Macroprudential Policy Coordination in Open Economies: A Multicountry Framework*

Camilo Granados †
University of Texas at Dallas
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Abstract

To understand the international nature of the macroprudential policy and the potential the latter opens for coordinated policy efforts, we develop a three-country center-periphery framework with financial frictions and limited financial intermediation in emerging economies. Each country has a macroprudential instrument to smooth credit spread distortions; however, the banking regulations can leak to other economies and be subject to costs, potentially opening a scope for international policy cooperation. Our results show the presence of cross-border regulation spillovers that increase with the extent of financial frictions. We analyze a menu of policy arrangements with different types of coordination and show that each setup can mitigate the financial frictions. However, the scope for coordination gains depends on the macroprudential instruments' flexibility, cost, and effectiveness; these features are more favorable in policy setups with lower levels of interventionism, which we associate with internationally coordinated policy initiatives.

JEL Codes: F38, F42, E44, G18

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†School of Economic, Political and Policy Sciences, University of Texas at Dallas. Richardson, TX 75080, USA. Email: camilo.granados@utdallas.edu

1 Introduction

Over the past few decades, there has been a global trend toward liberalizing financial markets, driven by the intention to direct resources to their most productive destinations. However, this has led to higher volatility in financial markets, global imbalances, and a global financial cycle that disproportionately affects emerging economies (Rey, 2013). To address these issues, policymakers have implemented new macroprudential regulations, such as those in the Basel Accords, and established new institutions, including the Financial Stability Board. The effectiveness of these regulations has been evaluated (e.g., Hahm, Mishkin, Shin, and Shin, 2011; Akinci and Olmstead-Rumsey, 2018, among others), along with their broader effects and interactions with other sectors and between countries (e.g., Aiyar, Calomiris, and Wieladek, 2014; Aizenman, Chinn, and Ito, 2017; Coimbra and Rey, 2017; Buch and Goldberg, 2017). One question that arises is whether there is a need for coordinated regulatory arrangements between economies to address potential cross-border spillovers from these leakages.

In this study, we explore the potential benefits of international policy coordination setups in a context where emerging economies interact with a financial center in global markets. For these economies, the international consequences of nationally implemented regulations are particularly relevant, given their increased fragility to the shocks of global markets (Chang and Velasco, 2001; Reinhart and Rogoff, 2009). As policymakers recognize the borderless effects of their implementation, regulations in different locations may become interdependent, prompting policymakers to react with their own toolkit in response. As a result, coordinated multilateral regulatory frameworks could potentially improve nationally-oriented policies, given their costs and trade-offs.[1]

We develop an open economy framework that includes multiple peripheries, a center, and international financial intermediation to examine the presence of policy leakages and the potential for international cooperation from a multi-peripheral perspective. We investigate the nature of international policy spillovers and how they are shaped by the presence of financial frictions and the direction of the policy leakages. Our study is innovative in that we explore the possibility of cooperation in a multi-peripheral environment while allowing other parts of the world to react to the coordination efforts of other locations. This allows us to analyze a wide range of policy setups with different degrees of cooperation, including global cooperative initiatives and coalitions formed by foreign economies that cooperate regionally or with a subset of the rest of the world. Our approach extends the usual center-periphery or periphery-periphery setups with an exogenous center, enabling us to account for how other parts of the world may react to policy coordination efforts made by foreign economies' coalitions.

To address the question of whether financial frictions call for policy cooperation in this en-

[1]The costs of these regulations are attributed to their implementation, increases in operational costs of the financial sector, and subsequent effect on lending rates (see, for example Eling and Pankoke, 2016; Elliott and Santos, 2012), but are also given in terms of their macroeconomic impact as discussed in Richter, Schularick, and Shim (2019); Kim and Mehrotra (2022).

vironment, we consider the presence of the banking sector explicitly in our framework along the lines of Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Adrian and Shin (2010), but extended to an open economy environment as in Céspedes, Chang, and Velasco (2017), with the difference that we allow for a multi-peripheral economic structure.[2] Therefore, this work is related to the studies exploring whether changing financial conditions increase the scope for coordination (e.g., in Fujiwara and Teranishi, 2017; Banerjee, Devereux, and Lombardo, 2016; Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva, 2021) (e.g., Fujiwara and Teranishi, 2017; Banerjee, Devereux, and Lombardo, 2016; Agénor et al., 2021).[3] We build on these studies and, in addition, analyze the potential for regional and global cooperation in an environment characterized by strong financial center spillovers.

We focus on financial frictions caused by a limited enforcement agency distortion, as described by Gertler and Karadi (2011) and Mendoza (2010), which will be more prevalent in emerging markets and leads to a default premium on interbank lending relationships, amplifying the scale of financial intermediation, and potentially shaping the international financial spillovers. We examine the existence and nature of cross-border policy spillovers and evaluate the effectiveness of several policy regimes in mitigating this distortion and smoothing the credit spreads. Specifically, we consider a macroprudential instrument that taxes banking sector revenues, similar to Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021). It's worth noting that this policy tool may impact capital flows across borders and could be seen as a form of capital control. However, we argue that it's better described as a macroprudential tool with potential capital flows implications. To see this, we first demonstrate that it's equivalent to a leverage-ratio requirement, and secondly, we note that it primarily regulates the scale of financial intermediation, which could be international or domestic, without significant effects on capital flows.[4]

Our framework is set as a large open economy model similar to Banerjee, Devereux, and Lombardo (2016), Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021), and Aoki, Benigno, and Kiyotaki (2018), but with the abstraction from monetary policy concerns. This simplification enables us to extend the environment to that of a multi-peripheral financially integrated economy, facilitating the examination of strategic interactions between macroprudential regulators in different types of economies.

[2]See Brunnermeier, Eisenbach, and Sannikov (2013) for a literature survey on the macroeconomic implications of financial frictions and the existing approaches to model the banking sector.

[3]A related literature preceding this question and our paper (e.g., Obstfeld and Rogoff, 2002; Devereux and Engel, 2003; Corsetti and Pesenti, 2001; Fujiwara and Wang, 2017) explore the benefits from policy coordination under nominal rigidities and conclude that the welfare gains, if present, are small. However, subsequent studies (Sutherland, 2004; Corsetti and Pesenti, 2005; Banerjee, Devereux, and Lombardo, 2016; Bodenstein, Corsetti, and Guerrieri, 2020) revisit this question, and the potential for more sizable welfare gains, in presence of changing financial conditions. Our work aligns closer to this second group of studies.

[4]The separation line between these two types of policies has become less clear over time, as both in the literature (e.g., Farhi and Werning, 2016; Cesa-Bianchi et al., 2018; Korinek, 2022) and policy work (IMF, 2017) has been stated that the capital controls have systemic risk and financial stability effects and thus could be set with those effects in mind and not only with the goal of stabilizing the exchange rates. Moreover, our setup is that of a real economy in which the exchange rate fluctuations play not role, and the only implications of policy are those of mitigating a financial accelerator mechanism.

Considering a large open economy setting is particularly relevant in this context despite our focus on emerging economies. Peripheral economies may be viewed as inconsequential to financial centers, as assumed in Jin and Shen (2020), where the financial center is passive to any peripheral coordination attempt. However, the policy stances of peripheral countries may have non-trivial effects on the center, leading to potential strategic policy reactions (retaliative or cooperative). For example, if a block of peripheral economies jointly holds significant weight, the center perceives that its own welfare is no longer unaffected by such foreign coordination efforts. At the same time, by accounting for such international spillovers dictated by financial centers, our study is also related to the global financial cycle literature (Rey, 2013, 2016) and to studies on the stabilizing role of financial regulations for emerging economies (Nuguer, 2016; Cuadra and Nuguer, 2018), we add to these studies by considering also the possibility of implementing different types of policy cooperation (regional, center-peripheral but limited, and global).

International policy externalities manifest through various channels. First, the profits of exiting bankers are directly affected by domestic and foreign policy tools, and these changes enter the households' budgets due to ownership. Second, firms fund their input acquisitions with banking loans, and the costs of these loans depend on the policy instruments. Cooperative policymakers can already better internalize the effects of their regulations on the resources of coalition participants through these channels. However, there is another potentially more relevant externality mechanism that implies an interlink between financial distortions at different locations. This mechanism consists of the general equilibrium effects of implementing a policy action. For example, if a center regulator implements a tightening to decrease the external finance premium locally, it inadvertently decreases the cost of debt in other locations since its creditor banks must be indifferent between funding local and foreign projects in equilibrium. This has the unintended effect of increasing the financial frictions and external finance premia abroad, prompting foreign regulators to make additional policy adjustments. This effect is not internalized by nationally-oriented regulators, which strengthens the case for coordinated policy actions to prevent costly regulatory wars and excessive interventionism along similar lines to the discussions in Jeanne (2014, 2021) and Blanchard (2017).

Our results suggest the presence of important international policy spillovers that arise from the interaction of two features: the strong cross-border effects stemming from the financial center and the weaker domestic policy effects 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 center's role as a global creditor. 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 composition of the demand for funding by borrowers that partially offset the intended local effect on intermediation targeted by regulators.

Additionally, we observe that the impact of policy measures increases in the extent of financial distortions, a finding that aligns with the conventional wisdom that these policies are more useful in emerging markets (Alam et al., 2019; Boz, Unsal, Roch, Basu, and Gopinath, 2020). Other factors influencing these effects include the net foreign asset positions, the price and demand changes in the interbank sector, and the disruption in real production activities, which is a prevalent concern in regulation circles and recent empirical studies (e.g., Richter, Schularick, and Shim, 2019; Kim and Mehrotra, 2022).

In our baseline setup, we find that international policy coordination yields trivially small welfare gains, as every policy regime —whether nationally-oriented, semi-cooperative, or cooperative— can reduce the financial distortions and mimic the first-best equilibrium. However, the optimal policies of these regimes differ, with policies becoming more conservative as the degree of cooperation increases. This implies a property of cooperative policy setups: they limit the level of interventionism necessary for mitigating financial frictions.

We explore our results further —drawing from the conclusions of Korinek (2016), which argues that the benefits of international policy coordination depend on the economic environment and properties of the policy toolkit- and find that with costly policymaking, coordinated setups can generate significant gains, successfully undoing the remaining share of the welfare loss from the frictions that the non-cooperative regimes fail to mitigate. We also investigate whether richer policy dynamics lead to more significant welfare effects, potentially creating divergent outcomes between cooperative and nationally-oriented regimes. To achieve this, we allow the banking sector to retain profits and continue in business so that policy effects persist on the balance sheet of financial firms. We find that when policies become more persistent, policy effects are magnified, potentially increasing the scope for cooperation gains.

Our study is closely related to the work of Davis and Devereux (2019), Korinek (2016), Bengui (2014), Jin and Shen (2020), and Kara (2016), which show how macroprudential cooperation can be beneficial in different environments, but from diverging reasons; in some of these studies the gains arise from preventing unnecessary interventionism, while from the latter two, the reverse holds. Our results align with the first group of studies, emphasizing the importance of containing regulatory costs. At the same time, our approach differs from previous studies in several ways, including our explicit modeling of banking frictions and the consideration of a multi-peripheral structure, which allows for potential retaliative policy actions by regulators outside foreign cooperative coalitions. These features can be critical in determining whether cooperation is recommended and allows us to reconcile the seemingly opposing results in the literature.

The rest of the paper is organized as follows: section 2 explains the baseline 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. In the later sections we explore alternative specifications to further explore features that could increase the scope for policy coordination gains. Finally, we conclude.

2 The Model

Our framework is based on Banerjee, Devereux, and Lombardo (2016), meaning that it essentially follows the banking sector modelation of Gertler and Karadi (2011) applied to an open economy setup. In this paper, however, we introduce a multiperipheral environment, where the peripheric block of the economy is allowed to have several emerging economies that interact with one financial center. At the same time it includes a macroprudential policy in the form of a tax to the return on capital as in Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021) and Aoki, Benigno, and Kiyotaki (2018), among others. The advantage of this formulation is that the policy instrument will be attached directly to the credit spreads that are augmented by the friction and drive the capital flows at the cross country level. On the other hand, to keep the model simple, our initial formulation will only consider a simple financial intemediation period, but this is extended in the later sections.

2.1 Economic Environment

The main feature defining whether a country is an emerging economy is that its financial sector has a limited intermediation capacity, meaning it is unable to issue deposits claims for their households to some extent. As a consequence, it will have to resort to the international financial banking sector to make up for the difference and being able to meet their firms' funding needs. This environment is depicted in Figure 1, where the red arrows represent financial flows.

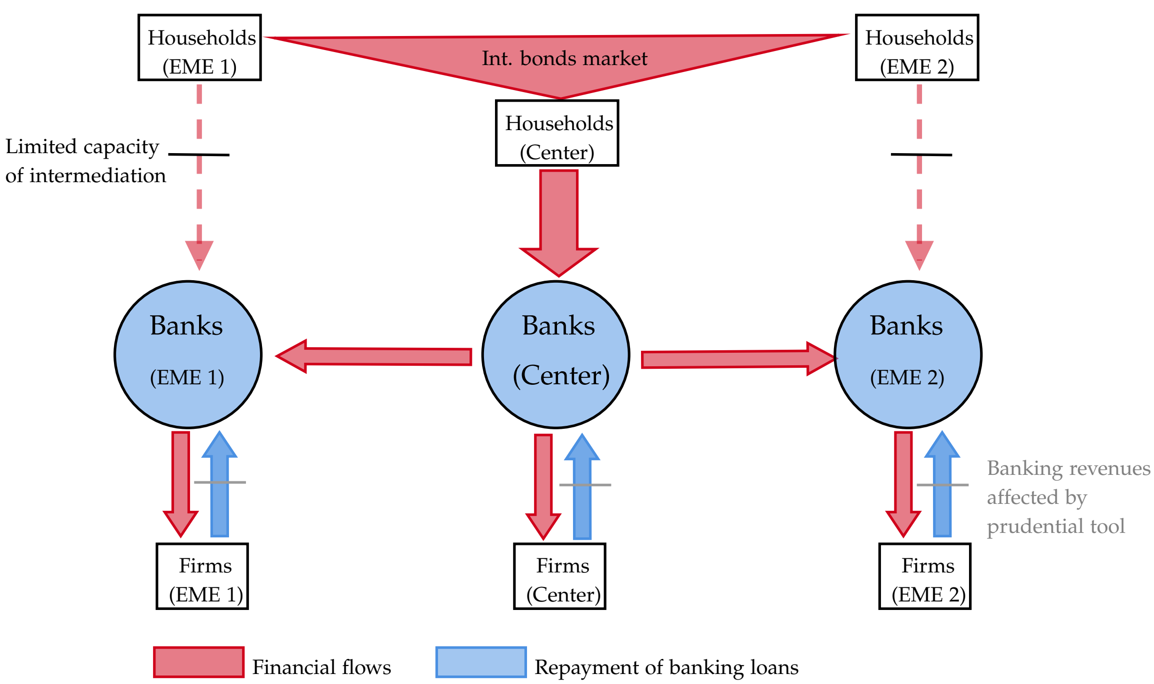

Figure 1: Financial flows environment in the model

Such structure implies that the emerging economies are financially dependent on the funding from center banks, and in an environment of imperfect information in the lending contracts 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. We also we assume the friction is more accentuated in the peripheries.

For simplicity, the real sector will consist only on one consumption good and there will be no deviations from the law of one price. Preferences are identical between agents, implying the parity or purchasing power holds and the real exchange rate will be constant (equal to one), playing no role in this version of the model. Additionally, the households will have access to an international market of non-contingent bonds. This is relevant as it implies that, despite the limited capacity to hold deposits, the saving decisions of emerging economies' households are not curtailed in any way once they trade these assets.

Finally, the lending relationships are subject to a limited enforceability friction which induces an external finance premium and augments the scale of intermediation and credit cycles. The external premium takes the form of an increased return rate for the banks which raises their revenues. Such revenues, will be targeted by the macroprudential regulation meaning it will attack the financial friction at its origin.

2.2 Timing and Countries Setup

The world consists of three economies that live for two periods $t = 1, 2$. The economies are indexed by $i = a, b, c$, the first two will be emerging 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_i with $1 - (n_a + n_b) \geq \frac{1}{2}$. Each economy has five types of agents: Households, final consumption good producers, capital producers, banks and a government sector.

As mentioned before, preferences across countries' households are identical and there is only one final consumption good worldwide that is freely traded and produced in all locations.

In terms of notation, 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.

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 reference level for defining the adjustment cost; The reference level is usually set at the steady state, the previous level of investment or a combination. In any case, it must hold that $C(0) = 0,\ C''(\cdot) > 0$.

The capital producing firms (investors) buy back the old capital stock from the banks at price Q_1^i 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,

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

2.4 Firms

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

The capital dynamics for the only period of accumulation are,

$$K_1 = I_1 + (1 - \delta)\xi_1 K_0.$$

The technology that aggregates capital inputs into final goods is,

$$Y_t = A_t(\xi_t K_{t-1})^{\alpha},$$

where A_t is the aggregate productivity, and ξ a capital specific productivity shock.

Given the timing of the model, there is only one period of intermediation ($t = 1$) when lending is extended to acquire capital for production in the final period ($t = 2$). On the other hand, the capital used for production in the initial period is already given and held by the households' hands.

With that, the firms solve a slightly different problem each period. First they decide how much capital to rent from households:

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

the F.O.C. are,

$$[K_0]: \qquad r_1 = \alpha A_1 \xi_1^{\alpha} K_0^{\alpha - 1},$$

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:

$$\max_{K_1} \ \pi_{f,2} = Y_2 + Q_2(1-\delta)\xi_2 K_1 - R_{k,2}Q_1K_1,$$
$$s.t. \quad Y_2 = A_2(\xi_2 K_1)^{\alpha},$$

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 follow the same definition for r_2, that is, $r_2 = \alpha A_2 \xi_2^{\alpha} K_1^{\alpha-1}$.

Substituting in the optimality condition for K_1 we obtain that the rate paid to the banks by the firms is given by $\tilde{R}_{k,2} = \frac{r_2+(1-\delta)\xi_2 Q_2}{Q_1}$. Moreover, by taking into account the possibility of a macroprudential tax on the marginal return on capital, such as in Agénor et al. (2021), we have that the effective rate obtained by the banks, that is, after paying the macroprudential taxes ($\tau r_2 K_1$) to the government is given by:

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

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.[5] We elaborate on the policy tool and the role of this return rate in later subsections.

2.4.1 Capital dynamics and ownership

The dynamics of the model will be driven (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 that period as K_0. Then, by the end of the accumulation period the capital in the economy will be given by K_1. That capital will be used for the following period's production. The capital ownership between agents throughout each period is shown in the figure 2, which explains a typical period with intermediation.

[5]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.

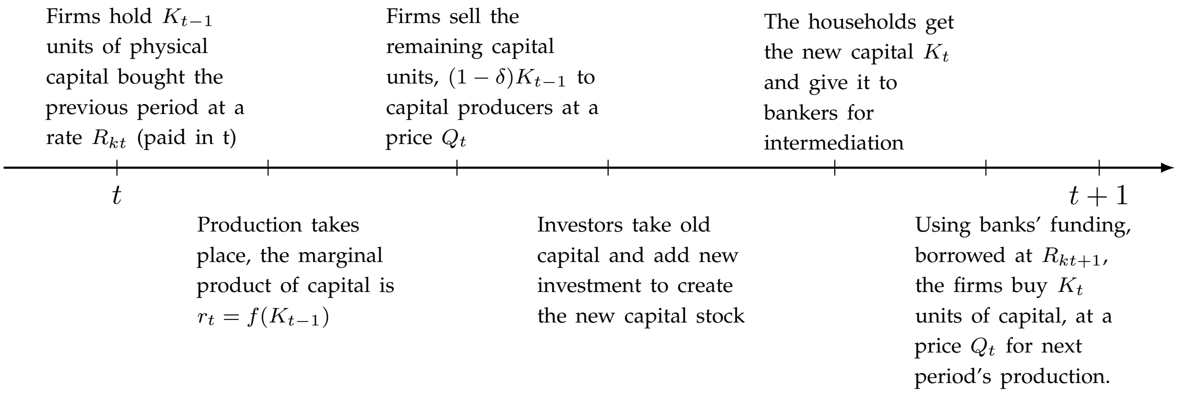

Figure 2: Capital ownership within a period

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 banks themselves are owned household agents). Therefore, the pre-existing capital stock (K_0) will be provided directly from households to firms 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 funding for firms at the local level. In addition, the bank at the Center is also a global creditor and extends loans to banks in other locations.

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 as profits.

There will be a costly enforcement agency friction where its possible for the banks to divert a portion of the assets they intermediate. The eventual implication of this is the imposition of a external finance premium to the banking revenue rates, which is imposed to prevent the banks from absconding assets and to align their incentives with those of the assets' owners. This is the financial friction in this environment that augments the credit cycles.

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 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 intermediated assets.[6] In either case (default or not) the gross return from intermediation for the bank is R_{k2} as defined in equation (1).

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

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

$$s.t. \quad L_1^e = F_1^e + \delta_b Q_1^e K_0^e, \qquad \text{[balance sheet]}$$

$$J_1^e \geq \kappa \mathbb{E}_1 \Lambda_{1,2}^e R_{k,2}^e L_1^e, \qquad \text{[ICC]}$$

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

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 from defaulting.

The F.O.C. with respect to the foreign debt is:

$$[F_1]: \qquad \mathbb{E}_1(1+\mu^e)(R_{k,2}^e - R_{b,1}^e) = \mu^e \mathbb{E}_1 \kappa R_{k,2}$$

where μ^e is the lagrange multiplier of the ICC (there will be one for each emerging economy $e = \{a, b\}$). Based on the F.O.C. we can obtain an important result to understand the implications of the financial friction in the model.

Proposition 1: *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:

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

$\Phi > 1$ 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.

[6]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. In this case we assume it considers diverting after being paid by the firms. The constraint and implications are very similar in the alternative case. We explore such case in the extended version of the model in the last section.

$\mu > 0$ by definition of the ICC (and the fact that it binds). Hence, it follows that,

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

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

2.5.2 Advanced Economy

To simplify, here we assume there is no agency problems at the Center (we relax this in later sections). Then, the Center bank solves:

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

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:

$$\begin{aligned} [F^a_1]: &\quad \mathbb{E}_1(R^a_{b,1} - R_{D,1}) = 0 \\ [F^b_1]: &\quad \mathbb{E}_1(R^b_{b,1} - R_{D,1}) = 0 \\ [L^c_1]: &\quad \mathbb{E}_1(R^c_{k,2} - R_{D,1}) = 0 \end{aligned}$$

An important consequence of these optimality conditions is that a policy that affects the revenue rate $R^c_{k,2}$ will have general equilibrium effects and inadvertently lower the cost of debt for debtor economies ($R^a_{b,1}, R^b_{b,1}$). This implies an interaction between the credit spreads and financial frictions between countries that is overlooked by nationally-oriented planners.[7]

2.6 Macroprudential policy and public budget

Among the number of possible prudential policies[8] (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 (τ^i) on the return to capital ($R^i_{k2} = [(1-\tau^i) r^i_t + (1-\delta)\xi_2 Q_2]/Q_1$). This will be a tax levied on the banking sector, as shown in the equation (1).

The policy tool can be thought as a device to impose controls on capital flows. This is the case because the tax has the advantage of affecting directly the wedge between the return on capital

[7] In a subsequent section we explore the case of incorporating frictions at the Center. In such case this effect is also present even if not as evidently.

[8] see Cerutti, Claessens, and Laeven (2017) for a detailed classification of macroprudential policies

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.

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

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 regimes, for example worldwide cooperation, but also smaller coalitions such as regional between emerging economies, or between the center and one of the peripheries. Each case will imply a different welfare function as explained in section 3.

With this poilcy setup the following result follows:

Proposition 2: *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:

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

Φ_L denotes the leverage ratio.

We can substitute $R_{k,2}^e = [(1-\tau^e) r_2^e - (1-\delta)\xi_2^e Q_2]/Q_1$ and differentiate with respect to τ^e:

$$\frac{\partial \phi_L}{\partial \tau^e} = -\frac{(1-\kappa^e) R_{b,1}^e (r_2^e)}{(R_{b,1}^e - (1-\kappa^e) R_{k,2}^e)^2 Q_1^e} < 0$$

This result takes into account that the denominator is never zero given the ICC is binding and the credit spread is positive. ■

2.7 Households

The households derive utility from consumption and its lifetime utility is given by $U^i = u(C_1^i) + \beta u(C_2^i)$ with $u(C) = \dfrac{C^{1-\sigma}}{1-\sigma}$. The budget constraints in each period are the following:

Emerging markets:

$$C_1^e + \frac{B_1^e}{R_1^e} = r_1^e K_0^e + \pi_{f,1}^e + \pi_{inv,1}^e - \delta_b Q_1^e K_0^e,$$
$$C_2^e = \pi_{f,2}^e + \pi_{b,2}^e + B_1^e - T^e, \quad for\ e = \{a, b\},$$

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.

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

Advanced Economy:

$$C_1^c + \frac{B_1^c}{R_1^c} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_b Q_1^c K_0^c,$$
$$C_2^c = \pi_{f,2}^c + \pi_{b,2}^c + B_1^c + R_{D,1} D_1 - T^c,$$

here, the advanced economy also includes local deposits D in the budget constraint as these are intermediated by their banks. Additionally, the profits are given by:[9]

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

In the first period households maximize their life-time utility stream subject to the budget constraints for the first and second period. The F.O.C. for the three countries' households are:

$$u'(C_1) = \beta R_1 \mathbb{E}_1[u'(C_2)],$$
$$u'(C_1^c) = \beta R_{D,1} \mathbb{E}_1[u'(C_2^c)],$$

where the first equation is the Euler equation for bonds and applies to the three economies, while the last one is the Euler equation for local deposits and holds only for country c.

[9] 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 $\pi_{f,2} = A_2 K_1^\alpha - r_2 K_1$.

2.8 Market Clearing

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

$$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0$$

The goods market clearing conditions for each period are,

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

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

Finally, given that there is only one final good and the law of one price holds (so that the real exchange rate in all cases is one), we have by an uncovered interest rate parity argument that: $R_1^a = R_1^b = R_1^c = R_1$, where R_1 denotes the world interest rate on bonds in period 1.

Exogenous processes I consider three potential sources of exogenous variation in the model that are subject to shocks. First a productivity technology shock: $A_t^j = \rho_A A_{t-1}^j + \sigma_A \epsilon_{A,t}^j$ with $\epsilon_{A,t}^j \sim N(0,1)$, and a capital quality shock ξ_t that affects the stock of capital in the production function and the depreciation rate, given by $\xi_t^j = \rho_\xi \xi_{t-1}^j + \sigma_\xi \epsilon_{\xi,t}^j$ with $\epsilon_{\xi,t}^j \sim N(0,1)$.

2.9 Equilibrium

Given the policies $\{\tau^a, \tau^b, \tau^c\}$ the equilibrium consists of prices $\{Q_t^i\}$, rates $\{R_1, R_{k,2}^e\}$ and quantities $\{B_1^i, K_1^i, F_1^e, D, C_t^i, I_t^i\}$ for $t = \{1,2\}$, with $i = \{a,b,c\}$, $e = \{a,b\}$, such that the households solve their utility maximization problem, the firms solve their profits maximization problems, banks maximize their franchise value, and the goods and bonds market clear.

The simplified system of equations of the model we use to solve it is reported in table A1 in the appendix A.[10]

3 Welfare Effects between economies

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

We set the welfare based on a social planner problem along the lines of Davis and Devereux (2019) in order to find the equilibrium welfare effects of a change in the policy tools: Let the

[10] In addition, appendix E shows how the simplified final system is obtained from the equations described in this section.

welfare of country i be expressed as $W^i = U^i + \lambda_1^i BC_1^i + \beta\lambda_2^i BC_2^i$ for $i = \{a,b,c\}$,

$$W^e = U^e + \lambda_1^e \left(r_1^e K_0^e + \pi_{f,1}^e + \pi_{inv,1}^e - \delta_b Q_1^e K_0^e - C_1^e - \frac{B_1^e}{R_1^e} \right) + \beta\lambda_2^e \left(\pi_{f,2}^e + \pi_{b,2}^e + B_1^e - T^e - C_2^e \right), l \qquad \text{for } e = \{a,b\}$$

$$W^c = U^c + \lambda_1^c \left(r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_b Q_1^c K_0^c - C_1^c - \frac{B_1^c}{R_1^c} - D_1 \right) + \beta\lambda_2^c \left(\pi_{f,2}^c + \pi_{b,2}^c + B_1^c + R_{D,1} D_1 - T^c - C_2^c \right).$$

This problem is analogous to a standard planner problem. Nonetheless, the optimality conditions (equilibrium allocations) 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), the tax rebates and some of the interest rates (that in equilibrium are equalized):

$$W^e = u(C_1^e) + \beta u(C_2^e) + \lambda_1^e \left(A_1^e(\xi_1^e K_0^e)^\alpha + Q_1^e I_1^e - C(I_1^e) - C_1^e - \frac{B_1^e}{R_1} \right) + \beta\lambda_2^e \Big(\phi(\tau^e) A_2^e (\xi_2^e K_1^e)^\alpha + \kappa^e (1-\delta)\xi_2^e Q_2^a K_1^a + B_1^a - C_2^a \Big), \quad \text{for } e = \{a,b\}$$

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

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

We can see that, for the emerging 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 additional optimality conditions from the Private Equilibrium.

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

3.1 Direct Effects of Policy

The welfare effect of the tax for the emerging economies is given by[11],

$$\frac{dW^a}{d\tau^a} = \beta\lambda_2^a \left\{ R_1 I_1^a \frac{dQ_1^a}{d\tau^a} + \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^a} + \left(\phi(\tau^a) r_2^a + \kappa^a(1-\delta)\xi_2^a Q_2^a\right)\frac{dK_1^a}{d\tau^a} + \alpha(1-\kappa^a)Y_2 \right\}$$

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 $\frac{B_1^a}{R_1}$ (net foreign assets) which is positive for emerging markets (and negative for the center).

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. Even from a planners' perspective, this effect will not cancel out for the emerging markets (as in the center) because of the presence of a binding ICC for emerging markets. 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.[12]

For the center economy, the effect is:

$$\frac{dW^c}{d\tau^c} = \beta\lambda_2^c \left\{ R_1 I_1^c \frac{dQ_1^c}{d\tau^c} + \frac{B_1^c}{R_1}\frac{dR_1}{d\tau^c} + \left(r_2^c + (1-\delta)\xi_2^c Q_2^c\right)\frac{dK_1^c}{d\tau^c} + R_{b,1}^e \left(\frac{dF_1^a}{d\tau^c} + \frac{dF_1^b}{d\tau^c}\right) + \frac{dR_{b,1}^e}{d\tau^c} F_1^{ab} \right\},$$

where $F_1^{ab} = F_1^a + F_1^b$ is the total intermediation to emerging economies, and $R_{b,1}^e$ is the interest rate paid by emerging banks (these equalize in equilibrium). The interpretations for the first three terms are analogous to those of the emerging country mentioned above.

[11]The derivation of these results is shown in detail in the appendix B.

[12]Still, In a later section we approximate this effect numerically around the no policy equilibrium to gauge the relative importance of these effects. Although we also explain that to obtain the actual optimal policies we must introduce the Ramsey Planner Problem as a solution criterion.

The final two terms 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.

3.2 Cross-country Effects

The welfare effect between emerging countries is,

$$\frac{dW^a}{d\tau^b} = \beta\lambda_2^a \left\{ R_1 I_1^a \frac{dQ_1^a}{d\tau^b} + \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^b} + \left(\phi(\tau^a) r_2^a + \kappa^a(1-\delta)\xi_2^a Q_2^a\right) \frac{dK_1^a}{d\tau^b} \right\},$$

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, in contrast, 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 from a change in the center country tax is,

$$\frac{dW^a}{d\tau^c} = \beta\lambda_2^a \left\{ R_1 I_1^a \frac{dQ_1^a}{d\tau^c} + \frac{B_1^a}{R_1}\frac{dR_1}{d\tau^c} + \left(\phi(\tau^a) r_2^a + \kappa^a(1-\delta)\xi_2^a Q_2^a\right) \frac{dK_1^a}{d\tau^c} \right\}.$$

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

$$\frac{dW^c}{d\tau^e} = \beta\lambda_2^c \left\{ R_1 I_1^c \frac{dQ_1^c}{d\tau^e} + \frac{B_1^c}{R_1}\frac{dR_1}{d\tau^e} + \left(r_2^c + (1-\delta)\xi_2^c Q_2^c\right) \frac{dK_1^c}{d\tau^e} + R_{b,1}^e \left(\frac{dF_1^a}{d\tau^e} + \frac{dF_1^b}{d\tau^e} \right) + \frac{dR_{b,1}^e}{d\tau^a} F_1^{ab} \right\},$$

where as before F_1^{ab} is the total intermediation to the emerging economies, and $R_{b,1}^e = R_{b,1}^a = R_{b,1}^b$ is the interest rate paid by emerging banks to the center intemediary. The interpretations of each term follow analogous intuitions to those explained in the subsection 3.1.

3.2.1 Optimal tax

We can use these effects expressions as first-order conditions for national planners and derive the optimal taxes (i.e., setting $dW^i/d\tau^i = 0$ and solve for τ^i). The optimal emerging tax would be:

$$\tau^{e\,*} = \frac{-1}{\alpha(1-\kappa^e)} \left\{ \frac{1}{r_2^e} \left[\left(R_1 I_1^e \frac{dQ_1^e}{dK_1^e} + \frac{B_1^e}{R_1}\frac{dR_1}{dK_1^e} \right) + \kappa^a(1-\delta)\xi_2^e Q_2 \right] + 1 + \alpha(\kappa^e - 1) \right\}, \quad \text{for } e = \{a, b\}.$$

For c:

$$\tau^{c\,*} = \frac{Q_1^c}{r_2^a} \left\{ R_1 I_1^c \frac{dQ_1^c}{dF_1^{ab}} + \frac{B_1^c}{R_1}\frac{dR_1}{dF_1^{ab}} + \left(r_2^c + (1-\delta)\xi_2^c Q_2\right)\frac{dK_1^c}{dF_1^{ab}} + (F_1^a + F_1^b)\frac{dR_{b,1}^e}{dF_1^{ab}} + (1-\delta)\xi_2^c \frac{Q_2}{Q_1^c} \right\} + 1,$$

with $dF_1^{ab} = dF_1^a + dF_1^b$

from these expressions we get an idea about the effects driving the optimal taxes. 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, whose increases lead to lower tax values.

The intuition here is that, if capital becomes more productive, is better to distort the economy less. We will see in later sections that this is a part of what a coordinated policy effort achieves (less interventionism).

Here is useful to remember that, in equilibrium, the marginal product of capital is directly taxed by the 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, and in contrast, the extent of the financial distortion (κ^e) 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.

It should be noticed that both sides of these equations still depend on the taxes, so even if we can approximate the effects on the right-hand-side around points of interest, we need to introduce an additional solution criterion to find the optimal taxes. We do that in the following section by formulating the Ramsey Policy Problem associated to each considered policy regime.

3.3 Welfare effects in each policy regime

Before setting the Ramsey Policy Problem it is useful to understand the welfare effect of the taxes on the policy objective of the planners. For the case of non-cooperative planners, these effects correspond to the individual country welfare-effects described before as these policy makers are nationally-oriented. For cooperative or semi-cooperative planners, i.e., those belonging to a coalition, the welfare effects on their objective is given by the weighted averages of the country-wise effects, and the Pareto weights in each case are given by the relative population sizes of each economy.

Table 1 summarizes the effect of any policy change on the objective of each type of planner. 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.

Table 1: Welfare spillovers in the model

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

Note: $i = a, b, c$

4 The Ramsey Planner problem

In the previous sections, we set up a framework to explore 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 with different degrees of cooperation between planners.

It should be noted that in such analysis, there is a substantial 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 pre-defined level of the taxes, it is difficult to solve for the actual optimal policy instruments and thus for the policy distorted equilibrium under each regime.

For carrying such task it is more convenient to set a Ramsey problem consisting on maximizing a welfare objective function subject to the private equilibrium optimality conditions.

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

Second, let $F(\cdot)$ be the set of equations representing the optimality constraints of private agents that characterize the private equilibrium, $\mathbf{x}$ 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. In general, we solve the following problem for each Ramsey planner involved:

$$\max_{\mathbf{x_t}, \tilde{\tau}_t} \quad W_t^{objective} = f(\alpha^i, W_t^i),$$

$$s.t. \qquad \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta),$$

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

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 (i.e., the system of equations in table A1). 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.[13]

4.1 Non-Cooperative Framework

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

$$\max_{\mathbf{x_t^i}, \tau_t^i} \quad W^{i,Nash} = W^i,$$
$$s.t. \quad \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta), \qquad \text{for } t = 1.$$

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

4.2 Cooperative Frameworks

We will consider three types of cooperative frameworks. Full cooperation, where the tools for all countries are set cooperatively by an single central planner, and two semi-cooperative cases where regional coalitions are formed. First, between emerging economies, and second between the center and one emerging economy. In the semi-cooperative regimes each coalition will have a central planner setting the participants' toolkit.

4.2.1 World Cooperation

The cooperative Ramsey planner solves:

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

Thus, it sets all the tools in order to maximize global (weighted) welfare. The welfare weights correspond to the relative population sizes of the economies.

[13]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.

4.2.2 Regional cooperation between emerging countries

A coalition between emerging economies implies a regional level planner solving:

$$\max_{\mathbf{x_t^a},\mathbf{x_t^b},\tau_t^a,\tau_t^b} \quad W^{Coop,EMEs} = n_a W^a + n_b W^b,$$
$$s.t. \quad \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta), \qquad \text{for } t = 1.$$

In this 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_1^c, analogously to the nationally-oriented non-cooperative 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:

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

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

In the rest of the paper, we compare the welfare delivered by all regimes in terms of consumption equivalent compensation units with respect to a benchmark equilibrium. In doing this we measure the relative welfare in terms of the proportional increase in the steady state consumption for a benchmark model (e.g., non-cooperation), where 1 implies that the models compared deliver the same 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 equal to the improvement such economy would experiment if their consumption at their baseline levels were to increase by 20%.

When carrying this comparison for all regimes and with respect to the non-cooperative (Nash) equilibrium in our baseline, we obtain that the welfare delivered by all regimes is equivalent. That is, the proportional gross increase in consumption units is 1 in all cases (and for all economies). This means, that at least in the baseline model, there are no gains from cooperative policy setups. 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.

Now, similar welfare does not imply analogous policies throughout regimes. In fact, we can see the optimal policies in each case and verify that they imply different levels of interventionism.

5.1 Level of the policy tool in each arrangement

The results, shown in table 2, 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 higher tax when not engaging in cooperative arrangements.

Table 2: 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 non-cooperative 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 two patterns in the all policy frameworks, first, the center applies much stronger taxes than other economies, and second, cooperative economies implement lower levels of taxes, i.e., intervene more conservatively with their tools. A potential interpretation for the former is that the center perceives the negative welfare effect from more stringent prudential regulators in other economies, and thus, may attempt to offset their policies. This is consistent with the fact that the center tax increases for lower extents of cooperation which is intuitive: a non-cooperative center does not care about the peripheral efforts to deal with local frictions.

Related to the second pattern, we even have that the global cooperation regime is the only one in which the emerging economies apply subsidies. In that case, the cross-border welfare effect of policy changes at the center are fully internalized by the planner, leading to lower taxes at the center, and thus to weaker upward pressures on emerging credit spreads, this in turn opens space for subsidization policies at the emerging level in a way that mitigates the welfare negative effect of prudential policies in the financial center.

Notice something important, in this simplistic baseline setup there are no explicit costs of regulation. With such feature the cooperative outcome would become more beneficial in relative terms which may lead to important welfare outcomes between regimes.

5.2 Approaching the First Best

A natural question about the Ramsey policy equilibria is whether these schemes can successfully undo the distortion created by the financial agency friction and bring the economies closer to the First Best, that is, the equilibrium allocation with no frictions in place. Similarly, it would be interesting to know what are the gains from conducting policy at all in this environment.

Table 3: Welfare comparison across policy schemes with respect to the First Best allocation (left panel) and with respect to the no policy equilibrium (right panel)

	Bechmark: First Best				Bechmark: No Policy equilibrium			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.01	1.01	1.01	1.01	1.06	1.06	1.06	1.06
A	0.99	0.99	0.99	0.99	1.02	1.03	1.02	1.02
B	0.99	0.99	0.99	0.99	1.02	1.03	1.02	1.02
World	1.00	1.00	1.00	1.00	1.04	1.04	1.04	1.04
EME Block	0.99	0.99	0.99	0.99	1.02	1.03	1.02	1.02

Units: Proportional steady state consumption increase in the benchmark model. That is, by how much would consumption in benchmark be scaled to match welfare in the column's model.

Table 3 shows a welfare comparison of the policy setups with the first best allocation in the left panel and with respect to a no policy equilibrium in the right panel. 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 (frictionless) allocation.

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 with different combinations of the policy tools.

This is consistent with Korinek (2016) stance about the gains from international macroprudential coordination. Namely, that for these gains to be present the Nash non-cooperative 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 exploring features we would need to modify in our framework for obtaining important welfare differences between regimes and cooperation gains.

Gains with respect to a No Policy setup A related relevant question whether policy is helpful at all. To explore that we also compare the equilibria outcome of the regimes relative to an equilibrium with no policymaking in place. The results are shown in the right panel of table 3.

We can see that every regime implies a substantial welfare improvement with respect to the no policy equilibrium. In effect, switching from the absence of policymaking to any active (cooperative or not) optimal policy setup leads to a compensatory increase in steady state consumption of 4%. This welfare improvement is distributed asymmetrically across countries with the center absorbing a higher improvement, and the least favored economies still receving a sizable welfare increase equivalent to a 2% change in consumption.

6 Achieving Gains from Coordination

In the previous section, we found that the baseline model does not yield gains from coordination at any level (global or regional). We also verified that although there are policy spillovers between the economies, various policy configurations still allow the planners to approach the first best.

The welfare equivalence, between policies designed while internalizing non-trivial international spillovers and those abstracting from such effects can be puzzling. To understand it we can refer to Korinek (2016), 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.

The lesson from this theorem is that, as long as the flow of resources in the international markets is efficient and we have a flexible and effective toolkit to set allocations at desired levels, any policy can achieve the first best and the international externalities represent only efficient spillovers.

On the other hand, it is possible that the policy spillovers are not strong enough in our simplistic setup to deliver important welfare differences between regimes. For example, and to elaborate on this point, the policies in our setup have short-lived effects as the banks intermediate only once.

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, and finally, we extend the model to one where the effects of policy are now dynamic in the sense that they affect the balance sheet of banks for several periods.

6.1 Financial Frictions in the Center

This version of the model includes a financial friction in the center banking sector. In that case, the center bank solves:

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

with associated F.O.C. analogous to the emerging banks' problem but yielding expressions for positive credit spreads between the Center's revenue rates $(R^a_{b,1}, R^b_{b,1}, R^c_{k2})$ and the deposit rates.

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 intermediation rates of the center $(R^c_{k,2},\ R^a_{b,1},\ R^b_{b,1})$ will also be subject to a premium.

In this version of the model we still obtain no gains from coordination (results are shown in appendix G). However, as new result, we get lower gains with respect to the no policy case and that the peripheries will apply more subsidization.

The intuition for this new finding is that the friction in the center works in the opposite direction on the emerging credit spreads. That is, a premium in the center lending rates 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 now opt for subsidizing the intermediation rather than undoing the friction.

6.2 Policy costs of macroprudential intervention

Now 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:

$$\max_{\mathbf{x_t},\tilde{\tau}_t} \quad W^{objective}_t = f(\alpha^i, W^i_t) - \Gamma(\tau^i),$$
$$s.t. \qquad \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta),$$

with $\tilde{\tau} \subseteq \tau$ and welfare weights $\alpha^i \geq 0$. Here, $f(\alpha^i, W^i_t)$ corresponds to the same objective functions considered in section 4 and $\Gamma(\tau^i) = \psi(\tau^i)^2$ denotes a quadratic policy implementation cost. We solve 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 4 and the comparison with respect to the first best allocation and the policy toolkit they imply is shown in the appendix C (tables C5 and C6). We obtain that now there are 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.

Interestingly, this result exploits a property of cooperative policies to generate sizable welfare differences between regimes, namely the reduced level of interventionism that is more salient as more countries join the cooperative policy initiatives.

Table 4: Welfare comparison across policy schemes with respect to the Nash Equilibrium (model with policy implementation costs)

	Policy Scheme		
Country	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
C (Center)	1.02	1.02	1.02
A	1.01	1.01	1.01
B	1.01	1.01	1.01
World	1.01	1.01	1.01
EME Block	1.01	1.01	1.01

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

Putting these results in perspective, the nationally oriented policies (non-cooperative) can mitigate about half of the welfare cost of a financial friction that in our simplistic baseline amounted to about 4% of consumption losses per period. In contrast, the cooperative regimes are able to bring the economy even closer to the first-best allocation, effectively undoing the remaining welfare cost implied by the friction.

7 An Extended Three-Period Model

A natural extension that we apply is to consider a framework where intermediation occurs more than once. In this case, we increase the timing horizon by one period, and implement a key property, which is that banks can continue in business with a probability rate θ. Crucially, when banks remain in business, they will retain the profits from the next period as part of their net worth. That is, as before, banks only report profits to their owner households when they exit the financial intermediation market.[14]

General economic environment. The setup is analogous to the previous one, but now there are three periods $t = \{1, 2, 3\}$. The world consists of three countries, two emerging countries and one center, and each economy is populated by five types of agents: households, final goods firms, investors, the government and a representative bank.

[14]The profit retention property is standard in this literature (e.g., Gertler and Karadi, 2011) and captures the notion that banks consider they are a better investment choice that any other alternative feasible to their owners.

The initial capital endowments are given (K_0) and afterwards, physical capital is acquired by firms for production with banking funding. In that sense there are now two periods of intermediation, the first at the end of the first period, and one more a period later. Importantly, as long as there are intermediation activities in the future, the banks may continue in business and in that case retain profits, thus, the banking decisions are dynamic, or forward looking, in $t = 1$, while in $t = 2$ the banking problem is static. In what follows I emphasize on the differences in the decision making of the bankers and policy-makers between these two periods.

7.1 Banks

EME-Banks. The problem of the bank is extended to account for the probability of continuation in the intermediation activities. This is also reflected in the constraints that now includes the balance sheet period of future periods, which importantly, is affected by the net worth of the bank that now includes the profits from previous periods.

In the first period of intermediation (end of t=1) the bank aims to maximize its expected franchise value, given by J_1 and solves:

$$J_1^e = \max_{F_1^e, L_1^e} \mathbb{E}_1 \left\{ (1-\theta)\Lambda_{1,2}^e (R_{k,2}^e L_1^e - R_{b,1}^e F_1^e) + \Lambda_{1,3}^e \theta (R_{k,3}^e L_2^e - R_{b,2}^e F_2^e) \right\},$$

$$s.t \quad L_1^e = F_1^e + \delta_B Q_1^e K_0^e, \qquad \text{[Balance sheet in t=1]}$$

$$L_2^e = F_2^e + \delta_B Q_2^e K_1^e + \theta [R_{k,2}^e L_1^e - R_{b,1}^e F_1^e], \qquad \text{[Balance sheet in t=2]}$$

$$J_1^e \geq \kappa Q_1^e K_1^e, \qquad \text{[ICC, t=1]}$$

where the country index for emerging economies is e with $e = \{a, b\}$, $L_t = Q_t K_t$ is the total lending intermediated with the local firms, F_t is the cross-border borrowing they obtain from the Center, $R_{k,t}$ is the gross revenue rate of the banking services, paid by the firms, $R_{b,t}$ is the interbank borrowing rate for the banks, Q_t is the price of capital, $\delta_B Q_t K_{t-1}$ a start-up capital the bankers get from their owner households, and $\Lambda_{t,t+j}$ is the stochastic discount factor between periods t and $t + j$. The last term in the objective function, and the second constraint are the new terms relative to the previous setup of the bank's problem.

The present value of the bank, will be given by the expected profits in the next period. For this, I include the possibility of exit from the banking business, with an associated probability of survival θ. [15] Thus, with probability $(1 - \theta)$ the bank will fail and transfer back its profits to the household, and with probability θ the bank will be able to continue and pursue future profits.

In this new setup, a key property is that of profits retention. That is, the banks will retain any profits and reinvestment in their business as long as they are allowed to. They continue doing this until they exit the business and report the accumulated profits to the households. As we will, see,

[15] This feature is critical in the main model framework as it allows the incentive compatibility constraint to bind and will prevent the presence of Ponzi schemes in the model

this new feature will boost the effects of policy in these economies because now a prudential tool has a longer lasting effect on the balance sheets of surviving banks.

The remaining constraint is the ICC, imposed to align the incentives of banks with lenders in a way that the former don't abscond assets. This friction will lead to amplified credit spreads.

In the second period, the banks solve a simpler problem, as their objective will not depict a continuation value (making their decisions static):

$$\begin{aligned} J_2^e &= \max_{F_2^e, L_2^e} \mathbb{E}_2 \left\{ \Lambda_{2,3}^e (R_{k,3}^e L_2^e - R_{b,2}^e F_2^e) \right\}, \\ s.t. \quad & L_2^e = F_2^e + \delta_B Q_2^e K_1^e + \theta [R_{k,2}^e L_1^e - R_{b,1}^e F_1^e], \\ & J_2^e \geq \kappa Q_2^e K_2^e, \end{aligned}$$

it can be noticed the problem they solve is affected by their previous intermediation decisions as the balance sheet constraint includes the retained profits from last period.

From these two problems, we can obtain the following first order conditions:

$$[F_1^e]: \quad \mathbb{E}_1 \Omega_1^e (1+\mu_1^e)(R_{k,2}^e - R_{b,1}^e) = \kappa \mu_1^e, \qquad [F_2^e]: \quad \mathbb{E}_2 (1+\mu_2^e)(R_{k,3}^e - R_{b,2}^e) = \kappa \mu_2^e,$$

where μ_t^e is the lagrange multiplier of the ICC of e country bank in each period and $\Omega_1^e = (1-\theta)\Lambda_{1,2}^e + \theta^2 R_{k,3}^e \Lambda_{1,3}^e$ is the effective stochastic discount factor of the bankers that accounts for the probability of a bank failure in the future.

With these conditions the results of the Proposition 1 also apply here, i.e., a binding ICC leads to a positive credit spread that grows with the extent of the friction κ.[16]

Center-Banks. In $t = 1$ the Center-Bank solves:

$$\begin{aligned} J_1^c = \max_{F_1^a, F_1^b, L_1^c, D_1} \mathbb{E}_1 \Big\{ &(1-\theta)\Lambda_{1,2}^c (R_{k,2}^c L_1^c + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b - R_{D,1} D_1) \\ &+ \Lambda_{1,3}^c \theta (R_{k,3}^c L_2^c + R_{b,2}^a F_2^a + R_{b,2}^b F_2^b - R_{D,2} D_2), \Big\} \end{aligned}$$

$$\begin{aligned} s.t \quad & L_1^c + F_1^a + F_1^b = D_1 + \delta_B Q_1^c K_0^c, && \text{[Balance sheet in t=1]} \\ & L_2^c + F_2^a + F_2^b = D_2 + \delta_B Q_2^c K_1^c \\ & \qquad + \theta [R_{k,2}^c L_1^c + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b - R_{D,1} D_1], && \text{[Balance sheet in t=2]} \end{aligned}$$

this problem is dynamic, as it accounts for the potential profits and balance sheets of every intermediation period. These profits also reflect that the bank is a global creditor.

In contrast, in the next period the bank will solve a simpler (static) problem, consisting of

[16] the proof for this extended setup is shown in the appendix D

maximizing the profits of a single term.

$$J_2^c = \max_{F_2^a, F_2^b, L_2^c, D_2} \mathbb{E}_2 \left\{ \Lambda_{2,3}^c (R_{k,3}^c L_2^c + R_{b,2}^a F_2^a + R_{b,2}^b F_2^b - R_{D,2} D_2) \right\}$$

$$s.t. \quad L_2^c + F_2^a + F_2^b = D_2 + \delta_B Q_2^c K_1^c + \theta [R_{k,2}^c L_1^c + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b - R_{D,1} D_1]$$

The resulting first order conditions just reflect that the expected credit spread is zero for all of the assets considered by the center (F_2, L_2, D_2). By using that result and the perfect foresight assumption, we can drop the borrowing cross-border rates ($R_{b,t}$) as they are all equal to the rate for deposits ($R_{D,t}$). Furthermore, the Euler equations for the households with respect to bonds and deposits can be used to simplify further and replace the deposits rate with that of the bonds.

7.2 Production Sectors

There are two types of firms. Here I describe them briefly as the structure is analogous to the main model and the detailed formulation is explained in the previous sections.

Final Good Firm. There is a firm that maximizes their profits, given by the value of the production, plus the sales of undepreciated capital after production, minus the payment of banking loans. The only constraint it faces is the production technology. From the first order condition with respect to the capital, we can pin down the gross rate of return paid to the banks as $R_{k,t} = \frac{r_t + (1-\delta) Q_t}{Q_{t-1}}$ with $t = \{2, 3\}$. Here , $r_t = \frac{\alpha Y_t}{K_{t-1}}$ is the marginal product of capital.

Capital Producers. There is a firm carrying out the investments in each economy. They buy the undepreciated capital from the final good firms and produce the new physical capital for future production. They are subject to a adjustment costs relative to the previous investment level.

7.3 Households

The households own the three types of firms (final goods, capital and banks), and use their profits for consumption, saving, and for supplying the bequests to their banks. They don't pay the banking taxes directly, instead, these are paid by the banks before distributing profits. However, they receive a lump sum transfer from the government.Since the capital is already predetermined in the initial period, there is no intermediation for K_0. Instead, and only for that period, the households rent the capital to the firms directly.

EME-households. The households maximize the present value of their life-stream of utility:

$$\max_{\{C_t^e\}_{t=1}^3, \{B_t^e\}_{t=1}^2} u(C_1^e) + \beta u(C_2^e) + \beta^2 u(C_3^e),$$

$$s.t.$$

$$C_1^e + \frac{B_1^e}{R_1^e} = r_1^e K_0^e + \pi_{f,1}^e + \pi_{inv,1}^e - \delta_B Q_1^e K_0^e,$$

$$C_2^e + \frac{B_2^e}{R_2^e} = \pi_{f,2}^e + \pi_{inv,2}^e + \pi_{bank,2}^e - \delta_B Q_2^e K_1^e + B_1^e - T_2^e,$$
$$C_3^e = \pi_{f,3}^e + \pi_{bank,3}^e + B_2^e - T_3^e, \qquad for\ e = \{a, b\},$$

here B_t denotes the bonds or net foreign assets position, R_t the interest rate on bonds, and T_t the lump sum taxes. As for the profits terms, $\pi_{f,t}$ corresponds to the final goods firms profits, $\pi_{inv,t}$ to the capital firms profits, and $\pi_{bank,t}$ to the banking profits.

Center-households. The households at the Center solve a similar problem. The only difference is that they do have access to local deposits and that their banking profits account for the fact that their banks act as creditors of the EMEs:

$$\max_{\{C_t^c\}_{t=1}^3, \{B_t^c\}_{t=1}^2} u(C_1^c) + \beta u(C_2^c) + \beta^2 u(C_3^c),$$

$s.t.$

$$C_1^c + \frac{B_1^c}{R_1^c} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_B Q_1^c K_0^c,$$
$$C_2^c + \frac{B_2^c}{R_2^c} + D_2 = \pi_{f,2}^c + \pi_{inv}^c + \pi_{bank,2}^c - \delta_B Q_2^c K_1^c + B_1^c + R_{D,1} D_1 - T_2^c,$$
$$C_3^c = \pi_{f,3}^c + \pi_{bank,3}^c + B_2^c + R_{D,2} D_2 - T_3^c.$$

7.4 Macroprudential Policy

The frictions in the banking sector generate a role for policymaking. This policy takes the form of a macroprudential policy tax that targets the banks. A government will tax the rate of return of the bankers in each period, and afterwards, rebates the tax income ($\tau_t r_t K_t$) back to the households.

As a result, the effective revenue rate perceived by the banks after paying their taxes is: $R_{k,t} = \frac{(1-\tau_t) r_t + (1-\delta) Q_t}{Q_{t-1}}$, where τ_t is the macroprudential tax.

Notice that since τ_2 affects the first intermediation period, when the banks' decisions are forward looking, and τ_3 the terminal period, where the decisions are static, it also follows that τ_2 and τ_3 are, respectively, a forward-looking and a static policy tool. Finally, in this case the Proposition 2 also follows, i.e., an increase in the macroprudential tool decreases the leverage ratio of the banking sector.[17]

7.5 Equilibrium

Market Clearing and International Links. The bonds market depicts a zero-net-supply in the first two periods. The uncovered parity holds, which allows us to equate the interest rate of bonds in each location $R_t^a = R_t^b = R_t^c = R_t$. Furthermore, from the Center's Euler equations for the deposits and bonds we can determine that $R_{D,t} = R_t$ for $t = \{1, 2\}$.

[17]The proof for this result is shown in the appendix D.

Equilibrium. Given the policies $\tau_t = \{\tau_t^a, \tau_t^b, \tau_t^c\}_{t=2,3}$, the equilibrium consists on the prices $\{Q_t^i\}$, rates $\{R_1, R_2, R_{k,2}^i, R_{k,3}^i\}$ and quantities $\{B_1^i, B_2^i, K_1^i, K_2^i, F_1^e, F_2^e, D_1, D_2\}$ and $\{C_t^i\}$ for $t = \{1,2,3\}$, with $i = \{a,b,c\}$ and $e = \{a,b\}$ such that: in each period, the households solve their utility maximization problem, the firms solve their profit maximization problems, the banks maximize their value, the government runs a balanced budget, and the goods and bonds markets clear.[18]

7.6 Welfare Effects of Policy

Based on the 3-period model approximate the welfare effects of policy at the local and cross-border level. In this case, we can pay special attention to the effects of forward-looking policies.

Numerical solution. I solve the model private equilibrium using the parameters shown in table A.2. The agents take the taxes as given, and hence, I have to provide them exogenously when solving for the private equilibrium. I solve the model with zero taxes and compare it with the solution for different levels of the policy tools. The results are shown in table 5.

Table 5: Welfare effects in 3-period model

Effect		Change in tax			
		1%	3%	5%	8%
Direct effect	$\tau_2^a \rightarrow W^a$	0.146	0.144	0.142	0.138
of τ_2	$\tau_2^b \rightarrow W^b$	0.146	0.144	0.142	0.138
	$\tau_2^c \rightarrow W^c$	-0.242	-0.457	-0.179	-0.027
Cross-border	$\tau_2^a \rightarrow W^b$	-0.047	-0.047	-0.047	-0.048
effect	$\tau_2^a \rightarrow W^c$	-0.016	-0.017	-0.017	-0.017
	$\tau_2^b \rightarrow W^a$	-0.047	-0.047	-0.047	-0.048
	$\tau_2^b \rightarrow W^c$	-0.016	-0.017	-0.017	-0.017
	$\tau_2^c \rightarrow W^a$	-0.162	-0.226	-0.180	-0.155
	$\tau_2^c \rightarrow W^b$	-0.162	-0.226	-0.180	-0.155
Direct effect	$\tau_3^a \rightarrow W^a$	0.057	0.057	0.056	0.056
of τ_3	$\tau_3^b \rightarrow W^b$	0.057	0.057	0.056	0.056
	$\tau_3^c \rightarrow W^c$	-0.087	-0.122	-0.243	-0.134
Cross-border	$\tau_3^a \rightarrow W^b$	-0.018	-0.018	-0.018	-0.018
effect	$\tau_3^a \rightarrow W^c$	0.006	0.005	0.004	0.003
	$\tau_3^b \rightarrow W^a$	-0.018	-0.018	-0.018	-0.018
	$\tau_3^b \rightarrow W^c$	0.006	0.005	0.004	0.003
	$\tau_3^c \rightarrow W^a$	-0.051	-0.059	-0.087	-0.074
	$\tau_3^c \rightarrow W^b$	-0.051	-0.059	-0.087	-0.074

Note: Each column denotes a different size of the change in taxes. The specific tax changed is indicated in the second column, as well as the welfare affected. The effect is obtained by the numerical approximation to the derivative of welfare with respect to a change in the tax ($\frac{\Delta W}{\Delta \tau}$). The superindexes refer to the countries with a: EME-A, b: EME-B and c: Center.

[18] A summary of the final set of equilibrium conditions used for solving the model can be found in table D7. I solve this system of equations non-linearly and using a perfect foresight approximation.

The table shows the numerical approximation to the derivative in welfare with respect to a change in a tax. The results indicate that the welfare effect of forward-looking taxes (τ_2) is stronger than that of the terminal (static) tax (τ_3). This is particularly true for the cross-border effects of the taxes in both the Center and peripheral countries. This is consistent with studies such as Davis and Devereux (2019) and Gertler, Kiyotaki, and Prestipino (2020) where the taxes that are pre-emptive and prudential in nature are more effective than crisis-management policies.

In terms of international policy effects, these results indicate there is a negative cross-border policy spillover from setting taxes set in the EMEs as the local and international welfare responses to a change in the emerging taxes have opposite signs. Finally, the spillovers from the Center tax are positive, suggesting potential policy free-riding incentives by the peripheries that may want to rely on the Center macroprudential taxes.

Importantly, the new feature on the relative effect of the taxes, namely that taxes with longer-lived effects on the profits of intermediaries magnify the effect of policy, which we can obtain as a result of profit retention and continuation in the banking business, could in principle lead to more sizable welfare differences between cooperative and non-cooperative regimes.

Analytical Welfare Effects We can do a similar exercise as in the simpler model to get the analytical welfare effects along the lines of Davis and Devereux (2019). The key difference here is that we track the effect of one more tax, and more importantly, the tax with persistent effects on the balance sheets will depict now both dynamic welfare effects, i.e., it affects future utility flows through their effect on future net-worth of the banks and capital accumulation.

A social planner will consider the following welfare expressions.

$$\begin{aligned} W_0^a = u\left(C_1^a\right) + \beta u\left(C_2^a\right) + \beta^2 u\left(C_3^a\right) + \lambda_1^a \left\{ A_1^a K_0^{a\ \alpha} + Q_1^a I_1^a - C(I_1^a, I_0^a) - \delta_B Q_1^a K_0^a - C_1^a - \frac{B_1^a}{R_1} \right\} \\ + \beta\lambda_2^a \left\{ \varphi(\tau_2^a) A_2^a K_1^{a\ \alpha} + Q_2^a I_2^a - C(I_2^a, I_1^a) - \delta_B Q_2^a K_1^a + \kappa\left(\frac{Q_1^a K_1^a}{\Lambda_{12}} - \Lambda_{23}\theta Q_2^a K_2^a\right) + B_1^a - C_2^a - \frac{B_2^a}{R_2} \right\} \\ + \beta^2 \lambda_3^a \left\{ \left(1 - \alpha\left(1 - \tau_3^a\right)\right) A_3^a K_2^{a\ \alpha} + \kappa \frac{Q_2^a K_2^a}{\Lambda_{12}} + B_2^a - C_3^a \right\}, \end{aligned} \tag{2}$$

with $\varphi(\tau) = (1 - \alpha\,(1 - \tau))$

$$\begin{aligned} W_0^c = u\left(C_1^c\right) + \beta u\left(C_2^c\right) + \beta^2 u\left(C_3^c\right) + \lambda_1^c \left\{ A_1^c K_0^{c\ \alpha} + Q_1^c I_1^c - C(I_1^c, I_0^c) - \delta_B Q_1^c K_0^c - C_1^c - \frac{B_1^c}{R_1} - D_1 \right\} \\ + \beta\lambda_2^c \Big\{ \left(1 - \alpha\theta\left(1 - \tau_2^c\right)\right) A_2^c K_1^{c\ \alpha} + Q_2^c I_2^c - C\left(I_2^c, I_1^c\right) \\ + (1-\theta)\left((1-\delta) Q_2^c K_1^c + R_{b1}^a F_1^a + R_{b1}^b F_1^b\right) - \theta R_1 D_1 - \delta_B Q_2^c K_1^c + B_1^c - C_2^c - \frac{B_2^c}{R_2} - D_2 \Big\} \\ + \beta^2 \lambda_3^c \Big\{ A_3^c K_2^{c\ \alpha} + (1-\delta) Q_3 K_2^c + R_{b2}^a F_2^a + R_{b2}^b F_2^b + B_2 - C_3^c \Big\}. \end{aligned} \tag{3}$$

These expressions are obtained by setting the welfare plus the budget constraints in each period and imposing the private equilibrium conditions. These are equivalent to the usual welfare as the constraints are binding, however, this setup allows to gauge the effects of policy more broadly.

Next, I obtain the welfare effects from changing the taxes. Here, a planner setting the tax in the last period[19] takes the taxes and variables from the previous period as given, hence, we just need to differentiate with respect to $R_2, Q_2, I_2.K_2$ for both types of countries plus $R_{b,2}, F_2$ for the center. In contrast, for the first period we must also consider the lagged versions of these variables.

The welfare effects of the taxes are:

For the EMEs:

$$\frac{dW_0^a}{d\tau_2^a} = \beta\lambda_2^a\Bigg\{\overbrace{\alpha_1(\kappa)\frac{dK_1^a}{d\tau_2^a} + \alpha_2(\kappa)\frac{dQ_1^a}{d\tau_2^a} + \frac{B_1^a}{R_1}\frac{dR_1}{d\tau_2^a} + \alpha Y_2^a}^{\text{static effects}} + \overbrace{\alpha_3(\kappa)\frac{dK_2^a}{d\tau_2^a} + \alpha_4(\kappa)\frac{dQ_2^a}{d\tau_2^a} + \frac{B_2^a}{(R_2)^2}\frac{dR_2}{d\tau_2^a}}^{\text{dynamic effects}}\Bigg\},$$

$$\frac{dW_0^a}{d\tau_3^a} = \beta\lambda_2^a\Bigg\{\overbrace{\alpha_5(\kappa)\frac{dK_2^a}{d\tau_3^a} + \alpha_4(\kappa)\frac{dQ_2^a}{d\tau_3^a} + \frac{B_2^a}{(R_2)^2}\frac{dR_2}{d\tau_3^a} + \alpha\frac{Y_3^a}{R_2}}^{\text{(only) static effects}}\Bigg\},$$

with $\alpha_1(\kappa) = \kappa R_1 Q_1^a + \varphi(\tau_2^a) r_2^a$, $\alpha_2(\kappa) = R_1(I_1^a + \kappa K_1^a)$, $\alpha_3(\kappa) = \kappa(1-\theta\Lambda_{23})Q_2^a + \varphi(\tau_3^a)\Lambda_{12} r_3^a$, $\alpha_4(\kappa) = I_2^a + \kappa(1-\theta\Lambda_{23})K_2^a$, $\alpha_5(\kappa) = \kappa(1-\theta\Lambda_{23})Q_2^a + \varphi(\tau_3^a)\Lambda_{23} r_3^a$, and $\frac{\partial\alpha_s}{\partial\kappa} > 0$ for $s = \{1, ..., 5\}$.

For the Center:

$$\frac{dW_0^c}{d\tau_2^c} = \overbrace{\beta\lambda_2^c\left\{\gamma_1\frac{dK_1^c}{d\tau_2^c} + \left(\tfrac{B_1^c}{R_1} - \theta D_1\right)\frac{dR_1}{d\tau_2^c} + \tfrac{K_1^c}{R_1}\frac{dQ_1^c}{d\tau_2^c} + \alpha\theta Y_2^c + (1-\theta)\left(F_1^{ab}\frac{dR_{b,1}^{eme}}{d\tau_2^c} + R_{b,1}^{eme}\frac{dF_1^{ab}}{d\tau_2^c}\right)\right\}}^{\text{static effects}}$$
$$\underbrace{+\beta^2\lambda_3^c\left\{\gamma_2\frac{dK_2^c}{d\tau_2^c} + \tfrac{B_2^c}{R_2}\frac{dR_2}{d\tau_2^c} + \gamma_3\frac{dQ_2^c}{d\tau_2^c} + F_2^{ab}\frac{dR_{b,2}^{eme}}{d\tau_2^c} + R_{b,2}^{eme}\frac{dF_2^{ab}}{d\tau_2^c}\right\}}_{\text{dynamic effects}},$$

$$\frac{dW_0^c}{d\tau_3^c} = \beta^2\lambda_3^c\left\{\gamma_2\frac{dK_2^c}{d\tau_3^c} + \frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \gamma_3\frac{dQ_2^c}{d\tau_3^c} + F_2^{ab}\frac{dR_{b,2}^{eme}}{d\tau_3^c} + R_{b,2}^{eme}\frac{dF_2^{ab}}{d\tau_3^c}\right\},$$

with $\gamma_1 = (1-\alpha\theta(1-\tau_2^c))r_2^c + (1-\theta)(1-\delta)Q_2^c$, $\gamma_2 = (r_3^c + (1-\delta)Q_3)$, $\gamma_3 = R_2(I_2^c + (1-\theta)(1-\delta)K_1^c)$, and $F_t^{ab} = F_t^a + F_t^b$.

The interpretation of these effects goes as follows: First, we can see that there are more sources of variations for taxes that are forward-looking in nature (τ_2), whereas for the terminal taxes we only get the static effects, which might explain why the former have stronger effects.

On the other hand, there are four drivers of the static welfare effects of the tax as pointed in previous sections, these are changes in welfare from (i) hindering the capital accumulation, (ii) changes in the global interest rate, which are proportional to the net foreign asset position, (iii) changes in the prices of capital, and in addition, for the Center, (iv) changes in the cross-border

[19]The time index of the tax corresponds to the period in which the banks pay it, i.e., the initial tax is τ_2 and the one for the final intermediation period is τ_3.

lending rates and quantities. The welfare effects (i) and (iv) are negative and capture a halting in banking intermediation, while the sign of (ii) and (iii) depends, respectively, on whether an economy is a net creditor or on the investment growth, in that sense, we expect (ii) to be positive for an emerging economy and negative for the Center.

The dynamic effects will have similar drivers. However, in all cases these also include effects on future variables, for instance, (i) would include the effect on future capital accumulation and (ii) on the future net assets position. The signs for the dynamic effects may not be as straightforward. Then, we may expect similar signs but with potential corrections, for example, when tighter initial taxes imply delaying investment or capital accumulation plans for future periods.

Optimal taxes. We can obtain expressions for the optimal taxes by taking these welfare effects as first-order conditions for the planner as in prior sections. The features driving each tool are analogous to the ones described before. As before, we have that regulators at the Center trade-off local intermediation for global lending, a relevant feature for understanding the importance of the Center could have in generating gains from policy cooperation.

In addition to the previous findings, now we have that the forward-looking taxes now are driven by the changes on future variables, e.g., capital accumulation with after changes in the level of banking intermediation. The expressions for these optimal taxes are shown in the appendix D.

Welfare differences between regimes Our simplified baseline setup delivered cross-border welfare effects of policy that can be relevant depending on the type of economy where it originates and the extent of the financial frictions. However, a simple welfare comparison between regimes delivered similar outcomes.

With two extensions, namely the addition of policy costs and the higher persistence of policy effects on the balance sheet of the intermediaries due to profits retaining, we can see how the welfare differences between regimes are increased, either by limiting the level of interventionism allowed, or by magnifying the effect of the prudential tools in the economy. In this vein, it would not be sensible to propose, as a generality, the absence of welfare gains from policy cooperation based on our baseline setup, but instead, that it is important to acknowledge how the inclusion of additional features can open a broader scope for meaningful departures between nationally-oriented and cooperative policies.[20]

[20] Another important feature could be that considering a stochastic environment where the co-movement of country shocks can be incorporated into the regimes welfare accounting exercise, we do this in Granados (2021).

8 Conclusions

In this paper we study the international policy leakages at the macroprudential level for economies that are financially integrated. The environment we consider is one with a financial center that acts as a global creditor for a set of emerging economies. We aim to verify their existence in different types of economies, their drivers, the policies they generate and whether they open a scope for policy coordination at different aggregation levels (global, regional, center-periphery).

For that, we propose a multilateral open economy framework in which financial frictions create a wedge between the cost of capital and the deposits rate (or return on non-banking activities) that create a role for macroprudential interventions. The regulator may want to mitigate the financial friction, but due to the policy leakages, new policy incentives may arise that push national regulators to pursue local benefits at the expense of other economies.

Our setup is simplified and allows to find analytical expressions for the welfare effects of policies and optimal national tools, as well as obtain numerical solutions for the equilibria in a menu of policy regimes. Our findings suggest that, the policy spillovers exist and are stronger when originating from financial centers, but can also originate at emerging economies. Additionally, the effect of the macroprudential toolkit (and leakages) are magnified by the extent of the frictions.

Based on these results we verify of policy coordination. In our simplified setup we find no gains. Instead, we obtain a different combination of optimal policies. The optimal toolkit under cooperation, however, will be more conservative and allow for lower levels of interventionism.

We inquire further into this result with a number of extensions and obtain that: (i) gains emerge in scenarios where policies are costly, and (ii) environments with more persistent effects of policies, where they affect future banking profits magnifies the effects of policy further. Both (i) and (ii) open scope for higher welfare differences between national-oriented and cooperative regimes, and are related to primary concerns of financial regulators about how to mitigate or share the burden of regulation costs as well as manage their effect in the real economy.

The extended results show how important it is to account for the entire effects of policies over time, which together with the application of higher order welfare approximations in stochastic settings may allow for and justify a comprehensive welfare accounting exercise. Such approach is left for future research. Similarly, other related directions worth exploring for future research are the interaction with other policy instruments when more distortions are present.[21]

[21]Previous bilateral or within-country studies in these directions are found in Mandelman (2010) and Fujiwara and Teranishi (2017) and De Paoli and Paustian (2017)

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A Baseline model description and results

A.1 Summary of baseline model equations

The small scale model after simplifications features 29 variables in total (for the three economies together).

Each equation "Common to all countries" enters the system thrice (each with different country variables) for each period indicated, the second group equations "for EMEs" enters the system twice (one for each EME country $\{a, b\}$), the rest of equations are counted only once.

Table A1: Summary of equilibrium equations of the small scale model

Common to all countries:	
$Q_t = 1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \zeta\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - \Lambda_{t,t+1}\zeta\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2$	[Price of Capital, t={1,2}]
$K_1 = I_1 + (1-\delta)K_0$	[Capital Dynamics]
$R_{k,2} = \frac{(1-\tau_2)\alpha A_2 K_1^{\alpha-1} + (1-\delta)Q_2}{Q_1}$	[Banks rate of return]
$C_1^{-\sigma} = \beta R_1 C_2^{-\sigma}$	[Euler Equation, bonds]
for EMEs:	
$Q_1 K_1 = F_1 + \delta_B Q_1 K_0$	[bal. sheet of banks]
$R_{k,2} Q_1 K_1 - R_1 F_1 = k R_{k,2} Q_1 K_1$	[ICC]
$(1+\mu)\left(R_{k,2} - R_1\right) = \mu \cdot \kappa R_{k,2}$	[Credit spread]
$C_1 + \frac{B_1}{R_1} = r_1 K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0$	[BC for t=1]
$C_2 = \pi_{f,2} + \pi_{b,2} + B_1 - T_2$	[BC for t=2]
for the Center:	
$Q_1^c K_1^c + F_1^a + F_1^b = D_1 + \delta_B Q_1^c K_0^c$	[Bal. sheet of banks]
$C_1^c + \frac{B_1^c}{R_1} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{1nv,1}^c - \delta_B Q_1^c K_0^c$	[BC for t=1]
$C_2^c = \pi_{f,2}^c + \pi_{b,2}^c + R_1 D_1 + B_1^c - T_2^c$	[BC for t=2]
International Links:	
$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0$	[Net Supply of Bonds]

Note: when solving the model I normalize the initial world capital to 1 and distribute it across countries according to their population sizes. Initial investment is set as $I_0 = \delta K_0$, and an additional simplification is considered (but not substituted) as $R_{k,2}^c = R_1$.

Auxiliary definitions:

Stochastic discount factor: $\Lambda_{1,2} = \beta\left(\frac{C_2}{C_1}\right)^{-\sigma}$,

Lump-sum taxes: $T_2 = -\tau_2 r_2 K_1$,

Marginal product of capital: $r_2 = \alpha A_2 K_1^{\alpha-1}$,

Profits of firms: $\pi_{f,t} = (1-\alpha)A_t K_{t-1}^{\alpha}$, for $t = \{1, 2\}$,

Profits of investors: $\pi_{inv,1} = Q_1 I_1 - C(I_1, I_0) = Q_1 I_1 - I_1\left(1 + \frac{\zeta}{2}\left(\frac{I_1}{I_0} - 1\right)^2\right)$,

Profits of bankers in EMEs, t=2: $\pi_{b,2}^e = R_{k,2}^e Q_1^e K_1^e - R_1 F_1^e$,

Profits of bankers in Center, t=2: $\pi_{b,2}^c = R_{k,2}^c Q_1^c K_1^c + R_1^a F_1^a + R_1^b F_1^b - R_1 D_1$.

Finally, due to the optimally conditions we can equalize several related rates: $R_{k,2}^c = R_1^a = R_1^b = R_{D,1} = R_1$

A.2 Parameters of the models

The table contains the parameter used in the baseline and extended 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
Survival rate of banks	θ	0.9	Gertler and Karadi (2011)

Table A2: Parameters in the model

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

C Numerical simulation results for model extensions

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 $\psi = 1$

	Policy Scheme			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
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

D Results from Extended Three-Periods Model

Table D7: Summary of equilibrium equations of the three-period model

Common to all countries:

$Q_t = 1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \zeta\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - \Lambda_{t,t+1}\zeta\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2$	[Price of Capital, t={1,2}]
$K_t = I_t + (1-\delta)K_{t-1}$	[Capital Dynamics, t={1,2}]
$R_{k,t} = \frac{(1-\tau_t)\alpha A_t K_{t-1}^{\alpha-1} + (1-\delta)Q_t}{Q_{t-1}}$	[Banks rate of return, t={2,3}]
$C_t^{-\sigma} = \beta R_t C_{t+1}^{-\sigma}$	[Euler Equation, bonds, t={1,2}]

for EMEs:

$Q_1K_1 = F_1 + \delta_B Q_1 K_0$	[bal. sheet of banks, t=1]
$Q_2K_2 = F_2 + \delta_B Q_2 K_1 + \theta\left[R_{k,2}Q_1K_1 - R_{b,1}F_1\right]$	[bal. sheet of banks, t=2]
$(1-\theta)\Lambda_{1,2}\left(R_{k,2}Q_1K_1 - R_1F_1\right) + \Lambda_{1,3}\theta\left(R_{k,3}Q_2K_2 - R_2F_2\right) = kQ_1K_1$	[ICC, t=1]
$\Omega_1(1+\mu_1)\left(R_{k,2} - R_1\right) = \mu_1\kappa$	[Credit spread, t=2]
$\Lambda_{2,3}\left(R_{k,3}Q_2K_2 - R_2F_2\right) = kQ_2K_2$	[ICC, t=2]
$(1+\mu_2)\Lambda_{2,3}\left(R_{k,3} - R_2\right) = \mu_2\kappa$	[Credit spread, t=3]
$C_1 + \frac{B_1}{R_1} = r_1K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0$	[BC for t=1]
$C_2 + \frac{B_2}{R_2} = \pi_{f,2} + \pi_{inv,2} + \pi_{b,2} - \delta_B Q_2 K_1 + B_1 - T_2$	[BC for t=2]
$C_3 = \pi_{f,3} + \pi_{b,3} + B_2 - T_3$	[BC for t=3]

for the Center:

$Q_1^cK_1^c + F_1^a + F_1^b = D_1 + \delta_B Q_1^c K_0^c$	[Bal. sheet of banks, t=1]
$Q_2^cK_2^c + F_2^a + F_2^b = D_2 + \delta_B Q_2^c K_1^c + \theta\left[R_{k,2}^c Q_1^c K_1^c + R_1^a F_1^a + R_1^b F_1^b - R_1 D_1\right]$	[Bal. sheet of banks, t=2]
$C_1^c + \frac{B_1^c}{R_1} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{1nv,1}^c - \delta_B Q_1^c K_0^c$	[BC for t=2]
$C_2^c + \frac{B_2^c}{R_1} + D_2 = \pi_{f,2}^c + \pi_{inv,2}^c + \pi_{b,2}^c - \delta_B Q_2^c K_1^c + R_1 D_1 + B_1^c - T_2^c$	[BC for t=2]
$C_3^c = \pi_{f,3}^c + \pi_{b,3}^c + B_2^c + R_2 D_2 - T_3^c$	[BC for t=3]

International Links:

$n_a B_t^a + n_b B_t^b + n_c B_t^c = 0$	[Net Supply of Bonds, t = {1,2}]

Note: when solving the model normalize the initial world capital to 1 and distribute it across countries according to their population sizes. Initial investment is set as $I_0 = \delta K_0$, and since $I_3 = 0$ the price Q_3 is a constant.

Auxiliary definitions:

Stochastic discount factor: $\Lambda_{t,t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}$

Effective discount factor of banks: $\Omega_1 = (1-\theta)\Lambda_{1,2} + \theta^2 R_{k,3}\Lambda_{1,3}$

Taxes: $T_t = -\tau_t r_t K_{t-1}$

Marginal product of capital: $r_t = \alpha A_t K_{t-1}^{\alpha-1}$

Profits of firms: $\pi_{f,t} = (1-\alpha)A_t K_{t-1}^{\alpha}$

Profits of investors: $\pi_{inv,t} = Q_t I_t - C(I_t, I_{t-1}) = Q_t I_t - I_t\left(1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)$

Profits of bankers in EMEs, t=2: $\pi^e_{b,2} = (1-\theta)\left(R_{k,2}Q^e_1K^e_1 - R_1F^e_1\right)$

Profits of bankers in EMEs, t=3: $\pi^e_{b,3} = R^e_{k,3}Q^e_2K^e_2 - R_2F^e_2, \qquad$ e = {a,b}

Profits of bankers in Center, t=2: $\pi^c_{b,2} = (1-\theta)\left(R^c_{k,2}Q^c_1K^c_1 + R^a_1F^a_1 + R^b_1F^b_1 - R_1D_1\right)$

Profits of bankers in Center, t=3: $\pi^c_{b,3} = R^c_{k,3}Q^c_2K^c_2 + R^a_{b2}F^a_2 + R^b_2F^b_2 - R_2D_2$

Proof of proposition 1 for extended model.

Proof. W.L.O.G. I will work in a perfect foresight setup, otherwise the same result applies to the expected credit spread.

The time index of the spread is given by the time in which the revenue rate is paid. We can obtain the credit spreads from the EME-Banks F.O.C. with respect to F_1 and F_2.

For $t = 2, 3$ the spreads are given by:

$$Spr_2 = R_{k,2} - R_{b,1} = \frac{\mu_1\kappa}{(1+\mu_1)\Omega_1}$$
$$Spr_3 = R_{k,3} - R_{b,2} = \frac{\mu_2\kappa}{(1+\mu_2)\Lambda_{2,3}}$$

if the ICCs bind we have $\mu_t > 0$ and it follows that:

$$\frac{\partial Spr_2}{\partial\kappa} = \frac{\mu_1}{(1+\mu_1)\Omega_1} > 0$$
$$\frac{\partial Spr_3}{\partial\kappa} = \frac{\mu_2}{(1+\mu_2)\Lambda_{2,3}} > 0$$

■

Proof of proposition 2 for extended model.

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

From the ICC of the EME-Banks for each period I obtain the leverage, defined as total assets over net worth. Then I differentiate the resulting expression with respect to the tax.

For the last period:

The ICC is: $\qquad J_2 = \Lambda_{2,3}(R_{k,3}L_2 - R_{b,2}F_2) = \kappa_2L_2$

By substituting the foreign lending $F_2 = L_2 - N_2$, where N_2 is the net worth in the last period (bequests plus retained previous profits) and solving for L_2:

$$L_2 = \overbrace{\frac{-\Lambda_{2,3} R_{b,2}}{\Lambda_{2,3}(R_{k,3} - R_{b,2}) - \kappa}}^{\phi_2} N_2$$

where ϕ_2 denotes the leverage. Now, I substitute $R_{k,3}(\tau_3) = [(1-\tau_3)r_3 + (1-\delta)Q_3]/Q_2$ and differentiate with respect to the policy instrument:

$$\frac{\partial \phi_2}{\partial \tau_3} = -\frac{(\Lambda_{2,3})^2 R_{b,2} \cdot r_3}{(\Lambda_{2,3}(R_{k,3} - R_{b,2}) - \kappa)^2 Q_2} < 0$$

For the first period:

The procedure is the same but the algebra is a bit lengthier as I substitute both balance sheets ($F_1 = L_1 - \delta_B Q_1 K_0$, and $F_2 = Q_2 K_2 - N_2$) in the value of the bank in the right hand side of the ICC for the first intermediation period $J_1 = \kappa L_1$.

After substitutions and some algebra the ICC becomes:

$$[\tilde{\Omega}_1(R_{k,2} - R_{b,1}) - \kappa]L_1 + [\tilde{\Omega}_1 R_{b,1}]\delta_B Q_1 K_0 + \Lambda_{1,3}\delta[(R_{k,3} - R_{b,2})L_2 + R_{b,2}\delta_B Q_2 K_1] = 0$$

With $\tilde{\Omega}_1 = (1-\theta)\Lambda_{1,2} + \Lambda_{1,3}\theta^2 R_{b,2}$

The leverage is given by:

$$\phi_1 = \frac{L_1}{\delta_B Q_0 K_1} = \frac{-[\tilde{\Omega}_1 R_{b,1}] - \Lambda_{1,3}\theta[(R_{k,3} - R_{b,2})L_2 + R_{b,2}\delta_B Q_2 K_1]/(\delta_B Q_0 K_1)}{[\tilde{\Omega}_1(R_{k,2} - R_{b,1}) - \kappa]}$$

Then,

$$\frac{\partial \phi_1}{\partial \tau_2} = -\frac{\tilde{\Omega}_1 R_{b,1} + \Lambda_{1,3}\theta[(R_{k,3} - R_{b,2})L_2 + R_{b,2}\delta_B Q_2 K_1]/(\delta_B Q_0 K_1)}{[\tilde{\Omega}_1(R_{k,2} - R_{b,1}) - \kappa]^2} \cdot \left(\frac{r_2(\tau_2)}{Q_1}\right) < 0$$

Finally, notice how in the expressions $\frac{\partial \phi_1}{\partial \tau_2}$ and $\frac{\partial \phi_2}{\partial \tau_3}$ the denominator implies that the derivatives grow with the friction parameter κ. ∎

D.1 Optimal Taxes in extended model

Individual optimal taxes. The procedure for obtaining the optimal taxes consists in equating the welfare effects $\frac{dW}{d\tau}$ to zero and then solving for the tax. This is done via backwards induction. First, I solve the last period case for τ_3, and afterwards in the first period for $\tau_2(\tau_3, \cdot)$. Afterwards, I replace the solution found in the first step to obtain τ_2.

In the case of the Center and for the last period, there is no explicit τ_3^c terms in the welfare effect. Then, to pintpoint the tax I use the fact that banking returns show the tax explicitely ($R_{k,3}(\tau_3)$) to back out the tax after substituting it for one of the rates it equates.

$$\tau_2^a = \overbrace{\frac{\alpha-1}{\alpha} - \frac{1}{\alpha r_2^a}\left\{(I_1+\kappa K_1)\frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a} + \kappa R_1 Q_1^a\right.}^{\text{contemporaneous component}}$$
$$\underbrace{\left. + \left(1-\frac{\Lambda_{1,2}}{\Lambda_{2,3}}\right)\alpha_4(\kappa)\frac{dQ_2^a}{dK_1^a} + (1-\Lambda_{1,2})\frac{B_2^a}{R_2}\frac{dR_2}{dK_1^a} + \kappa\left(1+\theta\left(\Lambda_{1,2}-\Lambda_{2,3}\right)-\frac{\Lambda_{1,2}}{\Lambda_{2,3}}\right)Q_2^a\frac{dK_2^a}{dK_1^a}\right\}}_{\text{forward-looking component}}$$

$$\tau_3^a = -\frac{1}{\Lambda_{2,3}\alpha r_3^a}\left\{\alpha_4(\kappa)\frac{dQ_2^a}{dK_2^a} + \Lambda_{2,3}\frac{B_2^a}{R_2}\frac{dR_2}{dK_2^a} + \kappa\left(1-\theta\Lambda_{2,3}\right)Q_2^a\right\} + 1 - \frac{1}{\alpha}$$

$$\tau_2^c = \overbrace{-\frac{1}{\theta\alpha r_2^c}\left\{(1-\theta)(1-\delta)Q_2^c + \left(\tfrac{B_1^c}{R_1}-\theta D_1\right)\frac{dR_1}{dK_1^c} + R_1 K_1^c\frac{dQ_1^c}{dK_1^c} + (1-\theta)\left(\frac{dR_{b,1}^{eme}}{dK_1^c}F_1^{ab} + R_{b1}^{eme}\frac{dF_1^{ab}}{dK_1^c}\right)\right.}^{\text{contemporaneous component}}$$
$$\underbrace{\left. + \frac{1}{R_2}\left[\gamma_2\frac{dK_2^c}{dK_1^c} + \frac{B_2^c}{R_2}\frac{dR_2}{dK_1^c} + \gamma_3\frac{dQ_2^c}{dK_1^c} + \left(\frac{dR_{b2}^{eme}}{dK_1^2}F_2^{ab} + R_{b2}^{eme}\frac{dF_2^{ab}}{dK_1^c}\right)\right]\right\}}_{\text{forward looking component}} + \frac{\alpha\theta-1}{\alpha\theta}$$

$$\tau_3^c = \frac{Q_2^c}{r_3^c}\left\{\gamma_2\frac{dK_2^c}{dF_2^{ab}} + \Lambda_{2,3}B_2^c\frac{dR_2}{dF_2^{ab}} + \gamma_3\frac{dQ_2^c}{dF_2^{ab}} + \left(F_2^{ab}\right)\frac{dR_{b2}^{\text{eme}}}{dF_2^{ab}}\right\} + \frac{(1-\delta)Q_3}{r_3^c} + 1$$

With $\alpha_4(\kappa) = I_2^a + \kappa\left(1-\theta\Lambda_{2,3}\right)K_2^a$, $\gamma_2 = r_3^c + (1-\delta)Q_3$, $\gamma_3 = R_2\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)$, $F_t^{ab} = F_t^a + F_t^b$, and $\frac{\partial\alpha_4(\kappa)}{\partial\kappa} > 0$.

Online Appendix

E Solution of the Model

Original System:

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

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

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

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

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

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

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

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

$$\pi_{b,2} \geq k R_{k,2} Q_1 K_1 \tag{(27)-(28)}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

We replace the following profits:

$$\pi_{f,t} = A_t(\xi_t K_{t-1})^\alpha - r_t K_{t-1}, \quad for\ t = \{1, 2\}$$
$$\pi_{inv,1} = Q_1 I_1 - I_1 \left(1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2\right)$$
$$\pi^s_{b,2} = R^s_{k,2} Q^s_1 K^s_1 - R^s_{b,1} F^s_1, \quad for\ s = \{i, e\}$$
$$\pi^c_{b,2} = R^a_{b,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} Q^c_1 K^c_1 - R_{D,1} D_1$$

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

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

- *S2:* Remove already solved equations (function of parameters or pre-defined variables, hence we drop $Q2, Y_1$). Replace $Y_2,\ r_1,\ r_2$, $F^s_1 = Q^s_1 K^s_1 - \delta_b Q^s_1 K^s_0$. From (41) and (42) obtain $R_1 = R_{D,1}$ and replace.

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

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

$$Q^a_1 = 1 + \frac{\zeta}{2}\left(\frac{I^a_1}{\bar{I}^a} - 1\right)^2 + \zeta\left(\frac{I^a_1}{\bar{I}^a} - 1\right)\frac{I^a_1}{\bar{I}^a} \tag{1}$$
$$Q^b_1 = 1 + \frac{\zeta}{2}\left(\frac{I^b_1}{\bar{I}^b} - 1\right)^2 + \zeta\left(\frac{I^b_1}{\bar{I}^b} - 1\right)\frac{I^b_1}{\bar{I}^b} \tag{2}$$
$$Q^c_1 = 1 + \frac{\zeta}{2}\left(\frac{I^c_1}{\bar{I}^c} - 1\right)^2 + \zeta\left(\frac{I^c_1}{\bar{I}^c} - 1\right)\frac{I^c_1}{\bar{I}^c} \tag{3}$$
$$K^a_1 = I^a_1 + (1-\delta)\xi^a_1 K^a_0 \tag{4}$$
$$K^b_1 = I^b_1 + (1-\delta)\xi^b_1 K^b_0 \tag{5}$$
$$K^c_1 = I^c_1 + (1-\delta)\xi^c_1 K^c_0 \tag{6}$$
$$R^a_{k,2} = \frac{(1-\tau^a)\alpha A^a_2 \xi^a_2{}^{\alpha} K^a_1{}^{\alpha-1} + (1-\delta)\xi^a_2 Q_2}{Q^a_1} \tag{7}$$
$$R^b_{k,2} = \frac{(1-\tau^b)\alpha A^b_2 \xi^b_2{}^{\alpha} K^b_1{}^{\alpha-1} + (1-\delta)\xi^b_2 Q_2}{Q^b_1} \tag{8}$$
$$R_1 = \frac{(1-\tau^c)\alpha A^c_2 \xi^c_2{}^{\alpha} K^c_1{}^{\alpha-1} + (1-\delta)\xi^c_2 Q_2}{Q^c_1} \tag{9}$$
$$R^a_{k,2} Q^a_1 K^a_1 - R_1 Q^a_1 K^a_1 + R_1 \delta_B Q^a_1 K^a_0 = \kappa^a R^a_{k,2} Q^a_1 K^a_1 \tag{10}$$
$$R^b_{k,2} Q^b_1 K^b_1 - R_1 Q^b_1 K^b_1 + R_1 \delta_B Q^b_1 K^b_0 = \kappa^b R^b_{k,2} Q^b_1 K^b_1 \tag{11}$$
$$R^a_{k,2} - R_1 = \mu^a \left(\kappa^a R^a_{k,2} - (R^a_{k,2} - R_1)\right) \tag{12}$$
$$R^b_{k,2} - R_1 = \mu^b \left(\kappa^b R^b_{k,2} - (R^b_{k,2} - R_1)\right) \tag{13}$$
$$Q^a_1 K^a_1 - \delta_B Q^a_1 K^a_0 + Q^b_1 K^b_1 - \delta_B Q^b_1 K^b_0 + Q^c_1 K^c_1 = D_1 + \delta_B Q^c_1 K^c_0 \tag{14}$$
$$C^a_1 + \frac{B^a_1}{R_1} = A^a_1(\xi^a_1 K^a_0)^\alpha + Q^a_1 I^a_1 - I^a_1 \left(1 + \frac{\zeta}{2}\left(\frac{I^a_1}{\bar{I}^a} - 1\right)^2\right) - \delta_B Q^a_1 K^a_0 \tag{15}$$

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

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

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

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

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

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

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

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

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

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

This final system of 24 equations corresponds to the system in table A1, which in addition also has three equations for the price of investment in $t = 2$ (that is constant since there is no investment in the terminal period), and two equations for the interbank lending to emerging economies F_1^e with $e = \{a, b\}$.

F Steady State of the Baseline Model

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

We depart from the system of equations in table A1. Some variables are pinned down directly from a static version of the equations:

$$Q^i = 1$$

$$I^i = \delta K^j$$

$$B^i = 0$$

$$R = \frac{1}{\beta}$$

$$K^c = \left(\frac{R - (1-\delta)}{\alpha(1-\tau^c)}\right)^{\frac{1}{\alpha-1}}$$

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

$$R_k^a = (1-\tau^a)\alpha K^{a\ \alpha-1} + 1 - \delta$$

$$R_k^b = (1-\tau^b)\alpha K^{b\ \alpha-1} + 1 - \delta$$

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

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

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

G Additional Ramsey Policy Equilibria results

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

Table G8: Welfare comparison for model with higher financial friction in both emerging economies ($\kappa^a = \kappa^b = \frac{1}{2}$)

Country	Bechmark: Nash Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)	Bechmark: First Best 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 G9: Ramsey-Optimal taxes for the model with higher financial friction in both emerging economies ($\kappa^a = \kappa^b = \frac{1}{2}$)

	Policy Scheme			
Country	Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
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 G10: 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 G11: 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 G12: Welfare comparison for model with larger financial center. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$.

Country	Bechmark: Nash			Bechmark: First Best			
	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 G13: Ramsey-Optimal taxes for the model larger financial center. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$.

Country	Policy Scheme			
	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 G14: Welfare comparison for model with smaller periphery. Population sizes: $(n_a, n_b, n_c) = (\frac{1}{3}, \frac{1}{6}, \frac{1}{2})$.

Country	Bechmark: Nash				Bechmark: First Best				
	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 G15: 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 G16: Welfare comparison for model with unfeasibly aggresive subsidization

	Bechmark: Nash		Bechmark: First Best	
Country	Cooperation (EMEs)	Cooperation (Center and EME-A)	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 G17: Ramsey-Optimal taxes for model with unfeasibly aggresive subsidization

	Policy Scheme	
Country	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