

$$\max_{I_1}\ Q_1 I_1 - I_1 \left(1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2\right)$$

the F.O.C. is,

$$[I_1]: \qquad Q_1 = 1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2 + \zeta\left(\frac{I_1}{\bar{I}} - 1\right)\frac{I_1}{\bar{I}} \tag{1)-(3}$$

Similarly, for period 2 (when investment is zero),

$$Q_2 = 1 + \frac{\zeta}{2} \tag{4)-(6}$$

2.4 Firms

The firms will operate with a Cobb-Douglas technology that aggregates capital. The capital in the first period will be provided directly by the households in the quantity predetermined (K_0). However, in the next period, the emergent economy will rely on foreign lending for funding capital accumulation, and then, the firms will rent the capital (K_1) from the banks instead.

The capital dynamics for the only period of accumulation are,

$$K_1 = I_1 + (1-\delta)\xi_1 K_0 \tag{7)-(9}$$

The technology that aggregates capital inputs into final goods is,

$$Y_1 = A_1(\xi_1 K_0)^{\alpha} \tag{10)-(12}$$

$$Y_2 = A_2(\xi_2 K_1)^{\alpha} \tag{13)-(15}$$

where K_0 is given.

Given the finite nature of the model, intermediation activities only take place in one period, whereas in the other the capital stock will be given and freely available for production. This implies that there is a different profit maximization problem for the final good firms to consider in each period:

In the first period the firm will solve:

$$\max_{K_0} \ \pi_{f,1} = Y_1 - r_1 K_0$$
$$s.t. \quad Y_1 = A_1(\xi_1 K_0)^{\alpha}$$

the F.O.C. are,

$$[K_0]: \qquad r_1 = \alpha A_1 \xi_1^{\alpha} K_0^{\alpha-1} \tag{16)-(18}$$

For the second period, the firms take into account the cost of funding and the revenue of selling the remaining capital stock to capital good producers that carry out the necessary investment to build the capital stock for the next period.

In the second period the firm will solve:

$$\max_{K_1} \ \pi_{f,2} = Y_2 + Q_2(1-\delta)\xi_2 K_1 - R_{k,2} Q_1 K_1$$
$$s.t. \quad Y_2 = A_2(\xi_2 K_1)^{\alpha}$$

the F.O.C. are,

$$[K_1]: \qquad \alpha A_2 \xi_2^{\alpha} K_1^{\alpha-1} + (1-\delta)\xi_2 Q_2 = R_{k,2} Q_1$$

To facilitate the model notation, we will follow the same definition for r_2, that is,

$$r_2 = \alpha A_2 \xi_2^{\alpha} K_1^{\alpha-1} \tag{19)-(21}$$

Substituting in the optimality condition for K_1 we obtain that the rate paid to the banks by the firms is given by $R_{k,2} = \frac{r_2 + (1-\delta)\xi_2 Q_2}{Q_1}$. Moreover, by taking into account the possibility of a macroprudential tax on the marginal return on capital, such as in Agénor et al. (2017), we have that the effective rate obtained by the banks, that is, after paying the macroprudential taxes to the government is given by:

$$R_{k,2} = \frac{(1-\tau)r_2 + (1-\delta)\xi_2 Q_2}{Q_1} \tag{22)-(24}$$

For the sake of clarity, it is important to notice that the firms will pay the pre-taxes banking rate. Only afterwards, the banks will consider the effect of the taxes in their profits. [2] We will elaborate on the policy tool and the role of this return rate in posterior subsections.

2.4.1 Capital dynamics and ownership

The dynamics of the model will be driven at every level (within and cross-country) by the capital flows. For that reason, and after laying out the problem the firm faces in a period with intermediation, it is relevant to clarify how capital is held, and profited from, by several types of agents in a single period.

There is only one period of capital accumulation ($t = 1$). The initial capital will be given for such period as K_0. Then, by the end of the accumulation period the capital in the economy will be given by K_1 as in (7)-(9).

The capital ownership between agents throughout each period is shown in the figure 2, which explains a typical period with intermediation. At first, the firms will hold the capital they bought to the households by the end of the previous period. The firms will use the capital for production and will sell the after-depreciation capital stock to capital goods producers that will generate the physical capital stock for the production of the next period (K_t). The new stock goes back to the households, that in turn, will sell it to the firms that will fund the purchase with banking loans. The loan is payable the next period at a promised gross rate R_{kt+1}

[2] With that in mind, we can obtain that the profits of the firms in the second period, after replacing the rate they pay to banks will have the usual form ($\pi_{f,2} = A_2(\xi_2 K_1)^\alpha - r_2 K_1$), consistent with a zero-profit competitive firm, and therefore, the net effect of the the taxes, after the rebate to the households will be zero as usual.

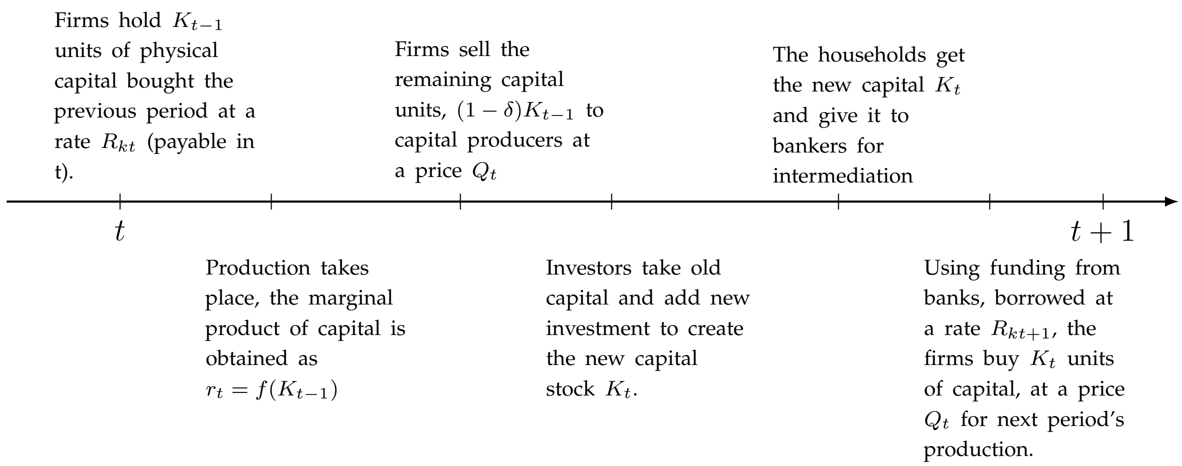

Figure 2: Capital ownership within a period

On the other hand, it should be noticed that the capital used for production in the period $t = 1$ cannot be subject to intermediation since there are no banks before the rest of the agents exist (the bankers themselves are household agents). Therefore, the pre-existing capital stock (K_0) will be provided directly from households to firms following the usual structure without explicit financial intermediation.

2.5 Banks

This is the target sector of the macroprudential policies. The set up is largely based on Gertler and Karadi (2011).

There is a financial intermediation sector in the first period that facilitates foreign funding from the center economy to the emerging countries. The creditors will be subject to an incentive compatibility constraint due to the fact that they can divert a portion of the assets intermediated (after realizing the return on the capital holdings).

The bank receives a start-up capital by their owner household and will try to maximize the value of the banking actitivies, given by the present value of its profits. Finally, at the end of its life, the bank will give back their net worth to the households in the form of profits.

2.5.1 Emerging Countries

The financial system of the emerging countries will have a limited capacity of intermediation of deposits from local households. For simplicity, I assume that there are not any local deposits in these economies, impliying that they rely almost entirely on foreign lending from the center banks for providing funding to firms for production. Therefore, the balance sheet of the bank includes, on the asset side, the lending provided to firms, and on the liability and equity side, the foreign lending from center banks and a start-up capital they receive from the local households.

The lending relationship between foreign and local banks will be subject to agency frictions, arising from the fact that creditor banks could default on their debt repayment and divert a portion κ of their (post-return) intermediated assets.[3] In either case (default or not) the gross return from intermediation for the bank is R_{k2} as given by the equations (22)-(24).

The emerging market bank maximizes the value of the bank in the period 1 (J_1):

$$\max_{F_1, L_1} J_1 = \mathbb{E}_1 \Lambda_{1,2} \pi_{b,2} = \mathbb{E}_1 \Lambda_{1,2} (R_{k,2} L_1 - R_{b,1} F_1)$$

$$s.t. \quad L_1 = F_1 + \delta_b Q_1 K_0 \tag{25)-(26}$$

$$J_1 \geq \kappa \mathbb{E}_1 \Lambda_{1,2} R_{k,2} L_1 \tag{27)-(28}$$

where the $L_1 = Q_1 K_1$ is the total intermediated lending, F_1 is the foreign interbank lending borrowed from the center bank and $\delta_b Q_1 K_0$ is the bequest or start-up capital received from households. Finally, $\Lambda_{1,2} = \beta u'(C_2)/u'(C_1)$ is the stochastic discount factor.

The constraints correspond to the balance sheet of the bank and incentive compatibility constraint (ICC), in the former we impose that the value of the bank has to be larger or equal than the value they can abscond.

the F.O.C. with respect to the foreign debt (one for each emerging country $s = \{a, b\}$) are:

$$[F_1] : \qquad \mathbb{E}_1 (R_{k,2} - R_{b,1}) = \mu \mathbb{E}_1 \left(\kappa R_{k,2} - (R_{k,2} - R_{b,1}) \right) \tag{29)-(30}$$

where μ is the lagrange multiplier of the ICC (there will be one for each emerging economy).

Based on the F.O.C. we can obtain a result that we will use throughout several sections of the paper for analyzing the implications of the financial friction in the model:

[3] A bank can divert assets as soon as they get the foreign funding or after the firms pay them the loan in the last period. I take into account only the second case when formulating the associated incentive compatibility constraint because it involves a stricter constraint which, when binding, makes redundant the constraint related to the first type of absconding.

Proposition: *If the ICC binds the credit spread is positive and increases in κ and μ*

Proof: W.L.O.G. we will work in a perfect foresight setup, otherwise the same result applies to the expected credit spread. From the F.O.C. above, we can obtain:

$$R_{k,2} = \underbrace{\frac{1+\mu}{1+(1-\kappa)\mu}}_{\Phi} R_1$$

$\Phi > 1$ represents the proportionality scale between $R_{k,2}$ and $R_{b,1}$ and guarantees the credit spread is positive in the model. The larger Φ the greater the spread.

$\mu > 0$ by definition of the ICC. Hence, it follows that,

$$\frac{\partial \Phi}{\partial \kappa} = \frac{\mu(1+\mu)}{(1-(1-\kappa)\mu)^2} > 0$$

and,

$$\frac{\partial \Phi}{\partial \mu} = \frac{2(1-\kappa)\mu - \kappa}{(1-(1-\kappa)\mu)^2} > 0$$

The last inequality holds for $\mu > \frac{\kappa}{2(1-\kappa)}$ which is the case in every parametrization. ■

2.5.2 Advanced Economy

Given we are assuming there is no agency problem at the local level, the center economy bank solves:

$$\max_{F_1, L_1, D_1} J_1 = \mathbb{E}_1 \Lambda_{1,2} \pi^c_{b,2} = \mathbb{E}_1 \Lambda_{1,2} (R^a_{b,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} L^c_1 - R_{D,1} D_1)$$
$$s.t. \quad F^a_1 + F^b_1 + L_1 = D_1 + \delta_b Q^c_1 K^c_0 \tag{31}$$

The only restriction will be the balance sheet of the bank that now counts with the foreign interbank flows on the asset side and the local center deposits on the liability side (D_1).

the associated F.O.C. are:

$$[F^a_1]: \qquad \mathbb{E}_1(R^a_{b,1} - R_{D,1}) = 0 \tag{32}$$
$$[F^b_1]: \qquad \mathbb{E}_1(R^b_{b,1} - R_{D,1}) = 0 \tag{33}$$
$$[L^c_1]: \qquad \mathbb{E}_1(R^c_{k,2} - R_{D,1}) = 0 \tag{34}$$

2.6 Macroprudential policy and public budget

Among the number of possible prudential policies[4] (VaR regulations, leverage caps, loan/value ratios, etc) we consider a general type of policy that encompasses a broad set of macroprudential regulations: a tax on the return to capital. This will be a tax levied on the banking sector, as shown in equations (22)-(24).

The policy tool can be thought as a device to impose controls on international capital flows. This is the case because the tax has the advantage of affecting directly the wedge between the return on capital and borrowing rate (cost of funds for the bank), i.e., the credit spread, that in turn drives financial flows at the interbank level. Thus, we are taxing the source of inefficiencies directly.

On the public budget level this is reflected as a distortionary tax funded with lump-sum taxes in each period, i.e., we assume a balanced fiscal budget.

$$\tau^j r_2^j K_1^j + T^j = 0, \qquad j = \{a, b, c\}$$

When setting the taxes optimally, each social planner will consider whether to join a cooperative arrangement or to do it independently (Nash). We consider several types of cooperation, namely worldwide, or smaller coalitions such as regional-emerging economies, or center with one of the peripheries. Each case will imply a different welfare function as explained in section 3.

Having set up the banks and policy tool, we can determine its effect on the leverage ratio of banks:

Proposition: *An increase in the macroprudential tax decreases the leverage ratio of banks*

Proof: W.L.O.G. we will work in a perfect foresight setup, otherwise the same result applies to the expected value of the leverage.

In the ICC (binding) we substitute the total foreign lending $F_1^e = Q_1^e K_1^e - \delta_B Q_1^e K_0^e$ for any emerging economy $e = \{a, b\}$ and solve for the total assets $L_1^e = Q_1^e K_1^e$ in terms of the initial net worth of banks:

$$L_1 = \underbrace{\frac{R_{b,1}^e}{R_{b_1}^e - (1 - \kappa^e) R_{k,2}}}_{\phi_L} \delta_B Q_1^e K_0^e$$

[4] see Cerutti et al. (2017) for a detailed classification of macroprudential policies

Φ_L denotes the leverage ratio.

We can substitute $R^e_{k,2} = [(1-\tau^e)r^e_2 - (1-\delta)\xi^e_2 Q_2]/Q_1$ and differentiate with respect to τ^e:

$$\frac{\partial \phi_L}{\partial \tau^e} = -\frac{(1-\kappa^e)R^e_{b,1}(r^e_2)}{(R^e_{b,1} - (1-\kappa^e)R^e_{k,2})^2 Q^e_1} < 0$$

This result takes into account that the denominator is never zero given the ICC is binding and the credit spread is positive (see equations (29)-(30)). ■

2.7 Households

The household derives utility from consumption and its lifetime utility is given by $U^j = u(C^j_1) + \beta u(C^j_2)$ with $u(C) = \dfrac{C^{1-\sigma}}{1-\sigma}$.

The budget constraints in each period are the following:

Emerging markets:

$$C^s_1 + \frac{B^s_1}{R^s_1} = r^s_1 K^s_0 + \pi^s_{f,1} + \pi^s_{inv,1} - \delta_b Q^s_1 K^s_0 \tag{35)-(36}$$

$$C^s_2 = \pi^s_{f,2} + \pi^s_{b,2} + B^s_1 - T^s, \quad for\ s = \{a, b\} \tag{37)-(38}$$

where C is the final consumption good, B a non-contingent international traded bond, r_1 the rental rate of capital, Q the relative price of capital, K the capital stock and T is a lump-sum tax.

π stands for profits which can come from production activies in final goods (f), capital goods (inv) or banking services (b).

Advanced Economy:

$$C^c_1 + \frac{B^c_1}{R^c_1} + D_1 = r^c_1 K^c_0 + \pi^c_{f,1} + \pi^c_{inv,1} - \delta_b Q^c_1 K^c_0 \tag{39}$$

$$C^c_2 = \pi^c_{f,2} + \pi^c_{b,2} + B^c_1 + R_{D,1} D_1 - T^c \tag{40}$$

The advanced economy also includes local deposits D in the budget constraint as these are intermediated by their banks.

the profits are given by:[5]

$$\begin{aligned}
\pi_{f,1} &= A_1 \xi_1^\alpha K_0^\alpha - r_1 K_0 \\
\pi_{f,2} &= A_2 \xi_2^\alpha K_1^\alpha + Q_2(1-\delta)\xi_2 K_1 - R_{k,2} Q_1 K_1 \\
\pi_{inv,1} &= Q_1 I_1 - I_1 \left(1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2\right) \\
\pi_{b,2}^s &= R_{k,2}^s Q_1^s K_1^s - R_{b,1}^s F_1^s, \quad for\ s = \{a, b\} \\
\pi_{b,2}^c &= R_{b,1}^a F_1^a + R_{b,1}^b F_1^b + R_{k,2}^c Q_1^c K_1^c - R_{D,1} D_1
\end{aligned}$$

In the first period each household will maximize the present value of its life-time utility subject to the budget constraints for the first and second period. The associated F.O.C. for the three households are:

$$u'(C_1) = \beta R_1 \mathbb{E}_1[u'(C_2)] \tag{41)-(43}$$

$$u'(C_1^c) = \beta R_{D,1} \mathbb{E}_1[u'(C_2^c)] \tag{44}$$

The first three are the Euler Equations for bonds and the last one, applying only for country c, is the Euler Equation for local deposits.

2.8 Market Clearing

At the world level the bonds are characterized by zero-net-supply:

$$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0 \tag{45}$$

The goods market clearing conditions for each period are,

$$\begin{aligned}
n_a \left(C_1^a + I_1^a \left(1 + \frac{\zeta}{2}\left(\frac{I_1^a}{\bar{I}} - 1\right)\right)\right) + n_b \left(C_1^b + I_1^b \left(1 + \frac{\zeta}{2}\left(\frac{I_1^b}{\bar{I}} - 1\right)\right)\right) \\
+ n_c \left(C_1^c + I_1^c \left(1 + \frac{\zeta}{2}\left(\frac{I_1^c}{\bar{I}} - 1\right)\right)\right) = n_a Y_1^a + n_b Y_1^b + n_c Y_1^c
\end{aligned}$$

$$n_a C_2^a + n_b C_2^b + n_c C_2^c = n_a Y_2^a + n_b Y_2^b + n_c Y_2^c$$

Finally, given that there is only one final good and the law of one price holds (so that

[5]The firm's profits are zero for both periods. Moreover, given the value of r_2 we can get from the firm optimality condition that the profits in the second period are also equivalent to $\pi_{f,2} = A_2 K_1^\alpha - r_2 K_1$

the real exchange rate in all cases is one), we have by an uncovered interest rate parity argument that:

$$R_1^a = R_1^b \tag{46}$$

$$R_1^c = R_1^b = R_1 \tag{47}$$

where R_1 denotes the world interest rate on bonds in period 1.

2.9 Exogenous processes

I consider three sources of exogenous variation in the model that are subject to shocks. First a productivity technology shock:

$$\begin{aligned} A_t^j &= \rho_A A_{t-1}^j + \sigma_A \epsilon_{A,t}^j \\ \epsilon_{A,t}^j &\sim N(0,1) \end{aligned} \qquad \text{(48)-(50)}$$

At the same time, I consider a capital quality shock ξ_t that affects the stock of capital in the production function and the depreciation rate,

$$\begin{aligned} \xi_t^j &= \rho_\xi \xi_{t-1}^j + \sigma_\xi \epsilon_{\xi,t}^j \\ \epsilon_{\xi,t}^j &\sim N(0,1) \end{aligned} \qquad \text{(51)-(53)}$$

2.10 Equilibrium

Equations (1) to (47) solve for 47 endogenous variables:

$Q_1^a, Q_1^b, Q_1^c, Q_2^a, Q_2^b, Q_2^c, I_1^a, I_1^b, I_1^c, K_1^a, K_1^b, K_1^c, Y_1^a, Y_1^b, Y_1^c, Y_2^a, Y_2^b, Y_2^c, r_1^a, r_1^b, r_1^c, r_2^a, r_2^b, r_2^c$

$F_1^a, F_1^b, D_1, R_{b,1}^a, R_{b,1}^b, R_{D,1}, R_{k,2}^a, R_{k,2}^b, R_{k,2}^c, C_1^a, C_1^b, C_1^c, C_2^a, C_2^b, C_2^c, B_1^a, B_1^b, B_1^c, R_1^a, R_1^b, R_1^c, \mu^a, \mu^b$

Notice that one budget constraint (or market clearing equation for the goods market) becomes redundant in each period due to the Walras law.

Also, for cases in which stochastic analysis is carried, the system would include a number of shocks, described by the equations (48)-(50) to (51)-(53).

3 Welfare Effects between economies

As a first approximation we can verify, both analitically, and numerically in the next subsection, what are the welfare spillover effects between economies in each policy setup.

We set the welfare based on a social planner problem and follow Davis and Devereux (2019) for finding the equilibrium welfare effects of a change in the policy tools: Let the welfare of country j be expressed as $W^j = U^j + \lambda_1^j BC_1^j + \beta\lambda_2^j BC_2^j$ for $j = \{a, b, c\}$

$$\begin{aligned}
W^s = U^s &+ \lambda_1^s \left(r_1^s K_0^s + \pi_{f,1}^s + \pi_{inv,1}^s - \delta_b Q_1^s K_0^s - C_1^s - \frac{B_1^s}{R_1^s} \right) \\
&+ \beta\lambda_2^i \left(\pi_{f,2}^s + \pi_{b,2}^s + B_1^s - T^s - C_2^s \right) \qquad \text{for } s = \{a, b\} \\
W^c = U^c &+ \lambda_1^c \left(r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_b Q_1^c K_0^c - C_1^c - \frac{B_1^c}{R_1^c} - D_1 \right) \\
&+ \beta\lambda_2^c \left(\pi_{f,2}^c + \pi_{b,2}^c + B_1^c + R_{D,1} D_1 - T^c - C_2^c \right)
\end{aligned}$$

This problem is analogous to a standard planner problem. Nonetheless, the optimality conditions (equilibrium outcomes) for other agents are accounted for by the planner.

We substitute the profits for banks and firms in accordance with the Competitive Equilibrium (ICCs included) and the tax rebates:

$$\begin{aligned}
W^a = u(C_1^a) + \beta u(C_2^a) &+ \lambda_1^a \left(A_1^a (\xi_1^a K_0^a)^\alpha + Q_1^a I_1^a - C(I_1^a) - C_1^a - \frac{B_1^a}{R_1^w} \right) \\
&+ \beta\lambda_2^a \Big(\phi(\tau^a) A_2^a (\xi_2^a K_1^a)^\alpha + \kappa^a (1-\delta) \xi_2^a Q_2^a K_1^a + B_1^a - C_2^a \Big) \\
W^b = u(C_1^b) + \beta u(C_2^b) &+ \lambda_1^b \Big(A_1^b (\xi_1^b K_0^b)^\alpha + Q_1^b I_1^b - C(I_1^b) - C_1^b - \frac{B_1^b}{R_1} \Big) \\
&+ \beta\lambda_2^b \Big(\phi(\tau^b) A_2^b (\xi_2^b K_1^b)^\alpha + \kappa^b (1-\delta) \xi_2^b Q_2^b K_1^b + B_1^b - C_2^b \Big) \\
W^c = u(C_1^c) + \beta u(C_2^c) &+ \lambda_1^c \left(A_1^c (\xi_1^c K_0^c)^\alpha + Q_1^c I_1^c - C(I_1^c) - C_1^c - D_1^c - \frac{B_1^c}{R_1^w} \right) \\
&+ \beta\lambda_2^c \Big(A_2^c (\xi_2^c K_1^c)^\alpha + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b + (1-\delta) \xi_2^c Q_2^c K_1^c + B_1^c - C_2^c \Big)
\end{aligned}$$

with $\phi(\tau^s) = 1 + (\kappa^s - 1)(1 - \tau^s)\alpha \qquad \text{for } s = \{a, b\}$

We can see that, for the emergent markets, the direct effect of the regulation tax is not inmediately eliminated from the welfare, even from the perspective of the planner. This occurs due to the effect of accounting for a binding ICC in the profits. Conversely, in the advanced economy and in absence of financial frictions, the rebate cancels out with the taxed revenue in the second period.

From these welfare expressions we will obtain the effects of taxes, via implicit differentiation, and will simplify our resulting expressions by substituting the optimality conditions of the Private Equilibrium.

This method is convenient, because the number of variables we have to consider is decreased considerably since we can ignore the effects on decision variables of the households. For these, the optimality conditions (that bind and are equal to zero) will always be a factor of the tax effect on each variable and hence will be canceled out.

3.1 Nash Case

The planner of each economy will take W^j as their welfare objective function. In contrast, the cooperative welfare would be a weighted sum of the individual welfare expressions of the countries.

3.1.1 Direct Effects

The welfare effect of the tax for the emerging economies is given by[6],

$$\frac{dW^a}{d\tau^a} = \lambda_1^a I_1^a \frac{dQ_1^a}{d\tau^a} + \beta\lambda_2^a \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^a} + \beta\lambda_2^a \left(\phi(\tau^a)\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1} + \kappa^a(1-\delta)\xi_2^a Q_2^a\right)\frac{dK_1^a}{d\tau^a} + \beta\lambda_2^a \alpha(1-\kappa^a)A_2^a(\xi_2^a K_1^a)^\alpha$$

The same functional form applies for b.

Each term in this expression is associated with a source of variations on the welfare:

Changes in investment profits: The first term corresponds to changes in the investment profits and its sign depends on whether the country is investing above or below the reference level in the adjustment cost function. For our parameters and initial state values the sign is positive.

Changes in external assets position: The second term, reflects the welfare effects from changes in the international debt position. $\frac{dR_1}{d\tau^a}$ is negative as there is a lower demand for funds by the levied banks. The sign of the whole term, however, depends on the sign of $\frac{B_1^a}{R_1}$ which is positive for emerging markets (and negative for the center), given that, by

[6]The derivation of these results is shown in detail in the appendix A.

purchasing these assets, the households save the resources that cannot be deposited in their own countries.

Change in welfare by distorting K accumulation: The third term reflects the change in welfare after hindering capital accumulation, hence, it will be proportional to the change in physical capital holdings and to the sources of profit from holding capital, i.e., the marginal product of capital as well as its after-depreciation resale value. The sign of this term is negative as capital accumulation lowers with a tax raise.

Finally the last term reflects the direct effect of the policy tool on welfare. This effect will not cancel out for the emerging markets, as in the center, because of the presence of a binding ICC for emerging countries. Its sign is positive.

We can see there are offsetting welfare effects. Moreover, the signs and magnitudes depend on the reference point and scale of the policy change that each country planner would plan to implement. In the subsection 3.3 we find these effects for a small change around the no policy case based on the numerical solution of the model.

For the center economy, the effect is:

$$\frac{dW^c}{d\tau^c} = \lambda_1^c I_1^c \frac{dQ_1^c}{d\tau^c} + \beta\lambda_2^c \frac{B_1^c}{R_1}\frac{dR_1}{d\tau^c} + \beta\lambda_2^c \left(\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2^c\right)\frac{dK_1^c}{d\tau^c} + \beta\lambda_2\left[R_{b,1}^{eme}\left(\frac{dF_1^a}{d\tau^c} + \frac{dF_1^b}{d\tau^c}\right) + \frac{dR_{b,1}^{eme}}{d\tau^c}\left(F_1^a + F_1^b\right)\right]$$

The interpretations for the first three terms are analogous to those of the emerging country mentioned above. The final term corresponds to:

Welfare effect from changes in intermediation profits: this is the welfare effect coming from the change of the tax on the funding quantities or gross rates related to cross-border lending. Both terms in the squared brackets will be negative.

3.1.2 Cross-country Effects

The welfare effect between emergent countries is,

$$\frac{dW^a}{d\tau^b} = \lambda_1^a I_1^a \frac{dQ_1^a}{d\tau^b} + \beta\lambda_2^a \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^b} + \beta\lambda_2^a \left(\phi(\tau^a)\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1} + \kappa^a(1-\delta)\xi_2^a Q_2^a\right)\frac{dK_1^a}{d\tau^b}$$

With an analogous counterpart following for the effect in W^b when τ^a is changed. Notice this expression is similar to the within country effect of their own tax. Although, conversely, the last term is absent given there is not a direct welfare effect from a tax at the cross-country level.

The emerging country welfare effect of a change in the center country tax is,

$$\frac{dW^a}{d\tau^c} = \lambda_1^a I_1^a \frac{dQ_1^a}{d\tau^c} + \beta\lambda_2^a \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^c} + \beta\lambda_2^a \left(\phi(\tau^a)\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1} + \kappa^a(1-\delta)\xi_2^a Q_2^a\right)\frac{dK_1^a}{d\tau^c}$$

On the other hand the center economy welfare effect of a change in the emerging economy tax is,

$$\frac{dW^c}{d\tau^a} = \lambda_1^c I_1^c \frac{dQ_1^c}{d\tau^a} + \beta\lambda_2^c \frac{B_1^c}{R_1}\frac{dR_1}{d\tau^a} + \beta\lambda_2^c \left(\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2^c\right)\frac{dK_1^c}{d\tau^a}$$
$$+ \beta\lambda_2^c\left[R_{b,1}^{eme}\left(\frac{dF_1^a}{d\tau^a} + \frac{dF_1^b}{d\tau^a}\right) + \frac{dR_{b,1}^{eme}}{d\tau^a}\left(F_1^a + F_1^b\right)\right]$$

The interpretations of each term follow analogous intuitions to those explained in the subsection 3.1.1.

3.1.3 Optimal tax

For obtaining the optimal tax we set $\frac{dW^a}{d\tau^a} = 0$ and solve for τ^a:

$$\tau^{a\ *} = \frac{-1}{\alpha(1-\kappa^a)}\left\{\frac{1}{\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1}}\left[\left(R_1 I_1^a \frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a}\right) + \kappa^a(1-\delta)\xi_2^a Q_2\right] + 1 + \alpha(\kappa^a - 1)\right\}$$

The result for b will be analogous.

For c:

$$\tau^{c\ *} = \frac{Q_1^c}{\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1}}\left\{R_1 I_1^c \frac{dQ_1^c}{dF_1^S} + \frac{B_1^c}{R_1}\frac{dR_1}{dF_1^S} + (\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2)\frac{dK_1^c}{dF_1^S}\right.$$
$$\left. + (F_1^a + F_1^b)\frac{dR_{b,1}^{eme}}{dF_1^S} + (1-\delta)\xi_2^c \frac{Q_2}{Q_1^c}\right\} + 1$$

with $dF_1^S = dF_1^a + dF_1^b$

These expressions allow us to get an idea about the effects driving the optimal taxes. We can see that the peripheral tax depends on the effect on prices and interest rates from changes in the capital stock, which is proportional to the investment and foreign bonds position. Other relevant features are the resale price of capital and the marginal product of capital, and in fact, the absolute value of the tax will decrease if the latter increases.

Here is useful to remember that, in equilibrium, the marginal product of capital is directly taxed by the prudential tool, and hence we could interpret that for having a meaningful effect, the tax (or subsidy) will have to be set more strongly in countries with lower marginal product of capital. Finally, the deepness of the financial distortion, captured by κ^a plays an amplifying role: the higher the distortion, the stronger would the policy stance (tax or subsidy) implemented by the policymaker.

Regarding the financial center optimal tax, we have a different structure with a more relevant role for variables related to cross-border lending, in fact a role similar to the one played by domestic capital in the optimal tax of the periphery, will be enacted by the foreign interbank lending for the center.

We can approximate the signs for these expressions based on a particular solution, for example with the zero tax equilibrium as reference point. By doing this, we obtain for both equations that the terms inside the square brackets will not have the same sign, meaning we have offsetting forces driving the tool towards subsidizing or taxing the banking sector. That will reflect the policy tradeoff these economies face, they can tax the banks and undo the friction, or they can subsidize and increase capital accumulation and production.

More importantly, both the right and left hand side of the equations depend on the taxes, i.e., the equilibrium solution is a function of the taxes themselves, that the agents are taking as given, and hence, we cannot draw general conclusions on signs and magnitudes easily from these equations. Instead, we have to follow a somewhat more nuanced approach and solve a Ramsey policy problem. In the section 4 we set and solve such policy problem based on the optimality conditions of the planners.

3.2 Cooperative cases

For the cooperative cases we follow a similar strategy but focusing on the objective welfare of interest as follows:

Table 2: Welfare spillovers in the model

Case	Planners	Obj. Function	Effect of taxes
Cooperation (all countries)	World	$W = n_a W^a + n_b W^b + n_c W^c$	$\frac{dW}{d\tau^j} = n_a \frac{dW^a}{d\tau^j} + n_b \frac{dW^b}{d\tau^j} + n_c \frac{dW^c}{d\tau^j}$
Semi-Cooperation (EMEs vs. Center)	Emerging block A+B	$W^{ab} = n_a W^a + n_b W^b$	$\frac{dW^{ab}}{d\tau^j} = n_a \frac{dW^a}{d\tau^j} + n_b \frac{dW^b}{d\tau^j}$
	Center	W^c	$\frac{dW^c}{d\tau^j}$
Semi-Cooperation (EME-A + C vs. EME-B)	Cooperative A+C	$W^{ac} = n_a W^a + n_c W^c$	$\frac{dW^{ac}}{d\tau^j} = n_a \frac{dW^a}{d\tau^j} + n_c \frac{dW^c}{d\tau^j}$
	EME-B	W^b	$\frac{dW^b}{d\tau^j}$

Note: $j = a, b, c$

It turns out that the effects in the cooperative cases can be recovered from the individual results in section 3.1, that is, the effects will be given by weighted averages of the individual effects for the Nash case.

With no individual null effects, we have that the total spillover effects between Nash and cooperative cases will differ. As a result, when solving the Ramsey Planning models we should obtain different optimal tool levels across policy setups.

3.3 Numerical Effects

The effects are computed around zero, meaning that we are assessing the effect of a marginal increase in the taxes with respect to a initial point when there is no policy in place.

This section includes the welfare effects of implementing a macroprudential tax in the baseline model. The paremeters used are shown in the table B.1 in the appendix B.

Table 3: Welfare effect of 1% increase in taxes - parameter changes

	Baseline	Symmetric country size	Smaller periphery	Lower financial friction	Larger financial friction
Direct Effects					
$\tau_a \to W^a$	-1.560	-1.637	-1.498	-1.375	-1.763
$\tau_b \to W^b$	-1.560	-1.637	-1.498	-1.375	-1.763
$\tau_c \to W^c$	-0.847	-0.877	-0.811	-0.819	-0.870
Cross-country Effects					
$\tau_a \to W^b$	-0.078	-0.045	-0.089	-0.092	-0.062
$\tau_a \to W^c$	-0.039	-0.012	-0.056	-0.056	-0.025
$\tau_b \to W^a$	-0.078	-0.045	-0.089	-0.092	-0.062
$\tau_b \to W^c$	-0.039	-0.012	-0.056	-0.056	-0.025
$\tau_c \to W^a$	-0.308	-0.221	-0.308	-0.254	-0.374
$\tau_c \to W^b$	-0.308	-0.221	-0.308	-0.254	-0.374

Smaller periphery: Center country's size increase to 2/3 of world population.
Units: Numerical approximation to the derivative $\frac{\Delta W}{\Delta \tau}$

Before analyzing this figures, we must note that the numbers just indicate how much is changing the welfare, relative to the change in the taxes. However, a change in terms of welfare units does not have any cardinal economic interpretation, given it is denotes in utility units. Instead, we intend to show the relative sizes of the effects between countries for changes in each type of taxes (e.g. the fact that the direct effects are stronger than the cross-country ones).

The results indicate that, departing from a no policy world, a marginal increment in the tax decreases welfare. This may indicate subsidizing the banking sector takes priority over taxing the capital spread to ameliorate the financial friction. At the same time the within country effect is stronger than the cross-country effect.

Additionally, the cross country effect is negative as well. This implies there are positive policy spillovers between economies from implementing the macroprudential tax, i.e., a welfare improving tax (or subsidy) for a country will have prosper-thy-neighbor effects on the other countries.

Jointly, this suggests that policies are interdependent and there can be some free-riding policy incentives. However, with a stronger local effect of the tool, there still would be an active policy implementation in each economy when applying an optimal level of the subsidy.

It can also be noted that, as expected, the stronger cross country effect comes from policies implemented at the center economy and the weakest from emergent economies towards the center. However, the effect between emerging economies is relatively strong. This can be considered a relevant welfare effect taking into account that, in contrast than with the center, there are no financial flows between emerging countries.

Finally, we find that depreciation plays a relevant role in facilitating the cross-border welfare spillovers. With complete depreciation the within country (direct) effects will be stronger and the cross country effect will be at most a fourth of the one with undepreciated capital (see table B2 in the appendix B). In contrast, with incomplete depreciation, the within country (direct) welfare effects weaken and the cross country effects increase considerably. The cross country effect now can reach a level of about more than four times the maximum effect found in the case with complete depreciation.

We should remark that in any case, these results correspond to the numerical counterparts of the welfare effects explored at the beginning of this section and that the signs and magnitudes will hinge heavily on the reference point and magnitude of the change in the policy tools. The utility of this exercise, in our view, consists on verifying the presence of welfare spillovers and their drivers.

The take away from this exercise will be that the within country effects of taxes are stronger in peripheries. A result consistent with the fact that the optimal taxes for the center are larger in absolute value for every policy setup (see section 5). That is, given a weaker effect in the center, its tool is set to follow stronger policy stances for a similar inteded effect. At the same time this may have strong cross country unintended consequences since it also happens that the stronger cross-country effect is exerted by changing the center taxes.

For an actual determination of the taxes and effects of the policy tools we will go a step beyond the social planner framework and set up the associated Ramsey policy problems for these economies in the following section.

4 The Ramsey Planner problem

In the previous sections, we set up the model for these economies and explored the welfare spillovers from setting the macroprudential tools, including the within effect and the effect between economies. The objective was to understand what drives the welfare effect of setting the tools in general and across policy frameworks changing by their degree of cooperation between planners.

It should be noted that in such analysis, there is a substantial level of endogeneity given that all the equations (on both sides) depend on the taxes. Hence, other than studying the structure of the effects, or the numerical effect at a given level of the taxes, it is difficult to solve for the actual optimal level of the policy tool and thus for the policy distorted equilibrium allocation under each policy.

For such end, we will set a Ramsey problem consisting on maximizing a welfare objective function subject to the private equilibrium optimality conditions.

First, we will use the country-wise welfare definition from previous sections: $W^j = u(C_1^j) + \beta u(C_2^j)$ with $j = \{a, b, c\}$ and $u(C) = \frac{C^{1-\sigma}}{1-\sigma}$.

Second, following the notation for a Ramsey problem in Bodenstein et al., 2019, let $F(\cdot)$ be the set of equations representing the optimality constraints of private agents that characterize the private equilibrium, x the system of endogenous or decision variables for the agents, θ the parameters of the model and $\tau = \{\tau^a, \tau^b, \tau^c\}$ the vector of policy instruments for all countries. We will solve the following problem for each Ramsey planner involved:

$$\begin{aligned} \max_{\mathbf{x_t}, \tilde{\tau}_t} \quad & W_t^{objective} = f(\alpha^j, W_t^j) \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \end{aligned}$$

with $\tilde{\tau} \subseteq \tau$ and welfare weights $\alpha^j \geq 0 \quad \forall j$.

The set up of this problem will vary in each policy framework by changing the objective function, whereas the constraints will always refer to all the equations defining the equilibrium of the model ((1) to (47)). The latter assumption is set for consistency with an open economy setup and implies that the planners acknowledge they have an effect in the endogenous variables of the other countries.[7]

[7]This assumption is standard for Ramsey problem solutions and guarantees the optimization will yield enough equations as unknowns to solve for. Other ways to go about this would be to make small open economy assumptions. However, we take the standard path while accounting for smaller economy effects by adjusting the population size of the economies.

4.1 Non-Cooperative Framework

Without cooperation we will have one planner for each country, each one solving:

$$\begin{aligned} \max_{\mathbf{x_t^j}, \tau_t^j} \quad & W^j_{Nash,t} = W^j_t \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \qquad \text{for } t = 1. \end{aligned}$$

The first order conditions for the three planners will be used to solve for the Ramsey Nash equilibrium.

4.2 Cooperative Framework

We will consider three types of cooperative frameworks. Full cooperation, where the tools for all countries are set cooperatively by a simple planner, and two semi-cooperative cases where regional coalitions are formed. First, between emerging economies, and second between the center and one emerging economy.

4.2.1 World Cooperation

The cooperative Ramsey planner solves:

$$\begin{aligned} \max_{\mathbf{x_t}, \tau_t} \quad & W_{Coop,t} = n_a W^a_t + n_b W^b_t + n_c W^c_t \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \qquad \text{for } t = 1. \end{aligned}$$

4.2.2 Regional cooperation between emerging countries

A coalition between Emerging Economies implies a regional level planner solving:

$$\begin{aligned} \max_{\mathbf{x_t^a}, \mathbf{x_t^b}, \tau_t^a, \tau_t^b} \quad & W_{CoopEMEs,\ t} = n_a W^a_t + n_b W^b_t \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \qquad \text{for } t = 1. \end{aligned}$$

In this framework there is a second planner, in the center country, that chooses the decision variables and policy tool for its country in order to maximize W^c_1, analogously to the Nash center planner.

4.2.3 Coalition between the advanced economy and one emerging country

The coalition between the center or advanced economy and one emerging economy (EME-A) implies a semi-cooperative Ramsey planner that solves:

$$\max_{\mathbf{x_t^a}, \mathbf{x_t^c}, \tau_t^a, \tau_t^c} \quad W_{CoopAC,\ t} = n_a W_t^a + n_c W_t^c$$
$$s.t. \quad \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \qquad \text{for } t = 1.$$

In this case there is a second planner in the second emerging country (B), i.e., the economy outside the coalition, that chooses the B country decision variables and policy tool in order to maximize W_1^b, analogously to one of the Nash emerging planners.

5 Welfare Accounting Comparison

Table 4 shows the welfare outcomes comparison between the cooperative policy frameworks and the Nash equilibrium. It is expressed in units of a proportional increase in the steady state consumption for a benchmark model, i.e., 1 would imply that the models compared are equivalent in terms of welfare, whereas a higher number, $\phi > 1$, would denote a welfare improvement, equivalent to what would be generated by a $(\phi - 1) \times 100\%$ increase in the stream of consumption. For example, 1.2 would denote a welfare gain with respect to the benchmark model equal to the improvement such economy would experiment if the steady state consumption generating their baseline welfare levels were to increase by 20%.

Table 4: Welfare comparison across policy schemes with respect to the Nash Equilibrium

	Policy Scheme		
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.00	1.00	1.00
A	1.00	1.00	1.00
B	1.00	1.00	1.00
World	1.00	1.00	1.00
EME Block	1.00	1.00	1.00

Units: Proportional steady state consumption increase in the baseline (Nash) model

Our results suggests there are not gains from cooperative policy setups with respect to the Nash policy equilibrium. This includes the semi-cooperative setups where coalitions of countries, that is peripheries or the center with an emergent, set jointly their macroprudential policy tools.

This summarizes how the Ramsey equilibria fare with respect to each other, and how in the baseline framework they provide the same welfare outcomes. Just as importantly, we can examine what combination of policy leads to this result and whether the planners are effective in mitigating the agency financial friction in place.

5.1 Level of the policy tool in each arrangement

In section 3 we observed that the optimal action, around a no policy scenario, points to subsidizing the banking sector so as to induce a compulsory increment of savings from households in favor of the banks. The Ramsey equilibrium allocation results, conversely, show the opposite result in most of the cases.

The results, shown in table 5, reflect the policy trade-off the planners face: they can implement a tax to undo the financial friction, or instead, increase financial intermediation and production by subsidizing the banking sector. In general, we have that the planners want to implement a tax that will be higher for economies not engaging in cooperative arrangements.

Table 5: Ramsey-Optimal taxes under each policy setup

	Policy Scheme			
Country tool	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
τ^a	0.38	-0.11	0.15	0.30
τ^b	0.38	-0.11	0.15	0.34
τ^c	1.19	0.96	1.11	1.14

Units: proportional tax on banking rate of return

More specifically, we find that the uncooperative optimal policy by each planner consists on setting a tax on banking revenues. The tax rate imposed by the center will be about three times that of the emerging economies planners. We see a similar pattern in the remaining policy frameworks, i.e., a center policy tool implemented more aggressively than in other economies. Our interpretation is twofold: First, the peripheral planners attempt to undo the financial friction by taxing the credit spread directly while, second, the financial center policy maker that is not subject to frictions, will tax the banking sector with a different aim. Its objective is to lower the expected returns of a number of assets and the price of bonds, which in turn, will facilitate the flow of resources at the country level.

Hence, we believe the center tool is used to fight the second shortcomming of our setup, the financial under development in peripheries that prevent them from intermediating local deposits directly. This is done by facilitating risk sharing at the international level by trading financial assets.

In that spirit, when a single planner sets all the policy tools with the world welfare in mind (cooperation) we see that the tax imposed in the center country is not as large as when they do not cooperate. This reflects the that the cross-country welfare effects of the center tax are being accounted for by the world-wide cooperative policymaker. As for the peripheries, we have that the non-cooperative tax is the largest across policy setups. Additionally, the global cooperation setup is the only one in which a subsidy to the banking sector is implemented.

In this case, the same planner has control over every policy tool, and thus, can replicate the first best allocation by using a more conservative combination of taxes that still maintains similar relative differences between the tools levels as in the Nash case. In that way, the planner still has additional space to further encourage capital accumulation in the emerging economies by subsidizing the financial intermediation. Notice that, in this spirit, no other policy framework includes subsidies to the banking sector.

Another contrast between policies is that, in the three setups with cooperation, the members of cooperative coalitions will implement lower taxes with respect to the uncooperative case counterparts. This occurs even in this simple framework where there are no explicit policy costs or trade-offs from setting the taxes. Along that line, if we could consider that policy makers prefer to distort the economy at the lowest possible extent, we would have that a cooperative planner attempts to treat the friction in the most conservative way, i.e. with lower taxes or subsidies.

However, in the most basic version we do not have explicit costs from setting taxes at different levels, instead, the cooperative planner is internalizing the policy spillover that a larger tax (or subsidy) would have on the other members of the coalition. This is consistent with the analytic result we obtain in section 3 where there is a negative policy spillover of a marginal tax increase on the welfare of other countries.

5.2 Approaching the First Best

A natural question about the Ramsey policy equilibria is whether these schemes can succesfully undo the distortion created by the financial agency friction and deliver an allocation equivalent to the First Best, that is, the allocation obtained when there is no friction in place.

Table 6: Welfare comparison across policy schemes with respect to the First Best allocation

	Policy Scheme			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.01	1.01	1.01	1.01
A	0.99	0.99	0.99	0.99
B	0.99	0.99	0.99	0.99
World	1.00	1.00	1.00	1.00
EME Block	0.99	0.99	0.99	0.99

Units: Proportional steady state consumption increase in the baseline (First Best) model

Table 6 shows a welfare comparison of the policy setups with the first best allocation. We can see that every policy framework mimics the first best, delivering the same welfare outcome at the world level. This implies the policy tool is flexible and effective enough that can be set by each type of policy planners at levels that allows them to mimic the best possible allocation. Nevertheless, there are still small asymmetric welfare differences in the resulting equilibria that affects the welfare distribution among countries in detriment of the emerging countries but in favor of the center economy. The latter suggests it would not be possible to implement a Pareto improvement on the Ramsey outcomes via transfers, as long as we assume no feasible equilibrium could Pareto dominate the first best.

This result is relevant for understanding why there are no apparent gains from coordination. In a nutshell, each combination of policy makers, cooperative or not, can approach the best possible allocations of the model with different combinations of the policy tools.

This is consistent with Korinek (2020) stance about the gains from international macroprudential coordination. Namely, that for these gains to be present the Nash equilibrium must be Pareto inefficient. That is, even with strong international spillovers the non-cooperative equilibrium can have no scope for cooperation. In such case, we say the spillovers and externalities (e.g. pecuniary) are efficient.

We will discuss this result in more detail when proposing what features we would need to modify in our baseline model for obtaining such cooperation gains.

5.3 Gains with respect to a No Policy setup

With these mixed results, on one side indicating that the policy frameworks are equivalent from a welfare perspective and on the other that they mimic the first best allocation, it is unavoidable to inquire about whether the macroprudential tools are worth implementing to begin with. That is, is there even a gain at all from an active policy setting?. To answer that, we compare the model without any policy in place against the rest of setups. The results are shown in table 7.

Table 7: Welfare comparison across policy schemes with respect to the No Taxes allocation

	Policy Scheme				
Country	First Best	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.05	1.06	1.06	1.06	1.06
A	1.03	1.02	1.03	1.02	1.02
B	1.03	1.02	1.03	1.02	1.02
World	1.04	1.04	1.04	1.04	1.04
EME Block	1.03	1.02	1.03	1.02	1.02

Units: Proportional steady state consumption increase in the baseline (No Policy) model

Every Ramsey policy implies a substantial welfare improvement for every country with respect to the no policy equilibrium. The welfare loss of not setting any policy in presence of the financial frictions amounts approximately to a 4% consumption decrease at the world level, or more accurately, switching from a non existent policy making to any active (cooperative or not) optimal policy setup would be equivalent to a compensatory increase in steady state consumption of 4%. This welfare improvement is distributed asymmetrically across countries with the center absorbing thrice the improvement of the least favored economies that still would receive a welfare increase equivalent to a 2%

change in consumption.

We then have, in light of these results, that setting actively these taxes would certainly be welfare improving.

6 Achieving Gains from Coordination

In the previous sections, we found that the baseline model, does not yield gains from policy coordination at any level (global or regional). We verified there are policy spillovers between the economies and that an active policy setting allows the planners to approach the best possible results, i.e., to undo the effect of the financial agency friction.

The equivalence, from a welfare perspective, between the outcome of policies designed while internalizing international spillovers and one abstracting from such effects is certainly puzzling. To understand it we can refer to Korinek (2020), who develops a first welfare theorem for open economies. In a nutshell, the premise from which a call for policy coordination departs is that the de-centralized equilibrium is inefficent and could be subject to Pareto improvements if coordinated. However, there is a number of sufficient conditions that allow the non-cooperative outcome to become efficient:

1. *Competition:* The policy makers act as price takers by not exerting market power over international assets prices.
2. *Sufficient Instruments:* The policy is flexible and effective enough to achieve the targeted level in the international variables of interest.
3. *Frictionless International Markets:* The international market for assets is free of imperfections or frictions that would impair risk sharing.

Notice that no other conditions are necessary, that is, there can be a number of domestic frictions in place and the non-cooperative outcome will still be efficient and coordination would be redundant.

The lesson from this theorem is that as long as the flow of resources in the international markets is efficient and we have an effective toolkit (and enough tools) to set external allocations at desired levels, any policy, even de-centralized, can achieve the first best and the international externalities represent only efficient spillovers.

We can verify that these three conditions hold in our baseline model: Our setup is competitive given it abstracts from nominal rigidities and market power features. At the same time, each economy has access to a tool and, most importantly, policy making is not explicitely costly. The latter point is very important, since it is the usual motivation behind coordination policies, namely, there could be gains from (i) Sharing the regulatory burden or cost, and (ii) Avoiding wasteful competivite intervention. It turns out that there is not an actual burden to bear in our framework and hence wasteful intervention is not really detrimental.

Finally, the international markets of our framework are frictionless. The flow of bonds allow countries to allocate resources in the center as if they could deposit in their own market, this means that the savings of private agents are not hampered in any way, despite the financial underdevelopment. Simultaneously, the financial center, is completely frictionless, and in equilibrium will serve as the basis for setting the interest rates and prices of assets for the international markets.

Another way to state this is that our framework has two potential sources of distortions, agency frictions in the emerging countries and, as an additional drawback, lack of intermediation by banks in peripheries. But we count with three policy tools that we can change at no cost as well as an international financial assets structure that is flexible. Hence we have the conditions to allow each combination of planners to achieve efficiency.

With this in mind, in the following subsections we modify our framework in a number of directions. First, we allow the center economy to be subject to a financial agency friction in the lending relationship between depositors and banks. Second, we explore the addition of costs of policy making.

6.1 Financial Frictions in the Center

To explore the case when the whole world is subject to frictions, we consider a different version of the model with financial distortions in the center. In this case the center bank solves the following problem:

$$
\begin{aligned}
\max_{F_1, L_1, D_1} J_1 = \mathbb{E}_1 \Lambda_{1,2} \pi^c_{b,2} = \mathbb{E}_1 & \left[\Lambda_{1,2} (R^a_{b,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} L^c_1 - R_{D,1} D_1) \right] \\
s.t. \quad & F^a_1 + F^b_1 + L^c_1 = D_1 + \delta_b Q^c_1 K^c_0 \\
& J_1 \geq k^c \mathbb{E}_1 \Lambda^c_{1,2} \left[R^a_{a,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} L^c_1 \right]
\end{aligned}
$$

with associated F.O.C.,

$$
\begin{aligned}
[F^a_1]: \qquad & \mathbb{E}_1 (R^a_{b,1} - R_{D,1}) = \mu^c_1 \left[\kappa^c R^a_{b,1} - (R^a_{b,1} - R_{D,1}) \right] \\
[F^b_1]: \qquad & \mathbb{E}_1 (R^b_{b,1} - R_{D,1}) = \mu^c_1 \left[\kappa^c R^b_{b,1} - (R^b_{b,1} - R_{D,1}) \right]
\end{aligned}
$$

$$[L_1^c]: \qquad \mathbb{E}_1(R_{k,2}^c - R_{D,1}) = \mu_1^c \left[\kappa^c R_{k,2}^c - (R_{k,2}^c - R_{D,1})\right]$$

As a result, we no longer have that most interest rates in the model are equalized to R_1 (the world interest rate of bonds), but that the intermediation rates of the center ($R_{k,2}^c,\ R_{b,1}^a,\ R_{b,1}^b$) will also be subject to a premium and a positive credit spread. Finally, we will have a binding ICC for the center. These modifications imply a model with four more equations and variables.

The simulation results are shown in the appendix C. In this version of the model we still obtain no gains from coordination and that the First Best allocation is achieved at the world level. However, a new result we get lower gains with respect to the no policy case and that the peripheries will apply subsidies in all cases.

The intuition for these new finding is that the friction in the center will work in the opposite direction on the credit spreads for the peripheries. That is, a premium in the center lending rates as shown in the F.O.C. above will decrease the credit spreads in the EMEs. We could say that the frictions between lenders and borrowers are partially offsetting each other, the aggregate effects of the distortions are weaker and the peripheries would opt for subsidizing the banking intermediation rather than undoing the friction.

6.2 Policy costs of macroprudential intervention

To account for the case where the policy tool cannot be set up flexibly we also consider the case when there is an explicit cost of regulation. We solve the modified Ramsey problems where we include a convex cost of policy implementation. The objective function of the planner will now be given for:

$$\begin{aligned} \max_{\mathbf{x_t}, \tilde{\tau}_t} \quad & W_t^{objective} = f(\alpha^j, W_t^j) - \Gamma(\tau^j) \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \end{aligned}$$

with $\tilde{\tau} \subseteq \tau$ and welfare weights $\alpha^j \geq 0 \quad \forall j$.

$f(\alpha^j, W_t^j)$ corresponds to the same objective functions considered in section 4 and $\Gamma(\tau^j) = \psi(\tau^j)^2$ denotes a quadratic policy implementation cost. We solved the model with several levels of ψ and report the results for the value of the parameter that generates different qualitative results with respect to the baseline ($\psi = 1$).

The results are reported in the table C5 and C6 in the appendix C. We obtain that there are significant gains from coordination for every country and at the world level. Additionally, the high cost of policy implementation leads the countries to set their tools much more conservatively compared to the baseline. Finally, every cooperative setup matches the first best.

7 Additional exercises

In this section we explore whether some changes in the parameters structure of the model are relevant for shaping the welfare outcomes across policy setups. We consider changes ranging from deepening the effect of the financial agency distortions, to increase the asymmetry between center and peripheral countries, among others.

7.1 The degree of the agency distortion

First, we consider how the incentives of cooperation change when interacting with economies that count with a worse extent of agency problems, or in the context of this study with a larger divertable portion of the intermediated assets by the banks (κ).

The gains from coordination after increasing the degree of the financial distortion is shown in appendix C, in table C7. Initially, we consider an increment of 20% in the abscondable portion of the intermediated assets. This implies that the banks can now divert 50% of the assets. In that case, there are still no gains from any type of cooperation and the first best is still achieved by every policy setup. As expected, we have a larger welfare gain with respect to the no policy allocation, reflecting the fact that the distortion is stronger in general. As a result, we have the same qualitative results that are achieved with stronger policy stances, i.e., larger taxes or subsidies with respect to each policy in the baseline case.

Then, we consider models in which one of the peripheries suffers from a stronger distortion, that is, $\boldsymbol{\kappa} = \{\kappa^a, \kappa^b\} = \{0.399, 1/2\}$ or $\boldsymbol{\kappa} = \{1/2, 0.399\}$. The results are shown in table C9. We find there are small gains from worldwide cooperation and also that the planners can match the first best.

In terms of the policy stance we find that planners will set the tool for the country with the larger distortion as a subsidy, or a lower tax in one of the cooperative cases, while the center will set a stronger tax in all cases compared to the baseline. This is consistent with the results from section 3 where the welfare effects increase in κ. With stronger effects, the peripheral planner can set its tool more conservatively and obtain the same intended effects.

7.2 Different economies sizes

Secondly, we study whether different relative population sizes of the economies play a role in shaping the gains from cooperation. The results are shown in table C11.

In a first exercise, we consider whether having a larger center can change the baseline results, which also implies smaller countries subject to agency frictions and hence, that the presence of distortions in the world economy is less prevalent. For that, we change the vector of sizes from $\mathbf{n} = \{n_a, n_b, n_c\} = \{1/4, 1/4, 1/2\}$ to $\mathbf{n} = \{1/6, 1/6, 2/3\}$. The simulation results show that with a larger center size there will be a generalized welfare increase in every economy. This result is straightforward as the center departs from a higher initial pre-existing capital level. As in the baseline model there are no significant gains from cooperation. On the other hand, a new result is that the planners are no longer able to match the first best allocation, possibly because with a smaller country size the global effect of the taxes in the emerging countries will not be as relevant and effective as in the baseline. Moreover, the policy framework with the smallest departure from the first best is the one with worldwide cooperation.

When we consider only a smaller periphery, i.e., $\mathbf{n} = \{1/3, 1/6, 1/2\}$ we find that there are small gains from cooperation, in every cooperative framework for the smaller periphery and for both peripheries in the semi-cooperative framework where these two countries form a coalition. Consistently with this result, cooperative planners are able to match the first best allocation although the Nash equilibrium does not depart by much.

However, the size of the gains at the world level is small and could not be subject to redistributions leading to Pareto improving outcomes so as to enforce cooperation for all planners.

Finally, in terms of the tools, in every setup we notice that the optimal policy for the tool of the now smallest economy usually implies a subsidization to the banking sector, meaning that boosting the financial intermediation will become a priority and will precede the correction of the financial friction.

7.3 Aggresive subsidization

Finally, an experiment, we allowed the economies to apply very large subsidies (or taxes), even beyond what could be considered feasible. The results as shown in table C15 indicate that there are some semi-cooperative solutions to the Ramsey policy problems that can outperform the first best (making a stronger case for unfeasibility than merely the tools levels) and that would imply gains from cooperation, although the model with more potential for gains still display welfare losses for the country outside of the cooperative coalition. Nonetheless, as we hinted before, the policy tools levels that would make this possible imply subsidies that are prohibitively large (see table C16).

8 Value added from considering a second periphery

Some of the exercises carried in the previous sections explore the possibility of having asymmetric peripheries for delivering different equilibrium outcomes relative to the baseline model. Such exercises are only possible if we account for a three-country structure. In light of the results, here we comment how such multicountry structure is meaningful for allowing us to obtain results both in terms of the equilibrium solution and consequences of cooperation that would be omitted in simpler versions of the model.

Most of the results reported are given in a deterministic environment where idiosyncratic shocks are absent and do not play a role. In that environment, the third country will essentially be a replicate of the other EME in the baseline parametrization of the model and its inclusion represents only a scale effect where the features of the peripheral block would now describe a half of the world population. This is also seen in versions of the model with symmetric changes in the EMEs where the results are equivalent to two country model with a larger periphery.

For example, in one of the exercises where we decrease the relative size of the periphery block to a third of the population we obtain that the EMEs will be worse off by forming a coalition and that the first best is no longer achievable.

However, if we consider versions of the model where the second periphery is not a replicate of the first one, we obtain results that differ qualitatively from the baseline model. When we include a smaller second periphery (population size $1/6$) we find cooperation gains from any cooperative setup for the new country and gains for both EMEs in the case they cooperate regionally. Additionally, when we include a periphery with a stronger financial friction the first periphery benefits from any cooperation setup (table C9), while the second one would be better off only when worldwide cooperation is implemented. Only in the latter case we get a larger non-trivial welfare gain at the world level.

It is also important to remark how, by having a framework where the inclusion of an asymmetric second periphery leads to different resutls, we would have that when performing an stochastic analysis, the inclusion of the third country becomes meaningful, even if this one is identical to the other EME (unless we consider a special case when the shock faced by both EMEs is identical).

In this spirit, the stochastic component is abstracted for now in the most basic version of the model but remains one of the features we intend to explore in future research.

9 Conclusions

In this document we studied whether there are gains from international coordination of macroprudential policies, specifically aimed to the banking sector, in an environment with financial integration of emerging economies and a center. More specifically, we attempt to answer whether emerging countries are able to engage in cooperative arrangements that will improve the equilibrlium outcome imposed by bilateral banking relationships with a center in the presence of financial agency frictions.

To approach this question we set a three-country center-periphery model, with two emerging economies and one center. We add an additional emerging market to enhance the interaction leverage of the peripheral block, as well as to analyze policy interactions between emerging markets at the regional level, a feature not yet explored in the literature.

The baseline results show that the cooperative and semi-cooperative arrangements do not deliver sizable coordination gains and that the small gains found are usually concentrated on the participating parties in the cooperative arrangement.

With respect to the optimal taxes we find that in general, the optimal action is to tax the banking sector in order to decrease the credit spread created by the friction, that is, the policy makers attempt to undo the financial friction in place, rather than facilitating the intermediation made by the financial sector. Another result is that, for all policy setups, the center planner would choose to implement larger taxes, possibly because the center country banks, in their role as global lenders, are the most affected by the friction-augmented credit spread at the interbank level.

To explore this result, we analize a version of the model where every country is subject to the financial friction and where the policy instruments are not perfect because they are subject to implementation costs. The results with global frictions (agency costs in every country) are qualitatively equivalent to the baseline model. However, when we consider explicit implementation costs of policy making or restrictions to the usage of the taxes we find gains from cooperation in most cases. In these cases we are either increasing the burden of regulation, or decreasing the effectiveness of the tools. Either option limits the ability of regulators to hit their targets.

In additional exercises we explore departures from our baseline assumptions to assess the relative importance of our model's ingredients. For this end, we change the relative sizes of the peripheries and degree of financial frictions. The results are similar if both peripheries are changed symmetrically, but there are qualitative changes when we impose asymmetric features between the peripheries.

The baseline results, do not depart by much from the findings of studies that abstract from banks or use other policy tools. However, this remarks a contribution of this study: the consideration of the role of an second periphery in the world economy, with different features than the incumbent one. This feature generates different results with respect to the baseline Nash or global cooperation, as opposed to the case when the third country is a replicate of the other periphery.

For future research it is important to study whether features such as the timing of the policies, either prudential or as crisis management tools, can make any difference in creating incentives for coordination. Finally, the interaction with other frictions, such as the created by nominal rigidities, at the banking or final goods level can be relevant. The first one for augmenting the cycle-amplification effects of financial distortions (see Mandelman (2010) and Fujiwara and Teranishi (2017)) and the second one for generating a scope for gains from coordination with other policies (e.g. monetary as in De Paoli and Paustian (2017)) and instruments.

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A Analytic welfare effects derivations

This section explain the derivations of the expressions shown in the section 3.

We differentiate the welfare expression for the EME-A social planner:

$$\frac{dW^a}{d\tau^a} = \lambda_1^a \left[\frac{dQ_1^a}{dI_1^a} I_1^a + Q_1^a - C'(I_1^a) \right] \frac{dI_1^a}{d\tau^a} + \frac{\lambda_1^a}{R_1} \frac{B_1^a}{R_1} \frac{dR_1}{d\tau^a} \\ + \beta \lambda_2^a \left(\phi(\tau^a) \alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1} + \kappa^a (1-\delta) \xi_2^a Q_2 \right) \frac{dK_1^a}{d\tau^a} + \beta \lambda_2^a \alpha (1-\kappa^a) A_2^a (\xi_2^a K_1^a)^\alpha$$

To obtain the direct welfare effect of the tax we substitute the equilibrium expression for the price of capital for the competitive investor ($Q_1^a = C'(I_1^a)$) and the Euler equation for the consumer ($\lambda_1 = \beta R_1 \lambda_2$). After rearranging we obtain the expression shown in the main section:

$$\frac{dW^a}{d\tau^a} = \lambda_1^a I_1^a \frac{dQ_1^a}{d\tau^a} + \beta \lambda_2^a \frac{B_1^a}{R_1} \frac{dR_1}{d\tau^a} + \beta \lambda_2^a \left(\phi(\tau^a) \alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1} + \kappa^a (1-\delta) \xi_2^a Q_2^a \right) \frac{dK_1^a}{d\tau^a} \\ + \beta \lambda_2^a \alpha (1-\kappa^a) A_2^a (\xi_2^a K_1^a)^\alpha$$

The derivation of $\frac{dW^b}{d\tau^b}$ is analogous.

For $\frac{dW^c}{d\tau^c}$ we make the same substitutions for the first two terms and obtain,

$$\frac{dW^c}{d\tau^c} = \lambda_1^c \frac{dQ_1^c}{d\tau^c} I_1^c + \beta \lambda_2^c \frac{B_1^c}{R_1} \frac{dR_1}{d\tau^c} + \beta \lambda_2^c \left(\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta) \xi_2^c Q_2 \right) \frac{dK_1^c}{d\tau^c} \\ + \beta \lambda_2^c \left(R_{b,1}^a \frac{dF_1^a}{d\tau^c} + F_1^a \frac{dR_{b,1}^a}{d\tau^c} + R_{b,1}^b \frac{dF_1^b}{d\tau^c} + F_1^b \frac{dR_{b,1}^b}{d\tau^c} \right)$$

In the last term we use the private equilibrium result: $R_b^a = R_b^b = R_b^{eme}$

$$\frac{dW^c}{d\tau^c} = \lambda_1^c I_1^c \frac{dQ_1^c}{d\tau^c} + \beta \lambda_2^c \frac{B_1^c}{R_1} \frac{dR_1}{d\tau^c} + \beta \lambda_2^c \left(\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta) \xi_2^c Q_2 \right) \frac{dK_1^c}{d\tau^c} \\ + \beta \lambda_2 \left[R_{b,1}^{eme} \left(\frac{dF_1^a}{d\tau^c} + \frac{dF_1^b}{d\tau^c} \right) + \frac{dR_{b,1}^{eme}}{d\tau^c} \left(F_1^a + F_1^b \right) \right]$$

For the cross country effects we follow the same procedure. Notice that the last term of the EME effects will be absent since there is not any direct tax welfare effect at the international level.

To obtain the optimal taxes we set $\frac{dW^a}{d\tau^a} = 0$ and solve for $\phi(\tau^a)$:

$$\phi(\tau^a) = -\frac{1}{\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1}} \left[R_1 I_1^a \frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a} + \kappa^a (1-\delta)\xi_2^a Q_2 \right]$$

Where we made the assumption that $\frac{d\tau^a}{dK_1^a} = 0$. Assuming taxes exogeneity works here because these calculations based on the private equilibrium and not on the Ramsey planner equilibrium where the taxes are endogenous.

Now we substitute, $\phi(\tau^a) = 1 + (\kappa^a - 1)(1-\tau^a)\alpha$ and solve for τ^a:

$$\tau^{a\ *} = -\frac{1}{\alpha(1-\kappa^a)} \left\{ \frac{1}{\alpha A_2^a \xi_2^{a\ \alpha} K_1^{a\ \alpha-1}} \left[\left(R_1 I_1^a \frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a} \right) + \kappa^a (1-\delta)\xi_2^a Q_2 \right] + 1 + \alpha(\kappa^a - 1) \right\}$$

The result for b is analogous.

For c, τ^c will not show up in this case because there are not direct taxes welfare effects terms for the center. We work around it by using the equilibrium outcome $R_{b,1}^{eme} = R_{k,2}^c(\tau^c)$. Then we set $\frac{dW^c}{d\tau^c} = 0$ and solve for $R_{k,2}^c$:

$$-R_{k,2}^c = R_1 I_1 \frac{dQ_1^c}{dF_1^S} + \frac{B_1^c}{R_1}\frac{dR_1}{dF_1^S} + (\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2)\frac{dK_1^c}{dF_1^S} + (F_1^a + F_1^b)\frac{dR_{b,1}^{eme}}{dF_1^S}$$

We substitute $R_{k,2}^c = [(1-\tau^c)\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2]/Q_1^c$ and solve for τ^c:

$$\tau^{c\ *} = \frac{Q_1^c}{\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1}} \left\{ R_1 I_1^c \frac{dQ_1^c}{dF_1^S} + \frac{B_1^c}{R_1}\frac{dR_1}{dF_1^S} + (\alpha A_2^c \xi_2^{c\ \alpha} K_1^{c\ \alpha-1} + (1-\delta)\xi_2^c Q_2)\frac{dK_1^c}{dF_1^S} \right.$$
$$\left. + (F_1^a + F_1^b)\frac{dR_{b,1}^{eme}}{dF_1^S} + (1-\delta)\xi_2^c \frac{Q_2}{Q_1^c} \right\} + 1$$

with $dF_1^S = dF_1^a + dF_1^b$

B Parameters and other model simulation results

B.1 Parameters of the model

The table contains the parameter used in the baseline model.

Parameter		Value	Comment/Source
Adjustment costs of investment	ζ	4.65	Cespedes, Chang and Velasco (2017)
Start-up transfer rate to banks	δ_b	0.005	Gertler and Karadi (2011), Gertler and Kiyotaki (2010)
Divertable fraction of capital	$\kappa^a = \kappa^b$	0.399	Aoki, Benigno and Kiyotaki (2018)
Discount factor	β	0.99	Standard
Risk Aversion parameter	σ	2	Standard
Country size	$n_a = n_b$	0.25	
Depreciation rate	δ	0.6	Targets a longer period duration than quarterly
Capital share	α	0.333	Standard

Table B1: Parameters in the model

B.2 Welfare effects with complete depreciation

Table B2: Effects in welfare of 1% increase in taxes

		Shock and recipient country							
	No Shocks	Productivity (+)			Capital Quality (-)			Financial (+)	
		a	b	c	a	b	c	a	b
Direct Effects									
$\tau_a \to W^a$	-1.843	-1.768	-1.834	-1.825	-1.838	-1.841	-1.839	-1.848	-1.845
$\tau_b \to W^b$	-1.843	-1.834	-1.768	-1.825	-1.841	-1.838	-1.839	-1.845	-1.848
$\tau_c \to W^c$	-1.064	-1.056	-1.056	-1.007	-1.062	-1.062	-1.046	-1.065	-1.065
Cross-country									
$\tau_a \to W^b$	-0.044	-0.056	-0.022	-0.050	-0.047	-0.044	-0.046	-0.040	-0.043
$\tau_a \to W^c$	-0.014	-0.022	-0.018	-0.002	-0.016	-0.015	-0.011	-0.012	-0.013
$\tau_b \to W^a$	-0.044	-0.022	-0.056	-0.050	-0.044	-0.047	-0.046	-0.043	-0.040
$\tau_b \to W^c$	-0.014	-0.018	-0.022	-0.002	-0.015	-0.016	-0.011	-0.013	-0.012
$\tau_c \to W^a$	-0.072	-0.037	-0.078	-0.097	-0.072	-0.073	-0.078	-0.071	-0.070
$\tau_c \to W^b$	-0.072	-0.078	-0.037	-0.097	-0.073	-0.072	-0.078	-0.070	-0.071

C Ramsey Policy Equilibria results

In this section we report the simulation results for alternative versions of the model.

Table C3: Welfare comparison for model with frictions in every economy ($\kappa^a = \kappa^b = 0.399$ and $\kappa^c = 0.1$)

	Bechmark: Nash			Bechmark: First Best			
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.00	1.00	1.00	1.03	1.04	1.03	1.03
A	1.00	1.00	1.00	0.97	0.98	0.98	0.97
B	1.00	1.00	1.00	0.97	0.98	0.98	0.98
World	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EME Block	1.00	1.00	1.00	0.97	0.98	0.98	0.98

Units: Proportional steady state consumption increase in the benchmark model

Table C4: Ramsey-Optimal taxes for the model with frictions in every economy ($\kappa^a = \kappa^b = 0.399$ and $\kappa^c = 0.1$)

	Policy Scheme			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
τ^a	-0.11	-0.68	-0.19	-0.47
τ^b	-0.11	-0.68	-0.19	-0.22
τ^c	0.68	0.34	0.65	0.55

Units: proportional tax on banking rate of return

Table C5: Welfare comparison for model with frictions in every economy ($\kappa^a = \kappa^b = 0.399$ and $\kappa^c = 0.1$) and policy implementation costs $\psi = 1$

	Bechmark: Nash			Bechmark: First Best			
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.02	1.02	1.02	1.00	1.02	1.02	1.02
A	1.01	1.01	1.01	0.97	0.98	0.98	0.98
B	1.01	1.01	1.01	0.97	0.98	0.98	0.98
World	1.01	1.01	1.01	0.99	1.00	1.00	1.00
EME Block	1.01	1.01	1.01	0.97	0.98	0.98	0.98

Units: Proportional steady state consumption increase in the benchmark model

Table C6: Ramsey-Optimal taxes for the model with frictions in every economy ($\kappa^a = \kappa^b = 0.399$ and $\kappa^c = 0.1$) and policy implementation costs $\psi = 1$

Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
	Policy Scheme			
τ^a	0.20	-0.30	-0.04	0.15
τ^b	0.20	-0.30	-0.04	0.16
τ^c	1.29	1.09	1.23	1.25

Units: proportional tax on banking rate of return

Table C7: Welfare comparison for model with higher financial friction in both emerging economies ($\kappa^a = \kappa^b = \frac{1}{2}$)

	Bechmark: Nash			Bechmark: First Best			
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.00	1.00	1.00	1.01	1.01	1.01	1.01
A	1.00	1.00	1.00	0.99	0.99	0.99	0.99
B	1.00	1.00	1.00	0.99	0.99	0.99	0.99
World	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EME Block	1.00	1.00	1.00	0.99	0.99	0.99	0.99

Units: Proportional steady state consumption increase in the benchmark model

Table C8: Ramsey-Optimal taxes for the model with higher financial friction in both emerging economies ($\kappa^a = \kappa^b = \frac{1}{2}$)

Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
	Policy Scheme			
τ^a	0.20	-0.30	-0.04	0.15
τ^b	0.20	-0.30	-0.04	0.16
τ^c	1.29	1.09	1.23	1.25

Units: proportional tax on banking rate of return

Table C9: Welfare comparison for model with higher financial friction in one emerging economy ($\kappa^a = \frac{1}{2}$, $\kappa^b = 0.399$)

	Bechmark: Nash				Bechmark: First Best				
Country	Coop. (All)	Coop. (EMEs)	Coop. (C + EME-A)	Coop. (C + EME-B)	Nash	Coop. (All)	Coop. (EMEs)	Coop. (C + EME-A)	Coop. (C + EME-B)
C (Center)	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01
A	1.01	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99
B	1.01	1.01	1.01	1.01	0.98	0.99	0.99	0.99	0.99
World	1.01	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
EME Block	1.01	1.01	1.01	1.01	0.98	0.99	0.99	0.99	0.99

Units: Proportional steady state consumption increase in the benchmark model

Table C10: Ramsey-Optimal taxes for for model with higher financial friction in one emerging economy ($\kappa^a = \frac{1}{2}$, $\kappa^b = 0.399$)

	Policy Scheme				
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Cooperation (Center and EME-B)
τ^a	-0.05	-0.28	-0.08	0.08	0.11
τ^b	0.09	-0.12	0.18	0.40	0.37
τ^c	1.19	1.03	1.17	1.20	1.20

Units: proportional tax on banking rate of return

Table C11: Welfare comparison for model with larger financial center. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$.

	Bechmark: Nash			Bechmark: First Best			
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.00	1.00	1.00	0.98	0.98	0.98	0.98
A	1.00	0.99	1.00	0.99	1.00	0.99	1.00
B	1.00	0.99	1.01	0.99	1.00	0.99	1.00
World	1.00	1.00	1.00	0.98	0.99	0.98	0.99
EME Block	1.00	0.99	1.01	0.99	1.00	0.99	1.00

Units: Proportional steady state consumption increase in the benchmark model

Table C12: Ramsey-Optimal taxes for the model larger financial center. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$.

	Policy Scheme			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
τ^a	-0.71	-0.90	-0.44	-1.14
τ^b	-0.71	-0.91	-0.44	-0.92
τ^c	0.09	-0.05	0.30	-0.11

Units: proportional tax on banking rate of return

Table C13: Welfare comparison for model with smaller periphery. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{3}, \frac{1}{6}, \frac{1}{2})$.

	Bechmark: Nash				Bechmark: First Best				
Country	Coop. (All)	Coop. (EMEs)	Coop. (C + EME-A)	Coop. (C + EME-B)	Nash	Coop. (All)	Coop. (EMEs)	Coop. (C + EME-A)	Coop. (C + EME-B)
C (Center)	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01
A	1.00	1.01	1.00	1.00	0.99	0.99	1.00	0.99	0.99
B	1.01	1.01	1.01	1.01	0.97	0.99	0.99	0.99	0.99
World	1.00	1.01	1.00	1.00	0.99	1.00	1.00	1.00	1.00
EME Block	1.01	1.01	1.00	1.00	0.98	0.99	0.99	0.99	0.99

Units: Proportional steady state consumption increase in the benchmark model

Table C14: Ramsey-Optimal taxes for model with smaller periphery. $(n_a, n_b, n_c) = (\frac{1}{3}, \frac{1}{6}, \frac{1}{2})$.

	Policy Scheme				
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Cooperation (Center and EME-B)
τ^a	0.30	0.25	0.13	0.32	0.35
τ^b	-0.16	0.11	-0.67	0.33	0.27
τ^c	1.12	1.06	0.97	1.14	1.15

Units: proportional tax on banking rate of return

Table C15: Welfare comparison for model with unfeasibly aggresive subsidization

Country	Bechmark: Nash Cooperation (EMEs)	 Cooperation (Center and EME-A)	Bechmark: First Best Cooperation (EMEs)	 Cooperation (Center and EME-A)
C (Center)	1.03	1.04	1.03	1.05
A	1.00	1.10	0.99	1.08
B	1.00	0.99	0.99	0.98
World	1.01	1.04	1.01	1.04
EME Block	1.00	1.04	0.99	1.03

Units: Proportional steady state consumption increase in the benchmark model

Table C16: Ramsey-Optimal taxes for model with unfeasibly aggresive subsidization

Country	Policy Scheme Cooperation (EMEs)	 Cooperation (Center and EME-A)
τ^a	-0.75	-1.66
τ^b	-8.21	-2.37
τ^c	-8.21	-15.09

Units: proportional tax on banking rate of return

D Solution of the Model

Original System (follows the numbering in the body of the paper):

$$Q_1 = 1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2 + \zeta\left(\frac{I_1}{\bar{I}} - 1\right)\frac{I_1}{\bar{I}} \tag{(1)-(3)}$$

$$Q_2 = 1 + \frac{\zeta}{2} \tag{(4)-(6)}$$

$$K_1 = I_1 + (1-\delta)\xi_1 K_0 \tag{(7)-(9)}$$

$$Y_1 = A_1(\xi_1 K_0)^\alpha \tag{(10)-(12)}$$

$$Y_2 = A_2(\xi_2 K_1)^\alpha \tag{(13)-(15)}$$

$$r_t = \alpha A_t \xi_t^\alpha K_{t-1}^{\alpha-1}, \quad t = \{1, 2\} \tag{(16)-(21)}$$

$$R_{k,2} = \frac{r_2 + (1-\delta)\xi_2 Q_2}{Q_1} \tag{(22)-(24)}$$

$$Q_1 K_1 = F_1 + \delta_b Q_1 K_0 \tag{(25)-(26)}$$

$$\pi_{b,2} \geq kR_{k,2}Q_1K_1 \tag{27-28}$$

$$(R_{k,2} - R_{b,1}) = \mu\left(\kappa R_{k,2} - (R_{k,2} - R_{b,1})\right) \tag{29-30}$$

$$F_1^a + F_1^b + Q_1^c K_1^c = D_1 + \delta_b Q_1^c K_0^c \tag{31}$$

$$R_{b,1}^a - R_{D,1} = 0 \tag{32}$$

$$R_{b,1}^b - R_{D,1} = 0 \tag{33}$$

$$R_{k,2}^c - R_{D,1} = 0 \tag{34}$$

$$C_1^s + \frac{B_1^s}{R_1^s} = r_1^s K_0^s + \pi_{f,1}^s + \pi_{inv,1}^s - \delta_b Q_1^s K_0^s \tag{35-36}$$

$$C_2^s = \pi_{f,2}^s + \pi_{b,2}^s + B_1^s - T^s, \quad for\ s = \{a, b\} \tag{37-38}$$

$$C_1^c + \frac{B_1^c}{R_1^c} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_b Q_1^c K_0^c \tag{39}$$

$$C_2^c = \pi_{f,2}^c + \pi_{b,2}^c + B_1^c + R_{D,1}D_1 - T^c \tag{40}$$

$$u'(C_1) = \beta R_1 u'(C_2) \tag{41-43}$$

$$u'(C_1^c) = \beta R_{D,1} u'(C_2^c) \tag{44}$$

$$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0 \tag{45}$$

$$R_1^a = R_1^b \tag{46}$$

$$R_1^c = R_1^b = R_1 \tag{47}$$

We replace the following profits:

$$\pi_{f,t} = A_t(\xi_t K_{t-1})^\alpha - r_t K_{t-1}, \quad for\ t = \{1, 2\}$$
$$\pi_{inv,1} = Q_1 I_1 - I_1\left(1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2\right)$$
$$\pi_{b,2}^s = R_{k,2}^s Q_1^s K_1^s - R_{b,1}^s F_1^s, \quad for\ s = \{i, e\}$$
$$\pi_{b,2}^c = R_{b,1}^a F_1^a + R_{b,1}^b F_1^b + R_{k,2}^c Q_1^c K_1^c - R_{D,1} D_1$$

Simplifications (reduction of number of equations) are applied in the following order:

- *S1:* Replace all related interest rates (we can drop $R_{b,1}^a, R_{b,1}^b, R^i, R^e, R^c$)

- *S2:* Remove already solved equations (function of parameters or pre-defined variables, hence we drop $Q2, Y_1$). Replace $Y_2,\ r_1,\ r_2$, $F_1^s = Q_1^s K_1^s - \delta_b Q_1^s K_0^s$. From (41) and (42) obtain $R_1 = R_{D,1}$ and replace.

- *S3:* Substitute $R_{k,2}^c = R_1$, $-T = \tau r_2 K_1$

Then, the final system of equations used for solving the model is:

$$Q_1^a = 1 + \frac{\zeta}{2}\left(\frac{I_1^a}{\bar{I}^a} - 1\right)^2 + \zeta\left(\frac{I_1^a}{\bar{I}^a} - 1\right)\frac{I_1^a}{\bar{I}^a} \tag{1}$$

$$Q_1^b = 1 + \frac{\zeta}{2}\left(\frac{I_1^b}{\bar{I}^b} - 1\right)^2 + \zeta\left(\frac{I_1^b}{\bar{I}^b} - 1\right)\frac{I_1^b}{\bar{I}^b} \tag{2}$$

$$Q_1^c = 1 + \frac{\zeta}{2}\left(\frac{I_1^c}{\bar{I}^c} - 1\right)^2 + \zeta\left(\frac{I_1^c}{\bar{I}^c} - 1\right)\frac{I_1^c}{\bar{I}^c} \tag{3}$$

$$K_1^a = I_1^a + (1-\delta)\xi_1^a K_0^a \tag{4}$$

$$K_1^b = I_1^b + (1-\delta)\xi_1^b K_0^b \tag{5}$$

$$K_1^c = I_1^c + (1-\delta)\xi_1^c K_0^c \tag{6}$$

$$R_{k,2}^a = \tfrac{(1-\tau^a)\alpha A_2^a \xi_2^a{}^{\alpha} K_1^a{}^{\alpha-1} + (1-\delta)\xi_2^a Q_2}{Q_1^a} \tag{7}$$

$$R_{k,2}^b = \tfrac{(1-\tau^b)\alpha A_2^b \xi_2^b{}^{\alpha} K_1^b{}^{\alpha-1} + (1-\delta)\xi_2^b Q_2}{Q_1^b} \tag{8}$$

$$R_1 = \tfrac{(1-\tau^c)\alpha A_2^c \xi_2^c{}^{\alpha} K_1^c{}^{\alpha-1} + (1-\delta)\xi_2^c Q_2}{Q_1^c} \tag{9}$$

$$R_{k,2}^a Q_1^a K_1^a - R_1 Q_1^a K_1^a + R_1 \delta_B Q_1^a K_0^a = \kappa^a R_{k,2}^a Q_1^a K_1^a \tag{10}$$

$$R_{k,2}^b Q_1^b K_1^b - R_1 Q_1^b K_1^b + R_1 \delta_B Q_1^b K_0^b = \kappa^b R_{k,2}^b Q_1^b K_1^b \tag{11}$$

$$R_{k,2}^a - R_1 = \mu^a\left(\kappa^a R_{k,2}^a - (R_{k,2}^a - R_1)\right) \tag{12}$$

$$R_{k,2}^b - R_1 = \mu^b\left(\kappa^b R_{k,2}^b - (R_{k,2}^b - R_1)\right) \tag{13}$$

$$Q_1^a K_1^a - \delta_B Q_1^a K_0^a + Q_1^b K_1^b - \delta_B Q_1^b K_0^b + Q_1^c K_1^c = D_1 + \delta_B Q_1^c K_0^c \tag{14}$$

$$C_1^a + \frac{B_1^a}{R_1} = A_1^a(\xi_1^a K_0^a)^\alpha + Q_1^a I_1^a - I_1^a\left(1 + \frac{\zeta}{2}\left(\frac{I_1^a}{\bar{I}^a} - 1\right)^2\right) - \delta_B Q_1^a K_0^a \tag{15}$$

$$C_1^b + \frac{B_1^b}{R_1} = A_1^b(\xi_1^b K_0^b)^\alpha + Q_1^b I_1^b - I_1^b\left(1 + \frac{\zeta}{2}\left(\frac{I_1^b}{\bar{I}^b} - 1\right)^2\right) - \delta_B Q_1^b K_0^b \tag{16}$$

$$C_2^a = (1-\alpha)A_2^a(\xi_2^a K_1^a)^\alpha + R_{k,2}^a Q_1^a K_1^a - R_1 Q_1^a K_1^a + R_1 \delta_B Q_1^a K_0^a + B_1^a + \tau^a r_2^a K_1^a \tag{17}$$

$$C_2^b = (1-\alpha)A_2^b(\xi_2^b K_1^b)^\alpha + R_{k,2}^b Q_1^b K_1^b - R_1 Q_1^b K_1^b + R_1 \delta_B Q_1^b K_0^b + B_1^b + \tau^b r_2^b K_1^b \tag{18}$$

$$C_1^c + \frac{B_1^c}{R_1} + D_1 = A_1^c(\xi_1^c K_0^c)^\alpha + Q_1^c I_1^c - I_1^c\left(1 + \frac{\zeta}{2}\left(\frac{I_1^c}{\bar{I}^c} - 1\right)^2\right) - \delta_b Q_1^c K_0^c \tag{19}$$

$$\begin{aligned} C_2^c = (1-\alpha)A_2^c(\xi_2^c K_1^c)^\alpha + R_1 Q_1^a K_1^a - R_1 \delta_B Q_1^a K_0^a + \\ + R_1 Q_1^b K_1^b - R_1 \delta_B Q_1^b K_0^b + R_1 Q_1^c K_1^c + B_1^c + \tau^c r_2^c K_1^c \end{aligned} \tag{20}$$

$$C_1^a{}^{-\sigma} = \beta R_1 C_2^a{}^{-\sigma} \tag{21}$$

$$C_1^b{}^{-\sigma} = \beta R_1 C_2^b{}^{-\sigma} \tag{22}$$

$$C_1^c{}^{-\sigma} = \beta R_1 C_2^c{}^{-\sigma} \tag{23}$$

$$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0 \tag{24}$$

Variables: $Q_1^a, Q_1^b, Q_1^c, I_1^a, I_1^b, I_1^c, K_1^a, K_1^b, K_1^c, D_1, R_{k,2}^a, R_{k,2}^b, C_1^a, C_1^b, C_1^c, C_2^a, C_2^b, C_2^c, B_1^a, B_1^b, B_1^c, R_1, \mu^a, \mu^b$

E Steady State of the Model

In this section we show deterministic steady state equations and solution of the model.

We depart from the system of equations (1)-(24) at the end of the appendix D. Some variables are pinned down directly from a static version of the equations:

$$\begin{aligned} Q^j &= 1 \\ I^j &= \delta K^j \\ B^j &= 0 \\ R &= \frac{1}{\beta} \\ K^c &= \left(\frac{R-(1-\delta)}{\alpha(1-\tau^c)}\right)^{\frac{1}{\alpha-1}} \end{aligned}$$

The rest of the system, expressed in static terms leads to the following system of equations:

$$\begin{aligned} R_k^a &= (1-\tau^a)\alpha K^{a\ \alpha-1} + 1 - \delta \\ R_k^b &= (1-\tau^b)\alpha K^{b\ \alpha-1} + 1 - \delta \\ \beta(R_k^a - (1-\delta_b)R) &= \kappa^a \\ \beta(R_k^b - (1-\delta_b)R) &= \kappa^b \\ \beta(R_k^a - R) &= \mu^a(\kappa^a - \beta(R_k^a - R)) \\ \beta(R_k^b - R) &= \mu^b(\kappa^b - \beta(R_k^b - R)) \\ (1-\delta_b)K^a + (1-\delta_b)K^b + (1-\delta_b)K^c &= D \\ C^a\left(1+\frac{1}{R}\right) &= \left(1+\frac{1-\alpha}{R}\right)K^{a\ \alpha} + \frac{R_k^a - R}{R}K^{a\ \alpha} + \frac{\tau^a\alpha}{R}K^{a\ \alpha} \\ C^b\left(1+\frac{1}{R}\right) &= \left(1+\frac{1-\alpha}{R}\right)K^{b\ \alpha} + \frac{R_k^b - R}{R}K^{b\ \alpha} + \frac{\tau^b\alpha}{R}K^{b\ \alpha} \\ C^c\left(1+\frac{1}{R}\right) + D &= \left(1+\frac{1-\alpha}{R}\right)K^{c\ \alpha} + (1-\delta_b)K^a + (1-\delta_b)K^b + (1-\delta_b)K^c + \frac{\tau^c\alpha}{R}K^{c\ \alpha} \end{aligned}$$

Where the last three equations are obtained from the life-time budget constraint of each representative household.

We solve this system of equations for: $C^a,\ C^b,\ C^c,\ K^a,\ K^b,\ D,\ R_k^a,\ R_k^b,\ \mu^a,\ \mu^b$