Strategic Macroprudential Policy Setting in Emerging Economies: Does Cooperation Pay Off?*

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Abstract

I study the usefulness of coordinated macroprudential policy frameworks for emerging economies. Specifically, I look for the long-run gains of cooperative regimes and whether these can shield the emerging economies from external shocks. For this, I set an open economy model of banks with financial frictions in an environment with multiple emerging economies and a center. I verify the cross-border policy effects and the new policy incentives under cooperation, then, I perform a welfare comparison of a number of policy regimes that vary by the degree of cooperation and explore their short-run performance. The results suggest that not every type of cooperation is beneficial with respect to nationally-oriented policies. Instead, only schemes where the financial center acts cooperatively would generate gains. Two mechanisms generate the gains: a cancellation effect of national incentives to manipulate the global interest rates and a new incentive to substitute local with foreign intermediation at the Center. Both channels will improve the financial stability and the second will increase the efficiency of the capital flows. Finally, the short-run dynamics show these mechanisms allow for a better performance of the peripheries after a shock, while generating leverage dynamics that favor a faster global recovery.

JEL Codes: F38, F42, E44, G18

Key words: Macroprudential Policies, International Coordination, Cooperation, banking.

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1 Introduction

The emerging economies fragility to the global financial cycle has become a core concern in international finance in the last decade.[1] Simultaneously, their capital flows have gained traction, making these markets the new potential sources of global financial risk.[2] As a result, there are a number of co-existing policy challenges at play. For the emerging markets it would be important to facilitate the participation in the global financial markets while still protecting their economies from negative international shocks. On the other hand, for the financial centers and multilateral institutions, mitigating new sources of risk becomes crucial. As a result, we have seen a general increase in the use and intensity of macroprudential policies, in particular in emerging economies.

At the same time, the nature of these policies has an international dimension as their effects are not bounded by national borders. With that in mind, I study whether the international macroprudential policy cooperation is beneficial for these economies and could be used to improve their macroeconomic performance and financial resilience. In particular I formulate two specific questions: (i) is macroprudential cooperation beneficial for these economies in general?, and (ii) are cooperative policies useful in protecting these economies from external shocks?.

To answer these questions, I study the policy mechanisms at work, the long run economic implications and the short run dynamics of these economies in an environment where there is a strong financial interdependency between the emerging markets and a financial center. For identifying the mechanisms I set a tractable, simplified, small scale model with dynamic banking and policies, and for the long and short run dynamics I set a larger scale quantitative model, that allows me to take into account the total effects of these policies over time in a stochastic environment.

The macroeconomic framework used for modelling the banking sector is based on Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), and can be seen as an open economy version of these. At the same time, it is similar to Banerjee et al. (2016) with the difference that the we consider multiple peripheral economies and we focus on the flexible prices case. The reason for these assumptions is that we want to focus on the potential interactions between emerging economies at the regional level, and that we want to restrict our analysis to the potential advantages of coordination between macroprudential

[1] See Rey (2013).

[2] See McQuade and Schmitz (2017) and Forbes and Warnock (2020).

policymakers only. To the best of my knowledge, this is the first paper that studies the potential benefits of coordinating the financial regulation of emerging economies, both considering they still can have global general equilibrium effects, and acknowledging their fragility to the dynamics of a financial center that can also carry out policy actions in response. [3]

The results I obtain suggest there are important direct and cross-border effects of the macroprudential policies that grow when the instruments in consideration are forward looking, as their effect builds into the future via retained profits and net worth dynamics of the financial intermediaries. In addition, the effects will grow with the financial distortion, suggesting the policies can be more effective for more distorted economies. At the same time, when looking at the policy mechanisms under cooperation and the drivers of the optimal associated taxes, I obtain two new policy action motives. The first, working in every economy, is an off-setting effect that mitigates the national incentives to manipulate the interest rates to benefit from fluctuations in the net foreign assets position. The second, applicable to the Center, consists of a new incentive for increasing the financial intermediation and capital inflows in the peripheries, at the expense of local capital accumulation.

In terms of the long run performance of the policy regimes, I carry out a conditional welfare comparison and obtain that there are important gains from cooperation. However, these exist only for frameworks where the Center acts cooperatively, with the global gains maximized in the world-wide cooperation regime. In that spirit, not every type of cooperation is beneficial, and in fact, a cooperative arrangement that only includes peripheries can be detrimental. Simultaneously, the implementation of the best policy regime, global cooperation, can be challenging as the national distribution of welfare gains are more favorable for the coalition participants under the second best regime, the cooperation between the Center and only one periphery. In that case, these countries will be better off than in the socially optimal equilibrium at the expense of the remaining periphery, which in turn, ends up worse than at any other regime.

The main sources of the welfare gains are the two new cooperative policy mechanisms mentioned above, the first, by cancelling out the incentives to move the taxes to generate yield-seeking fluctuations in the interest rates will imply smoother policy and capital accumulation dynamics for all countries, and the second will facilitate a more efficient allocation of the international capital flows, which the cooperative planner will direction

[3] For a framework with small open economies interactions with an exogenous center see Jin and Shen (2020).

towards the most productive destinations. Furthermore, both channels will work more strongly when the welfare weights of the involved peripheries become more comparable to that of the Center. We will use the relative economic population size as the weight, which in turn, implies that the social gains are maximized for regimes where more peripheries engage in cooperation with the Center.

These mechanisms are also helpful to understand why the regime where the emerging economies cooperate among themselves does not yield gains. The first channel is not present as all the national incentives to manipulate the interest rate, within the coalition, go in the same direction, i.e., for the cancellation to take effect, we need both global creditors (Center) and debtors (EMEs) to engage in cooperation. In contrast, in this semi-cooperative regime there can be a larger incentive to manipulate the interest rates as the incentive of debtors is pooled in a single policy effort, which in turn, explains why this regional cooperation can even be counterproductive. On the other hand, the second policy incentive is absent as it appears only for a cooperative global intermediator (Center).

At the same time, the model with a stochastic and cyclical component will also show that an active cooperative effort by the Center will translate in a countercyclical implementation of its policy. This will be important as it recognizes the general procyclical features of these policies (Fernández et al. (2015) and Uribe and Schmith-Grohe (2017)), but also that among optimal regimes, the best performing policies will adopt countercyclical features as intuition would dictate (Bianchi (2011) and Jeanne and Korinek (2019)).

All of these features are also reflected in the short run performance of the policy regimes, which point to the conclusion that the world cooperation regime is the most effective in protecting the emerging economies from external shocks and providing them with better output dynamics. We associate this to a higher and smoother accumulation of capital in the peripheries which comes at the expense of the capital stock at the Center, and that occurs as the global planner internalizes that the global output recovery is faster and more efficient with larger capital flows towards the emerging markets. Finally, there is another benefit of cooperation that can only be seen in the short run exercise: the typical deleveraging processes that slows down the economic recovery after financial shocks will be noticeably mitigated under cooperation and make a stronger case for the promotion of cooperative global policies by financial regulators.

Related Literature. This paper is related to the literature that studies the role of financial frictions in shaping macroeconomic fluctuations that started with the seminal financial accelerator studies of Bernanke et al. (1999) and Kiyotaki and Moore (1997). There, the presence of financial frictions resulted in a procyclical external financial premium that amplified the business cycles. It also borrows from studies that model the banking sector explicitly by integrating the balance sheet of the financial intermediaries in the rest of the economic structure, for example, Adrian and Shin (2010), Gertler and Kiyotaki (2010), and Gertler and Karadi (2011). In fact, the model used in this paper can be seen as an open economy version of the last two. Other studies also account for such structure in an open economy setting, for example, Banerjee et al. (2016) considers an open economy environment to study the potential benefits of coordinating monetary policies in presence of financial frictions, or in Aoki et al. (2018) a small open economy model with banking is developed. This work can also be seen as a simplified version of these two, that abstracts from monetary policy but considers a multiperipheral environment.

Other papers also study the open economy dimension of the financial frictions with a focus on the pecuniary externalities between individual agents that fail to recognize the effects of their borrowing decisions on asset prices and interest rates, some important examples are Mendoza (2010), Bianchi (2011), Jeanne and Korinek (2010), Jeanne and Korinek (2019). These papers elaborate in the dynamic consequences of the colateral prices and how they can lead to a Fisherian debt deflation process with a prolonged deleveraging. I will have some of these features, particularly the deleveraging which will help differentiate the short run performance of the policy regimes under consideration.

At the same time, this paper overlaps with the literature on the effects of the global financial cycle and the presence of strong international spillovers on emerging economies. The idea of an increased emerging fragility to the international capital dynamics and the global financial cycle is mentioned in Rey (2013) and Rey (2016) where it is explained how an active participation in international markets creates macroeconomic stability and monetary independence challenges for small economies. Furthermore, Gourinchas and Jeanne (2006) and Gourinchas and Jeanne (2013) mention how the presence of financial frictions can prevent the emerging economies from the expected benefits of opening its financial markets as capitals may fail to flow in their direction even it they are more productive destinations. With these spillovers in mind, Céspedes et al. (2017) and Cuadra and Nuguer (2018) develop frameworks where they propose the use of macroprudential policies and unconventional policies at the financial intermediary level to mitigate the fragility of the emerging countries to external financial shocks. As the latter study, we will consider a fiscal type of policy targeted at the banks. However, we will focus on the potential additional benefits of coordinated instruments between economies.

Finally, this paper also relates to the literature on economic policy cooperation with financial frictions. In this group there are two types of studies, the first one considers the potential coordination of different types of policies in presence of financial frictions or imbalances, for example the potential for monetary policy coordination as in Sutherland (2004), Fujiwara and Teranishi (2017), and Bodenstein et al. (2020), or also includes studies where macroprudential regulators interact with other types of policymakers, such as in De Paoli and Paustian (2017) and one of the applications of Bodenstein et al. (2019)[4] where the gains from coordination between monetary and financial regulators are evaluated.

On the other hand, the second type, and where this paper falls more closely, is the literature on the international coordination between macroprudential regulators. In this regard, some studies have analyzed the potential coordination of capital controls, for example Jin and Shen (2020) formulate an environment with a large number of small open economies that may coordinate their net foreign assets accumulation and obtains that welfare gains arise when the atomistic policy makers join efforts and internalize their aggregated general equilibrium effects in the global markets. In a related fashion, but with a potentially opposite source of gains, Davis and Devereux (2019) study the policy coordination of capital control taxes in large open economies and obtain these will gain from cooperation precisely because their incentive to manipulate the terms of trade and interest rate is cancelled under cooperation. Similarly, Korinek (2020) formulates a first welfare theorem for open economies where the countries set taxes on the capital flows. He finds the conditions that make the non-cooperative equilibrium Pareto optimal and explains how violations to these will lead to the existence of welfare gains.

Other types of policy instruments have also been explored in studies such as Bengui (2014) who analyzes the cooperation of liquidity requirements and finds that potential gains arise as cooperative planners internalize the invididual incentives to manipulate the terms of trade, and Kara (2016) that studies the coordination of capital adequacy requirements in a two-country model with financial autarky and finds gains from cooperation that arise due to strong free riding policy incentives at the national level.

On the other hand, as in this paper, a tax on the banking sector is analyzed in Agénor et al. (2017) who consider a two country center-periphery model to compare the response

[4]This paper provides a toolbox for solving two-players policy games and apply their method to an extension of Gertler and Karadi (2011) where a monetary and a financial regulator interact.

to the economy to macroprudential policies under cooperation and finds dynamics that differ substantially to the non-cooperative case that also generate welfare gains.

This paper differs from these studies in which it simultaneously considers the presence of banking frictions, a large open economy environment with multiple peripheries where each country can have general equilibrium effects, and active policymaking actions in the financial center. The papers above will abstract from one or more of these features, which in turn, are what allow us to consider a larger set of policy regimes that vary by the extent of policy cooperation.

Lastly, I also consider a similar multi-country framework in Granados (2020) where I analyze the one-shot policy problem in a static environment. In this paper, however, I extend the main methodology to allow for a dynamic banking sector and forward-looking macroprudential policies with potentially persistent effects, and thus, develop a framework that permits me to study the cyclical properties of these policies under several types of cooperation.

The rest of this paper is structured as follows. Section 2 briefly describes the recent empirical trend of the capital flows to emerging markets and the associated macroprudential policy responses. In Section 3 I show a simplified version of the main model and use it to analyze the policy mechanisms at play in a deterministic environment. Sections 4 and 5 describe the main model of the paper and the considered policy regimes. Then, in Section 6 I show the results and explain how they answer the research questions. Finally, Section 7 provides some concluding remarks.

2 Capital Flows Dynamics After the Crisis and Policy Response

The period before the global financial crisis was characterized by a strong flow of capitals towards advanced economies (see figure 1), such phenomenon, denoted as the global savings glut[5], was partly explained by a financial deregulation process in the largest advanced economies after the termination of the main banking separation Acts put in place as a response to the financial crises of the early 1900s,[6] and contributed to

[5] See Justiniano et al. (2013) and Bernanke (2005) for a discussion on this topic.
[6] In the USA the Glass-Steagal Act of 1933

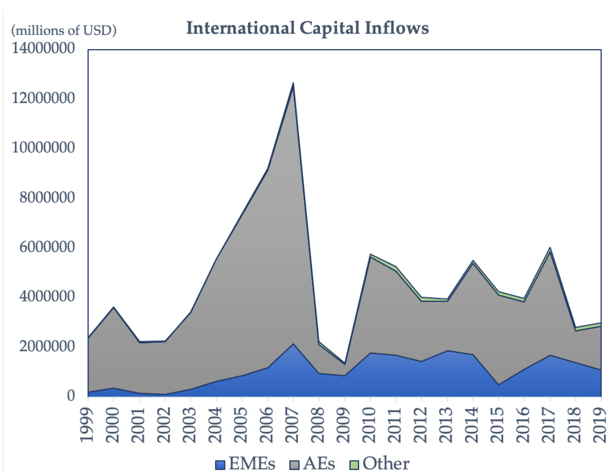
the downward trend of the interest rates of traditional assets in the main economies (Bernanke et al., 2011).

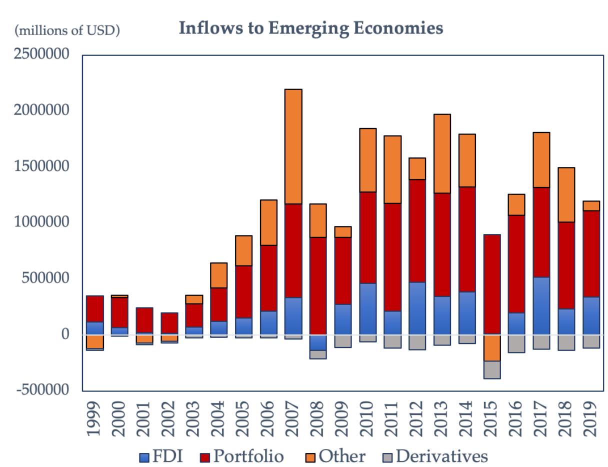
Rather than a change in the direction of the capital flows, the observed response of the markets in the 2000's, was a reliance on high leveraged intermediation, together with financial innovation efforts (e.g., securitization of assets) to continue attracting investments with competitive returns but at the expense of a substantial build-up of risk.

Once the bubble burst and the crisis ensued there was a strong institutional effort towards strengthening the financial regulation, and a higher recognition of the threat posed by the risk of financial contagion prompted an urgent revision of the Basel accords. The G-20 met for the first time in history to deal with an economic matter and as result founded the Financial Stability Board, an institution that has as one of its objectives to promote the coordination of financial regulations.

After that, the financial markets have featured stricter regulations and a decrease in the level of interbank connectedness in advanced economies. Simultaneously, and as a byproduct, the international investment flows have shifted their direction towards the emerging economies. Furthermore, the main type of flows entering these economies were the portfolio and banking flows (Other in the figure 1). These items, that take place within the financial intermediation sector, represent the most volatile types of capital flows. Thus, the banking sector in the emerging economies happens to be at the core of the post-global financial crises potential sources of risk.

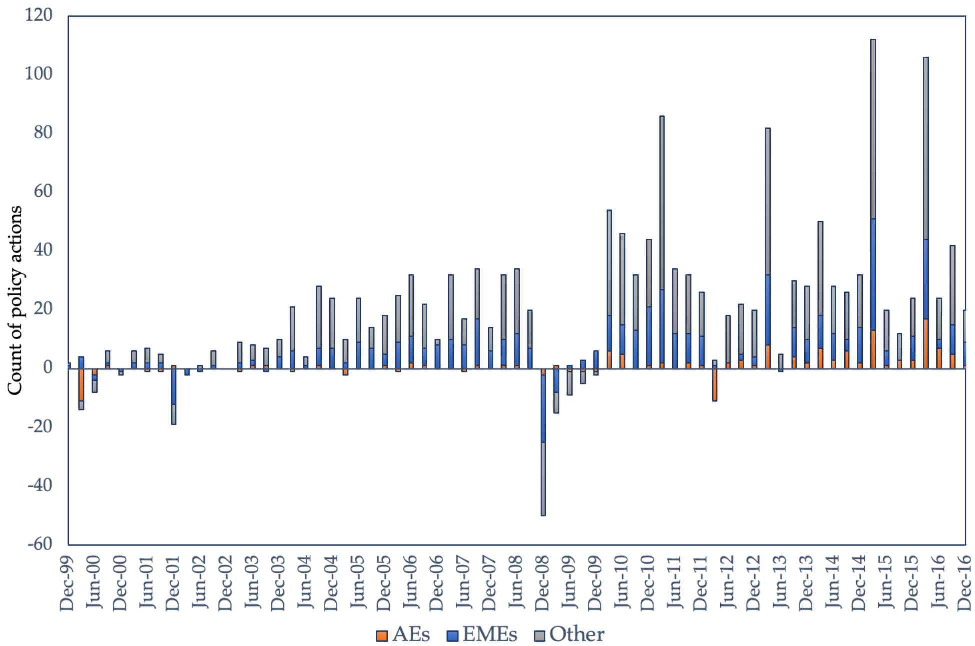
Figure 1: Global Capital Inflows: 1999-2019





Source: IMF-IFS and BOP Statistics. Note: the countries in each group follow the IMF definitions. That is, 23 advanced economies, 58 emerging economies and 199 developing countries (other in the graph).

Figure 2: Macroprudential policies stance by type of economy



Source: IMF - Integrated Macroprudential Policy Database (iMaPP) by Alam et al. (2019). Note: the countries in each group follow the IMF definitions. The figure includes information for 23 advanced economies, 52 emerging economies and 135 developing countries (other in the graph).

The observed associated policy response consisted in stricter macroprudential with respect to pre-crisis times, both globally, and specially in the emerging and developing economies. This can be seen in the figure 2 that shows the policy stance by type of economy. There, a tightening of a macroprudential instrument is counted as (+1) and a loosening as (-1), and then the indexes are aggregated for all economies. For example, it can be seen that globally, and in the last quarter of 2015 there were more than 100 tightenings in the instruments (e.g. an increase in the Loan-to-Value requirements or in the banking taxes).

One possible interpretation is that the use of these policies has increased, both in general in much more strongly in the emerging economies and developing countries. Moreover, it could be suggested, from the overall and compositional policy stance dynamics that there are potential instruments comovement patterns at the cross-country level and with the business cycles.

In that regard, several papers document the presence of significant external policy effects, for example, Forbes et al. (2017) study the UK case and show that these policies can have large spillovers in the international capital flows. Buch and Goldberg (2017) document how the macroprudential policies generate significant cross-border credit effects that spills over through the interbank lending, and Aiyar et al. (2014) show how stricter capital requirements on the UK made the foreign banks to increase their activities in the UK, in an attempt of substituting the curtailed intermediation that resulted from the macroprudential tightenings. Similarly, but finding international spillovers in a Center-periphery environment, Tripathy (2020) studies the spillover of banking regulations from Spain to Mexico through Mexican subsidiaries of Spanish banks and explains how the borderless nature of the banking business, operated by large global banks can imply significant cross-country spillovers.

Judging from the findings of these studies, and as explained by Forbes (2020), we may think that the presence of these leakages can mitigate the effectiveness of the macroprudential policies or generate new vulnerabilities and risks.

In that vein, it is interesting to determine from a theoretical perspective, if these spillovers may open some scope for cooperative policy schemes, or if instead they just represent efficient adjustment effects, that still render the cooperation redundant.

To contribute to the understanding of these policy effects, in the next section we show in a modelling framework the direct and cross-border spillovers of a macroprudential instrument, and explore whether the cross-border policy effects have the same mechanisms at work under cooperation.

3 Simple Three-Period Model

Before analyzing the main dynamic model of this paper, we will lay out a simplified setup in finite horizon for building intuition about the main mechanisms at work. In that spirit, we will consider the simplest possible model that still features a dynamic decision making by banks and macroprudential regulators.[7] This model shares the essential features of the main one, and can be thought of as a small scale version of it, with the advantage of allowing to analytically disentangle the welfare effects of different types of policies, for example, tools that are forward looking, static, nationally-oriented or cooperative. Clearly, there is a trade-off between the improved tractability, and the potential uses of a more quantitatively involved model, e.g., the smaller scale model would not allow for a

[7]For reference an even simpler finite time horizon version of this model, with static banks and one-shot policies can be found in Granados (2020).

complete study of the response of the economy to shocks, or a comprehensive welfare accounting comparison between models. We will leave such additional applications for subsequent sections of the paper that are based on the larger-scale model.

Similarly, when a sector is completely analogous to that of the main model explained in section 4 we will review it more briefly, and instead will focus more in the sectors with meaningful differences, the banks and the households.

3.1 Setup

General economic environment. Time is discrete and there are three periods, $t = \{1, 2, 3\}$. The world economy is populated by three countries, two emerging economies or periferies, labeled as a and b, and a financial center c. The relative population size of each economy is given by n_i with $i = \{a, b, c\}$ and these sizes are such that the sum of the periferies is never larger than the population size at the center, that is, $n_c \geq \frac{1}{2}$, with $n_c = 1 - n_a + n_b$. Each economy is populated by five types of agents: households, final goods firms, investors or capital good firms, the government and a representative bank.

The households will own the firms (final good, capital and banks) and there is a production technology that transforms the predetermined capital into a final consumption good with a Cobb-Douglas agregator: $Y_t^i = A_t^i K_{t-1}^i$. This good will be identical across countries.

The economies are endowed with a predetermined level of capital in the first period (K_0), after that, a bank will intermediate the physical capital acquisition for production. For this, at the end of each period, the firm will take its input and indebtedness decisions, the bank will provide the funds and will be repaid the next period after production takes place.

This implies that there are two periods of financial intermediation, the first at the end of the first period, and one more a period later. Notice something important, the banking decisions will be dynamic, or forward looking in $t = 1$, while in $t = 2$ the banking problem will be static as there are not further intermediation activities. We will focus on the differences in the decision making of the bankers and policy-makers between these two periods.

The households will have standard preferences over consumption and their welfare is given by: $W^i = u(C_1^i) + \beta u(C_2^i) + \beta^2 u(C_3^i)$, with $u(C) = C^{1-\sigma}/(1-\sigma)$.

Additionally, given the homogeneous good assumption, and the identical preferences at the world level, we have that the law of one price and purchasing power parity will hold. Consequently, we can abstract from the real exchange rate. Finally, for this simple model we will work with a perfect foresight assumption.

3.2 Banks

Each economy will have a representative bank that aims to maximize the present value of its franchise. There are two important features that distinguish emerging economy (EME) banks from that of the Center: First, the EME banks will be subject to a financial friction in the form of agency costs, and second, the Center bank will act as creditor of the EME banks in the interbank market. The latter feature will appear due to the limited capacity of local intermediation in the peripheries.

EME-Banks. The banks in the emerging economies will intermediate funds in order to provide resources to local firms for capital acquisition and production. These banks will be financially constrained and depict a lower level of financial development, in the spirit of Chang and Velasco (2001). As a consequence, two features arise that characterize these banks. First, these firms will have a lower capacity of financial intermediation at the local level, and to compensate they rely on borrowing money from the Center in an international interbank market. Second, their lending relationships are subject to a costly-enforcement agency friction where the banks could divert a portion κ of the assets they intermediate.

The friction creates a distortion in the credit spread of these banks, in the form of a default risk premium. This features are modelled following the structure of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010).

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

$$
\begin{aligned}
J_1 = \max_{F_1, L_1} \mathbb{E}_1 & \left\{ (1-\theta)\Lambda_{1,2}(R_{k,2}L_1 - R_{B,1}F_1) + \Lambda_{1,3}\theta(R_{k,3}L_2 - R_{B,2}F_2) \right\} \\
s.t \quad & L_1 = F_1 + \delta_B Q_1 K_0 && \text{[Balance sheet in t=1]} \\
& L_2 = F_2 + \delta_B Q_2 K_1 + \theta[R_{k,2}L_1 - R_{B,1}F_1] && \text{[Balance sheet in t=2]} \\
& J_1 \geq \kappa Q_1 K_1 && \text{[ICC, t=1]}
\end{aligned}
$$

Where L_t is the total lending intermediated with the local firms, F_t is the cross-border borrowing they obtain from the Center, $R_{k,t}$ is the gross revenue rate of the banking services, paid by the firms, and $R_{b,t}$ is the interbank borrowing rate for the banks that they pay to the Center intermediary.

The present value of the bank, will be given by the expected profits in the next period. For this, we include the posibility of exit from the banking business, with an associated probability of survival θ. [8] In that sense, with probability $(1-\theta)$ the bank will fail and report back its profits to the household, and with probability θ the bank will be able to continue its business and pursue future profits.

The constraints are given by the balance sheets of the bank for each period in which they operate and an incentive compatibility constraint. These balance sheets have, on the asset side, the loans that are intermediated, and on the liabilities side, the interbank foreign borrowing and their net worth, which, in the initial period is only a bequest, or start-up capital that they receive from their household owners, while later also accounts for previously retained earnings. That is, we assume the bank will retain its earnings as long as it operates.[9]

Finally, the incentive compatibility constraint (ICC) reflects the imposition that the value of the franchise has to equal or larger than the value the bank could divert after defaulting its creditors, which is given by a fraction κ of the intermediated assets.[10] For simplicity, this divertable fraction will be constant across locations and time.

In the second period, the banks solve a simpler problem, as their objective will not depict a continuation value:

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

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

[9] This assumption is common in the literature and also particularly reasonable in this model environment as, given the friction, the returns from banking tend to be higher than those of other assets.

[10] We follow Gertler and Karadi (2011) closely in the formulation of the ICC and assume the bank only considers to divert assets as soon as they obtain the funds. Other formulations are also possible, e.g., in Granados (2020) I explore a stricter ICC case where the potential diversion occurs the next period, after the firms repay their debt.

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

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

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

With these conditions we can state an initial result:

Proposition 1: *If the ICC binds the credit spread is positive in each period and increases in κ*

Proof: See appendix A. ■

Since the friction is embodied in a positive spread, this result implies we can talk about κ and the extent of the distortion as analogous concepts.

Center-Banks. The Center representative intermeriary will solve a similar problem. But it will not be subject to frictions. This means that the only constraints it faces are given by the balance sheets in each period. These reflect that the Center-Bank acts as the creditor of the EME-Banks.

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

$$J_1 = \max_{F_1^a, F_1^b, L_1^c, D_1} \mathbb{E}_1 \Big\{(1-\theta)\Lambda_{1,2}(R_{k,2}L_1 + R^a_{B,1}F^a_1 + R^b_{B,1}F^b_1 - R_{D,1}D_1) + \Lambda_{1,3}\theta(R_{k,3}L_2 + R^a_{B,2}F^a_2 + R^b_{B,2}F^b_2 - R_{D,2}D_2)\Big\}$$

$$s.t \quad L_1 + F^a_1 + F^b_1 = D_1 + \delta_B Q_1 K_0 \qquad \text{[Balance sheet in t=1]}$$

$$L_2 + F^a_2 + F^b_2 = D_2 + \delta_B Q_2 K_1 + \theta[R_{k,2}L_1 + R^a_{B,1}F^a_1 + R^b_{B,1}F^b_1 - R_{D,1}D_1] \qquad \text{[Balance sheet in t=2]}$$

This problem will be dynamic, as it accounts for the potential profits and balance sheets of every intermediation period. Also, notice we omit the superindexes when the variables correspond to the countries where the bank is based (e.g., L_1 is L^c_1 in the expression above.).

In contrast, in the next period the bank will solve a simpler problem, consisting of maximizing the profits of a single term.

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

$$s.t$$

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

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

3.3 Production Sectors

There will be two types of firms. Here we will describe them briefly as the structure is analogous to the main model and the detailed formulation is explained in subsequent sections.

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

Capital Producers. There will be a firm that will carry out the investments in each economy. Their job will be to buy any remaining undepreciated capital from the final good firms and to produce the new physical capital. Moreover, the investment will be subject to a cost of adjustment that depends on the investment growth with relation to that of the previous period.

3.4 Macroprudential Policy

There will be a role for policy in the model, that is justified by the friction in the banking sector. In that spirit, we consider a macroprudential policy that targets the banks. A government, will tax the rate of return of the bankers in each period. Afterwards, it will rebate the tax income back to the households.

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

With such structure, the following proposition holds:

Proposition 2: *An increase in the macroprudential tax decreases the leverage ratio of banks and its effect grows with the friction*

Proof: See appendix A. ■

This result suggests that, in addition to the direct effect in mitigating the credit spread of a distorted economy, the macroprudential tax will also lower the banking leverage of the banking sector. Furthermore, the extent at which it does this increases with the financial friction (κ).

In addition, notice that, since τ_2 affects the first banking period, which is forward looking, and τ_3 the terminal period, where the banking decisions are static, it also follows that τ_2 and τ_3 are, respectively, a forward-looking and a static tool.

3.5 Households

The households will own the three types of firms (final goods, capital and banks) and will use their profits for consumption, saving, and for supplying the bequests to their banks. They will not pay the banking taxes directly, these are paid by the banks before distributing profits. However, they will receive a lump sum transfer from the government once the latter levies the financial intermediaries.

Since the capital is already predetermined in the initial period, there is no intermediation for K_0. Instead, and only for that period, the households will rent the capital to the firms directly.

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

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

$$\begin{aligned} s.t.& \\ C_1 + \frac{B_1}{R_1} &= r_1 K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0 \\ C_2 + \frac{B_2}{R_2} &= \pi_{f,2} + \pi_{inv} + \pi_{bank,2} - \delta_B Q_2 K_1 + B_2 - T_2, \quad for \\ C_3 &= \pi_{f,3} + \pi_{bank,3} + B_2 - T_3 \end{aligned}$$

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

I also assume that the household does not have access to deposits. This is a simplification that reflects the lower financial development in the periphery and that generates the financial dependency from EME-Banks on Center-Banks. It is important to remember that this assumption does not have consequences in the saving decisions of the households as they can freely access the bonds market for such purposes.

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

$$\max_{\{C^c_t\}_{t=1}^{3},\{B^c_t\}_{t=1}^{2}} u(C^c_1) + \beta u(C^c_2) + \beta^2 u(C^c_3)$$

$$\begin{aligned} s.t.& \\ C^c_1 + \frac{B^c_1}{R^c_1} + D_1 &= r^c_1 K^c_0 + \pi^c_{f,1} + \pi^c_{inv,1} - \delta_B Q^c_1 K^c_0 \\ C^c_2 + \frac{B^c_2}{R^c_2} + D_2 &= \pi^c_{f,2} + \pi^c_{inv} + \pi^c_{bank,2} - \delta_B Q^c_2 K^c_1 + B^c_2 + R_{D,1} D_1 - T^c_2, \quad for \\ C^c_3 &= \pi^c_{f,3} + \pi^c_{bank,3} + B^c_2 + R_{D,2} D_2 - T^c_3 \end{aligned}$$

3.6 Equilibrium

Market Clearing and International Links. The bonds market will depict a zero-net-supply in the first two periods:

$$n_a B_t^a + n_b B_t^a + n_c B_t^c = 0, \quad \text{for} t = \{1, 2\}$$

In addition, we assume the uncovered parity holds which allows us to equate the interest rate of the bonds in each country:

$$R_t^a = R_t^b = R_t^c = R_t$$

Furthermore, we will make use of the Euler equation for the deposits and bonds from the first order conditions of the Center, according to which ${C_t^c}^{-\sigma} = \beta R_{D,t} {C_{t+1}^c}^{-\sigma}$ and ${C_t^c}^{-\sigma} = \beta R_t {C_{t+1}^c}^{-\sigma}$, to determine that $R_{D,t} = R_t$ for $t = \{1, 2\}$.

Equilibrium. A summary of the final set of equations used for solving the model can be found in table 6. For a total of 49 variables for the three countries and three periods. I solve this model non-linearly and using a perfect foresight approximation.

3.7 Welfare Effects of Policy

Based on the 3-period model we can approximate the welfare effects of policy at the national and cross-border level.

Numerical approximation. I solve the model private equilibrium non-linearly, using the parameters shown in table 7. The agents will take the taxes as given, and hence, we have to provide them exogenously when solving for the private equilibrium. We solve the model with zero taxes and compare it with the solution after marginal changes in each of the taxes. The results are shown in table 1.

Table 1: Welfare effects in the 3-period model

		Change in tax			
		1%	**3%**	**5%**	**8%**
Direct effect of τ_2	$\tau_2^a \rightarrow W^a$	0.1458	0.1437	0.1416	0.1382
	$\tau_2^b \rightarrow W^b$	0.1458	0.1437	0.1416	0.1382
	$\tau_2^c \rightarrow W^c$	-0.2421	-0.457	-0.1786	-0.0268
Cross-border effect	$\tau_2^a \rightarrow W^b$	-0.0465	-0.0468	-0.0471	-0.0475
	$\tau_2^a \rightarrow W^c$	-0.0163	-0.0166	-0.0168	-0.0172
	$\tau_2^b \rightarrow W^a$	-0.0465	-0.0468	-0.0471	-0.0475
	$\tau_2^b \rightarrow W^c$	-0.0163	-0.0166	-0.0168	-0.0172
	$\tau_2^c \rightarrow W^a$	-0.162	-0.2257	-0.1803	-0.1548
	$\tau_2^c \rightarrow W^b$	-0.162	-0.2257	-0.1803	-0.1548
Direct effect of τ_3	$\tau_3^a \rightarrow W^a$	0.0573	0.0568	0.0564	0.0558
	$\tau_3^b \rightarrow W^b$	5.73E-02	5.68E-02	5.64E-02	5.58E-02
	$\tau_3^c \rightarrow W^c$	-0.0871	-0.1218	-0.243	-0.1341
Cross-border effect	$\tau_3^a \rightarrow W^b$	-0.0175	-0.0178	-0.0181	-0.0184
	$\tau_3^a \rightarrow W^c$	0.006	0.0049	0.0039	0.0025
	$\tau_3^b \rightarrow W^a$	-0.0175	-0.0178	-0.0181	-0.0184
	$\tau_3^b \rightarrow W^c$	0.006	0.0049	0.0039	0.0025
	$\tau_3^c \rightarrow W^a$	-5.05E-02	-5.87E-02	-8.73E-02	-7.41E-02
	$\tau_3^c \rightarrow W^b$	-0.0505	-0.0587	-0.0873	-0.0741

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

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

I also obtain that for most of the changes sizes, the direct effect of the Center tax, i.e., on its own welfare, is weaker than its cross-border effects. This is similar to what we found in the purely static version of this model, however, it is also compensated by the effect of the terminal tax.

In terms of international policy effects, these results indicate that there is a negative policy spillover from the taxes set in the EMEs, i.e., the local and international welfare responses from a change in their taxes have opposite signs. This constrasts with the results of the static policy model in Granados (2020), although the differences may not only be due to the inclusion of dynamics but to the fact that the ICC is formulated differently in this model, in a way that the value of banking reacts less to the banking interest rate and tax. Finally, the spillovers from the Center tax are positive, suggesting the presence of potential policy free-riding incentives by the peripheries that may want to rely on the Center macroprudential taxes.

Analytical Welfare Effects In order to understand the mechanisms that generate these spillovers I set a Social Planner Problem and obtain the analytical welfare effects, following the methodology of Davis and Devereux (2019). For this, I set the welfare equations and simplify them using the private equilibrium conditions. Then, the welfare effects are obtained via implicit differentiation.

A social planner will consider the following simplified welfare expressions.

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

with $\varphi(\tau) = \left(1-\alpha\left(1-\tau\right)\right)$

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

To obtain these expressions, I set the welfare as the sum utilities in present value plus a sum-product of Lagrange multipliers times the budget constraints in each period. Then, I replace the profits and tax rebates in the constraints. Notice that these expresions are correct since the constraints are binding, and hence sum to zero, leaving the usual definition of welfare as result.

Setting the welfare in this fashion is very convenient, since the algebra and differentiation is greatly simplified by the fact that we can ignore the effect of the decision variables of the households since the first order conditions, equal to zero, will be a factor of the resulting expressions.

Next, I obtain the welfare effects from changing each type of tax. For that, we should remember than a planner setting the tax in the last period,[11] will take the taxes and variables from the previous period as given, hence, we just need to differentiate with respect to $R_2, Q_2, I_2.K_2$ for both types of countries plus $R_{b,2}, F_2$ for the center. In contrast, for the first period we must also consider the lagged versions of these variables.

The welfare effects of the taxes are:

For the EMEs:

$$\frac{dW^a}{d\tau_2^a} = \beta\lambda_2^a\left(\kappa R_1 Q_1^a + \varphi\left(\tau_2^a\right) r_2^a\right)\frac{dK_1^a}{d\tau_2^a} + \lambda_1^a\left(I_1^a + \kappa K_1^a\right)\frac{dQ_1^a}{d\tau_2^a} + \beta\lambda_2^a\frac{B_1^a}{R_1}\frac{dR_1}{d\tau_2^a} + \beta\lambda_2\alpha Y_2^a \qquad \text{static effects}$$

$$+\beta\lambda_2^a\left(\kappa\left(1-\theta\Lambda_{23}\right)Q_2^a + \varphi\left(\tau_3^a\right)\Lambda_{12} r_3^a\right)\frac{dK_2^a}{d\tau_2^a} + \beta\lambda_2^a\left(I_2^a + \kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{d\tau_2^a} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_2^a} + \beta^2\lambda_3^a\alpha Y_3^a \qquad \text{dynamic effects}$$

$$\frac{dW^a}{d\tau_3^a} = \beta\lambda_2^a\left(\kappa\left(1-\theta\Lambda_{23}\right)Q_2^a + \varphi\left(\tau_3^a\right)\Lambda_{23} r_3^a\right)\frac{dK_2^a}{d\tau_3^a} + \beta\lambda_2^a\left(I_2^a + \kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{d\tau_3^a} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^a} + \beta^2\lambda_3^a Y_3^a$$

and for the Center:

$$\frac{dW^c}{d\tau_2^c} = \beta\lambda_2^c\left(\left(1-\alpha\theta\left(1-\tau_2^c\right)\right)r_2^c + (1-\theta)(1-\delta)Q_2^c\right)\frac{dK_1^c}{d\tau_2^c} + \beta\lambda_2^c\left(\frac{B_1^c}{R_1} - \theta D_1\right)\frac{dR_1}{d\tau_2^c} + \lambda_1^c K_1^c\frac{dQ_1^c}{d\tau_2^c} + \beta\lambda_2^c\alpha\theta Y_2^c + \beta\lambda_2^c(1-\theta)\left(\frac{dR_{b1}^{eme}}{d\tau_2^c}\left(F_1^a + F_1^b\right) + R_{b1}^{eme}\left(\frac{dF_1^a}{d\tau_2^c} + \frac{dF_1^b}{d\tau_2^c}\right)\right) \qquad \text{static effects}$$

$$+\beta^2\lambda_3^c\left(r_3^c + (1-\delta)Q_3\right)\frac{dK_2^c}{d\tau_2^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_2^c} + \beta\lambda_2^c\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{d\tau_2^c} + \beta^2\lambda_3^c\left(\frac{dR_{b2}^{eme}}{d\tau_2^c}\left(F_2^a + F_2^b\right) + R_{b2}^{eme}\left(\frac{dF_2^a}{d\tau_2^c} + \frac{dF_2^b}{d\tau_2^c}\right)\right) \qquad \text{dynamic effects}$$

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

$$\frac{dW^c}{d\tau_3^c} = \beta^2\lambda_3^c\left(r_3^c + (1-\delta)Q_3\right)\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \beta\lambda_2^c\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{d\tau_3^c}$$
$$+\beta^2\lambda_3^c\left(\frac{dR_{b2}^{eme}}{d\tau_3^c}\left(F_2^a + F_2^b\right) + R_{b_2}^{eme}\left(\frac{dF_2^a}{d\tau_3^c} + \frac{dF_2^b}{d\tau_3^c}\right)\right)$$

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

On the other hand, there are four drivers of the static welfare effects of the tax: (i) the effect from hindering the capital accumulation, (ii) the effect from changes in the global interest rate, which will be proportional to the net foreign asset position, (iii) the effect from changes in the prices of capital, and for the center (iv) the effect of changes in the cross-border lending rates and quantities. The effects of (i) and (iv), that is, of a curtailed local and global intermediation, will be negative, while the effect of (ii) and (iii) depends on whether an economy is a net creditor or on the investment growth, respectively, in that sense, we expect (ii) to be positive for an emerging economy and negative for the Center. Finally, assuming that the investment in these economies is growing, (iii) is expected to be negative if the investment after the change in the tax is still larger than that of to the previous period.

The dynamic effects will have similar drivers, however, in all cases it will refer to the effect in future variables, for example, (i) would refer to the effect on future capital accumulation and (ii) on the future net assets position. The signs for the dynamic effects will not be as straightforward, we can expect similar signs, but potential corrections, for example if tighter initial taxes imply delaying investment or capital acumulation plans for future periods when the taxes return to their previous level.

It is also important to mention that the negative effects are reflective of the potentially negative growth consequences of setting these taxes as they are akin to putting sand in the wheels of the financial sector. That is what some literature refers to when pointing out the potential immiserizing growth effects of these tools.[12] Of course, the policy trade-off here is that mitigating the friction may be well worth such cost.

A critical feature that can be observed is that the welfare effects from changes in capital

[12]See Boar et al. (2017) and Belkhir et al. (2020) for a discussion on the growth effects of macroprudential policies

accumulation and capital prices are augmented by the degree of financial distortion in the peripheries (κ). This is very important, as it indicates that these taxes are potentially more effective for highly distorted economies.

Optimal taxes. I use the welfare effects expressions to derive the optimal taxes. These expressions are left for the appendix A.

There are two relevant features I find in both types of taxes (forward-looking or static), first, the peripheral taxes will grow in scale with the financial distortion and second, the center depicts a substitution effect motive between local and foreign intermediation that will push the tax upwards to favor local intermediation when the foreign lending grows ($\frac{\partial F_t^{eme}}{\partial K_1^c}$ terms). This latter effect helps to understand how the optimal tax setting of the Center differs from the periphery, given its role of international creditor. This particular feature will be important when understanding the importance of the Center in generating gains from the international coordination of policies in the main model of the section 4.

Finally, in terms of the dynamic effects, the initial period taxes, being forward-looking in nature, will reflect the effect of the tax in future variables, through variations in the capial accumulation in the economy that is setting the tax.

Welfare effects and Policy in Cooperative Settings. I have analyzed the spillover effects of these policies and optimal taxes for individual policy makers (non-cooperative). In addition, for the analytical expressions we considered the direct effects only (the effect on the welfare of a country from a change in its own tax). The cross-border effects, will have similar expressions, except that there will be no direct welfare effects from changing the taxes, i.e., any welfare change will come only from variations in the endogenous economic variables, and the variable driving the changes in the differentials will be that of a foreign country.

On the other hand, in cooperative settings the planners will join efforts and act as one with the objective of maximizing the aggregate welfare of their coalition members, the policy cases I consider are shown in detail in table 2. As a result the global welfare effects will be given by weighted averages of the expressions shown previously.

With these new welfare expressions we can find the associated optimal cooperative taxes in an analogous fashion. I do it for a cooperative planner that sets the tax of the Center. The corresponding expression is shown as the equation (23) in the appendix A.

Something crucial that occurs when a Center cooperating is that the welfare effects associated to changes in the global interest rates, that are proportional to the net foreign assets positions of the economies will cancel out between creditors and debtors that engage in cooperation. Additionally, an new motive for increasing the Center taxes emerges, which in addition, will be proportional to the increase in capital accumulation at the EMEs after a change in global banking intermediation.

These two features, the first one present in every country, and the second in the Center, will be the main factors explaining welfare differences between cooperative and non-cooperative policy settings as we will see in the results section.

As for the presence of welfare gains from cooperation and, if they exist, their distribution between economies, I set a more comprehensive model that accounts for the entire path of the taxes and the persistency of their effects in a stochastic environment. For that, I will endogeneize the taxes by formulating a Ramsey policy problem. I do that in the following two sections.

4 The Main Model

In this section we set the main model of this study and analyze how the perfect-foresight results hold in a stochastic environment. The model borrows standard elements from the literature for representing each agent. In particular, we take elements from Banerjee et al. (2016), Agénor et al. (2017) and Gertler and Karadi (2011) and incorporate them into a three country center-periphery framework with incomplete markets.

Our world economy consists of three countries, one financial center with population size $1 - n_a - n_b$ and two periferies, A and B, with population sizes n_a and n_b, with $n_a + n_b \leq \frac{1}{2}$.

The agents will have access to an international bonds market where they can trade non-contingent bonds. There is a single consumption good in the world which is freely traded. The model is set in real terms. Also, the preferences are identical between agents in each country and the law of one price holds. Thus, the purchasing power parity holds and the real exchange rate is one. In addition, the uncovered interest rate parity holds.

This implies that the only friction present in our model will be the financial agency friction in borrower-lending relationships. In that regard, this is a costly-enforcement model like Gertler and Kiyotaki (2010).

As for the key features we consider, other than introducing the lending friction, we will differentiate the banking sector in the financial center and emerging economies. For doing this, we consider a setup of limited financial development in the emerging economies, that makes necessary for the banks of these countries to rely on funding from financial centers in order to fulfill its intermediary role with the firms.

Throughout this section, the superindex i will be used when the expression applies to each country $i = \{a, b, c\}$, otherwise we use the corresponding specific superindex.

4.1 Households

The households in each economy will choose consumption, savings (with bonds or deposits) and leisure to maximize their welfare, given by the present value of their life-stream utility:

$$\max_{\{C_t, H_t, B_t, D_t\}_{t=0}^{\infty}} W_0^i = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{i(1-\sigma)}}{1-\sigma} - \frac{H_t^{i(1+\psi)}}{1+\psi} \right) \tag{1}$$

s.t.,

$$C_t^i + B_t^i + \frac{\eta}{2}(B_t^i)^2 + D_t^i + \frac{\eta}{2}(D_t^i - \bar{D}^i)^2 = R_{t-1}^i B_{t-1}^i + R_{D,t-1}^i D_{t-1}^i + w_t^i H_t^i + \Pi_t^i \tag{2}$$

With $i = \{a, b, c\}$ and where B_t^i: non-contingent international bonds, D_t^i: domestic deposits, $w_t^i H_t^i$: labor income (wages times hours supplied), Π_t^i : profits from banks and other firms net of lump-sum taxes.

In addition, adjustment costs from changes in assets positions are included to prevent non-stationarity of the model in an incomplete markets setup (see Schmitt-Grohe and Uribe (2003)).

The consumption of the final good by the home household in the country i is C^i. Since only one good is produced, that is, there are no country-specific commodities, a retail and intermediate goods sector is not included. That implies there is no home bias in consumption generated by the asymmetric size of the countries. Furthermore, since no departure from the law of one price is assumed the relative prices across countries and real exchange rates are abstracted from.

Financial Center. The F.O.C. for the households of the Center are:

$$\mathbb{E}_t\left[R_t\Lambda^c_{t+1}\right] = 1 + \eta(B^c_t)$$
$$\mathbb{E}_t\left[R^c_{D,t}\Lambda^c_{t+1}\right] = 1$$
$$C_t^{c\ -\sigma} = \frac{H_t^{c\ \psi}}{(1-\alpha)A^c_t\xi_t^{c\ \alpha}K_{t-1}^{c\ (\alpha)}H_t^{c\ (-\alpha)}}$$

Where $\Lambda_{t+1} = \beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor and λ_t is the marginal utility of consumption.

Emerging Economy Households. One difference between the households of the advanced economy and the emerging one is that the former will be able to freely purchase deposits from the Center country banks (i.e., without limitations as in the periphery) while the emerging economy banks will have a limited local intermediation capacity. This implies the banks in these countries will hold less deposits. As a simplification I drop the deposits for these countries altogether (i.e., D^a_t and D^b_t are zero). Note that this feature is not reflected in the household budget constraint above.

The F.O.C. of the emerging economy A are:

$$\mathbb{E}_t\left[R_t\Lambda^a_{t+1}\right] = 1 + \eta(B^a_t)$$
$$C_t^{a\ -\sigma} = \frac{H_t^{a\ \psi}}{(1-\alpha)A^a_t\xi_t^{a\ \alpha}K_{t-1}^{a\ (\alpha)}H_t^{a\ (-\alpha)}}$$

The F.O.C. of the emerging economy B will be analogous.

4.2 Final Goods Firms

There is one single good produced in the world that is obtained from a CD technology:

$$Y^i_t = A^i_t\left(\xi^i_t K^i_{t-1}\right)^\alpha H_t^{i(1-\alpha)} \tag{3}$$

H^i, K^i are labor and capital, A^i is a labor productivity shock, and ξ^i is a capital-quality shock (both are first-order AR processes).

The capital quality shock implies the depreciation rate is given by $\delta_t^i(\xi_t^i) = 1 - (1-\delta)\xi_t^i$.

Each period, the firms will choose labor and capital inputs to maximize the profits obtained from producing and from the sales of undepreciated physical capital to investors, while paying both wages and the banking loan with which they funded the acquisition of physical capital:

$$\max_{K_{t-1}^i, H_t^i} \Pi_t^{i,prod} = Y_t^i + (1-\delta)\xi_t^i Q_t^i K_{t-1}^i - w_t^i H_t^i - \tilde{R}_{k,t}^i Q_{t-1}^i$$
$$\text{s.t.} \quad (3)$$

We define the marginal product of capital as $r_t^i \equiv \alpha A_t^i \xi_t^{i\ \alpha} K_{t-1}^{i\ \alpha-1} H_t^{i\ 1-\alpha}$ and obtain from the FOCs with respect to labor and capital the wages and gross rate of returns paid to the banking sector:

$$w_t^i = (1-\alpha) A_t^i H_t^{i(-\alpha)} \xi_t^{i\ \alpha} K_{t-1}^{i(\alpha)}$$
$$\tilde{R}_{k,t}^i = \frac{r_t^i + (1-\delta)\xi_t^i Q_{t-1}^i}{Q_{t-1}^i}$$

As we will see when describing the banking sector, the capital is funded by selling company securities to domestic banks in a one to one relationship, i.e., $Z_t^i = K_t^i$, where Z_t^i is the stock of securities from the representative final goods firm in the country i. In that spirit, the marginal product of capital r_t^i can also be interpreted as the return from the firm securities.[13]

4.3 Capital Goods Firms

Physical capital is produced in a competitive market by using old capital and investment. The depreciation rate of capital is $1-(1-\delta)\xi_t^i$. The investment will be subject to convex adjustment costs, i.e., the total cost of investing I_t^i is:

$$C(I_t^i) = I_t^i \left(1 + \frac{\zeta}{2}\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)^2\right)$$

[13] For simplicity, when solving the model, I replace $\tilde{R}_{k,t}$ back in the profit function so that I can drop $\tilde{R}$ as a variable and work only with the effective (after tax) revenue rate perceived by banks. When we do such substitution we obtain the standard expression for the profits: $\Pi_t^{i,prod} = Y_t^i - r_t^i K_t^i + W_t^i H_t^i$.

The capital dynamics will be given by:[14]

$$K_t^i = I_t^i + (1-\delta)\xi_t^i K_{t-1}^i \tag{4}$$

The firms will buy back the old capital stock from the final goods firms at price Q_t^i and produce new capital subject to the adjustment cost.

The problem of the capital goods firm choosing the investment level is given by:

$$\max_{\{I_t^i\}_{t=0}^{\infty}} E_0 \sum_{s=0}^{\infty} \Lambda_{t,t+s}^i \left\{ Q_{t+s}^i I_{t+s}^i - I_{t+s}^i \left(1 + \frac{\zeta}{2}\left(\frac{I_{t+s}^i}{I_{t+s-1}^i - 1}\right)^2\right)\right\}$$
$$\text{s.t.} \quad (4)$$

From the first order condition we can derive the dynamics for the price of capital:

$$Q_t^i = 1 + \frac{\zeta}{2}\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)^2 + \zeta\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)\frac{I_t^i}{I_{t-1}^i} - \mathbb{E}_t\left[\Lambda_{t+1}^i \zeta \left(\frac{I_{t+1}^i}{I_t^i}\right)^2\left(\frac{I_{t+1}^i}{I_t^i} - 1\right)\right] \tag{5}$$

4.4 Banking Sector

The set-up for this sector is based on Gertler and Karadi (2011). Each economy will have a financial firm that intermediates funds for capital accumulation between savers and firms. It will borrow funds from either the depositors or the interbank market and it will lend it to the local firms. The spread in the interest rates of lending and borrowing will generate the profits of the sector.

We consider a setup with entry and exit for banks. This prevents the banks from engaging in self-funding schemes that prevent the constraints that arise from the agency frictions to bind. The survival rate of banks is given by θ. At the same time, the banks entering each period will receive a start-up capital from their household owners. Such capital will be proportional to the scale of the banking assets in the preceding period. Each period the bank will re-invest its proceeds back in its business. However, when the bank fails and exit the market, it will give back its net worth in the form of profits to the owners.

In each case, we consider an incentive compatibility constraint (ICC) that will reflect the

[14] In this notation, the time index of capital denotes the period in which it was determined, rather than the period when it is used for production.

agency problem in the lending relationships of the bank. We will assume these constraints are binding.

The structure of the sector in each country and the decisions they face are explained in detail in the following subsections. However, it can be said that in general, the problem of the bank in t consists in maximizing a financial intermediation value function $J(N_{j,t}) = \mathbb{E}_t \max \Lambda_{t,t+1}[(1-\theta)N_{j,t+1} + \theta J(N_{j,t+1})]$ subject to the dynamics of the net worth of the bank (N), the balance sheet and the ICC.

The emerging market banks will also have the additional constraint of having a limited intermediation capacity. This eventually implies funding flows from the Center economy to the peripheries that results in balance sheet effects at the cross country level.

EME Banks. The banks start with a bequest from the households and continue their activities with probability θ. The index e refers to either emerging market with $e = \{a, b\}$.

Let N^e_{jt} be the net worth and F^e_{jt} the amount borrowed from center banks at a real rate $R^e_{b,t}$. The balance sheet of the bank j is given by:

$$Q^e_t Z^e_{jt} = N^e_{jt} + F^e_{jt} \tag{6}$$

We also have that there is a one to one relationship between the securities of the bank and the physical capital units, i.e., $Z^e = K^e$.

The aggregate net worth of the banking system is:

$$N^e_t = \underbrace{\theta N^e_{j,t}}_{\text{surviving banks}} + \underbrace{\delta_T Q^e_t K^e_t}_{\substack{\text{new banks} \\ \text{start-up K}}}$$

We can see that the bequests provided by the households to the banks are proportional to the pre-existing level of intermediation (capital) times the current price of capital.

At the same time, $N^e_{j,t}$ is the net-worth of surviving banks which displays the following dynamics:

$$N^e_{j,t} = R^e_{k,t} Q^e_{t-1} K^e_{j,t-1} - R^e_{b,t-1} F^e_{j,t-1} \tag{7}$$

The gross return on capital, $R^e_{k,t}$, will account for the payment of the macroprudential tax:

$$R^e_{k,t} = \frac{(1-\tau^e_t)r^e_t + (1-\delta)\xi^e_t Q^e_t}{Q^e_{t-1}}$$

with $\tau^e_t \gtrless 0$ representing a tax/subsidy.

The contracts between savers and banks will be subject to limited enforceability, i.e., a bank can default, in which case, the savers will take it to court but will only be able to recover a portion of the promised payment. In practice, this implies the bank can run away with a portion κ^e of the assets.

The problem of the j banker is to maximize the value of the bank:[15]

$$J^e_{j,t}(N^e_{j,t}) = \mathbb{E}_t \max_{N^e_{j,t}, Z^e_{j,t}, V^e_{j,t}} \Lambda^e_{t+1}\left[(1-\theta)N^e_{j,t+1+s} + \theta J^e_{j,t+1}(N^e_{j,t+1})\right]$$

subject to the net worth dynamics (7), the balance sheet constraint (6) and the associated Incentive Compatibility Constraint:

$$J^e_{j,t} \geq \kappa^e Q^e_t K^e_{j,t} \tag{8}$$

This ICC condition states that the continuation value of the bank is larger than the potential profit of defaulting.[16]

The bank problem yields the following optimality conditions:

F.O.C. with respect to intermediated capital:

$$[K^e_{j,t}]: \qquad \mathbb{E}_t \Omega^e_{t+1|t}\left(R^e_{k,t+1} - R^e_{b,t}\right) = \mu^e_t \kappa^e \tag{9}$$

and envelope condition:

$$[N^e_{j,t}]: \qquad J^{e'}(N^e_{j,t})(1-\mu^e_t) = \mathbb{E}_t \Omega^e_{t+1|t} R^e_{b,t} \tag{10}$$

where μ^e_t is the lagrange multiplier associated with the ICC and $\Omega^e_{t+1|t} = \Lambda^e_{t+1}\Big(1-\theta+\theta J^{e'}_{t+1}\Big)$

[15] An analogous sequential problem is given by maximizing: $J^e(N^e_{j,t}) = E_t \max_{\{N_t, Z^e_t, V^e_{j,t}\}^\infty_{t=0}} (1-\theta)\sum_{s=0}^{\infty} \Lambda^e_{t+1+s}[\theta^s N^e_{j,t+1+s}]$

[16] There are several feasible choices for the right hand side term depending on the timing of the assets absconding. Here we assume they compare the value of the bank to diverting assets as soon as they obtain them, i.e., before these yield returns.

is the effective stochastic discount factor of the bank.

Center Economy Banks. The structure of the center economy banks is similar. We only need to be careful when setting the balance sheet and net worth dynamics. Both need to reflect the foreign claims intermediated and the proceeds from being a global creditor.

The balance sheet of the global country bank j is:

$$F^a_{j,t} + F^b_{j,t} + Q^c_t Z^c_{j,t} = N^c_{jt} + D^c_t \tag{11}$$

where D^c are the deposits from the households, $F^e_{j,t}$ are the claims on the $e = \{a, b\}$ representative periphery banks (EMEs), and $Q^c_t Z^c_{j,t}$ are claims on the core country capital stock with $Z^c_{j,t} = K^c_{j,t}$.

Their net (after taxes) return on intermediated capital is:

$$R^c_{k,t} = \frac{(1-\tau^c_t) r^c_t + (1-\delta)\xi^c_t Q^c_t}{Q^c_{t-1}}$$

The bank j value function is:

$$J^c_{j,t}(N^c_{j,t}) = \mathbb{E}_t \max_{N^c_{j,t},\, Z^c_t,\, V^e_{j,t},\, D^c_t} \Lambda^c_{t+1}\Big[(1-\theta)(\underbrace{R^c_{k,t+1} Q^c_t Z^c_{j,t} + R^a_{b,t} V^a_{j,t} + R^b_{b,t} V^b_{j,t}}_{\text{gross return on assets}} - \underbrace{R^c_{D,t} D^c_t}_{\substack{\text{deposits}\\ \text{repayment}}}) + \theta J^c_{j,t+1}(N^c_{j,t+1})\Big]$$

The bank maximizes such value while being subject to the balance sheet constraint (11) and to an incentive compatibility constraint given by:

$$J^c_{j,t} \geq \kappa^c_{F_1} F^a_{jt} + \kappa^c_{F_2} F^b_{jt} + \kappa^c Q^c_t Z^c_{j,t} \tag{12}$$

with $\kappa^c_{F_i}, \kappa^c > 0$.

The optimality Conditions are:

$$[Z^c_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t}(R^c_{k,t+1} - R^c_{D,t}) = \kappa^c \mu^c_t \tag{13}$$

$$[F^a_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t}\left(R^a_{b,t} - R^c_{D,t}\right) = \kappa^c_{F_1} \mu^c_t \tag{14}$$

$$[F^b_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t} \left(R^b_{b,t} - R^c_{D,t} \right) = \kappa^c_{F_2} \mu^c_t \tag{15}$$

and the envelope condition,

$$[N^c_{j,t}]: \quad J^{c'}(N^c_{j,t})(1 - \mu^c_t) = \mathbb{E}_t \Omega^c_{t+1|t} R^c_{D,t} \tag{16}$$

4.5 Macroprudential Policy

The policy tool considered is a tax on the return to capital. This is a general enough instrument that encompasses several variaties of macroprudential instruments. For example, and as we showed in the proposition 2, it can have leverage implications.

Furthermore, setting the tool as a tax on the revenue rate of banking has the advantage of affecting the wedge between return on capital and deposit rate (credit spread) in a direct fashion. Therefore, policy actions can be applied right at the source of inefficiencies.

$$\tau^i_t r^i_t K^i_{t-1} + T^i_t = 0 \qquad i = \{a, b, c\}$$

Effect of the macroprudential tool in the model. In the finite horizon version of this model, with simple dynamics, we obtained that leverage is a function of the macroprudential and that their relation is negative. That is, an increase in the tax will decrease the leverage ratio of banks. As a result, by implementing a given tax, the planner would also enforce a leverage ratio in the banking sector, a commonly used macroprudential policy.

In the infinite horizon setup of this section, proving such result is less straightforward. Particularly, because the future effects of the policies show only implicitly in the continuation values of the recursive expressions for the value of the bank.

Nevertheless, it is still possible to describe the way leverage responds to an increase in the tax. I do it by following Gertler and Karadi (2011) and setting the value of the bank in terms of current lending and net worth and dynamic coefficients. We use the functions for the emerging economies, but the same results hold for the advanced one that intermediates more types of assets:

$$J^e_{jt} = \nu_t Q^e_t K^e_{jt} + \eta_t N^e_{jt}$$

with,

$$\nu_t = \mathbb{E}_t\{(1-\theta)\beta\Lambda^e_{t+1|t}(R^e_{k,t+1} - R^e_{b,t}) + \beta\Lambda^e_{t+1|t}\theta x_{t,t+1}\nu_{t+1}\}$$
$$\eta_t = \mathbb{E}_t\{(1-\theta) + \beta\Lambda^e_{t+1|t}\theta z_{t,t+1}\eta_{t+1}\}$$

Where $x_{t,t+i} = Q^e_{t+i}K^e_{j,t+i}/Q^e_t K^e_{j,t}$ and $z_{t,t+i} = N^e_{j,t+i}/N^e_{j,t}$

I now substitue J^e_{jt} from (8) when it binds and obtain the leverage as ϕ^e_t:

$$\frac{Q^e_t K^e_t}{N^e_t} = \phi^e_t = \frac{\eta_t}{\kappa^e - \nu_t} \tag{17}$$

Where I removed the j sub-index as the components of the leverage will not depend on firm-specific factors.

It also follows that $z_{t,t+1} = [(R^e_{k,t+1} - R_{b,t})\phi^e_t + R^e_{b,t}]$ and $x_{t,t+1} = (\phi^e_{t+1}/\phi^e_t)z_{t,t+1}$.

With this, we can see that as the tax increases and the spread goes down, η_t and ν_t will decrease. The overall effect on leverage would be negative. However, even if we can indicate the direction of the changes in the leverage expression, i.e., in the equation (17), it is difficult to pinpoint the change in leverage as the tax increases as in the simpler setup, as the terms in the right hand side of the equations will depend on current and future values of the leverage themselves.

4.6 Market Clearing Conditions

The corresponding market clearing conditions of the model, for the final goods market and bonds, are:

$$\text{Goods market:} \qquad \sum_i n_i Y^i_t = \sum_i n_i \left(C^i_t + I^i_t \left(1 + \frac{\zeta}{2}\left(\frac{I^i_t}{I^i_{t-1}} - 1\right)^2 \right) + \frac{\eta}{2}(B^i_t)^2 \right)$$
$$\text{Bonds market:} \qquad \sum_i n_i B^i_t = 0, \qquad \forall t$$

where i denotes a country index, i.e., $i = \{a, b, c\}$.

Notice that the market clearing condition for the final goods reflects, first, the adjustment cost of executing investment projects, and second, the fact that the final good is fully tradable and produced in each economy (no home bias).

Due to Walras law, when solving the model we can use either the budget constraints of each type of household, or two of them and the goods market clearing condition.

The final set of equations that we use for solving the model are listed in the appendix B.

5 Ramsey Policy Problem

So far we have characterized the private equilibrium for this economy. In that context the policy tools are exogenous to the agents, i.e., they take them as given when taking their optimal decisions. However, we are interested in the optimal endogenous determination of these tools for a set of policy arrangements that vary by the degree of international regulatory cooperation. For that, we will use the Ramsey Planner Problem, consisting on choosing the optimal level of the policy tools, and the rest of variables, subject to the conditions that characterize the private equilibrium.

The idea is to respect the private equilibrium structure, while still shaping the final resulting allocation by setting the policy instruments optimally. I consider four policy schemes that range from no-cooperation (Nash), to world cooperation while allowing for semi-cooperative cases where subsets of countries form regulatory coalitions:

Table 2: Policy Cases Considered

	Planners/Players	Obj. Function	Decision variables
Cooperation (all countries)	World	$W_t^{Coop} = n_a W_t^a + n_b W_t^b + n_c W_t^c$	$\mathbf{x_t}, \boldsymbol{\tau}_t$
Semi-Cooperation (EMEs vs. Center)	Periphery block A+B	$W^{ab} = n_a W^a + n_b W^b$	$\mathbf{x_t}, \tau_t^a, \tau_t^b$
	Center	W^c	$\mathbf{x_t}, \tau_t^c$
Semi-Cooperation (EME-A + C vs. EME-B)	Cooperative A+C	$W^{ac} = n_a W^a + n_c W^c$	$\mathbf{x_t}, \tau_t^a, \tau_t^c$
	EME-B	W^b	$\mathbf{x_t}, \tau_t^b$
Nash (One planner per country)	EME-A	W^a	$\mathbf{x_t}, \tau_t^a$
	EME-B	W^b	$\mathbf{x_t}, \tau_t^b$
	Center	W^c	$\mathbf{x_t}, \tau_t^c$

Note: $\boldsymbol{\tau}_t = (\tau_t^a, \tau_t^b, \tau_t^c)'$

As shown in table 2, two features are critical for differentiating the cases, first, the objective funtion of the planner will be the weighted welfare of the countries that belong to a coalition, that includes the non-cooperative case where each economy will have an individual planner whose objetive function will be the local (national) welfare. Secondly, the cooperative planners, by joining efforts and acting as one, will have a larger menu of policy tools available.

The detailed policy problems they solve will be described in the following subsection.

5.1 Planning Problems

In every case we will consider the planning problem under commitment with a timeless perspective. [17] As explained by King and Wolman (1999) this implies we are assuming the policy makers were making optimal decisions in the past in a time consistent manner. This

[17] See Woodford (2003) and Benigno and Woodford (2004) for a detailed discussion on the timeless perspective and time consistency in the policy problem.

formulation is the standard in the literature, given its property of avoiding indeterminacy issues in the model solution.

World Cooperation. Under commitment, a single planner, whose objective function is the worldwide welfare, chooses the vector of endogenous variables and the policy instruments to solve:

$$W_0^{coop} = \max_{\mathbf{x}_t, \boldsymbol{\tau}_t} [n_a W_0^a + n_b W_0^b + (1 - n_a - n_b) W_0^c] \tag{18}$$

subject to the system of equations that characterize the private equilibrium (private FOCs, budget constraints and market clearing conditions):

$$\mathbb{E}_t F(\mathbf{x}_{t-1}, \mathbf{x}_t, \mathbf{x}_{t+1}, \boldsymbol{\tau}_{t-1}, \boldsymbol{\tau}_t, \boldsymbol{\tau}_{t+1}; \boldsymbol{\varphi}_t) = 0$$

where W_0^i denotes the welfare of the country i as in (1), $\mathbf{x}_t$ is the vector of endogenous variables, $\boldsymbol{\tau}_t = (\tau_t^a, \tau_t^b, \tau_t^c)'$ is the vector of instruments and $\boldsymbol{\varphi}_t$ is a vector of exogenous variables and shocks.

Semi-cooperative case 1 - cooperation between the Center and the EME-A. The planners of the C and A economies will form a coalition, acting as one and solving:

$$W_0^{coop(C+A)} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^c} [n_a W_0^a + n_c W_0^c] \tag{19}$$

$$\text{s.t.,} \qquad \mathbb{E}_t F(\mathbf{x}_{t-1}, \mathbf{x}_t, \mathbf{x}_{t+1}, \boldsymbol{\tau}_{t-1}, \boldsymbol{\tau}_t, \boldsymbol{\tau}_{t+1}; \boldsymbol{\varphi}_t) = 0$$

where $F(\cdot)$ denotes the private equilibrium conditions. Notice that these system of constraints will be the same for every planner across all the policy frameworks.

The remaining country (B) will solve the same problem as in the Nash case.

Semi-cooperative case 2 - cooperation between the emerging countries. The planners of the A and B economies will form a coalition and solve:

$$W_0^{coopEME} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^b} [n_a W_0^a + n_b W_0^b] \tag{20}$$

$$\text{s.t.,} \qquad \mathbb{E}_t F(\mathbf{x}_{t-1}, \mathbf{x}_t, \mathbf{x}_{t+1}, \boldsymbol{\tau}_{t-1}, \boldsymbol{\tau}_t, \boldsymbol{\tau}_{t+1}; \boldsymbol{\varphi}_t) = 0$$

The remaining country (C) will solve the same problem as in the Nash case.

Nash. Finally, a non-cooperative policy-maker of the country $i = \{a, b, c\}$, with the domestic welfare as objective function, will solve:

$$W_0^{i\ nash} = \max_{\mathbf{x}_t, \tau_t^i} W_0^i \tag{21}$$

$$\text{s.t.,} \qquad \mathbb{E}_t F(\mathbf{x}_{t-1}, \mathbf{x}_t, \mathbf{x}_{t+1}, \boldsymbol{\tau}_{t-1}, \boldsymbol{\tau}_t, \boldsymbol{\tau}_{t+1}; \boldsymbol{\varphi}_t) = 0$$

5.2 Gains From Cooperation

To compare the performance of the models, we will compute the global expected conditional welfare and compute the welfare gains with respect to a benchmark. For example, the welfare gain of world cooperation, relative to the non-cooperative (Nash) model will be:

$$Gain_{Coop/Nash} \equiv W_{coop,0} - (n_a W^a_{nash,0} + n_b W^b_{nash,0} + (1 - n_a - n_b) W^c_{nash,0})$$

The gain will be approximated at the second order around the non-stochastic steady state. Moreover, as it is, this welfare gain is given in utility units, making difficult to assess the magnitude of the relative performance of each model. Then, for a better comparison, what we really look for is λ s.t.

$$W_0^{i\ coop}(\lambda) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{((1+\lambda) C_t^{i\ coop})^{1-\sigma}}{1-\sigma} - \frac{(H_t^{i\ coop})^{(1+\psi)}}{1+\psi} \right) = W_0^{i\ nash}$$

For each economy $i = \{a, b, c\}$. Then, the global consumption equivalent gain(cost) will be the weighted average of the national ones.

This parameter, λ, denotes the consumption equivalent variation that would make the private agents indifferent between the models compared, that is, the proportional increase in the steady-state consumption of the world cooperation model that would deliver the same welfare as the Nash case.

Clearly, an overperforming model, or in this example a model with gains from cooperation, would depict a positive λ. We approximate λ by normalizing the welfare gain (in utility units) by the increase in steady-state welfare that would be obtained from a 1% increment in consumption.

6 Results

In this section, we discuss the solution of the main model under different policy schemes and how it helps us answer our two research questions, namely, (i.) is the international cooperation of macroprudential policies convenient for emerging economies in general?, and (ii.) are cooperative policies useful in shielding the peripheric economies from external shocks and the global financial cycle?.

For (i.) we will compare the expected long run welfare that the policy frameworks in table 2 deliver. By construction, this will be a comparison of the long-run performance of the models. On the other hand, for (ii.) we will analyze how each policy setup fares when facing negative shocks that originate at the Center.

I use the parametrization shown in table 8. In most cases I borrow standard parameters from the literature that have the usual targets (e.g., discount factor and depreciation rate). However, there are other parameters that are chosen with the macroprudential litetarure on emerging markets in mind. This is particularly true for the divertable fraction of capital which we adopt from Aoki et al. (2018). At the same time, given the focus on the large open economy dimension of these policies, I set the population sizes of each emerging economy at 0.25 each ($n_a = n_b = 0.25$).

Table 3: Steady State values for the policy tools

	Nash	Cooperation (Center+EME-A)	Cooperation (EMEs)	Cooperation (All)
τ^c	-0.850	-0.530	-0.806	-0.864
τ^a	0.319	-0.164	0.348	-0.697
τ^b	0.319	0.328	0.348	-0.697

Steady State of the Policy Instruments. The table 3 shows the steady states of the policy taxes for each policy regime considered. The solution algorithm used implies computing an instrument conditional steady state and follows the steps outlined in Christiano, Rotto and Rostago (2007) and Bodenstein et al. (2019), a detailed explanation can be found in the appendix A. I obtain that the Center always applies subsidies to its banking sector in the long run, while planners of the EMEs subsidize its banking sector only when cooperating with the Center, and instead, set a tax to the financial intermediaries in the non-cooperative case or under the regional emerging coalition. Therefore, it follows, at least in the long-run, that cooperation with the center consists on setting higher subsidies (lower taxes).

6.1 Welfare Accounting Comparison

A comprehensive comparison of the models can be done in terms of the welfare they deliver. For this, we compute the conditional welfare in all cases. Being conditional on having the same initial state vector, the outcome allows us to compare and rank the policy frameworks in terms of their long run outcomes.

Table 4: Welfare cost in consumption equivalent compensation relative to the First Best

	Consumption Equivalent Compensation			
	Nash	Cooperation (Center+EME-A)	Cooperation (EMEs)	Cooperation (All)
C	-11.7	2.9	-13.2	-3.9
A	-19.5	0.4	-27.4	-2.4
B	-19.5	-28.3	-27.4	-2.4
World	**-15.6**	**-5.5**	**-20.4**	**-3.2**
EMEs	-19.5	-13.9	-27.4	-2.4

Notes: Compensation using the First Best as benchmark. The numbers in bold denote the departure from the FB model, in terms of steady state consumption. In Cooperation symmetry between instruments rules is assumed for EMEs

The table 4 shows the expected conditional welfare obtained by simulating the models solution at a second order of approximation. The associated welfare levels are shown in the table 10 in the appendix B. We compute the consumption equivalent compensation, by normalizing the welfare wedge between each policy model and a reference model (the First Best), by the increase in welfare that would be obtained if consumption were to increase by 1%.[18] These numbers can be interpreted as the equivalent consumption cost derived from transitioning from the first best model to each of the models in the table columns. For example, the world Cooperation model implies a welfare cost equivalent to a decrease of 2.9% in the consumption of every period.

I use the global welfare, in the fifth row, as the criterion for ranking the expected welfare performance of the models. We find that the best policy framework is the worldwide cooperation, followed by the cooperation between the Center and one periphery (A in Coop(Center+EME-A)), the third best policy would be the non-cooperative one (Nash) and, finally, the worst performing one is the regional cooperation between peripheries (CoopEMEs).

The implication is that not every type of cooperation will be welfare improving relative to the nationally-oriented regime (Nash case). On the contrary, the cooperation arrangements that are beneficial, globally and to the EMEs are those that involve a cooperative Center. This helps us answer the first question prompted at the beginning of the section: The emerging economies will not be better off from any type of cooperation, they will only benefit when they can cooperate with a financial center.

At the same time, when looking at the national distribution of the welfare gains, we can see that sustaining the global cooperation would be challenging, as the coalition participants will be better-off in the semi-cooperative arrangement (Coop(Center+EME-A) in the table or Coop(A+C) in the model notation). In that case, the gains for the EME-A and the Center are such that they can even overcome the first best allocation at the expense of the periphery that is left out of the coalition (EME-B).

Sources of Welfare Gains From Cooperation For identifying the origins and mechanishms that generate the welfare gains, we can resort to the analytical expression for the optimal tax in the Center under cooperation. Even if more complex, the structure of the

[18]The increase in consumption is applied to the consumption and utility levels used as the initial state for all models. As an alternative, the consumption equivalent cost is computed using a log-utility in consumption approximation, in Lucas (1987). The approximation is relatively valid as our CRRA parameter is close to one and the results are qualitatively the same. The table is reported in the table 9 in the appendix B.

taxes in the stochastic and infinite horizon model used to compute the table 4 would be similar.

After a number of simplifying steps, I find that the optimal tax in the financial center has the following form:

$$\tau_3^{c,coop} = \tau_3^{c,nash} - \underbrace{\varphi_3^{NFA}}_{\substack{\text{NFA-led Interest rate}\\ \text{manipulation motive}\\ \text{under Nash}}} + \underbrace{\psi_3^{eme}(\kappa)}_{\substack{\text{local capital for foreign (EME)}\\ \text{intermediation substitution motive}}} \tag{22}$$

This equation is obtained in the appendix A, and $\tau_3^{c,nash}$ corresponds, exactly, to the optimal tax for a nationally-oriented (non-cooperative) Center in the equation (23).

The equation (22), with $\varphi_3^{NFA} < 0$ and $\psi_3^{eme}(\kappa) > 0$ will imply that the taxes in the Center that are implemented under cooperation will tend to be larger and favor the capital accumulation in the emerging economies.

Furthermore, by differentiating we can get $\psi_3^{eme\,\prime}(\kappa) > 0$, which implies that the strength of this effect increases with the extent of the peripheral financial distortion.

The welfare enhancing mechanisms, explained by each of the last two terms in the right hand side of (22) work as follows:

Higher Smoothness of Cooperative Taxes: A Cooperative planner that can set the policy tools of the Center and of some or all peripheries (Coop and Coop(A+C)) will find that the incentives to manipulate the global interest rate to benefit from fluctuations in the net foreign assets position will dissapear ($-\varphi_3^{NFA}$ cancels out with the same positive term in $\tau_3^{c,nash}$). This happens because in the cooperative welfare expressions, the net foreign assets terms of debtor (EMEs) and creditor (Center) countries go in opposite directions and cancel out, partially or completely, with each other. As a result, there is one fewer source of fluctuations in the taxes that will render the cooperative ones less volatile.

The cancellation effect works better with more peripheries in the policy coalition, and if it is the case, as in our model, when the sum of the welfare weights of the participating EMEs equals that one of the Center.

This mechanism is also present in the literature on cooperative capital controls, such as Davis and Devereux (2019) who describe this effect as the absence of terms of trade manipulation motives by cooperative planners. However, something interesting in this case is that I obtain such result when regulating the banks, rather than taxing the NFA flows directly.

Substitution Motive of Local Capital for Foreign Intermediation: The cooperative planner will have an additional motive for increasing the taxes at the Center. By doing so, it will discourage the local capital accumulation, which in turn protects the capital inflows at the EMEs. The incentive increases with the friction and the scale of the increase in the capital acumulation abroad.

In terms of the expression, this motive is proportional to the variation in EMEs capital accumulation after a change in the global intermediation, as well as to the capital prices in the peripheries and the degree of the financial friction.

In summary, two main mechanisms at work, first a cancellation motive that lowers the volatility of the taxes under cooperation, something that is generally welfare increasing and favors a more efficient pursuit of financial stability goals, as other, potentiallly conflicting, policy incentives become absent, and second, a new policy motive towards encouraging the retention of capital flows in the peripheries, even if it comes at the expense of the local capital accumulation of the Center.

Both motives add to the overall financial stability of the world economy. The first one will prevent unnecessary fluctuations in the taxes and even in the global interest rate, hence would lead to less volatility in the international capital fluctuations as the yield-seeking reaction of non-cooperative regimes are muted. The second one, on the other hand, will be a specific motive towards encouraging capital flows to the peripheries, which in presense of external shocks at the Center, can be useful in preventing capital retrenchements episodes.

Simultaneously, the second motive also encourgaes a more efficient use of the capital flows, as these are allocated in the more productive destinations. In that spirit, the gains will be boosted as the welfare improving regimes will feature both a higher financial stability and efficiency in the use of capital.

Furthermore, it is important to remark that both motives are present only under cooperative frameworks that include the Center. The first, is a cancellation effect between global debtors and creditors incentives and will be absent if all the countries in the cooperative coalition are debtors as in the peripheric regional cooperation (CoopEMEs).

The second one, on the other hand, is an effect that is unique to the Center given its role as global creditor and recognizes the fact that the cooperative planner acting on behalf of the Center will now internalize the unique capacity she has for boosting the global welfare given the priviledged role of the financial center as global interbank lender. This means the tax is not set with the aim to boost the domestic welfare, something that would tentatively imply increasing the local accumulation of capital, but to boost the global output, which is done more efficiently at the peripheries, where capital is more productive.

On the other hand, an additional factor in favor of emering capital accumulation that is reflected in this model, and not in the simplified one of the previous section, is the fact that, unlike in every other regime and type of country, a cooperative planner will tend to set the macroprudential taxes at the Center in a countercyclical fashion.

Table 5: Correlations between output and macroprudential tools in each policy regime

$Corr(\tau^i, Y^i)$	Nash	Cooperation (EMEs)	Cooperation (Center+EME-A)	Cooperation (All)
EME-A	-0.164	-0.265	-0.611	-0.861
EME-B	-0.164	-0.265	-0.221	-0.861
Center	-0.419	-0.425	**0.085**	**0.138**

Cyclicality of the Optimal Policies. In table 5 I report the correlations of the output with the macroprudential tax. Given this tax limits intermediation (capital accumulation), we would have a countercyclical tax when the covariance between the output and the policy tool is positive ($Cov(Y_t, \tau_t) > 0$), i.e., a higher tax is implemented during booms in a way that cools down the banking activities.

The outcome that the Center, a key economy for generating cooperation gains, deviates towards a countercyclical behavior under cooperative frameworks is very important. First, it will implicate the Center planner wants to encourage the capital flows towards the EMEs, so as to prevent retrenchements, and second, it potentially reconciles opposing results of the literature in regards to the cyclicality dimension of these policies by exploiting the varying degree of cooperation across policy regimes.

In terms of the first point, we have that during a boom at the Center, the planner will discourage the inflow (towards the Center) of capital flows at the expense of outflows from the EMEs. It will do so by increasing its taxes and curbing the local financial intermediation.

For the second point, we have on one side, seminal studies as Bianchi (2011) and Jeanne and Korinek (2019) that find the optimal macroprudential policies to be counter-cyclical, as intuition would dictate, since these policies are supposed to cool down the economy rather than to amplify its cycles. On the other hand, Fernández et al. (2015) finds that actual macroprudential policies tend to be procyclical, while Uribe and Schmith-Grohe (2017) supports the procyclicallity of these policies in a theoretical context.

On this point, I exploit another dimension of these policies, the degree of cooperation, to find a result that is consistent with both sides of this dicussion.

The results indicate that these policies are procyclical for most of the countries and policy frameworks, as part of the mentioned literature states. However, it turns out that the models that deliver gains from cooperation, that originate from a cooperative Center, imply that the tax of that economy will be set countercyclically.

Role of the Welfare Weights. Both of the mechanisms that generate the welfare gains will work better for higher welfare weights of the peripheric welfare in the objective of the cooperative planner. In this paper, I use the relative economic sizes n_i for $i = \{a, b, c\}$ as the actual welfare weights for cooperative regimes. Furthermore, we are assuming that the sum of the peripheral economies sizes amount to that of the Center ($n_a + n_b = n_c$). With this assumption, first, the cooperative planner will cancel out more evenly the net foreign assets - interest rate manipulation motive of the individual countries, and second, it will have a stronger motive for facilitating the intermediation in the peripheries, as these will have a stronger positive effect in its objective, the global welfare.

In that vein, as the economy converges to a small open economy case ($n_a, n_b \to 0$) the cancellation of policy incentives to manipulate the interest rate will no longer work as the cooperative planner would be biased to favor the Center. Also the planner would not find worthwhile to sacrifice local capital accumulation at the Center to encourage peripheric intermediation as the latter, even if more efficient will not contribute substantially to the global GDP.

Finally, it is relevant to remark that the difference in the welfare gains in favor of the Center is the reason explaining why the semi-cooperative model Coop(A+C) does not perform as well as the global cooperation regime. The fact that the cooperative planner is more biased to increase the welfare of the Center will not allow for a strong enough offsetting of the national interest rate manipulation motives.

On Time Consistency. As part of the exercises I also solved a time variant version of this model to explore whether time consistency is relevant in this environment from a welfare perspective. I obtained potentially interesting results. On one hand, it is more difficult to solve the models, something relatively expected as a well known property of time inconsistent models is the presence of underterminacy and sunspots equilibria (Evans and Honkapohja (2003), Evans and Honkapohja (2006)). In fact it is not possible to obtain a solution for every policy framework. However, the world Cooperation and one of the semicooperative models does yield a solution. This can point to another advantage of cooperation, namely, overriding undeterminacy and non fundamental driven solutions. This may be relevant as the non-fundamental equilibria tend to be welfare decreasing.

Finally, even in the cooperative models that yield a solution, there is a substantial welfare loss with respect to every model we compute under the, time consistent, timeless perspective. With this, I confirm the conveniency of working with the timeless perspective approximation for the main simulations of this study. The welfare results for a time variant version of the Cooperative model is shown in the table 10 in the appendix B.

6.2 Short Run and Cyclical Performance of the Policy Setups

It is also possible to verify the short-run dynamics and optimal policy paths after financial and real shocks that originate at the Center. By doing this, we can answer the second question of this study, also stated at the beginning of this section: Are cooperative policies useful in protecting the emerging economies from external shocks?.

The type of situation I have in mind when formulating this question is one like the crisis of 2008, where a recessionary shock with origins in the advanced economies ended up having international consequenses as part of the global financial cycle.

Financial shock. The figure 3 shows the dynamic response in the real variables of these economies after a negative financial shock at the Center. the results suggest that, indeed, the global cooperation model protects better the output dynamics of the emerging economies, with the semi-cooperative model where the Center cooperates with a periphery (Coop(A+C)) coming in second place, although in the latter case, as expected, the expansionary effect is concentrated in the periphery that form a policy coalition with the Center. On the other hand, the dynamics of the regional cooperation case (CoopEMEs) and the Nash are virtually the same, meaning they will not get any extra resilience from engaging in a peripheral cooperation.

With this, we can answer to our second research question: the policy frameworks where the financial Center cooperates are helpful in protecting the emerging economies from external shocks. At the same time, other types of cooperation, such as that between emerging economies only, will not have this feature.

For this protection to happen, we see that the cooperative planners will increase the capital acumulation by EMEs in a much greater scale than non-cooperative planners (fourth row in figure 3). This will come at the expense of the acumulation in the Center. However, it will be deemed appropriate by the planners, as their priority now becomes the global output recovery and not only that of the Center. Clearly, such effect will depend on the fact that the relative sizes of the peripheries in our setup are sizable (each amounts to a quarter of the world).

Noticeably, even with a better output response, the emerging consumption is hit the most under cooperation (second row panel in the figure). This occurs because the cooperative planners prioritize boosting the investment and intermediation to support the economic activity in these economies. This is reflective of the stronger institutional effort towards aiding the global welfare recovery, even if the shock is not domestic. Finally, the labor supply dynamics will be a by-product of the consumption and capital fluctuations. The former decreases at first, increasing the marginal utility of consumption, while the latter increases, pushing upwards the salaries. As a result, the hours supply increases significantly under cooperation. [19]

The financial variables tell a similar story. We show these in the the figure 4. Consistently with the evolution of capital, we obtain that the lending is boosted more strongly under cooperation, although in this case, for every economy. The latter point is crucial, the Center is not accumulating more capital locally for production, however, increases its lending to expand its international financial intermediation activities. Additionally, we see a more persistent build-up of net-worth in the peripheries under cooperative schemes.

On the other hand, the credit spread dynamics reflect a substantial effort by cooperative

[19]This interpretation takes into account that this model displays a wealth effect in the labor supply optimal decisions.

planners to push up the interest rates in the hit country (Center, third column panel, third row), whereas for the emerging ones, we see the opposite, indicating that the optimal stance under cooperation consists in a fast and active compensation of the effect of the shock (that would push the spread upwards in the peripheries).

Finally, the leverage will go up in the EMEs by construction. However, it is noticeable that the increase is smoothed over time by the cooperative policymarkers. As for the Center, the non-cooperative planners will try to boost the local leverage, while those that cooperate (Coop and Coop(A+C)) would prefer to focus the intermediation and leverage stimulus on EMEs only. Again, this outlines the critical difference between cooperative and non-cooperative planners, the former internalize its global welfare effects and as a result will know better where to focus (on EMEs) to facilitate a speedier global economic recovery.

Optimal taxes dynamics. The policy response of the planners will be countercyclical on impact for all policy regimes (see fourth row panel in figure 4). That is, the peripheric planners will increase the taxes while planner at the Center will subsidize the banking sector. However, there are meaningful differences across regimes that explain the discrepancies between the cooperative and non-cooperative outcomes. First, the taxes will be smoother under cooperation and in particular during the first five to ten quarters after the shock. This reflects the comparative advantage of a coordinated policy scheme in avoiding unnecessary instrument fluctuations.

Secondly, the non-cooperative Center planner (Nash and Coop(EMEs) regimes) will exert a substantial effort towards increasing the local intermediation by implementing a stronger financial subsidization. The latter does not occur for the other regimes (Coop and Coop(A+C)) as the cooperative planner knows that it could affect negatively the credit spread and, more importantly, the intermediation at the emerging economies, a component the she deems crucial in her policy strategy to boost the global output.

Figure 3: Response to a negative financial shock at the Center economy

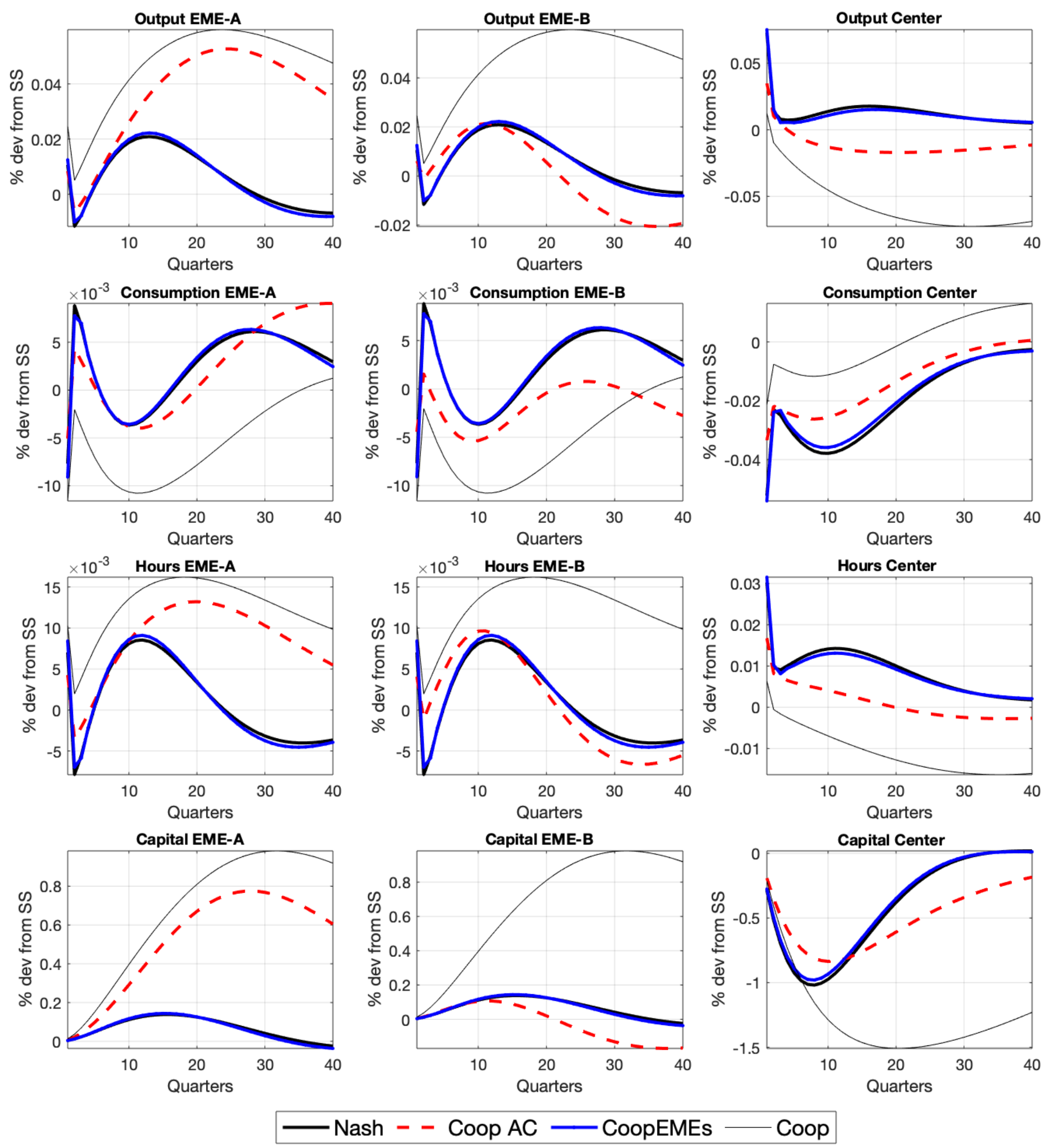
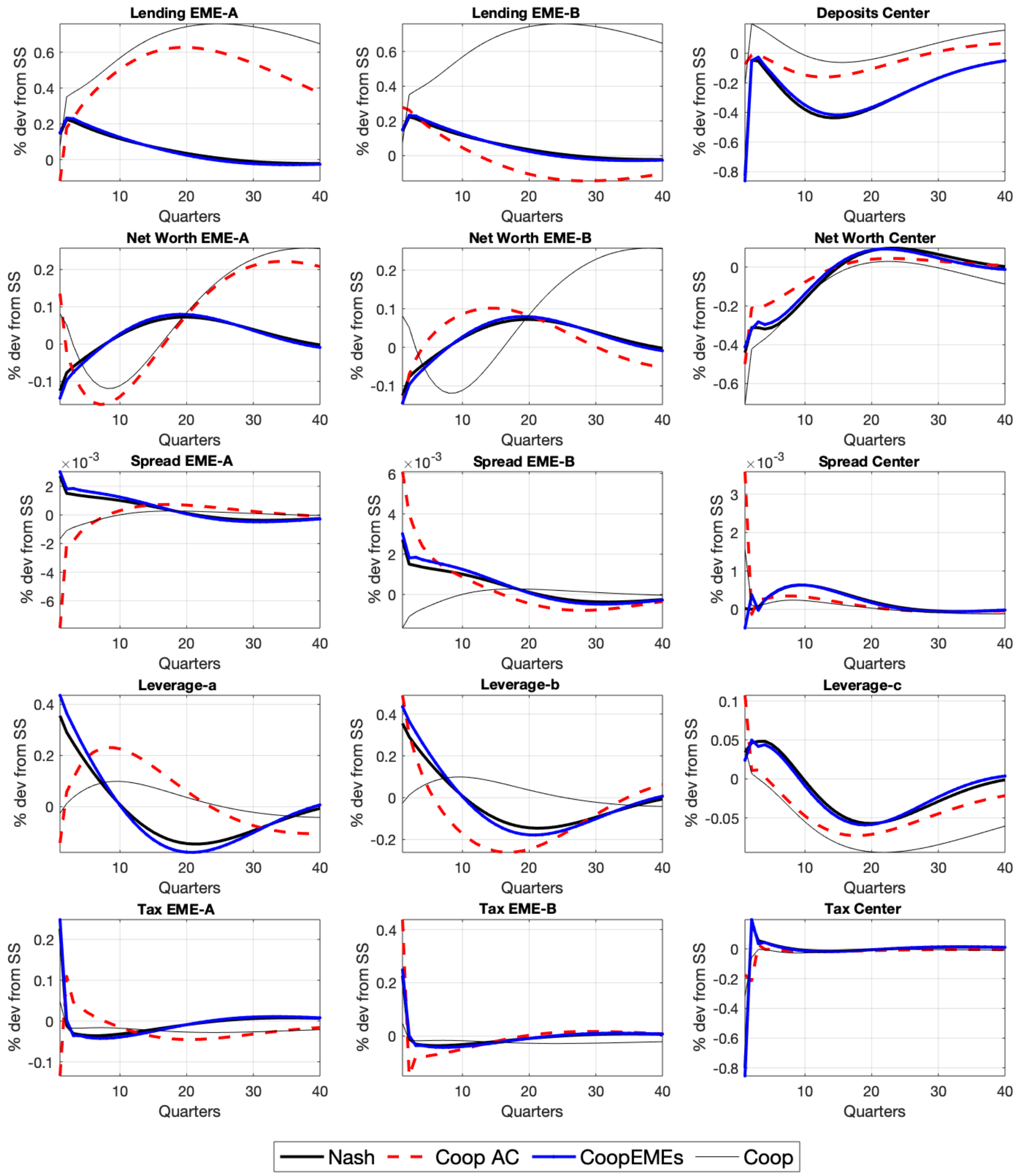
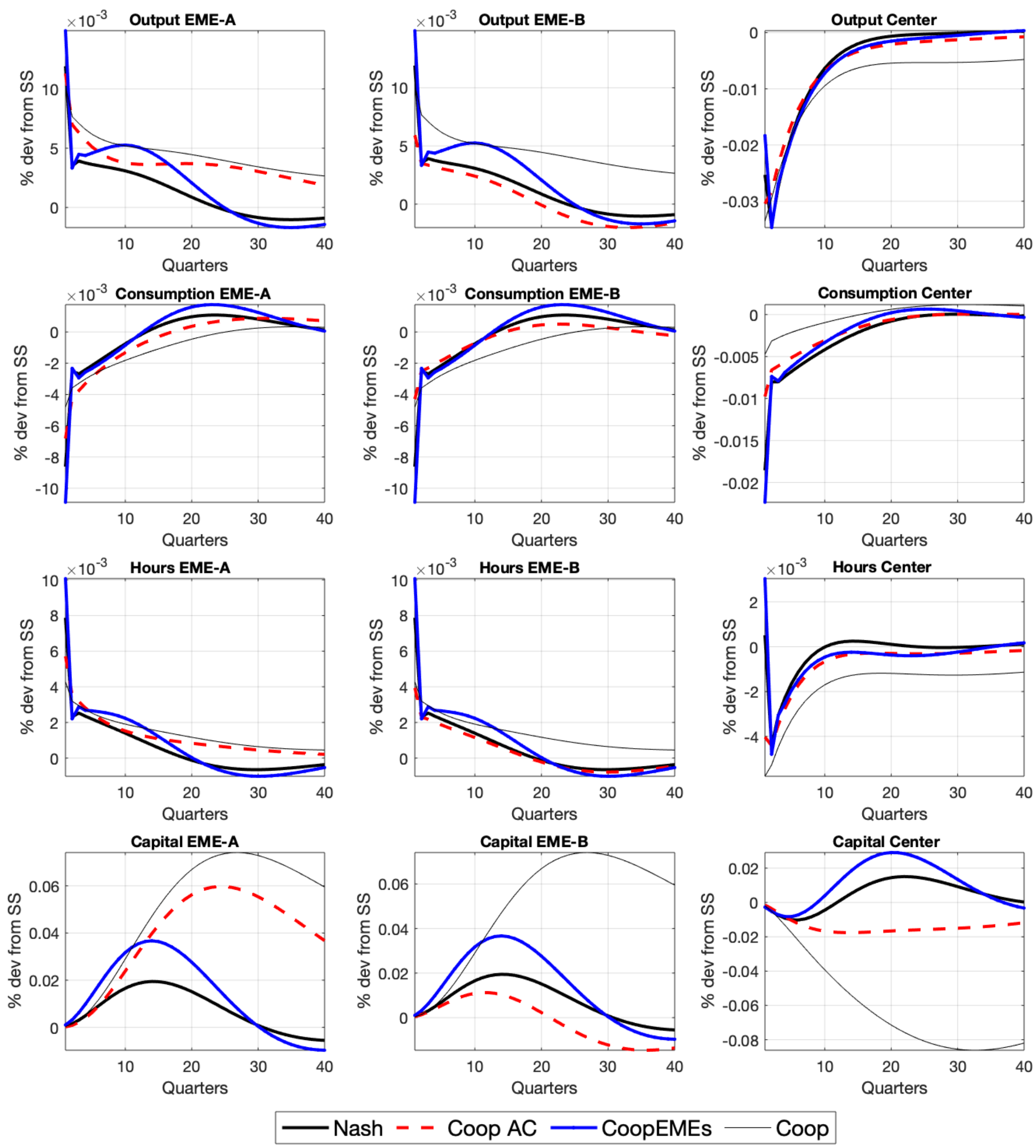


Figure 4: Response to a negative financial shock at the Center economy - Financial Variables and tools



Real Shock. We also report the dynamic response to a negative technological shock in the Center in figure 3. Similarly, we obtain a better output response in the emerging economies with a lengthier Center output recovery under cooperation. Likewise, the capital accumulation in the emerging countries will be larger in the centralized regimes. One difference, nevertheless, is that the increase in capital flows toward the EMEs will be delayed in comparison.

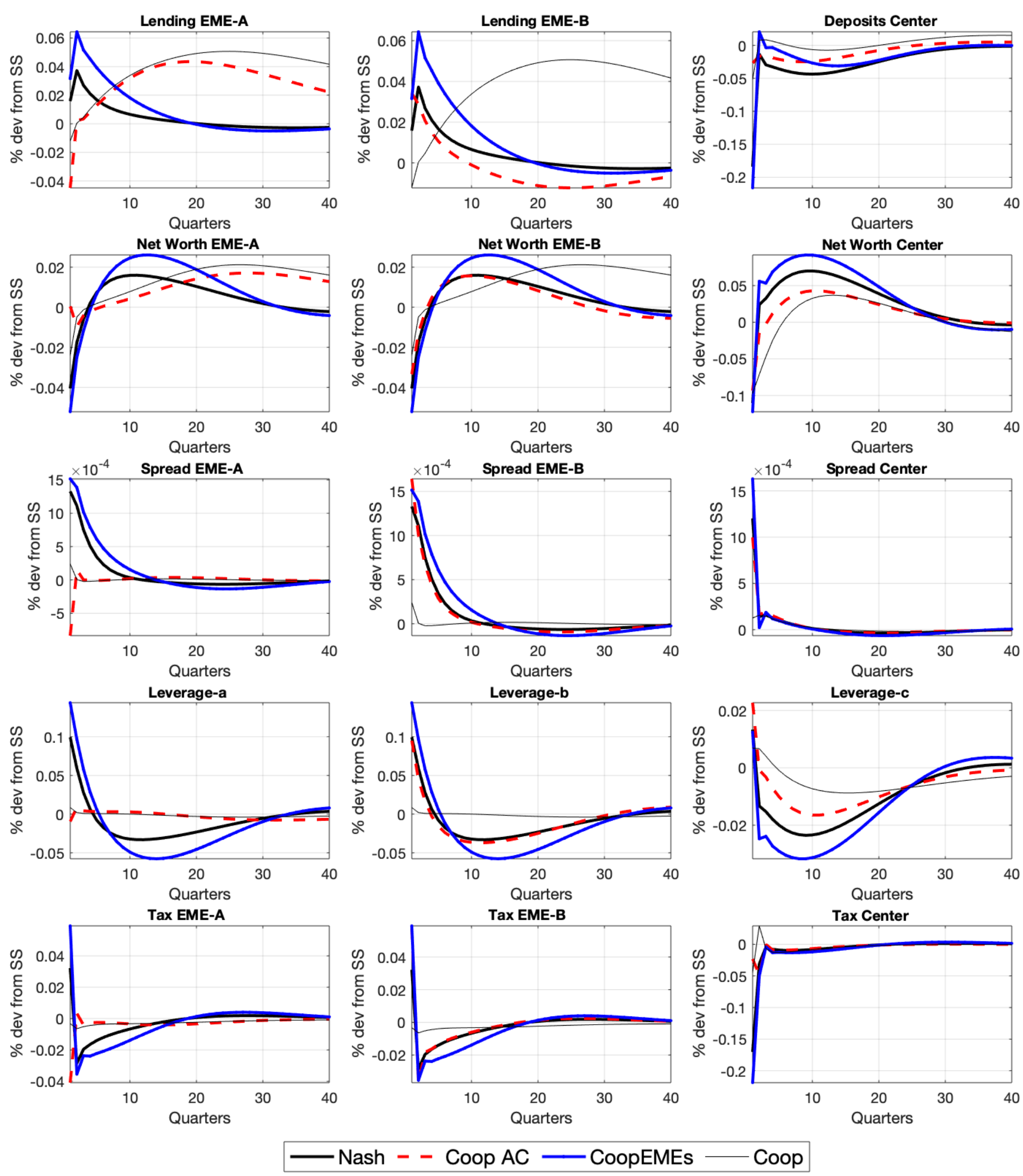
Figure 5: Response to a negative productivity shock at the Center economy



The same will occur with the financial variables as these comove with the level of intermediation. This delayed response feature, characterized by hump shaped responses, for example in the consumption, has been previously documented in Fujiwara et al. (2011) and Steinsson (2008) and reflects the presence of financial frictions in the model.

Simultaneously, the financial variables and the policy instruments will vary within a narrower range in the regimes where the center cooperates (Coop and Coop(A+C)).

Figure 6: Response to a negative productivity shock at the Center economy - Financial Variables and tools



7 Conclusions

In this paper I study whether the international macroprudential policy cooperation is beneficial for emerging economies and can be used to improve their macroeconomic performance and financial resilience. We formulate two specific questions: (i) is macroprudential cooperation beneficial for these economies in general?, and (ii) are cooperative policies useful in protecting these economies from external shocks?.

In a simplified framework, I characterize the structure of the cross-border policy effects and optimal macroprudential policies. As a result, I obtain that two new policy motives appear for a cooperative policymaker that sets the instrument of a financial center. These features will be translated in improved financial stability and an enhanced interbank intermediation towards the emerging economies, which in turn, will generate welfare gains in policy coordination frameworks. Noticeably, this features will be absent in frameworks where only emerging economies engage in cooperation.

I perform a welfare evaluation in an stochastic environment and confirm the existence of welfare gains for frameworks where peripheries collaborate with a Center, answering my first question: cooperation is indeed useful, however, not every type of cooperation will be fruitful, and the presence of a financial center in the arrangement will be crucial.

Nevertheless, I also obtain that the socially optimal policy regime will be the worldwide cooperation, followed by the cooperation between the Center and a subset of the peripheries. This is explained by the fact that the two mechanisms outlined above work better when more emerging economies join their planning efforts. Therefore, the policy recommendation for the peripheries would be that conditional on a participating Center, it is beneficial and advised that more emerging economies join the cooperative initiative.

However, I also obtain that there can be distributional challenges to the implementation of the best social outcome as the second best regime will be more beneficial for its participants and at the expense of the peripheries outside the cooperative coalition.

On the other hand, the cyclical properties and short run dynamics of the policies show that the worldwide cooperation and the cooperation between the Center and one emerging periphery will display better output dynamics after a recessionary episode at the Center. This answers the second question: Cooperation, with a Center, allows for an improved protection and output dynamics in the peripheries. This does not occur with the regional cooperation between peripheries. Simultaneously, the best performing regime will be the global cooperation which will display higher and smoother capital accumulation in the peripheries. In addition, the usual the deleveraging process after a financial shock, will be ameliorated under cooperation.

It should also be noted that an advantage of this study with respect to the rest of the literature, is that it provides a clear identification of the two main sources of the welfare gains, while also accounting for different types of cooperative and semi-cooperative policies. This allowed me to determine when cooperation works and when it does not and to generate a clear, and innovative, policy recomendation.

Finally, while I think this framework represents a contribution in understanding the international role of the macroprudential policies. I acknowledge it still corresponds to a simplified framework that abstracts from other relevant features, such as additional sources of risk (e.g., currency fluctuations) or the presence of regulatory arbitrage and shadowbanking, a core concern of financial regulators. We leave the inclusion of these elements for future work.

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A Results from the Simple Three Periods Model

Proof of proposition 1.

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

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

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

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

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

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

■

Proof of proposition 2.

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

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

For the last period:

The ICC is: $J_2 = \Lambda_{2,3}(R_{k,3}L_2 - R_{b,2}F_2) = \kappa_2 L_2$

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

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

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

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

For the first period:

The procedure is the same but the algebra is a bit lengthier as we will substitute both balance sheets ($F_1 = L_1 - \delta_B Q_1 K_0$, and $F_2 = Q_2K_2 - N_2$) in the value of the bank in the right hand side of the ICC for the first intermediation period $J_1 = \kappa L_1$.

After substitutions and some algebra the ICC becomes:

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

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

The leverage is given by:

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

Then,

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

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

Table 6: Summary of equilibrium equations of the three-period model

Common to all countries:

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

for EMEs:

$Q_1K_1 = F_1 + \delta_B Q_1 K_0$	[bal. sheet of banks, t=1]
$Q_2K_2 = F_2 + \delta_B Q_2 K_1 + \theta\left[R_{k,2}Q_1K_1 - R_{b,1}F_1\right]$	[bal. sheet of banks, t=2]
$(1-\theta)\Lambda_{12}\left(R_{k,2}Q_1K_1 - R_1F_1\right) + \Lambda_{13}\theta\left(R_{k,3}Q_2K_2 - R_2F_2\right) = kQ_1K_1$	[ICC, t=1]
$\Omega_1\left(1+\mu_1\right)\left(R_{k,2} - R_1\right) = \mu_1\kappa$	[Credit spread, t=2]
$\Lambda_{23}\left(R_{k,3}Q_2K_2 - R_2F_2\right) = kQ_2K_2$	[ICC, t=2]
$\left(1+\mu_2\right)\Lambda_{23}\left(R_{k,3} - R_2\right) = \mu_2\kappa$	[Credit spread, t=3]
$C_1 + \frac{B_1}{R_1} = r_1K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0$	[BC for t=1]
$C_2 + \frac{B_2}{R_2} = \pi_{f,2} + \pi_{inv,2} + \pi_{b,2} - \delta_B Q_2 K_1 + B_1 - T_2$	[BC for t=2]
$C_3 = \pi_{f3} + T_3 + B_2 - T_3$	[BC for t=3]

for the Center:

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

International Links:

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

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

Auxiliary definitions:

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

Effective discount factor of banks: $\Omega_1 = (1-\theta)\Lambda_{12} + \theta^2 R_{k,3}\Lambda_{13}$

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

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

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

Profits of investors: $\pi_{inv,t} = Q_t I_t - C(I_t, I_{t-1}) = Q_t I_t - I_t \left(1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)$
Profits of bankers in EMEs, t=2: $\pi^e_{b,2} = (1-\theta)\left(R_{k,2} Q^e_1 K^e_1 - R_1 F^e_1\right)$
Profits of bankers in EMEs, t=3: $\pi^e_{b,3} = R^e_{k,3} Q^e_2 K^e_2 - R_2 F^e_2,\qquad$ e = {a,b}
Profits of bankers in Center, t=2: $\pi^c_{b,2} = (1-\theta)\left(R^c_{k,2} Q^c_1 K^c_1 + R^a_1 F^a_1 + R^b_1 F^b_1 - R_1 D_1\right)$
Profits of bankers in Center, t=3: $\pi^c_{b,3} = R^c_{k,3} Q^c_2 K^c_2 + R^a_{b2} F^a_2 + R^b_2 F^b_2 - R_2 D_2$

Table 7: Parameters in the 3-period 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

A.1 Optimal Taxes

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

Also, in the case of the Center, for the last period, there is no explicit τ^c_3 terms in the welfare effect. I use the fact that $R_{k,3}(\tau_3)$ to back out the tax after substituting it for one of the taxes it will equate.

$$\tau^a_2 = -\frac{1}{\alpha r^a_2}\left\{(I_1 + \kappa K_1)\frac{dQ^a_1}{dK^a_1} + \frac{B^a_1}{R_1}\frac{dR_1}{dK^a_1}\right.$$

contemporaneous component

$$+\left(1-\frac{\Lambda_{12}}{\Lambda_{23}}\right)\left(I_2^a+\kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{dK_1^a}+\left(1-\Lambda_{12}\right)\frac{B_2^a}{R_2}\frac{dR_2}{dK_1^a}+$$
$$\kappa\left(1+\theta\left(\Lambda_{12}-\Lambda_{23}\right)-\frac{\Lambda_{12}}{\Lambda_{23}}\right)Q_2^a\frac{dK_2^a}{dK_1^a}\Bigg\}+1-\frac{1}{\alpha}$$

forward looking component

$$\tau_3^a=-\frac{1}{\Lambda_{23}\alpha r_3^a}\left\{\left(I_2^a+\kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{dK_2^a}+\Lambda_{23}\frac{B_2^a}{R_2}\frac{dR_2}{dK_2^a}+\kappa\left(1-\theta\Lambda_{23}\right)Q_2^a\right\}+1-\frac{1}{\alpha}$$

$$\tau_2^c=-\frac{1}{\theta\alpha r_2^c}\Bigg\{(1-\theta)(1-\delta)Q_2^c+\left(\frac{B_1^c}{R_1}-\theta D_1\right)\frac{dR_1}{dK_1^c}+R_1K_1^c\frac{dQ_1^c}{dK_1^c}$$

contemporaneous component

$$+(1-\theta)\left(\frac{dR_{b1}^{eme}}{dK_1^c}\left(F_1^a+F_1^b\right)+R_{b1}^{eme}\left(\frac{dF_1^a}{dK_1^c}+\frac{dF_1^b}{dK_1^c}\right)\right)$$

$$+\frac{1}{R_2}\left(r_3^c+(1-\delta)Q_3\right)\frac{dK_2^c}{dK_1^c}+\frac{B_2^c}{\left(R_2\right)^2}\frac{dR_2}{dK_1^c}+\left(I_2^c+(1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{dK_1^c}$$
$$+\frac{1}{R_2}\left(\frac{dR_{b2}^{eme}}{dK_1^2}\left(F_2^a+F_2^b\right)+R_{b2}^{eme}\left(\frac{dF_2^a}{dK_1^c}+\frac{dF_2^b}{dK_1^c}\right)\right)\Bigg\}+1-\frac{1}{\alpha\theta}$$

forward looking component

$$\tau_3^c=\frac{Q_2^c}{r_3^c}\left\{\left(r_3^c+(1-\delta)Q_3\right)\frac{dK_2^c}{dF_2^S}+\Lambda_{23}B_2^c\frac{dR_2}{dF_2^S}+R_2\left(I_2^c+(1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{dF_2^S}+\left(F_2^{ab}\right)\frac{dR_{b2}^{\mathrm{eme}}}{dF_2^S}\right\}$$
$$+\frac{(1-\delta)Q_3}{r_3^c}+1 \tag{23}$$

with $F_2^{ab}=F_2^a+F_2^b$

Optimal Taxes Under Cooperation. This section shows how to get the optimal Center tax under cooperation and the equation (22).

The procedure is analogous to the individual welfare case (non-cooperative), I will find the welfare effect of setting τ_3^c for the cooperative planner, i.e. $\frac{dW^{coop}}{d\tau_3^c}$, set it equal to zero and solve for the optimal policy $\tau_3^{c,coop}$.

$$\frac{dW^{coop}}{d\tau_3^c}=n_a\frac{dW^a}{d\tau_3^c}+n_b\frac{dW^b}{d\tau_3^c}+\left(1-n_a-n_c\right)\frac{dW^c}{d\tau_3^c}$$

Now, given the perfect foresight assumption, the equilibrium allocation and welfare is symmetric between peripheries:

$$\frac{dW^{coop}}{d\tau_3^c} = (n_a + n_b)\frac{dW^a}{d\tau_3^c} + (1 - n_a - n_c)\,\frac{dW^c}{d\tau_3^c}$$

Furthermore, I simplify further by using the parameter values $n_a = n_b = \frac{1}{4}$. That is, the summation of the sizes of the peripheral economies equals that of the Center,

$$\frac{dW^{coop}}{d\tau_3^c} = \frac{dW^a}{d\tau_3^c} + \frac{dW^c}{d\tau_3^c}$$

By substituting each of the individual welfare effects in the right hand side:

$$\begin{aligned}\frac{dW^{coop}}{d\tau_3^c} = &\left[\beta\lambda_2^a\left(\kappa\left(1-\theta\Lambda_{23}\right)Q_2^a + \varphi\left(\tau_3^c\right)\Lambda_{23}r_3^a\right)\frac{dK_2^a}{d\tau_3^c} + \beta\lambda_2^a\left(I_2^a + \kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\left(r_3^c + (1-\delta)Q_3\right)\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \beta\lambda_2^c\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\left(\frac{dR_{b2}^{eme}}{d\tau_3^c}\left(F_2^a + F_2^b\right) + R_{b_2}^{eme}\left(\frac{dF_2^a}{d\tau_3^c} + \frac{dF_2^b}{d\tau_3^c}\right)\right)\right]\end{aligned}$$

Or in simpler terms and with $F_2^{ab} = F_3^a + F_3^b$:

$$\begin{aligned}\frac{dW^{coop}}{d\tau_3^c} = &\left[\alpha_1\frac{dK_2^a}{d\tau_3^c} + \alpha_2\frac{dQ_2^a}{d\tau_3^c} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\alpha_3\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \alpha_4\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\frac{dR_{b2}^{eme}}{d\tau_3^c}F_2^{ab} + \beta^2\lambda_3^c R_{b_2}^{eme}\frac{dF_2^{ab}}{d\tau_3^c}\right]\end{aligned}$$

The first term in square brackets corresponds to the welfare effects for the peripheric block and the second to that of the Center. Now I use the UIP assumption and absence of a spread in the center to replace: $R_{b,2}^{eme} = R_{k,3}^c = \frac{(1-\tau_3^c)r_3^c + (1-\delta)Q_3}{Q_2^c}$ and equate $\frac{dW^a}{d\tau_3^c}$ to zero, meaning that τ_3^c in the expression becomes the optimal one $\tau_3^{c,coop}$:

$$\begin{aligned}\frac{dW^{coop}}{d\tau_3^c} = &\left[\alpha_1\frac{dK_2^a}{d\tau_3^c} + \alpha_2\frac{dQ_2^a}{d\tau_3^c} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\alpha_3\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \alpha_4\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\frac{dR_{b2}^{eme}}{d\tau_3^c}F_2^{ab} + \beta^2\lambda_3^c\frac{(1-\tau_3^{c,coop})r_3^c + (1-\delta)Q_3}{Q_2^c}\frac{dF_2^{ab}}{d\tau_3^c}\right] = 0\end{aligned}$$

Solving for $\tau_3^{c,coop}$, and replacing $\alpha_1, \alpha_2, \alpha_3, \alpha_4$, yields:

$$\tau_3^{c,coop} = \frac{Q_2^c}{\Lambda_{23} r_3^c} \frac{\lambda_2^a}{\lambda_2^c} \left\{ (\kappa(1-\theta\Lambda_{23})Q_2 + \varphi(\tau_3^a)\lambda_{23} r_3^a) \frac{dK_2^a}{dF_2^{ab}} + (I_2^a + \kappa(1-\theta\Lambda_{23}K_2^a)) \frac{dQ_2^a}{dF_2^{ab}} \right\}$$
$$+ \frac{Q_2^c}{\Lambda_{23} r_3^c} \left(\Lambda_{23} \left(r_3^c + (1-\delta) Q_3 \right) \frac{dK_2^c}{\partial F_2^{ab}} + (I_2^c + (1-\theta)(1-\delta)K_1^c) \frac{dQ_2^c}{dF_2^{ab}} + \Lambda_{23} F_2^{ab} \frac{dR_{b2}^{eme}}{dF_2^{ab}} \right)$$
$$+ \frac{(1-\delta)Q_3^c}{r_3^c} + 1 + \frac{Q_2^c}{r_3^c} \left(\frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}} - \frac{\lambda_2^a}{\lambda_2^c} \frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}} \right)$$

In this expression I substituted $B_2^a = -B_2^c$ for the last term.

We can notice the last two lines in the expression are equal to $\tau_3^{c,nash} - \frac{Q_2^c}{r_3^c} \frac{\lambda_2^a}{\lambda_2^c} \frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}}$ where $\tau_3^{c,nash}$ is the optimal individual planner tax given by the equation 23. Thus the optimal cooperative tax can be expressed as:

$$\tau_3^{c,coop} = \overbrace{\frac{Q_2^c}{\Lambda_{23} r_3^c} \frac{\lambda_2^a}{\lambda_2^c} \left\{ (\kappa(1-\theta\Lambda_{23})Q_2 + \varphi(\tau_3^a)\lambda_{23} r_3^a) \frac{dK_2^a}{dF_2^{ab}} + (I_2^a + \kappa(1-\theta\Lambda_{23}K_2^a)) \frac{dQ_2^a}{dF_2^{ab}} \right\}}^{\text{New substitution of Center capital accumulation for foreign intermediation (EMEs) motive under cooperation}}$$
$$+ \tau_3^{c,nash} - \frac{\lambda_2^a}{\lambda_2^c} \underbrace{\frac{Q_2^c}{r_3^c} \frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}}}_{\substack{\text{NFA-led interest rate} \\ \text{manipulation motive} \\ \text{at Center}}}$$

The first right hand side term will represent a new motive for pushing up the taxes in order to lower local Center capital accumulation in favor of emerging economies capital accumulation and intermediation. This term is unambiguously positive for the considered parameter values (as long as the taxes at the periphery is larger than -2).

On the other hand, the last term represents a cancelation term that offsets the policy incentives of the Center for manipulating the global interest rate to take benefit of their net foreign assets (bonds) position. This manipulation incentive is canceled out because the welfare effects of movements in the net foreign assets of the countries engaging in the cooperative arrangement will go in opposite directions between debtors and creditors.

We can make a further simplification[20], for a clearer argument and assume the $\lambda_2^a = \lambda_2^c$ which leads to the equation (22).

[20] Otherwise, and in general with $\lambda_2^a \neq \lambda_2^c$, the compensation effect acts even stronger and in favor of the peripheries as $\lambda_2^a > \lambda_2^c$.

B Results from the Main Model

B.1 Steady State of the Policy Models

In the Ramsey model works with a instrument conditional steady state, i.e., a value for the policy tools $\bar{\boldsymbol{\tau}}$ is set and the associated steady state for the rest of the variables is obtained. A related question of utmost importance would be, how to determine the instrument level ($\bar{\boldsymbol{\tau}}$) for conditioning?.

For that we follow an algorithm outlined in Christiano, Motto and Rostagno (2007):

1. set any value for $\bar{\boldsymbol{\tau}}$ and solve, using the static private FOCs, for the steady state of private variables: $\mathbf{x_t}$

2. replace $\mathbf{x_t}$ in remaining $N + k$ equations, the policy FOC w.r.t. the N endogenous variables and k tools: get a linear system of $N + k$ equations for N unknowns (policy multipliers)

3. With more equations than unknowns the solution is subject to an approximation error $\mathbf{u}$:

   (i) set the $N + k$ static equations in vector form as: $U_1 + \bar{\lambda}[1/\beta F_3 + F_2 + \beta F_1] = 0$

   (ii) let $Y = U_1'$, $X = [1/\beta F_3 + F_2 + \beta F_1]$ and $\beta = \bar{\lambda}'$

   (iii) get the tools as: $\beta = (X'X)^{-1}X'Y$ with error $\mathbf{u} = Y - X\beta$

   (iv) repeat for several values of the tools and choose $\bar{\boldsymbol{\tau}}$ such that: $\bar{\boldsymbol{\tau}} = \arg\min_{\tau} \mathbf{u}$

B.2 Parameters of the Model

The table contains the parameter used in the baseline model.

Table 8: Parameters in the model

Parameter		**Value**	**Comment/Source**
Adjustment costs of investment	ζ	3.456	Banerjee et al. (2016)
Adjustment costs of assets	η	0.0025	Ghironi and Ozhan (2020)
Start-up transfer rate to banks	δ_b	0.003	Gertler and Karadi (2011), Gertler and Kiyotaki (2010)
Survival rate of banking sector	θ	0.95	Gertler and Karadi (2011), Gertler and Kiyotaki (2010)
Divertable fraction of capital	$\kappa^a, \kappa^b, \kappa^c, \kappa^c_{F_1}, \kappa^c_{F_2}$	0.38	Banerjee et al. (2016) Aoki, Benigno and Kiyotaki (2018)
Discount factor	β	0.99	Standard
Risk Aversion parameter	σ	1.02	Standard
Inverse Frisch elasticity of labor supply	ψ	0.276	Standard
Country size	$n_a = n_b$	0.25	
Depreciation rate	δ	0.025	Standard
Capital share	α	0.333	Standard
Persistency of productivity shocks	ρ_A	0.85	Standard
Persistency of capital shock	ρ_{xi}	0.85	Standard
Std. Dev. of productivity shocks	σ_A	0.007	Standard
Std. Dev. of capital shock	σ_{xi}	0.005	Standard

B.3 Welfare Accounting Supplementary Exercises

Table 9: Welfare in consumption equivalent compensation units (alternative method)

	Consumption Equivalent % Compensation				
	Nash	Cooperation (Center+EME-A)	Cooperation (EMEs)	Cooperation (All)	Cooperation (Time Variant)
C	-10.1	4.8	-9.4	6.3	-88.9
A	-15.4	-3.0	-21.2	-11.3	-96.3
B	-15.1	-21.0	-20.6	-10.8	-96.3
World	**-12.7**	**-4.2**	**-15.4**	**-2.8**	**-93.6**
EMEs	-15.2	-12.5	-20.9	-11.1	-96.3

Notes: Compensation using the First Best as benchmark.

In Cooperation symmetry between instruments rules is assumed for EMEs

Table 10: Welfare levels and consumption equivalent compensation (includes Time Variant Model)

	Nash	Cooperation (Center+EME-A)	Cooperation (EMEs)	Cooperation (All)	Cooperation (Time Variant)
Welfare levels					
W^c	-4980.2	-4964.8	-4979.5	-4963.4	-5189.3
W^a	-5030.1	-5016.4	-5037.2	-5025.4	-5343.6
W^b	-5030.3	-5037.6	-5037.0	-5025.4	-5343.3
W	-5005.2	-4995.9	-5008.3	-4994.4	-5266.3
W^{ab}	-5030.2	-5027.0	-5037.1	-5025.4	-5343.4
Consumption Equivalent Compensation					
C	-10.9	4.8	-10.2	6.3	-224.9
A	-17.0	-3.1	-24.2	-12.2	-335.7
B	-16.6	-24.0	-23.4	-11.6	-334.5
World	**-13.9**	**-4.4**	**-17.0**	**-2.9**	**-280.2**
EMEs	-16.8	-13.5	-23.8	-11.9	-335.1

Notes: Compensation using the First Best as benchmark.

In Cooperation symmetry between instruments rules is assumed for EMEs

Summary of final model equations. For obtaining a summarized version of the model equations I substitute the marginal product of capital, wages, the tax rebates and the interest rates that are equalized due to the uncovered interest rate parity.

Table 11: Summary of private equilibrium equations of the baseline model

Common to all countries:

$$Q_t^i = 1 + \frac{\zeta}{2}\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)^2 + \zeta\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)\frac{I_t^i}{I_{t-1}^i} - \Lambda_{t+1}^i \zeta \left(\frac{I_{t+1}^i}{I_t^i}\right)^2\left(\frac{I_{t+1}^i}{I_t^i} - 1\right) \quad \text{[Price of Capital]}$$

$$K_t^i = I_t^i + (1-\delta)\xi_t^i K_{t-1}^i \quad \text{[Capital Dynamics]}$$

$$R_{k,t}^i = \frac{(1-\tau_t^i)\alpha A_t^i H_t^{i\ (1-\alpha)} \xi_t^{i\alpha} K_{t-1}^{i\ (\alpha-1)} + (1-\delta)\xi_t^i Q_t^i}{Q_{t-1}^i} \quad \text{[Banks rate of return]}$$

$$R_t \Lambda_{t+1}^i = 1 + \eta\left(B_t^i\right) \quad \text{[Euler Equation, bonds]}$$

$$C_t^{i\ -\sigma} = \frac{H_t^{i\ \psi}}{(1-\alpha)A_t^i(\xi_t^i K_{t-1}^i)^\alpha H_t^{i\ (-\alpha)}} \quad \text{[Intra-temporal Euler Equation, labor]}$$

$$Y_t^i = A_t^i\left(\xi_t^i K_{t-1}^i\right)^\alpha H_t^{i\ 1-\alpha} \quad \text{[Output]}$$

$$\Lambda_{t+1}^i = \beta\left(\frac{C_{t+1}^i}{C_t^i}\right)^{-\sigma} \quad \text{[Stochastic Discount Factor]}$$

$$A_t^i = \rho_A A_{t-1}^i + \sigma_A \epsilon_{A,t}^i \quad \text{[Aggregate Productivity]}$$

$$\xi_t^i = \rho_\xi \xi_{t-1}^i + \sigma_\xi \epsilon_{k,t}^i \quad \text{[Capital Quality]}$$

for EMEs:

$$Q_t^e K_t^e = N_t^e + F_t^e \quad \text{[Bal. sheet of banks]}$$

$$\mathbb{E}_t \Omega_{t+1|t}^i \left(R_{k,t+1}^i - R_{b,t}^i\right) = \mu_t^i \kappa^i \quad \text{[Credit Spread]}$$

$$j_t^e N_t^e = \kappa^e Q_t^e K_t^e \quad \text{[ICC]}$$

$$N_t^a = \theta\left[R_{k,t}^a Q_{t-1}^a K_{t-1}^a - R_{b,t-1}^a F_{t-1}^a\right] + \delta_B Q_t^a K_{t-1}^a \kappa \quad \text{[Net Worth Dynamics]}$$

$$j_t^e(1-\mu_t^e) = \mathbb{E}_t\left[\Omega_{t+1|t}^e R_{b,t}^e\right] \quad \text{[Envelope Condition for Net Worth]}$$

$$C_t^e + B_t^e + \frac{\eta}{2}(B_t^e)^2 = R_{t-1}B_{t-1}^e + (1-\alpha)A_t^e(\xi_t^e K_{t-1}^e)^\alpha H_t^{e\ (1-\alpha)} + \Pi_t^a \quad \text{[Budget Constraint, households]}$$

for the Center:

$$Q_t^c K_t^c + F_t^a + F_t^b = N_t^c + D_t^c \quad \text{[Bal. sheet of banks]}$$

$$\mathbb{E}_t \Omega_{t+1|t}^c \left(R_{k,t+1}^c - R_{D,t}^c\right) = \mu_t^c \kappa^c \quad \text{[Credit Spread for Local Intermediation]}$$

$$\mathbb{E}_t \Omega_{t+1|t}^c \left(R_{b,t}^a - R_{D,t}^c\right) = \mu_t^c \kappa_{F_a}^c \quad \text{[Spread for Foreign Lending to EME-A]}$$

$$\mathbb{E}_t \Omega_{t+1|t}^c \left(R_{b,t}^b - R_{D,t}^c\right) = \mu_t^c \kappa_{F_b}^c \quad \text{[Spread for Foreign Lending to EME-B]}$$

$$j_t^c N_t^c = \kappa^c Q_t^c K_t^c + \kappa_{F_a}^c F_t^a + \kappa_{F_b}^c F_t^b \quad \text{[ICC]}$$

$$N_t^c = \theta\left[R_{k,t}^c Q_{t-1}^c K_{t-1}^c + R_{b,t-1}^a F_{t-1}^a + R_{b,t-1}^b F_{t-1}^b - R_{D,t-1}^c D_{t-1}^c\right] + \delta_B Q_t^c K_{t-1}^c \quad \text{[Net Worth Dynamics]}$$

$$j_t^c(1-\mu_t^c) = \mathbb{E}_t\left[\Omega_{t+1|t}^c R_{D,t}^c\right] \quad \text{[Envelope Condition for Net Worth]}$$

$$C_t^c + B_t^c + \frac{\eta}{2}(B_t^c)^2 + D_t^c + \frac{\eta}{2}\left(D_t^c - \bar{D}^c\right)^2 = R_{t-1}^c B_{t-1}^c + R_{D,t-1}^c D_{t-1}^c + w_t^c H_t^c + \Pi_t^c \quad \text{[Budget Constraint, households]}$$

$$R_{D,t}^c \Lambda_{t+1}^c = 1 \quad \text{[Euler Equation, deposits]}$$

International Links:

$$n_a B_t^a + n_b B_t^b + n_c B_t^c = 0 \quad \text{[Net Supply of Bonds]}$$

Note: $i = \{a, b, c\}$, $e = \{a, b\}$ and $w_t^c = (1-\alpha)Y_t^c / H_t^c$ corresponds to the wages.

In this system of equations we use the following auxiliary definitions:

$$\Pi_t^c = (1-\theta)\left[Q_{t-1}^c R_{k,t}^c K_{t-1}^c + R_{b,t-1}^a F_{t-1}^a + R_{b,t-1}^b F_{t-1}^b - R_{D,t-1}^c D_{t-1}^c\right] - \delta_B Q_t^c K_{t-1}^c + Q_t^c I_t^c$$
$$- I_t^c\left(1+\frac{\zeta}{2}\left(\frac{I_t^c}{I_{t-1}^c}-1\right)^2\right) + \tau_t^c \alpha A_t^c H_t^{c\ (1-\alpha)} \xi_t^{c\ \alpha} K_{t-1}^{c\ (\alpha)}$$

$$\Pi_t^a = (1-\theta)\left[Q_{t-1}^a R_{k,t}^a K_{t-1}^a - R_{b,t-1}^a F_{t-1}^a\right] - \delta_B Q_t^a K_{t-1}^a + Q_t^a I_t^a - I_t^a\left(1+\frac{\zeta}{2}\left(\frac{I_t^a}{I_{t-1}^a}-1\right)^2\right)$$
$$+ \tau_t^a \alpha A_t^a H_t^{a\ (1-\alpha)} \xi_t^{a\ \alpha} K_{t-1}^{a\ (\alpha)}$$

$$\Pi_t^b = (1-\theta)\left[Q_{t-1}^b R_{k,t}^b K_{t-1}^b - R_{b,t-1}^b F_{t-1}^b\right] - \delta_B Q_t^b K_{t-1}^b + Q_t^b I_t^b - I_t^b\left(1+\frac{\zeta}{2}\left(\frac{I_t^b}{I_{t-1}^b}-1\right)^2\right)$$
$$+ \tau_t^b \alpha A_t^b H_t^{b\ (1-\alpha)} \xi_t^{b\ \alpha} K_{t-1}^{b\ (\alpha)}$$