Macroprudential Policy Coordination in Emerging Economies: A Multicountry Framework*

[Draft]

Joan-Camilo Granados †

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Abstract

Motivated by the presence of financial spillovers from advanced economies on emerging markets, and the apparent difficulties of the latter to shield their economies from external shocks, I set up a three-country center-periphery model (with two emerging economies and one advanced economy) with banks and financial agency frictions à la Gertler and Karadi (2011). The key defining feature of an emerging economy will be the limited capacity of financial intermediation that leads to a financial dependency relation with the center. Each country will have access to a macroprudential instrument that affects directly its source of inefficiencies and allows to smooth the credit spread distortions. However, such regulation can be costly and interdependent, opening a potential scope for coordination or strategic interactions. The addition of a second emerging country is relevant to enhance the interaction leverage of the peripheric block, as well as to allow for strategic interactions between emerging countries at the regional level. Within this framework, I aim to evaluate the optimal macroprudential instrument and welfare features of a variety of policy arrangements that differ by their degree of cooperation. In particular, I look for gains of coordination, but also for their distribution across economies. Finally, the framework allows to carry experiments with some of the peripheric features and explore whether global or regional incentives for coordination change meaningfully with the addition of new economies to a peripheric economic block.

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†Department of Economics, University of Washington, Seattle. Email: jcgc@uw.edu

1. Introduction

A global trend towards the liberalization of financial markets have been observed in recent decades. The motivation behind it is clear: resources should flow toward their most productive destination. However, there is a number of unintended associated effects that have been documented as result, such as the global imbalances and the global financial cycle (Rey, 2013). These phenomena are owned in part to the fact that open financial markets lead to a higher volatility in credit flows, characterized by excessive leverage and the presence of an external funding premium that increases the credit spreads, in the literature this is known as the financial accelerator channel, originated as the result of agency frictions between debtors and creditors Bernanke et al. (1999).

To limit the potentially negative effects of liberalization, there have been considerable efforts in the direction of pursuing financial stability, mostly through the implementation of new regulation and policy instruments that target specific financial variables, e.g., the Basel accords or the accumulation of reserves by central banks, among others. These are known as macroprudential policies (MaP).

The economic implications of these instruments have been a growing strand of the literature in the post Great Financial Crisis (GFC) years. A number of studies have tested their effectiveness (Hahm et al., 2011) while others have focused on the implications of this regulation for the design of other types of policy, for example monetary (e.g., Coimbra and Rey (2017) and De Paoli and Paustian (2017)).

In the same fashion, this regulation opens questions about the viability and scope for cooperative regulatory arrangements between economies. To begin with, there is a number of features of the MaP policies that may lead to cooperation welfare gains: first and foremost, the MaP policies seem to be interdependent, in the sense that they won't only affect their country of origin but also those financially connected to it (Boar et al. (2017), Aizenman et al. (2017) and Aiyar et al. (2012)). Moreover, implementing this type of regulation is costly and may be subject to trade-offs with other policy goals. In that sense, there are potential cross-country incentives to free-riding such policies, in the presence of positive spillovers, or to engage in regulatory wars in the case of negative ones.

This literature is of particular interest for emerging economies policymakers, as it turns out that these countries are the most vulnerable economies to volatile credit

cycles and the least capable of shielding their economies from global financial shocks. A critical feature of these countries is the underdevelopment of their financial sector that implies more difficult access to borrowing (Chang and Velasco, 2001), and hence, less capacity to smooth their credit cycle. As a result, the financial crises are about three times as frequent on these economies with respect to advanced economies (Reinhart and Rogoff, 2009).

An important question arises from these considerations: could these countries, relatively helpless on their own, react in any way (e.g., cooperatively) to compensate for their financial systems disadvantages and keep pursuing the promised benefits of financial globalization?. The scope for cooperation of these macroprudential regulatory instruments may be a potential solution to their problems.

In that spirit, this paper is not only aimed to study the presence and scale of the gains from coordination in a given framework, but also the change in the dynamics of the macroprudential instruments and the welfare implications for peripheral countries when a set of economies evaluate the best way to interact in a particular setup: multiple emerging markets and a financial center.

A related number of questions that I aim to address are: What can an emerging country do to manage their exposure to international market spillovers stemming from their economic centers?, is it worthy to engage into coalition arrangements between small players to minimize negative spillovers at the regional level?, what is the center country reaction when dealing with potential coalitions? Is it meaningfully different from non-cooperative policymaking?, how are the gains of coordination distributed between coalition partners?.

To explore these questions, I aim to compare the following scenarios from a welfare accounting perspective:

Table 1: Cases to Analize

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

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

In Table 1 RPP_i makes reference to the Ramsey Planner Problem of the social planner, consisting on maximizing the objective welfare function (maximand on the right hand side or the equation), in all cases, subject to the private equilibrium choices of the agents in each economy. Notice how the objective function under cooperation corresponds to a weighted welfare of the participating countries.

1.1. Contribution to the literature

The standard question posed by the literature (Fujiwara and Teranishi (2017), Banerjee et al. (2016) and Agénor et al. (2017)) is: Do Financial Frictions Call for Policy Cooperation?. Here in addition, I also explore whether peripheric countries should cooperate at a regional level when facing financial frictions and if by doing so they can secure access to the aggregate welfare gains.

For that end, the contribution of this paper consists in considering a multicountry setup through the inclusion of an additional emerging country to the peripheric block, i.e., the world economy will consist of two peripheries and a center country. In this setup, the emerging countries are characterized by a limited financial intermediation capacity which in turn implies a financial dependency on the resources stemming from the center economy banking sector.

As a result, the interbank lending relationships of the emerging economies will be subject to an agency friction, reflecting the underdevelopment of the emerging

banking sector, which in turn increases the credit spread of these economies after accounting for the increased risk of default.

At first, intuition may dictate that the policy stance of a periphery does not make any difference by itself because it may be too small to matter for shaping market outcomes, and by cooperating, a financial center would give away more than what it gains. However, if the periphery block is no longer very small in relative terms, for example, as a result of several small countries joining policy efforts, there could be a scope for cooperation. Moreover, for this to occur, just as having a larger peripheral block, the interactions within the periphery can be very important given that cooperation at the regional level,[1] or its absence, could determine if there is an actual improvement on the emerging countries bargaining power with respect to the center.

Clearly, this hypothesis relies heavily on the presence of externalities between the economies involved, and therefore it should be evaluated on a setup that accounts for these. Below, I briefly discuss how these interconnections appear in the framework we consider.

1.1.1. Externalities at the cross-border level and the role of expanding the peripheric block

The main model of the paper is explored in detail in Section 3. However, to grasp a better intuition of the mechanisms involved in this study, we briefly discuss which are the externalities between economies in the proposed setup.

In terms of the model the regulation is potentially costly and interdependent, thus, there can be incentives to free-ride on MaP policies at the regional or global level. In particular, more emerging markets will imply larger balance sheet effects interactions with the center. But also externalities between peripheries, even without direct regional capital flows.

The externalities between economies will appear through two channels: First, the profits of the bankers will be reflected on the households budget constraint, these profits are brought by exiting bankers and will depend on the credit spread of the country that is subject to a macroprudential tax, thus, they will have a direct impact on the period utility and on the welfare of the economy. Moreover, the presence of

[1] hereafter I refer to regional level cooperation as cooperative arrangements between peripheries.

such effect, together with the fact that each cooperative arrangement will internalize the budget constraint of its participants, will imply different optimality conditions with respect to the regulation instrument for the social planners under each of the cases portrayed in Table 1. This translates in different optimal macroprudential taxes under each policy arrangement.

Second, typically aimed variables of the macroprudential policies, for example, the volatility of the output or the credit spreads, will be interconnected between economies. In this case the externality transmission mechanism at the policy level goes as follows: Consider a shock that increases the spread of country i, its GDP will follow the direction of the spread via investment and larger capital inflows. The country j will mirror such movements due to capital outflows and lower relative returns on investment (capital). In absence of regulation, both economies will experiment an increase in the volatility of their output. Now, consider a tax that follows the cycle of the economy, i.e., increases with the spread and the output after the shock and compensates its effect in the opposite direction, this dampens the fluctuations of the return differential, capital inflows and GDP in country i. *Ceteris paribus*, the same stabilizing effect (or less distorting) will take place in country j, hence, there will be a positive policy spillover from the macroprudential instrument of country i on the economy j.

The rest of the paper is organized as follows: the second section includes a literature review, section 3 explains the main model of this study, section 4 contains a welfare effects exercise where we show what are the international policy spillovers between between economies, then in the section 5 we set the optimal policy problem and obtain solutions for the best tools for each policy setup, in section 6 we carry out the welfare comparison across policy setups for our baseline model, while in the sections 7 and 8 we explore different versions of the model, either for checking robustness or for comparison purposes. Finally, in the last sections, we discuss the value from considering a second periphery (section 9) in light of the simulation results and finally we conclude.

A number of appendices are reported to support the content and results of the sections.

2. Literature Review

Our work lies in the intersection of four areas of research: Modelation of financial intermediaries and financial frictions, international financial spillovers from advanced to emergent economies, macroprudential policies and international policy coordination. In this section we mention some of the most important works that are related to our study.

This paper borrows from the financial frictions literature with explicit modelation of financial intermediaries balance sheets. The framework will also follow the structure of an International RBC model in a multicountry setup. The financial frictions have been studied extensively[2] with key initial contributions made by Kiyotaki and Moore (1997), Bernanke and Gertler (1989) and Bernanke et al. (1999). These studies identified the role of information asymmetries and agency costs in generating a financial accelerator channel, defined as an amplification of the business cycles fluctuations, driven by an external financing premium that changed the cost of funding for borrowers countercyclicaly. In such setup, the excess volatility of the capital flows is incorporated in the discussion and modeling tools. However, the banks are only a conceptual veil, without any explicit modelation.

As relevant as the financial accelerator mechanism is, in its basic form it remains restricted to frictions on non-financial firms and to conventional monetary policy analysis. To complement the lessons learned from such literature, while updating the framework for modelling, the banking sector is explicitely included in the analysis of authors like Gertler and Karadi (2011), Gertler and Kiyotaki (2010) and Adrian and Shin (2010). The idea behind the inclusion of the banks in the models was to capture the disruption of financial intermediation experienced in the great financial crisis, as well as to allow for unconventional monetary policy to play a role in the models. In this framework is possible to consider financial intermediaries that face endogenous balance sheet constraints. At the same time, and relative to a crisis episode, ex-ante and ex-post unconventional monetary policy can be analyzed, e.g., macroprudential policy regulations and lending of last resort. In this study we focus on macroprudential policies targeted at banks, in particular, following the modelation strategy of Gertler and Karadi (2011) for the financial intermediation sector.

On the other hand, our study also fits in the literature that studies the financial

[2]See Brunnermeier et al. (2012) for a complete literature survey on this topic.

spillovers from financial centers in advanced economies to emerging markets. Knowing that the emerging markets are the main receptors of the externalities driving the global financial cycle (Rey, 2013) and that the dominant role of the financial centers cannot be abstracted, we follow the open economy setup of Banerjee et al. (2016). They study how the international spillovers from advanced economies to emergent are amplified by financial frictions and how this implies different monetary policy regime prescriptions.

Regarding macroprudential policies., literature contributions for small economies, such as, Nuguer (2016) and Cuadra and Nuguer (2018), incorporate the macroprudential policy tools in a modelation of financial intermediaries with spillovers toward emerging economies. They study how macroprudential instruments can mitigate the effects of advanced economies financial shocks. Another study with this structure, is that of Aoki et al. (2018), they study optimal macroprudential policies setting in a small open economy with different types of foreign debt risk. Finally, we also draw on the structure of Agénor et al. (2017), and Banerjee et al. (2016). The main difference with the former is that we do not focus on monetary policy and therefore consider a simpler pricing framework. And also, with respect to the latter, we focus on the policy interactions in emerging markets rather than only on the bilateral link between a core and a periphery economy.

Finally, in terms of policy coordination, there have been a number of studies on this direction and with emphasis in macroprudential tools. The benchmark for these studies is the literature on monetary policy coordination, which in most cases has concluded that the gains of coordination are positive but trivial (Obstfeld and Rogoff (2002)). However, the interaction of this policies with financial frictions and in an open economy setup may change such result (Sutherland (2004) and Corsetti et al. (2010)). In that spirit, some authors have explored coordination setups between financial regulators and monetary policy authorities, e.g., De Paoli and Paustian (2017) in a closed economy context, or Rubio and Carrasco-Gallego (2016) that explores how the presence of macroprudential policies may lead to coordination gains of monetary policy within a currency union. In an open economy setup the role of financial frictions on the coordination gains is also explored by Fujiwara and Teranishi (2017), however, they focus on frictions arising due to monopolistic power in the banking sector rather than due to lending agency frictions.

In our case, rather than interactions involving other type of policies, we focus only

on macroprudential policy interactions between several emerging economies and a financial center in presence of financial frictions due to information asymmetries, with a particular focus on the actions of emerging economies. Therefore, we believe that our study builds on the literature mentioned, but that is specially suited to study what is the role of emerging countries regulatory policies, globally and at the regional level, in shaping coordination policy gains for all countries involved, under different policy frameworks, i.e., either considering both different policy stances from the advanced economies or different semi-cooperative arrangements between countries.

3. The Model

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

3.1. Economic Environment

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

Such structure implies that the emerging economies have a financial dependency on the funding stemming from center banks, and in an environment of imperfect information between creditors and debtors, this could imply a double layer of agency frictions in the economy: that between center households and banks and another one between global banks and emerging country banks. However, we assume the friction

is more prevalent in countries that are financially underdeveloped at a greater extent, i.e., the distortion is more accentuated in the peripheries.

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

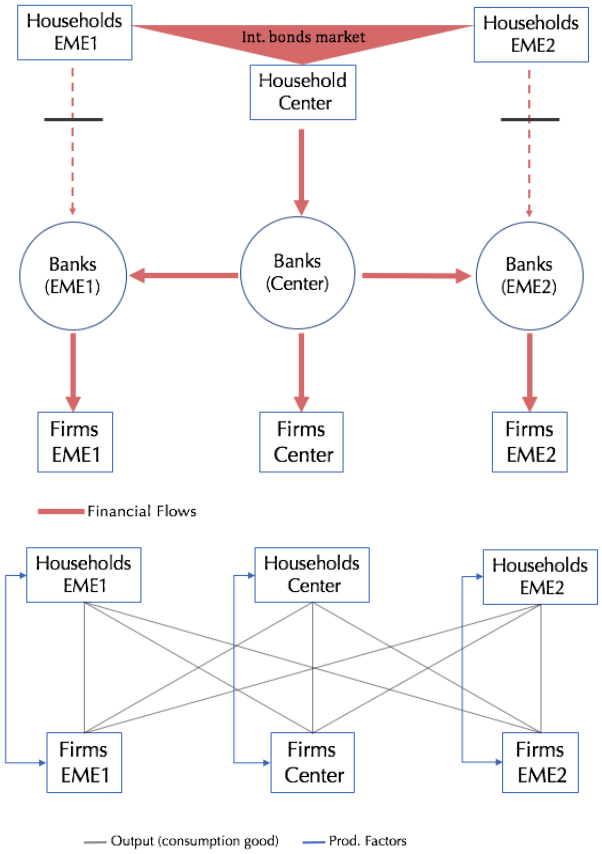

Figure 1: Financial (left) and Real (right) sector flows in the model

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

3.2. Model Setup

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

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

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

3.3. Investors

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

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

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

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

The investor solves:

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

the F.O.C. is,

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

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

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

3.4. Firms

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

The capital dynamics for the only period of accumulation are,

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

The technology that aggregates capital inputs into final goods is,

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

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

where K_0 is given.

Given the finite nature of the model, intermediation activities only take place in one

period, whereas in the other the capital stock will be given and freely available for production. This implies that there is a different profit maximization problem for the final good firms to consider in each period:

In the first period the firm will solve:

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

the F.O.C. are,

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

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

In the second period the firm will solve:

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

the F.O.C. are,

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

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

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

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

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

For the sake of clarity, it is important to notice that the firms will pay the pre-taxes banking rate. Only afterwards, the banks will consider the effect of the taxes in their profits. [3] We will elaborate on the policy tool and the role of this return rate in posterior subsections.

3.4.1. Capital dynamics and ownership

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

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

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

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

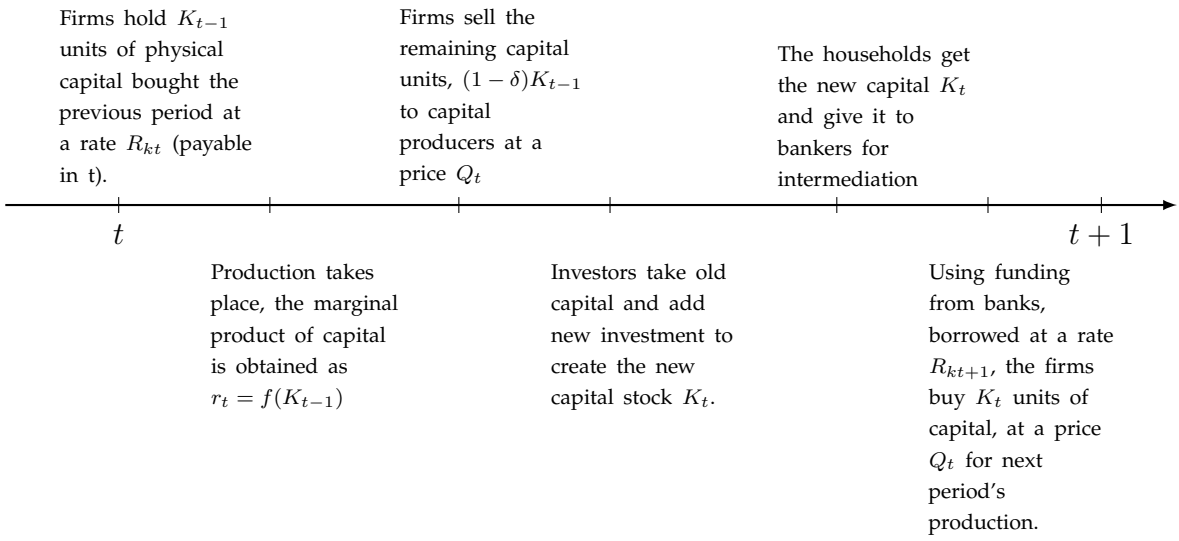

Figure 2: Capital ownership within a period

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

3.5. Banks

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

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

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

3.5.1. Emerging Countries

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

The lending relationship between foreign and local banks will be subject to agency frictions, arising from the fact that creditor banks could default on their debt repayment and divert a portion κ of their (post-return) intermediated assets.[4] In either case (default or not) the gross return from intermediation for the bank is R_{k2} as given by the equations (22)-(24).

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

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

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

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

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

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

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

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

are:

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

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

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

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

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

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

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

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

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

and,

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

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

■

3.5.2. Advanced Economy

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

$$\max_{F_1, L_1, D_1} J_1 = \mathbb{E}_1 \Lambda_{1,2} \pi^c_{b,2} = \mathbb{E}_1 \Lambda_{1,2} (R^a_{b,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} L^c_1 - R_{D,1} D_1)$$

$$s.t. \quad F_1^a + F_1^b + L_1 = D_1 + \delta_b Q_1^c K_0^c \tag{31}$$

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

the associated F.O.C. are:

$$[F_1^a]: \qquad \mathbb{E}_1(R_{b,1}^a - R_{D,1}) = 0 \tag{32}$$

$$[F_1^b]: \qquad \mathbb{E}_1(R_{b,1}^b - R_{D,1}) = 0 \tag{33}$$

$$[L_1^c]: \qquad \mathbb{E}_1(R_{k,2}^c - R_{D,1}) = 0 \tag{34}$$

3.6. Macroprudential policy and public budget

Among the number of possible prudential policies[5] (VaR regulations, leverage caps, loan/value ratios, etc) we consider a general type of policy that encompasses a broad set of macroprudential regulations: a tax on the return to capital. This will be a tax levied on the banking sector, as shown in equations (22)-(24).

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

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

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

When setting the taxes optimally, each social planner will consider whether to join a cooperative arrangement or to do it independently (Nash). We consider several types of cooperation, namely worldwide, or smaller coalitions such as regional-emerging economies, or center with one of the peripheries. Each case will imply a different welfare function as explained in section 4.

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

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

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

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

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

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

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 (see equations (29)-(30)).

■

3.7. Households

The household derives utility from consumption and its lifetime utility is given by $U^j = u(C_1^j) + \beta u(C_2^j)$ with $u(C) = \dfrac{C^{1-\sigma}}{1-\sigma}$.

The budget constraints in each period are the following:

Emerging markets:

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

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

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

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

Advanced Economy:

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

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

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

the profits are given by:[6]

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

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

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

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

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

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

3.8. Market Clearing

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

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

The goods market clearing conditions for each period are,

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

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

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:

$$R_1^a = R_1^b \tag{46}$$
$$R_1^c = R_1^b = R_1 \tag{47}$$

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

3.9. Exogenous processes

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

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

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

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

And finally, we include a financial friction shock, that has an effect on the degree of distortion implied by the agency problem in the banking sector of the emerging economies,

$$\kappa_t^s = \rho_\kappa \kappa_{t-1}^s + \sigma_\kappa \epsilon_{\kappa,t}^s \qquad (54)\text{-}(55)$$
$$\epsilon_{\kappa,t}^s \sim N(0,1)$$

These shocks are expressed in logaritmic form, meaning that when solving the model they will enter within an expotential function. In the first two types of shocks, the zero-mean of the shock implies that the mean of the level is one as it is usually the case with technological and factor augmenting shocks. In contrast, in the case of the financial friction the mean will be given by the pre-defined average degree of agency friction κ^s for $s = \{a, b\}$. Then, in the incentive compatibility constraints for the emergent countries we include a time varing friction given by:

$$\kappa_2^s = \kappa^s \cdot \exp(\kappa_t^s)$$

3.10. Equilibrium

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

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

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

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

Also, for cases in which stochastic analysis is carried, the system would include a number of shocks, described by the equations (48)-(50) to (54)-(55).

4. Welfare Effects between economies

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

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

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

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

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

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

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

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

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

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

4.1. Nash Case

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

4.1.1. Direct Effects

The welfare effect of the tax for the emerging economies is given by[7],

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

The same functional form applies for b.

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

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

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

Changes in external assets position: The second term, reflects the welfare effects from changes in the international debt position. $\frac{dR_1}{d\tau^a}$ is negative as there is a lower demand for funds by the levied banks. The sign of the whole term, however, depends on the sign of $\frac{B_1^a}{R_1}$ which is positive for emerging markets (and negative for the center), given that, by purchasing these assets, the households save the resources that cannot be deposited in their own countries.

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

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

We can see there are offsetting welfare effects. Moreover, the signs and magnitudes depend on the reference point and scale of the policy change that each country planner would plan to implement. In the subsection 4.3 we find these effects for a small change around the no policy case based on the numerical solution of the model.

For the center economy, the effect is:

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

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

Welfare effect from changes in intermediation profits: this is the welfare effect coming from

the change of the tax on the funding quantities or gross rates related to cross-border lending. Both terms in the squared brackets will be negative.

4.1.2. Cross-country Effects

The welfare effect between emergent countries is,

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

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

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

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

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

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

The interpretations of each term follow analogous intuitions to those explained in the subsection 4.1.1.

4.1.3. Optimal tax

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

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

The result for b will be analogous.

For c:

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

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

These expressions allow us to get an idea about the variables and effects driving the optimal taxes. We can see that the peripheral tax depends on the effect on prices and interest rates from changes in the domestic capital stock that will be proportional to the investment and net foreign bonds position. Other domestic factor of relevance will be the resale price of capital after depreciation and the marginal product of capital itself. For the latter, the more productive capital is, the lower the absolute value of the tax. By remembering that such marginal product is the variable directly taxed, we interpret that, with a low productivity of capital, the tax (or subsidy) will have to be set strongly, for it to have a significant policy effect. Finally, the deepness of the financial distortion, captured by κ^a will play an amplifying role, i.e., the higher the distortion the stronger would be the policy stance (tax or subsidy) implemented by the policymaker.

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

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

accumulation and production.

More importantly, both the right and left hand side of the equations depend on the taxes, i.e., the equilibrium solution is a function of the taxes themselves, that the agents are taking as given, and hence, we cannot draw general conclusions on signs and magnitudes easily from these equations. Instead, we have to follow a somewhat more nuanced approach and solve a Ramsey policy problem. In the section 5 we set and solve such policy problem based on the optimality conditions of the planners.

4.2. Cooperative cases

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

Table 2: Welfare spillovers in the model

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

Note: $j = a, b, c$

It turns out that the effects in the cooperative cases can be recovered from the individual results in section 4.1, that is, the effects will be given by weighted averages of the individual effects for the Nash case.

With no individual null effects, we have that the total spillover effects between Nash and cooperative cases will differ. As a result, when solving the Ramsey Planning

models we should obtain different optimal tool levels across policy setups.

4.3. Numerical Effects

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

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

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

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

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

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

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

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

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

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

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

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

The take away from this exercise will be that the within country effects of taxes are stronger in peripheries. A result consistent with the fact that the optimal taxes for the center are larger in absolute value for every policy setup (see section 6). That is,

given a weaker effect in the center, its tool is set to follow stronger policy stances for a similar inteded effect. At the same time this may have strong cross country unintended consequences since it also happens that the stronger cross-country effect is exerted by changing the center taxes.

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

5. The Ramsey Planner problem

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

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

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

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

Second, following the notation for a Ramsey problem in Bodenstein et al., 2019, let $F(\cdot)$ be the set of equations representing the optimality constraints of private agents that characterize the private equilibrium, $\mathbf{x}$ 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. We will solve the following problem for each Ramsey planner involved:

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

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

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

The set up of this problem will vary in each policy framework by changing the objective function, whereas the constraints will always refer to all the equations defining the equilibrium of the model ((1) to (47)). The latter assumption is set for consistency with an open economy setup and implies that the planners acknowledge they have an effect in the endogenous variables of the other countries.[8]

5.1. Non-Cooperative Framework

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

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

for $t = 1$.

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

5.2. Cooperative Framework

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

[8] 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.

5.2.1. World Cooperation

The cooperative Ramsey planner solves:

$$\begin{aligned} \max_{\mathbf{x_t}, \tau_t} \quad & W_{Coop,t} = n_a W_t^a + n_b W_t^b + n_c W_t^c \\ s.t. \quad & \mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta) \end{aligned}$$

for $t = 1$

5.2.2. Regional cooperation between emerging countries

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

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

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 Nash center planner.

5.2.3. 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:

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

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.

6. Welfare Accounting Comparison

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

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

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

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

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

This summarizes how the Ramsey equilibria fare with respect to each other, and how in the baseline framework they provide the same welfare outcomes. Just as

importantly, we can examine what combination of policy leads to this result and whether the planners are effective in mitigating the agency financial friction in place.

6.1. Level of the policy tool in each arrangement

In section 4 we observed that the optimal action, around a no policy scenario, points to subsidizing the banking sector so as to induce a compulsory increment of savings from households in favor of the banks. The Ramsey equilibrium allocation results, conversely, show the opposite result in most of the cases.

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

Table 5: Ramsey-Optimal taxes under each policy setup

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

Units: proportional tax on banking rate of return

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

returns of a number of assets and the price of bonds, which in turn, will facilitate the flow of resources at the country level.

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

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

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

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

However, in the most basic version we do not have explicit costs from setting taxes at different levels, instead, the cooperative planner is internalizing the policy spillover that a larger tax (or subsidy) would have on the other members of the coalition. This is consistent with the analytic result we obtain in section 4 where there is a negative policy spillover of a marginal tax increase on the welfare of other countries.

6.2. Approaching the First Best

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

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

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

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

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

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

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

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

6.3. Gains with respect to a No Policy setup

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

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

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

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

Every Ramsey policy implies a substantial welfare improvement for every country with respect to the no policy equilibrium. The welfare loss of not setting any policy in presence of the financial frictions amounts approximately to a 4% consumption

decrease at the world level, or more accurately, switching from a non existent policy making to any active (cooperative or not) optimal policy setup would be equivalent to a compensatory increase in steady state consumption of 4%. This welfare improvement is distributed asymmetrically across countries with the center absorbing thrice the improvement of the least favored economies that still would receive a welfare increase equivalent to a 2% change in consumption.

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

7. Achieving Gains from Coordination

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

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

1. *Competition:* The policy makers act as price takers by not exerting market power over international assets prices.

2. *Sufficient Instruments:* The policy is flexible and effective enough to achieve the targeted level in the international variables of interest.

3. *Frictionless International Markets:* The international market for assets is free of imperfections or frictions that would impair risk sharing.

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

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

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

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

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

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

7.1. Financial Frictions in the Center

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

center bank solves the following problem:

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

with associated F.O.C.,

$$[F^a_1]: \quad \mathbb{E}_1(R^a_{b,1} - R_{D,1}) = \mu^c_1\left[\kappa^c R^a_{b,1} - (R^a_{b,1} - R_{D,1})\right]$$
$$[F^b_1]: \quad \mathbb{E}_1(R^b_{b,1} - R_{D,1}) = \mu^c_1\left[\kappa^c R^b_{b,1} - (R^b_{b,1} - R_{D,1})\right]$$
$$[L^c_1]: \quad \mathbb{E}_1(R^c_{k,2} - R_{D,1}) = \mu^c_1\left[\kappa^c R^c_{k,2} - (R^c_{k,2} - R_{D,1})\right]$$

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

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

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

7.2. Policy costs of macroprudential intervention

To account for the case where the policy tool cannot be set up flexibly we also consider the case when there is an explicit cost of regulation. We solve the modified Ramsey

problems where we include a convex cost of policy implementation. The objective function of the planner will now be given for:

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

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

$f(\alpha^j, W_t^j)$ corresponds to the same objective functions considered in section 5 and $\Gamma(\tau^j) = \psi(\tau^j)^2$ denotes a quadratic policy implementation cost. We solved the model with several levels of ψ and report the results for the value of the parameter that generates different qualitative results with respect to the baseline ($\psi = 1$).

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

8. Additional exercises

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

8.1. The degree of the agency distortion

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

The gains from coordination after increasing the degree of the financial distortion is shown in appendix C, in table C7. Initially, we consider an increment of 20% in

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

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

In terms of the policy stance we find that planners will set the tool for the country with the larger distortion as a subsidy, or a lower tax in one of the cooperative cases, while the center will set a stronger tax in all cases compared to the baseline. This is consistent with the results from section 4 where the welfare effects increase in κ. With stronger effects, the peripheral planner can set its tool more conservatively and obtain the same intended effects.

8.2. Different economies sizes

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

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

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

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

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

8.3. Aggresive subsidization

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

9. The value added from considering a second periphery

Some of the exercises carried in the previous sections explore the possibility of having asymmetric peripheries for delivering different equilibrium outcomes relative to the baseline model. Such exercises are only possible if we account for a three-country

structure. In light of the results, here we comment how such multicountry structure is meaningful for allowing us to obtain results both in terms of the equilibrium solution and consequences of cooperation that would be omitted in simpler versions of the model.

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

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

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

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

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

10. Conclusions

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

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

In this setup each country has a representative bank and the emerging economies will be characterized by having limited capacity of financial intermediation and being subject to a financial agency friction in their lending lending relationships, which is incorporated in the model by following Gertler and Karadi (2011). This friction is included by several reasons. First, because it resembles the credit spreads observed in emerging economies; second, because it is consistent with the heterogeneity in financial development observed between advanced and emergent markets, and finally, because it allows to rationalize the fact that by undoing the financial frictions efficiently the economies could perform better by coordinating the implementation of their policy instruments.

The countries will have access to a macroprudential tax, levied on the bankers, that affects directly the source of the friction and can potentially smooth the credit spread and the generated financial augmented cycle. However, at the same time, the policy makers face a policy trade-off since they can also aim to increase the capital accumulation, and production, by subsidizing the financial intermediation activities. The economies are also connected via trade of goods and of an international bond, as well as, through inter-bank financial flows which implies there will be economic and policy welfare spillovers at the cross country level. The presence of these policy spillovers are the foundation that lead us to inquire about coordination gains.

Additionally, including several peripheral economies in the model allows us to

analyze additional semi-cooperative cases, namely regional cooperation between peripheries or the coalition faced by a subset of the peripheries with the financial center.

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

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

The absence of gains from cooperation can be explained, according to Korinek (2020), by the fact that the conditions for the uncooperative equilibrium to be efficient hold in our model, and thus, the cross-country welfare effects we verify are actually efficient international spillovers.

To explore this result, we analize a version of the model where every country is subject to the financial friction and where the policy instruments are not perfect because they are subject to implementation costs.

The results with global frictions (agency costs in every country) are qualitatively equivalent to the baseline model. However, when we consider explicit implementation costs of policy making or restrictions to the usage of the taxes we do find gains from cooperation in most cases. In these cases we are either increasing the burden of regulation, or decreasing the effetiveness of the tools which render the planners unable to implement their preferred allocations.

In general, in the baseline results and related exercises, we can see that the optimal taxes will reflect the disparities between participating members of the cooperative block.

As an additional set of exercises, we explore whether a number of features assumed in the baseline results are relevant in shaping the results. For this, we change the relative sizes of the (distorted) emerging economies and center as well as the degree

of the financial friction embodied by the incentive compatibility constraint of the model.

In most cases, the results do not change when simulating alternative versions of the model, namely with changes of parameters or with frictions in every country. However, when considering a smaller second periphery, the peripheral semi-cooperative policy case (Coop-EMEs) delivers gains for the coalition participants. Additionally, interacting with peripheries that are subject to stronger agency frictions, the EME with the milder financial friction will be better off in any cooperative setup. This result is interesting since it suggest that a periphery may not want to interact with another emerging economy with worse agency problems, unless cooperation policy framework are available.

The baseline results, i.e., those of the model with perfect policy tools, a center, two identical peripheries and frictions in the emerging countries only, do not depart by much from the findings of studies considering other settings, e.g., where banks are absent or the policy tools analyzed are different. However, this remarks an additional contribution of this study: The consideration of the role of an incumbent second periphery in the world economy, with different features than the other EME which generates different results with respect to the baseline Nash or worldwide cooperation, as opposed to the case when the third country is a replicate of the other periphery where the results of regional cooperative setups will be analogous to two country model outcomes.

Finally, it is important to mention that the breadth of these results is bounded by the features assumed or abstracted from the model, and further research is still needed in several directions before making general conclusions on the topic of coordination gains.

For future research it is particularly important to study whether features such as the timing of the policies, in periods of crises or for prudential purposes, can make any difference in creating incentives for coordination; or whether the role of the exchange rate or terms of trade is potentially important since they imply additional policy tradeoffs with welfare effects that the planners may fail to internalize. Finally, the interaction with other frictions, such as the created by nominal rigidities, at the banking or final goods level can be relevant. The first one for augmenting the cycle-amplification effects of financial distortions (see Mandelman (2010) and Fujiwara and Teranishi (2017)) and the second one for generating a scope for gains from

coordination with other policies (e.g. monetary as in De Paoli and Paustian (2017)) and instruments.

References

Adrian, T. and Shin, H. S. (2010). Financial Intermediaries and Monetary Economics. In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 12, pages 601–650. Elsevier.

Agénor, P.-R., Kharroubi, E., Gambacorta, L., Lombardo, G., and da Silva, L. A. P. (2017). The international dimensions of macroprudential policies. BIS Working Papers 643, Bank for International Settlements.

Aiyar, S., Calomiris, C. W., and Wieladek, T. (2012). Does macropru leak? Evidence from a UK policy experiment. Bank of England working papers 445, Bank of England.

Aizenman, J., Chinn, M. D., and Ito, H. (2017). Financial spillovers and macroprudential policies. Working Paper 24105, National Bureau of Economic Research.

Aoki, K., Benigno, G., and Kiyotaki, N. (2018). Monetary and Financial Policies in Emerging Markets . Working paper.

Banerjee, R., Devereux, M. B., and Lombardo, G. (2016). Self-oriented monetary policy, global financial markets and excess volatility of international capital flows. *Journal of International Money and Finance*, 68(C):275–297.

Bernanke, B. and Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, 79(1):14–31.

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics*, volume 1 of *Handbook of Macroeconomics*, chapter 21, pages 1341–1393. Elsevier.

Boar, C., Gambacorta, L., Lombardo, G., and da Silva, L. A. P. (2017). What are the effects of macroprudential policies on macroeconomic performance? *BIS Quarterly Review*.

Bodenstein, M., Guerrieri, L., and LaBriola, J. (2019). Macroeconomic policy games. *Journal of Monetary Economics*, 101:64 – 81.

Brunnermeier, M. K., Eisenbach, T. M., and Sannikov, Y. (2012). Macroeconomics with Financial Frictions: A Survey. NBER Working Papers 18102, National Bureau of Economic Research, Inc.

Cerutti, E., Claessens, S., and Laeven, L. (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability*, 28(C):203–224.

Chang, R. and Velasco, A. (2001). A Model of Financial Crises in Emerging Markets. *The Quarterly Journal of Economics*, 116(2):489–517.

Coimbra, N. and Rey, H. (2017). Financial Cycles with Heterogeneous Intermediaries. NBER Working Papers 23245, National Bureau of Economic Research, Inc.

Corsetti, G., Dedola, L., and Leduc, S. (2010). Optimal Monetary Policy in Open Economies. In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 16, pages 861–933. Elsevier.

Cuadra, G. and Nuguer, V. (2018). Risky Banks and Macro-Prudential Policy for Emerging Economies. *Review of Economic Dynamics*, 30:125–144.

Davis, J. S. and Devereux, M. B. (2019). Capital Controls as Macro-prudential Policy in a Large Open Economy. NBER Working Papers 25710, National Bureau of Economic Research, Inc.

De Paoli, B. and Paustian, M. (2017). Coordinating Monetary and Macroprudential Policies. *Journal of Money, Credit and Banking*, 49(2-3):319–349.

Fujiwara, I. and Teranishi, Y. (2017). Financial frictions and policy cooperation: A case with monopolistic banking and staggered loan contracts. *Journal of International Economics*, 104(C):19–43.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34.

Gertler, M. and Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 11, pages 547–599. Elsevier.

Hahm, J.-H., Mishkin, F. S., Shin, H. S., and Shin, K. (2011). Macroprudential policies in open emerging economies. *Proceedings*, (Nov):63–114.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.

Korinek, A. (2020). Currency Wars or Efficient Spillovers? A General Theory of International Policy Cooperation. *Review of Economic Studies, Forthcoming*.

Mandelman, F. S. (2010). Business cycles and monetary regimes in emerging economies: A role for a monopolistic banking sector. *Journal of International Economics*, 81(1):122–138.

Nuguer, V. (2016). Financial Intermediation in a Global Environment. *International Journal of Central Banking*, 12(3):291–344.

Obstfeld, M. and Rogoff, K. (2002). Global Implications of Self-Oriented National Monetary Rules. *The Quarterly Journal of Economics*, 117(2):503–535.

Reinhart, C. M. and Rogoff, K. S. (2009). *This Time Is Different: Eight Centuries of Financial Folly*. Number 8973 in Economics Books. Princeton University Press.

Rey, H. (2013). Dilemma not trilemma: the global cycle and monetary policy independence. *Proceedings - Economic Policy Symposium - Jackson Hole*, pages 1–2.

Rubio, M. and Carrasco-Gallego, J. A. (2016). Coordinating macroprudential policies within the Euro area: The case of Spain. *Economic Modelling*, 59(C):570–582.

Sutherland, A. (2004). International Monetary Policy Coordination and Financial Market Integration. CEPR Discussion Papers 4251, C.E.P.R. Discussion Papers.

A. Analytic welfare effects derivations

This section explain the derivations of the expressions shown in the section 4.

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

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

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

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

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

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

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

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

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

For the cross country effects we follow the same procedure. Notice that the last term

of the EME effects will be absent since there is not any direct tax welfare effect at the international level.

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

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

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

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

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

The result for b is analogous.

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

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

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

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

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

B. Parameters and other model simulation results

B.1. Parameters of the model

The table contains the parameter used in the baseline model.

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

Table B1: Parameters in the model

B.2. Welfare effects with complete depreciation

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

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

C. Ramsey Policy Equilibria results

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

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

Units: proportional tax on banking rate of return

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

Units: proportional tax on banking rate of return

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

Units: proportional tax on banking rate of return

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

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

Units: Proportional steady state consumption increase in the benchmark model

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

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

Units: proportional tax on banking rate of return

Table C15: Welfare comparison for model with unfeasibly aggresive subsidization

	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 C16: 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

D. Solution of the Model

Original System:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Replace the following profits:

$$\pi_{f,t} = A_t(\xi_t K_{t-1})^\alpha - r_t K_{t-1}, \quad for\ t = \{1, 2\}$$

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

$$\pi_{b,2}^s = R_{k,2}^s Q_1^s K_1^s - R_{b,1}^s F_1^s, \quad for\ s = \{i, e\}$$

$$\pi_{b,2}^c = R_{b,1}^a F_1^a + R_{b,1}^b F_1^b + R_{k,2}^c Q_1^c K_1^c - R_{D,1} D_1$$

Original System (with profits):

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

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

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

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

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

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

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

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

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

$$R_{k,2}^s Q_1^s K_1^s - R_{b,1}^s F_1^s = k R_{k,2}^s Q_1 K_1^S \tag{27)-(28}$$

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

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

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

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

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

$$C_1^a + \frac{B_1^a}{R_1^a} = A_1^a(\xi_1^a K_0^a)^\alpha + Q_1^a I_1^a - I_1^a\left(1 + \frac{\zeta}{2}\left(\frac{I_1^a}{\bar{I}^a} - 1\right)^2\right) - \delta_b Q_1^a K_0^a \quad (35)$$

$$C_1^b + \frac{B_1^b}{R_1^b} = A_1^b(\xi_1^a K_0^b)^\alpha + Q_1^b I_1^b - I_1^b\left(1 + \frac{\zeta}{2}\left(\frac{I_1^b}{\bar{I}^b} - 1\right)^2\right) - \delta_b Q_1^b K_0^b \quad (36)$$

$$C_2^a = A_2^a(\xi_2^a K_1^a)^\alpha - r_2^a K_1^a + R_{k,2}^a Q_1^a K_1^a - R_{b,1}^a F_1^a + B_1^a - T^a \quad (37)$$

$$C_2^b = A_2^b(\xi_2^b K_1^b)^\alpha - r_2^b K_1^b + R_{k,2}^b Q_1^b K_1^b - R_{b,1}^b F_1^b + B_1^b - T^b \quad (38)$$

$$C_1^c + \frac{B_1^c}{R_1^c} + D_1 = A_1^c(\xi_1^c K_0^c)^\alpha + Q_1^c I_1^c - I_1^c\left(1 + \frac{\zeta}{2}\left(\frac{I_1^c}{\bar{I}} - 1\right)^2\right) - \delta_b Q_1^c K_0^c \quad (39)$$

$$C_2^c = A_2^c(\xi_2^c K_1^c)^\alpha - r_2^c K_1^c + R_{b,1}^i F_1^i + R_{b,1}^e F_1^e + R_{k,2}^c Q_1^c K_1^c + B_1^c - T^c \quad (40)$$

$$C_1^{-\sigma} = \beta R_1 C_2^{-\sigma} \quad (41)\text{-}(43)$$

$$C_1^{c\ -\sigma} = \beta R_{D,1} C_2^{c\ -\sigma} \quad (44)$$

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

$$R_1^a = R_1^b \quad (46)$$

$$R_1^c = R_1^b = R_1 \quad (47)$$

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

$r_2^a, r_2^b, r_2^c, F_1^a, F_1^b, D_1, R_{b,1}^a, R_{b,1}^b, R_{D,1}, R_{k,2}^a, R_{k,2}^b, R_{k,2}^c, C_1^a, C_1^b, C_1^c, C_2^a, C_2^b, C_2^c, B_1^a, B_1^b, B_1^c,$

$R_1^a, R_1^b, R_1^c, \mu^a, \mu^b$

Now I simplify the system (substutite redundant variables and reduce the number of equations)

The simplications are applied in this order:

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

- *S2:* remove already solved equations (function of parameters or pre-defined variables, hence we drop $Q2, Y_1$). Replace $Y_2,\ r_1,\ r_2$, $F_1^s = Q_1^s K_1^s - \delta_b Q_1^s K_0^s$.

From (41) and (42) obtain $R_1 = R_{D,1}$ and replace.

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

Final system of equations used for solving the model:

$$Q^a_1 = 1 + \frac{\zeta}{2}\left(\frac{I^a_1}{\bar{I}^a} - 1\right)^2 + \zeta\left(\frac{I^a_1}{\bar{I}^a} - 1\right)\frac{I^a_1}{\bar{I}^a} \tag{1}$$

$$Q^b_1 = 1 + \frac{\zeta}{2}\left(\frac{I^b_1}{\bar{I}^b} - 1\right)^2 + \zeta\left(\frac{I^b_1}{\bar{I}^b} - 1\right)\frac{I^b_1}{\bar{I}^b} \tag{2}$$

$$Q^c_1 = 1 + \frac{\zeta}{2}\left(\frac{I^c_1}{\bar{I}^c} - 1\right)^2 + \zeta\left(\frac{I^c_1}{\bar{I}^c} - 1\right)\frac{I^c_1}{\bar{I}^c} \tag{3}$$

$$K^a_1 = I^a_1 + (1-\delta)\xi^a_1 K^a_0 \tag{4}$$

$$K^b_1 = I^b_1 + (1-\delta)\xi^b_1 K^b_0 \tag{5}$$

$$K^c_1 = I^c_1 + (1-\delta)\xi^c_1 K^c_0 \tag{6}$$

$$R^a_{k,2} = \frac{(1-\tau^a)\alpha A^a_2 {\xi^a_2}^{\alpha} {K^a_1}^{\alpha-1} + (1-\delta)\xi^a_2 Q_2}{Q^a_1} \tag{7}$$

$$R^b_{k,2} = \frac{(1-\tau^b)\alpha A^b_2 {\xi^b_2}^{\alpha} {K^b_1}^{\alpha-1} + (1-\delta)\xi^b_2 Q_2}{Q^b_1} \tag{8}$$

$$R_1 = \frac{(1-\tau^c)\alpha A^c_2 {\xi^c_2}^{\alpha} {K^c_1}^{\alpha-1} + (1-\delta)\xi^c_2 Q_2}{Q^c_1} \tag{9}$$

$$R^a_{k,2} Q^a_1 K^a_1 - R_1 Q^a_1 K^a_1 + R_1 \delta_B Q^a_1 K^a_0 = \kappa^a R^a_{k,2} Q^a_1 K^a_1 \tag{10}$$

$$R^b_{k,2} Q^b_1 K^b_1 - R_1 Q^b_1 K^b_1 + R_1 \delta_B Q^b_1 K^b_0 = \kappa^b R^b_{k,2} Q^b_1 K^b_1 \tag{11}$$

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

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

$$Q^a_1 K^a_1 - \delta_B Q^a_1 K^a_0 + Q^b_1 K^b_1 - \delta_B Q^b_1 K^b_0 + Q^c_1 K^c_1 = D_1 + \delta_B Q^c_1 K^c_0 \tag{14}$$

$$C^a_1 + \frac{B^a_1}{R_1} = A^a_1(\xi^a_1 K^a_0)^{\alpha} + Q^a_1 I^a_1 - I^a_1\left(1 + \frac{\zeta}{2}\left(\frac{I^a_1}{\bar{I}^a} - 1\right)^2\right) - \delta_B Q^a_1 K^a_0 \tag{15}$$

$$C^b_1 + \frac{B^b_1}{R_1} = A^b_1(\xi^b_1 K^b_0)^{\alpha} + Q^b_1 I^b_1 - I^b_1\left(1 + \frac{\zeta}{2}\left(\frac{I^b_1}{\bar{I}^b} - 1\right)^2\right) - \delta_B Q^b_1 K^b_0 \tag{16}$$

$$C^a_2 = (1-\alpha)A^a_2(\xi^a_2 K^a_1)^{\alpha} + R^a_{k,2} Q^a_1 K^a_1 - R_1 Q^a_1 K^a_1 + R_1 \delta_B Q^a_1 K^a_0 + B^a_1 + \tau^a r^a_2 K^a_1 \tag{17}$$

$$C^b_2 = (1-\alpha)A^b_2(\xi^b_2 K^b_1)^{\alpha} + R^b_{k,2} Q^b_1 K^b_1 - R_1 Q^b_1 K^b_1 + R_1 \delta_B Q^b_1 K^b_0 + B^b_1 + \tau^b r^b_2 K^b_1 \tag{18}$$

$$C^c_1 + \frac{B^c_1}{R_1} + D_1 = A^c_1(\xi^c_1 K^c_0)^{\alpha} + Q^c_1 I^c_1 - I^c_1\left(1 + \frac{\zeta}{2}\left(\frac{I^c_1}{\bar{I}^c} - 1\right)^2\right) - \delta_b Q^c_1 K^c_0 \tag{19}$$

$$\begin{aligned} C^c_2 = (1-\alpha)A^c_2(\xi^c_2 K^c_1)^{\alpha} + R_1 Q^a_1 K^a_1 - R_1 \delta_B Q^a_1 K^a_0 + \\ + R_1 Q^b_1 K^b_1 - R_1 \delta_B Q^b_1 K^b_0 + R_1 Q^c_1 K^c_1 + B^c_1 + \tau^c r^c_2 K^c_1 \end{aligned} \tag{20}$$

$$ {C^a_1}^{-\sigma} = \beta R_1 {C^a_2}^{-\sigma} \tag{21}$$

$$C_1^{b\ -\sigma} = \beta R_1 C_2^{b\ -\sigma} \tag{22}$$
$$C_1^{c\ -\sigma} = \beta R_1 C_2^{c\ -\sigma} \tag{23}$$
$$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0 \tag{24}$$

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

E. Steady State of the Model

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

We depart from the system of equations (1)-(24) at the end of the appendix D. Some variables are pinned down directly from a static version of the model equations or by following standard literature definitions:

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

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: $C^a,\ C^b,\ C^c,\ K^a,\ K^b,\ D,\ R_k^a,\ R_k^b,\ \mu^a,\ \mu^b$