Strategic Macroprudential Policymaking: When Does Cooperation Pay Off? *

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Abstract

We study whether emerging economies can navigate the global financial cycle more successfully by resorting to internationally coordinated macroprudential policies. For this, we set an open economy model with banking frictions in a center-periphery environment with multiple emerging economies. Then, we evaluate the performance of several policy arrangements that differ by the degree and type of cooperation. We find that cooperation can generate welfare gains but is not always beneficial relative to nationally-oriented policies. Instead, only regimes where the financial center acts cooperatively generate welfare gains. When present, two mechanisms generate the gains: a cancellation effect of national incentives to manipulate the global interest rate and a motive for steering capital flows to emerging economies. The first mechanism eliminates unnecessary policy fluctuations and the second helps prevent capital retrenchments in the center. These effects can be quantitatively relevant as good cooperation regimes can reduce the welfare losses induced by a financial friction between 60% and 80%.

JEL Codes: F38, F42, E44, G18

Key words: Macroprudential Policies, International Policy Coordination, Banking Frictions.

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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] As these economies started to attract more capital flows, they became a new source of (global) financial risk, presenting challenges to policymakers, which face the dilemma of promoting their economies' participation in international financial markets while protecting them from external shocks. On the other hand, financial centers and multilateral institutions prioritize mitigating the new sources of risk. Consequently, there has been a general increase in the usage of macroprudential policy regulations in the form of stricter balance sheet requirements at the banking level (e.g., leverage caps, loan-to-value ratios, or taxes). Crucially, these policies that regulate the scale of financial intermediation have strong national and cross-border effects as the balance sheet links of the banking sector extend beyond national borders, raising immediate questions over the potential gains from international policy cooperation.

In light of these concerns, our study aims to examine whether international cooperation among macroprudential regulators can benefit emerging economies and improve their economic performance. We focus on two specific questions: (i) whether macroprudential cooperation can benefit these and other economies over the business cycle, and (ii) what mechanisms drive the associated welfare gains.

To address these questions, we extend an open economy model with banking frictions to include two smaller economies that depend financially on a center but still have general equilibrium effects. Using this setup, we conduct a welfare analysis of wide menu of policy regimes that feature different types and extents of regulatory cooperation. Each policy problem is analyzed under a timeless perspective framework with commitment and solved using an open-loop Nash equilibrium.[2]

We model the banking sector following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) extended to an open economy environment. Unlike other open economy studies that explicitly consider the banking sector (e.g., Banerjee, Devereux, and Lombardo, 2016; Aoki, Benigno, and Kiyotaki, 2018), we abstract from monetary policy in our analysis. This simplification allows us to focus solely on the interactions of financial regulators while also extending the framework to include multiple peripheral economies that interact with a center (i.e., a three-countries environment). To the best of our knowledge, this is the first study that examines the coordination of macroprudential policies among emerging economies[3] (EMEs) that may feature general equilibrium effects but are also vulnerable to a financial center that can respond to their cooperative initiatives.[4]

Our framework aligns with the standard setups used in the literature about (monetary) policy

[1]See Rey (2013, 2016).

[2]See Bodenstein, Guerrieri, and LaBriola (2019) for a discussion on macroeconomic games in this setup and the open loop Nash equilibrium framework.

[3]Here an emerging economy is defined as an economy with an underdeveloped financial sector (in the spirit of Céspedes, Chang, and Velasco (2017)) and that in consequence relies on the funding from a center.

[4]See Jin and Shen (2020) for a setup with small open economies interactions and an exogenous, non-retaliative, center.

coordination in open economies,[5] as well as other studies where macroprudential regulators play a cooperative role, such as De Paoli and Paustian (2017) and Bodenstein et al. (2019). Specifically, our work is motivated by studies that revisit the coordination problem in the presence of changing financial conditions, but we pay particular attention to the coordination incentives of financial regulators who can potentially interact with policymakers in other economies. Additionally, our study contributes to the literature by analyzing the outcomes of internationally coordinated regulatory frameworks in an environment where regulators (including emerging ones) can decide to cooperate regionally rather than globally, but that when doing so, also face potential strategic retaliations by other (financially linked) economies not present in their policy coalitions. The task of analyzing these richer policy interactions is made possible by including a third economy in our analysis, as we can consider a wider array of policy regimes with varying degrees and types of cooperation. Based on our setup, we can identify when coordination is beneficial or counterproductive and analyze the potential regional cooperation of peripheral economies in the presence of strong policy spillovers from a center that may want to adjust its policies in response.

We incorporate financial frictions that arise from agency problems in the banks' lending, creating costly enforcement distortions due to the potential for default by financial intermediaries. As a result, interest rates are adjusted to reflect higher risk, leading to increased credit spreads and financially amplified credit cycles, in the vein of Bernanke, Gertler, and Gilchrist (1999) and Kiyotaki and Moore (1997). This distortion creates a role for policy, such as macroprudential regulations that take the form of taxes on the banking revenue rates in our setup. These policies shape the balance sheet dynamics of intermediaries and international links between banks, potentially leading to welfare-improving coordinated regulations.

The specific policy tool we consider targets financial intermediaries by taxing their banking revenues and regulating the scale of total intermediation and credit flows. While prudential in nature, this policy affects the dynamics of capital flows. Due to their implications on flows, similar tools have been denoted capital controls in other papers, for example in Boz, Unsal, Roch, Basu, and Gopinath (2020), however, our policy tool is more accurately described as a macroprudential tool with capital flows implications.[6] To support this view, we first demonstrate that our policy tool is equivalent to a leverage ratio requirement, encompassing more traditional macroprudential tools, as mentioned by Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021). Secondly, we note that our framework policy targets total financial intermediation, which can be international, leading to capital flows implications, but can also be domestic with no cross-border flows implications.[7]

[5] Seminal studies explore the possibility of monetary policy coordination (e.g., Obstfeld and Rogoff, 2002; Devereux and Engel, 2003; Corsetti and Pesenti, 2001; Fujiwara and Wang, 2017) and have stated that the gains are existent but small in environments with only nominal rigidities. Other studies have revisited the small gains result in the context of changing financial conditions and have shown that national oriented policies can be suboptimal (e.g., Sutherland, 2004; Corsetti and Pesenti, 2005; Banerjee, Devereux, and Lombardo, 2016; Bodenstein, Corsetti, and Guerrieri, 2020).

[6] To elaborate further, in the Boz, Unsal, Roch, Basu, and Gopinath (2020) setup, the tool also targets the bank, but a specific parameter makes all banking flows to be international; conversely, in our setup the intermediation is affected regardless of the residency of the parties involved in the lending transactions.

[7] The line between these two types of policies has become blurry in the literature as it has been noted that their

We have found that there are sizable social welfare gains from international cooperation, ranging from 12% to 15% of equivalent world consumption increases compared to a non-cooperative regime. However, these gains are only present when the financial center acts cooperatively. Worldwide cooperation results in the highest gains, followed by cooperation between the center and a subset of the peripheries, then by the non-cooperative (Nash) regime, and finally by regional (emerging) cooperation where the peripheries form a coalition and play against an independent center. Thus, emerging cooperative efforts can be counterproductive, resulting in a 6% consumption loss.

To understand the mechanisms behind these welfare gains, we simplify the main model to explore the welfare effects of these policies analytically in a modified social planner problem along the lines of Davis and Devereux (2022). We find that the policy effects increase with the extent of financial frictions, making these regulations more effective for more distorted economies. This is consistent with the fact that financial frictions are the feature that creates a role for policy in this environment.

We identify two fundamental mechanisms that shape macroprudential policy incentives under cooperation: the portfolio incentives cancellation effect and the capital relocation motive. The portfolio cancellation effect removes the national (individual) incentives to manipulate the global interest rate to improve their net foreign assets position. This mechanism arises from a cooperative planner pooling the conflicting national incentives of savers and borrowers of foreign assets affected by the same interest rate. In contrast, the capital relocation motive refers to an incentive for increasing capital inflows to peripheries at the expense of capital accumulation at the center. This is a by-product of the centralized planner's new policy aim based on boosting global welfare rather than any national economic performance.

Both these mechanisms are the primary sources of cooperation welfare gains (portfolio incentives cancellation effect and capital relocation). The portfolio cancellation effect generates smoother regulatory and capital accumulation dynamics by removing sources of variation from the policy tools. The capital relocation motive, on the other hand, facilitates a more efficient allocation of international capital flows toward the most productive destinations. Both these mechanisms work better when the peripheral block's welfare weights become more comparable to the center's. We use the relative economic population size as the weight, which implies that social gains increase for regimes where more peripheries participate in the cooperative arrangement with the center.

The rationale behind this result is that the cooperative planner relies on the welfare effects resulting from increased intermediation with the peripheries to boost its objective quantity, the global welfare. Naturally, the strategy of implementing welfare increments at the peripheries,

implications overlap; specifically, the capital controls have systemic risk and financial stability implications (e.g. Farhi and Werning, 2016; Cesa-Bianchi, Ferrero, and Rebucci, 2018; Korinek, 2022). In fact the IMF (2017) position is to consider capital controls as plausibly either or both having macroeconomic and prudential goals. Our paper aligns with this updated view where smoothing cross-border financial flows and intermediation can be a financial stability target. Moreover, our setup consists of a real economy (with a constant exchange rate) and thus we abstract from the usual capital control aims of stabilizing the currency fluctuations, which as mentioned by Korinek (2022) and Korinek and Sandri (2016) are the main reason behind different policy prescriptions for flows on the basis of residency, i.e., capital controls, as opposed to prudential regulations targeting the financial intermediaries.

despite the welfare cost from limiting investment flows at the center, is worth pursuing only if the net social welfare gain is positive. This condition only occurs when the planner cares comparably enough about the welfare effects originating in emerging economies. Therefore, for small open economy environments, cooperation gains will be absent.

These mechanisms, or their absence, also help explain why regimes with only regional cooperation among emerging economies fail to yield gains. In this case, the first channel, the portfolio incentives cancellation effect, is absent because all involved national incentives in the coalition to manipulate the interest rate go in the same direction. Thus, global creditors (center) and debtors (emerging market economies) must cooperate for the cancellation effect to take place. In contrast, debtors' portfolio incentives are pooled for emerging economies, enhancing the peripheral capacity to manipulate interest rates. Consequently, the center exerts a strong retaliative effort, engaging in a marked regulatory struggle that creates salient social and individual welfare losses. On the other hand, the second welfare-inducing mechanism, the capital relocation motive, is also not present as it only relates to coordinated policy efforts with a global financial intermediary (center).

The first mechanism shares similarities with the sources of gains found in studies, such as Davis and Devereux (2022) and Korinek (2016), who analyzed the gains from cooperation in the context of capital controls with collateral constraints, or Bengui (2014), who studied liquidity regulations in endowment economies. However, our study demonstrates that this mechanism applies to regulated banks with agency frictions, which represents a less straightforward outcome due to the absence of a direct off-setting of the policy-targeted variables in our context. Additionally, we establish a relationship between the importance of this mechanism and the relative economic sizes and composition of the potential policy coalitions.

On the other hand, our results contrast with Jin and Shen (2020), where regional cooperation enhances welfare by allowing the peripheral block to internalize and utilize its increased capacity to manipulate global interest rates; in our framework, conversely, this same reasoning results in welfare losses. This contrast can be explained by our consideration of potential retaliatory policy actions by the financial center regulator. Additionally, our results differ from those of Kara (2016), where decentralized planning leads to welfare losses due to suboptimal levels of regulation. In our setup, however, welfare is improved by eliminating regulatory actions that are not aligned with financial stability goals, preventing excessive intervention and yield-seeking behavior. As such, cooperative planners hold a comparative advantage over nationally-oriented policymakers by focusing solely on financial stabilization goals.

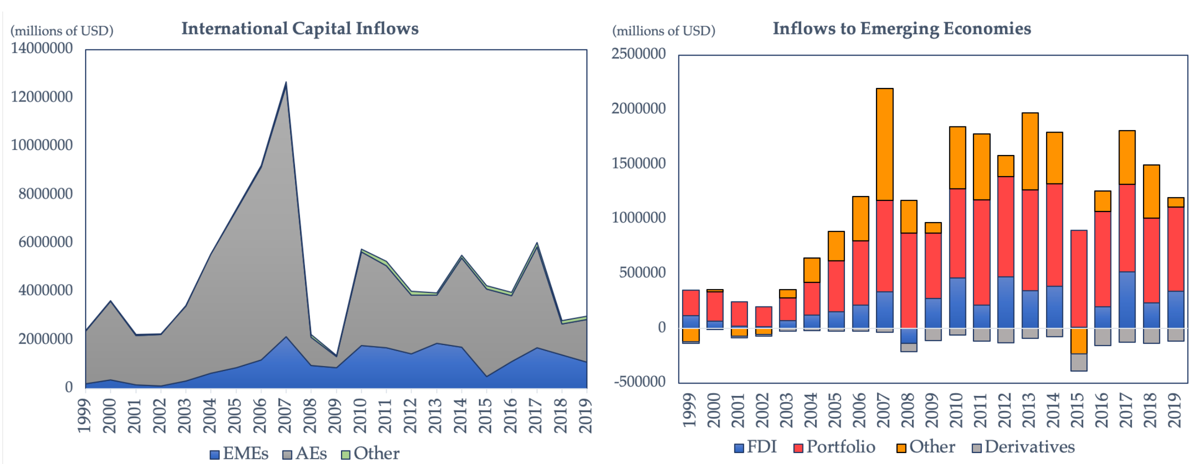
Finally, we observe challenges in enforcing the best policy framework given the national distribution of welfare gains obtained across regimes. While peripheral regions would always want to collaborate with the financial center, the center may prefer to cooperate with a subset of peripheries rather than the rest of the world. In cases where the center and one periphery form a coalition, they may improve their outcomes substantially at the expense of the second and left-out periphery, which could end up worse off than under any other regime. This final result may imply additional policy roles to be fulfilled by planners looking forward to ensuring the implementation of the best regime from a social perspective.

The rest of this paper is structured as follows. Section 2 describes the recent empirical trend of capital flows and associated policy responses. In section 3 and 4 we set the main framework and policy setups that are compared. Section 5 contains the results, showing when cooperation can be fruitful or counterproductive. In Section 6 we set a small scale model to obtain the mechanisms driving the welfare differences that are analyzed in 7 . Finally, Section 8 concludes.

2 Capital Flows 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[8], 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,[9] and contributed to the downward trend of the interest rates of traditional assets in the main economies (Bernanke, Demarco, Bertaut, and Kamin, 2011).

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).

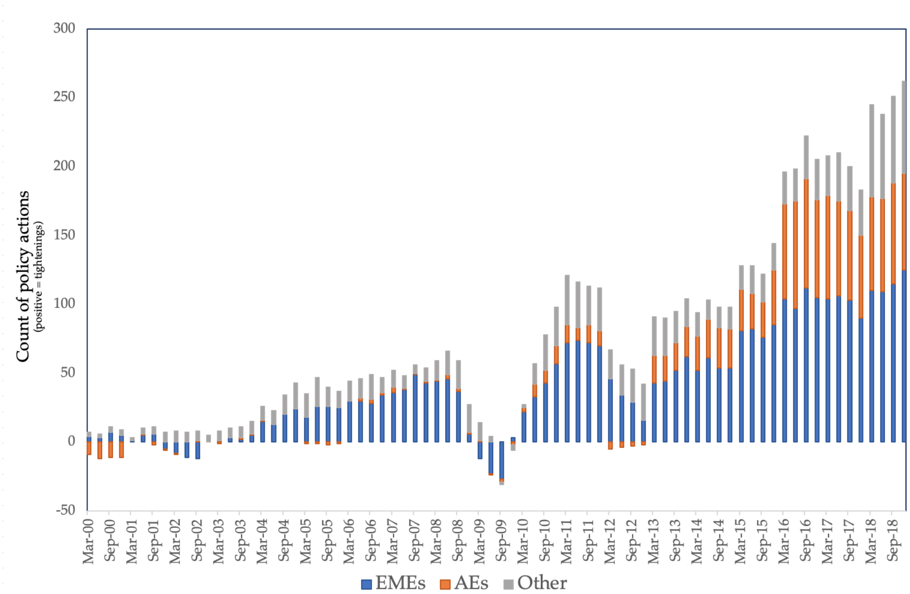
Rather than a change in the direction of the capital flows, given the lower average returns, the observed response of the markets in the 2000's was a reliance on high leveraged intermediation, together with financial innovation efforts (e.g., securitization of assets) to continue attracting investments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

[8]See Justiniano, Primiceri, and Tambalotti (2013) and Bernanke (2005) for a discussion on this topic.
[9]In the USA the Glass-Steagal Act of 1933.

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, right panel). 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 crisis potential sources of risk.

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, 52 emerging and 60 developing countries (other in the graph). The figure shows a four-quarter rolling window sum of the stances in each date.

The observed policy response consisted in stricter macroprudential regulations 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), this is computed and aggregated for 17 policy instruments and then by country groups. It can be seen that globally, and by the end of 2018, there were more than 200 tightenings in the instruments (e.g. an increase in the Loan-to-Value requirements or in the banking taxes).

In addition to the observed increase in the usage of these policies in emerging, and eventually in advanced economies, it can also be suggested, from the overall and compositional policy stance dynamics in figure 2, that there may be potential comovement patterns between the instruments, both 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, Reinhardt, and Wieladek (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 spill over through the interbank lending, and Aiyar, Calomiris, and Wieladek (2014) show how stricter capital requirements on UK-owned banks made the foreign banks operating in UK to increase their lending, in a regulatory arbitrage attempt to substitute the curtailed intermediation generated by the policy change, and thereby, (partially) off-setting the intended effect of the new regulations. 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 these findings, and as explained by Forbes (2020), it can be thougth that the presence of these leakages could 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 would render the cooperation redundant.

To contribute to the understanding of these policy effects, in the next section I set a framework where we can evaluate the role of different macroprudential policy configurations that will diverge by the extent of policy cooperation involved.

3 The Main Model

In this section I set the main model that will allow us to assess and compare different policy configurations that diverge by the degree of policy cooperation involved. The model borrows standard elements from the literature for representing each agent. In particular, I take elements from Banerjee, Devereux, and Lombardo (2016), Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021) and Gertler and Karadi (2011) and incorporate them into a three country center-periphery framework with incomplete markets.

The world economy will consist of three countries, one financial center (C) 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 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 this model is the financial agency friction in borrower-lending relationships. In that regard, this is a costly-enforcement framework like Gertler and Kiyotaki (2010). Thus, the effect friction is that of imposing a financial accelerator effect in the economy that will be reflected as an augmented credit spread. This effect is common to the decentralized economy as well as to all policy regimes, regardless of the extent of cooperation. Later, we will see how additional mechanisms are internalized by some types of policymakers to generate welfare differences.

To analyze the banking incentives in different types of economies I incorporate distinct levels of financial development across countries, with the emerging economies featuring lower financial development, which makes necessary for their banks to rely on funding from financial centers in order to fulfill their role as intermediaries with the local firms.

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

3.1 Households

The households in each economy 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), R^i the interest rate on bonds, R_D^i the interest rate on deposits, 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 induce 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, given 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 first-order-conditions (F.O.C.) for the households in the Center are:

$$\mathbb{E}_t\left[R_t \Lambda^c_{t,t+1}\right] = 1 + \eta(B^c_t),$$
$$\mathbb{E}_t\left[R^c_{D,t} \Lambda^c_{t,t+1}\right] = 1 + \eta(D^c_t - \bar{D}^c),$$
$$C^{c\ -\sigma}_t = \frac{H^{c\ \psi}_t}{w^c_t},$$

where $\Lambda_{t,t+1} = \beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor, λ_t the marginal utility of consumption, and the interest rate on bonds is such that their return is equalized across economies (via UIP).

Emerging Economy Households. One difference between the advanced economy and the emerging ones is that, at the former, households are able to freely purchase deposits from the Center banks while the emerging economy banks will have a limited local intermediation capacity. This is included along the lines of Banerjee, Devereux, and Lombardo (2016), and implies the banks in these countries 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 explicitely reflected in the household budget constraint above.

The F.O.C. for the emerging economy A households are:

$$\mathbb{E}_t\left[R_t \Lambda^a_{t,t+1}\right] = 1 + \eta(B^a_t),$$
$$C^{a\ -\sigma}_t = \frac{H^{a\ \psi}_t}{w^a_t},$$

The F.O.C. of the emerging economy B are analogous.

3.2 Final Goods Firms

A single final good is produced with a Cobb-Douglas (CD) technology:

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

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

The capital quality shock implies the depreciation rate is given by $\delta^i_t(\xi^i_t) = 1 - (1-\delta)\xi^i_t$. In addition, the capital used for production is acquired using funds borrowed from the banking sector, and after production, the remaining stock of capital is sold.

Each period, the firms choose labor and capital inputs to maximize the profits obtained from producing and from the sales of undepreciated capital to investors and after paying wages and the banking loan they used to fund the acquisition of physical capital:

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

We can 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 the wages and gross rate of returns paid to the banking sector from the first-order conditions with respect to labor and capital:

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

The physical 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.[10]

3.3 Capital Goods Firms

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

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

the capital dynamics are:[11]

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

After production takes place, these firms buy 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 their investment level is:

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

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

[11] The time index used for capital denotes the period in which it was determined, rather than the period when it is used for production.

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

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

3.4 Banking Sector

The set-up for this sector is based on Gertler and Karadi (2011). Each economy has a financial firm that intermediates funds between savers and firms. It borrows funds from either the depositors or the interbank market and lends them to local firms that use them for acquiring capital. The spread in the interest rates of lending and borrowing generates the profits for this sector.

I consider a setup with a continuum of symmetric banks that are subject to entry and exit to their business with a survival rate θ. This prevents the banks from engaging in self-funding schemes that would prevent the agency frictions constraints to bind. The entering banks receive a start-up capital from their household owners that is proportional to the scale of the banking assets in the preceding period. At each date, the continuing banks re-invest their proceeds back in its business. However, when the bank fails and exits the market, it gives back its net worth as profits to its owners.

In each case, I consider an incentive compatibility constraint (ICC) that reflects the agency problem in the lending relationships of the bank. I assume this constraint is binding.

The structure of the sector in each country and the decisions they make are explained in detail in the following subsections. However, in general, the problem of the j-th bank in t consists in maximizing the financial intermediation firm 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), its balance sheet and the ICC.

The emerging markets' banks 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_{jt}^e be the net worth and F_{jt}^e the amount borrowed from center banks at a real rate $R_{b,t}^e$. The balance sheet of the bank j is given by:

$$Q_t^e Z_{jt}^e = N_{jt}^e + F_{jt}^e, \tag{6}$$

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:

$$N_t^e = \overbrace{\theta N_{j,t}^e}^{\substack{\text{surviving banks'}\\ \text{net worth}}} + \overbrace{\delta_T Q_t^e K_{t-1}^e}^{\substack{\text{new banks'}\\ \text{start-up capital}}},$$

here, 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, $N_{j,t}^e$ is the net-worth of surviving banks and have the following dynamics:

$$N_{j,t}^e = R_{k,t}^e Q_{t-1}^e K_{j,t-1}^e - R_{b,t-1}^e F_{j,t-1}^e, \tag{7}$$

The gross return on capital, $R_{k,t}^e$, accounts for the payment of the macroprudential tax:

$$R_{k,t}^e = \frac{(1-\tau_t^e) r_t^e + (1-\delta)\xi_t^e Q_t^e}{Q_{t-1}^e},$$

with $\tau_t^e \gtrless 0$ representing a tax/subsidy.

The contracts between savers and banks are subject to a limited enforceability friction, i.e., a bank can default, in which case, the savers take it to court but can recover only a portion $(1-\kappa^e)$ of their payment. In practice, this implies the bank can divert a portion κ^e of the assets.

The problem of the j-th banker is to maximize the franchise value of the bank:[12]

$$J_{j,t}^e(N_{j,t}^e) = \max_{N_{j,t}^e, Z_{j,t}^e, F_{j,t}^e} \mathbb{E}_t \Lambda_{t,t+1}^e \left[(1-\theta) N_{j,t+1+s}^e + \theta J_{j,t+1}^e(N_{j,t+1}^e), \right]$$

subject to the net worth dynamics (7), their balance sheet (6) and associated ICC:

$$J_{j,t}^e \geq \kappa^e Q_t^e K_{j,t}^e, \tag{8}$$

this incentive compatibility constraint states that the continuation value of the bank is larger than the potential profit from defaulting.[13]

The bank's problem yields the following optimality conditions:

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

$$[K_{j,t}^e]: \qquad \mathbb{E}_t \Omega_{t+1|t}^e \left(R_{k,t+1}^e - R_{b,t}^e\right) = \mu_t^e \kappa^e, \tag{9}$$

[12]An analogous sequential problem is: $J^e(N_{j,t}^e) = \max_{\{N_t, Z_t^e, F_{j,t}^e\}_{t=0}^{\infty}} \mathbb{E}_t (1-\theta) \sum_{s=0}^{\infty} \Lambda_{t,t+1+s}^e [\theta^s N_{j,t+1+s}^e]$

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

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 $\Omega^e_{t+1|t} = \Lambda^e_{t,t+1}(1-\theta+\theta J^{e'}_{t+1})$ 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 (international) claims on the $e = \{a, b\}$ representative emerging economy banks (EMEs), and $Q^c_t Z^c_{j,t}$ are (local) claims on the Center country capital stock with $Z^c_{j,t} = K^c_{j,t}$.

Their net (after macroprudential 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:

$$J^c_{j,t}(N^c_{j,t}) = \max_{N^c_{j,t},\, Z^c_t,\, F^e_{j,t},\, D^c_t} \mathbb{E}_t \Lambda^c_{t,t+1}\Big[(1-\theta)(\overbrace{R^c_{k,t+1} Q^c_t Z^c_{j,t} + R^a_{b,t} F^a_{j,t} + R^b_{b,t} F^b_{j,t}}^{\text{gross return on assets}} - \overbrace{R^c_{D,t} D^c_t}^{\text{deposits' repayment}}) + \theta J^c_{j,t+1}(N^c_{j,t+1})\Big],$$

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

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

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, given by:

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

3.5 Macroprudential Policy

The policy tool I consider is a tax on the return on capital. This tax is effectively paid by the individual banks, hence it's macroprudential in nature. The choice of the policy tool follows a setup along the lines of papers such as Agénor, Jackson, Kharroubi, Gambacorta, Lombardo, and Silva (2021). Importantly, this is a general enough tool that encompasses several existing varieties of macroprudential instruments; for example, we show in Granados (2021) and in the Appendix A, for a simplified setup, that it is equivalent to setting a leverage-ratio cap regulation and discuss in the Appendix B how such result follows in the infinite horizon version of the model.

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

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

The regulators rebate the tax proceeds to their households citizens as a lump-sum tax.

Effect of the prudential tool and the nature of the financial friction. The financial friction in this setup follows Gertler and Karadi (2011) and in an international environment is analogous to Devereux, Engel, and Lombardo (2020) and Agénor et al. (2021), but in this case, with more economies involved, there are more potential cross-border effects.

The distortion is generated by a costly enforcement agency friction and asymmetric information (the lenders can default and the borrowers cannot recover their funds entirely if they do) where a financial accelerator mechanism emerges and is reflected in the model as a positive credit spread that prevents lenders from defaulting. In terms of the model, the ICC may be slack and for it to bind, the lender bank must be given an additional return (external finance premium).

The aggregate effect is a wedge between the cost of capital and the return of other assets (e.g., bonds) that augments the cyclical fluctuations of capital and other variables. This is a source of inefficiencies akin to monopolistic distortions that the planner may want to mitigate to bring the economy closer to the first-best equilibrium.

As explained by Korinek (2016), how this is done in an open economy setup, with international financial linkages and policy spillovers, is not independent of whether country social planners act cooperatively. This is because, additional distortions may arise, when nationally-oriented social planners fail to internalize the cross-border effect of their policies.

To understand this further, it will be critical to disentangle the drivers of the policy tools in each regime (strategic, cooperative, semi-cooperative) to determine when additional policy objectives arise or are removed once the policymakers internalize the cross-border effects of their actions. To that end, in Section 5 I show that welfare differences under several regimes and later unveil their driving mechanisms in Section 7.

3.6 Market Clearing Conditions

The corresponding market clearing conditions for the final goods and bonds markets are:

$$\begin{aligned} \text{Goods market:} \quad & \sum_i n_i Y_t^i = \sum_i n_i \left(C_t^i + I_t^i \left(1 + \frac{\zeta}{2} \left(\frac{I_t^i}{I_{t-1}^i} - 1 \right)^2 \right) + \frac{\eta}{2} (B_t^i)^2 + \frac{\eta}{2} \left(D_t^i - \bar{D}^i \right)^2 \right), \\ \text{Bonds market:} \quad & \sum_i n_i B_t^i = 0, \qquad \forall t, \end{aligned}$$

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

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

Equilibrium. For a given path of macroprudential policies $\boldsymbol{\tau_t} = \{\tau_t^a, \tau_t^b, \tau_t^c\}$ a tax-distorted competitive equilibrium is given by the prices $\{w_t^i, Q_t^i\}$, rates $\{R_t, R_{D,t}, R_{k,t}^i, R_{b,t}^e\}$ and quantities $\{C_t^i, H_t^i, B_t^i, D_t^c, K_t^i, I_t^i, N_t^i, F_t^e, Y_t^i\}$ with $i = \{a, b, c\}$ and $e = \{a, b\}$ such that,

Given $\{w_t^i, R_t, R_{D,t}\}$, the sequences $\{C_t^i, B_t^i, D_t^c, H_t^i\}$ solve the households utility maximization problem for each t.

Given $\{Q_t^i, w_t^i, R_{k,t}^i\}$ and the technological constraint $\{Y_t^i\}$, $\{K_t^i, H_t^i\}$ solve the final goods firms profit maximization problem for each t.

Given $\{Q_t^i\}$ and the expected path of prices $\{\mathbb{E}_t Q_{t+s}\}_{t=0}^{\infty}$, $\{I_t^i\}$ solves the capital producer profit maximization problem.

Given $\{Q_t^i, R_{k,t}^i, R_{b,t}^e, R_{D,t}\}$, $\{N_t^i, Z_t^i, F_t^e\}$, with $Z_t^i = K_t^i$ solves the franchise value maximization problem of the banks.

In addition, capital dynamics are given by (4), and the goods and bonds market clearing conditions hold for each t.

In the table 7 in the appendix B, I show the final system of equations that characterizes the equilibrium. These structural equations will be used as the set of constraints each policy makers faces when deciding the optimal level of the tools under each regime.

4 Ramsey Policy Problem

So far, I have characterized the private equilibrium for this economy. In that context, the policy tools are exogenous to the agents (they take them as given). However, I am interested in the endogenous determination of these tools for a set of regimes that vary by the degree of international cooperation. For that, I use the Ramsey Planner Problem, consisting on choosing the optimal level of the policy tools, and the rest of variables, subject to the private equilibrium conditions.

Table 1: Policy Cases Considered

Regime	Planners/Players	Objective Function	Decision variables
Cooperation (all countries)	World	$W_0^{Coop} = n_a W_0^a + n_b W_0^b + n_c W_0^c$	$\mathbf{x_t}, \boldsymbol{\tau}_t$
Semi-Cooperation 1 (EMEs vs. Center)	Periphery block A+B	$W_0^{ab} = n_a W_0^a + n_b W_0^b$	$\mathbf{x_t}, \tau_t^a, \tau_t^b$
	Center	W_0^c	$\mathbf{x_t}, \tau_t^c$
Semi-Cooperation 2 (EME-A + C vs. EME-B)	Cooperative A+C	$W_0^{ac} = n_a W_0^a + n_c W_0^c$	$\mathbf{x_t}, \tau_t^a, \tau_t^c$
	EME-B	W_0^b	$\mathbf{x_t}, \tau_t^b$
Nash (non-cooperative) One planner per country	EME-A	W_0^a	$\mathbf{x_t}, \tau_t^a$
	EME-B	W_0^b	$\mathbf{x_t}, \tau_t^b$
	Center	W_0^c	$\mathbf{x_t}, \tau_t^c$

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

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 regimes that range from no-cooperation (Nash) to world cooperation while allowing for semi-cooperative cases where subsets of countries form regulatory coalitions.

As shown in table 1, two features are critical for differentiating the cases: first, the objective funtion of the planner is the weighted welfare of the countries that belong to a coalition (in the non-cooperative case each economy has an individual planner whose objetive function will be the local welfare), and second, the cooperative planners, by joining efforts and acting as one, will have a larger menu of policy tools available.

4.1 Planning Problems

In every case I consider the planning problem under commitment with a timeless perspective.[14] As explained by King and Wolman (1999) this implies to assume the planners were making optimal

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

decisions in the past in a time consistent manner. This setup is standard in the literature given its property of avoiding indeterminacy issues in the model solution.[15]

In addition, I solve for the *open-loop Nash* equilibrium for the cases where there are two or more players interacting simultaneously.

Definition 1. *Open-loop Nash equilibrium*

An open-loop Nash equilibrium is a sequence of tools $\{\tau_t^{i\,*}\}_{t=0}^{\infty}$ *such that for all* t^*, $\tau_{t^*}^{i\,*}$ *maximizes the player* i*'s objective function subject* ~~*ot*~~ *the structural equations of the economy characterizing the private equilibrium for given sequences* $\{\tau_{-t^*}^{i\,*}\}_{t=0}^{\infty}$ *and* $\{\tau_t^{-i\,*}\}_{t=0}^{\infty}$*, where* $\{\tau_{-t^*}^{i\,*}\}_{t=0}^{\infty}$ *denotes the policy instruments of player* i *in other periods than* t^* *and* $\{\tau_t^{-i\,*}\}_{t=0}^{\infty}$ *the policy moves by all other players. In this sense, each player's action is the best response to the other players' best responses.*

Given that the policymakers specify a contingent plan at time 0 for the complete path of their instruments $\{\tau_t^i\}_{t=0}^{\infty}$ for $i = \{a, b, c\}$, the problem they solve can be interpreted as a static game, which allows me to recast their maximization problems as an optimal control problem where the instruments of the other planners are taken as given.

In that vein, and as in the static Nash equilibrium concept, the player i focuses on his own objective function. Having said this, the key difference across regimes is whether the planners maximize their national welfare or, jointly, that of a coalition.

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

$$W_0^{coop} = \max_{\mathbf{x}_t, \boldsymbol{\tau}_t} [n_a W_0^a + n_b W_0^b + (1 - n_a - n_b) W_0^c], \tag{17}$$

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 form a coalition, and jointly solve:

$$W_0^{coop(C+A)} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^c} [n_a W_0^a + n_c W_0^c], \tag{18}$$

[15] In the appendix B I discuss the solution of this model without time consistency and its welfare properties in regards to policy cooperation.

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

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) acts strategically and solves the same problem as in the Nash case.

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

$$W_0^{coopEME} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^b} [n_a W_0^a + n_b W_0^b], \tag{19}$$

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

The remaining country (C) acts strategically and solves the same problem as in the Nash case.

Nash (no cooperation). Finally, a non-cooperative policy-maker of the country $i = \{a, b, c\}$, with the domestic welfare as objective function (nationally-oriented), solves:

$$W_0^{i,nash} = \max_{\mathbf{x}_t, \tau_t^i} W_0^i, \tag{20}$$

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

4.2 Gains From Cooperation

To compare the performance of the models, I 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 is:

$$Gain_{Coop/Nash} \equiv W_0^{coop} - (n_a W_0^{a,nash} + n_b W_0^{b,nash} + (1 - n_a - n_b) W_0^{c,nash})$$

The gain is approximated at the second order around the non-stochastic steady state. Moreover, as it is, this welfare gain is given in utility units which makes difficult to assess the magnitude of the relative performance of each model. Then, for a better comparison, we can look for the consumption equivalent variation that would make the private agents indifferent between the models (regimes). For this case, that quantity is given by λ, the proportional increase in the steady-state consumption of the world cooperation model that would deliver the same welfare as the Nash case:

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

for each economy $i = \{a, b, c\}$. Similarly, the global consumption equivalent gain (cost) is the weighted average of the national ones.

In this example, an overperforming model with cooperation gains, would depict a negative λ. In that case, a negative λ would indicate that consumption in the cooperative regime would have to decrease in order to match the non-cooperative equilibrium, implying the cooperative regime is better from a welfare perspective. I approximate λ by normalizing the gains (in utility units) by the increase in steady-state welfare that would be obtained from a 1% increment in consumption.[16]

5 Results

In this section, I discuss the solution of the main model under different policy schemes and how it helps to answer (i) whether the international cooperation of macroprudential policies is convenient for emerging economies, and (ii) if so, what are the drivers of the associated welfare gains. For that, I compare the expected long run welfare that regimes in table 1 deliver. This is done by obtaining the welfare loss (in consumption variations) agents undergo when transitioning from the first-best to the economy in each regime. Then, in the following section, I set up a smaller scale model to unveil the mechanism driving the welfare differences between regimes.

Steady State of the Policy Instruments. The table 2 shows the steady states of the policy taxes for each policy regime considered. The algorithm used implies computing an instrument conditional steady state and follows the steps outlined in Christiano, Motto, and Rostagno (2007) and Bodenstein, Guerrieri, and LaBriola (2019). A detailed explanation can be found in the appendix B. I obtain that the Center applies subsidies to its banking sector in the long run in each regime, 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 emerging coalition. Thus, at least in the long-run, cooperation with the center consists on setting higher subsidies (lower taxes) while in absence of cooperation emerging planners will focus more on attacking.

Table 2: 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

We will see, when analyzing the additional mechanisms that emerge for cooperative social

[16]In the results (table 3) I show the consumption compensation variation that agents in the First Best model (with no frictions) would undergo in order to match each one of the considered regimes. In that setup, more negative λ values imply a further detrimental departure from the first-best.

planners, that this behavior is consistent with a higher incentive to steer capital flows to emerging economies.

5.1 Welfare Accounting Comparison

We can compare the regimes in terms of the welfare they deliver. For this, I compute the conditional welfare that yields comparable quantities across models (for details see Bilbiie, Fujiwara, and Ghironi, 2014). I condition all the models on the same initial state given by the average of the steady state values of a subset of the regimes. Based on the resulting welfare quantities I rank the regimes and verify the existence of cooperation gains.

Table 3: Welfare cost in consumption equivalent compensation units 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 (FB) as benchmark. The numbers in bold denote the departure from the FB model, in terms of steady state consumption, i.e., the equivalent variation in consumption agents undergo if they transition from the FB to the column's regime.
In Cooperation (all), symmetry between instruments rules is assumed for EMEs

The table 3 shows the expected conditional welfare gains obtained at a second order of approximation.[17] I 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 3.2% in the consumption.

Using the global welfare in the fifth row as the criterion for ranking the regimes, I find that the best policy framework is the worldwide cooperation, followed by the cooperation between the Center and one periphery (A in Center+EME-A), the third best policy would be the non-cooperative

[17]The associated welfare levels are shown in table 10 in the appendix B.

[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.

one (Nash) and, finally, the worst performing one is the regional cooperation between peripheries (EMEs).

These results suggest that not every type of cooperation is welfare improving relative to the nationally-oriented regime (Nash). On the contrary, the cooperation arrangements that are beneficial, globally and to the EMEs, are those involving a cooperative Center. This helps us answer the main question of this study: The emerging economies will not be better off under every type of cooperation, instead, they will only benefit when cooperating 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 are better-off in the semi-cooperative arrangement (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, although at the expense of the periphery that is left out of the coalition (EME-B).

Gains relative to non-cooperative regime The table 3 compares the welfare of each regime with respect to the first best. Similarly, we can also compare each regime's performance relative to the non-cooperative policies. In that case, the social welfare gains for global cooperation amount to a 15% in equivalent consumption units, 12% for the Coop(A+C) regime, and a 6% loss for the emerging cooperation framework (EMEs). The result by country (and region) are shown in table 8 in appendix B.

Unveiling the mechanisms behind the welfare differences In order to understand the sources of welfare gains it is critical for us to unveil the mechanisms driving the welfare differences between regimes as the only difference between these equilibria are the macroprudential taxes implemented. We obtain the mechanisms in the following section based on an analytical exploration of a smaller scale model and later come back to interpreting the welfare accounting exercise further.

6 A Simplified Model

We lay out a smaller scale version of the model, with only one period of intermediation to obtain analytical welfare expressions and policy effects. Ultimately, and based on such effects, we will obtain expressions for the optimal taxes for non-cooperative and cooperative policymakers where the constrasting policy incentives leading to the welfare differences in table 3 are described.

I explain in closer detail the most important sectors and agents (banks, households and policymakers), and leave the rest of the model equations in the appendix, understanding that in the rest of cases we obtain analogous expressions to those derived in the model in section 3.

6.1 Setup

General economic environment. Time is discrete and there are two periods, $t = \{1, 2\}$. 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 peripheries is no larger than the population size of 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, the government and a representative bank.

The households have standard preferences over consumption and their welfare is given by: $W^i = u(C_1^i) + \beta u(C_2^i)$, with $u(C) = u(C) = C^{1-\sigma}/(1-\sigma)$. They own the firms (final goods, capital and banks) and there is a production technology that transforms the predetermined capital into a final consumption good with an agregator: $Y_t^i = A_t^i K_{t-1}^i$. This good is identical across countries.

The economies are endowed with a predetermined level of capital in the first period (K_0), after that, a bank intermediates the physical capital acquisition for production. For this, at the end of each period, the firm will make its input and indebtedness decisions, the bank will provide the funds and will be repaid the next period after production takes place. This implies there is one period financial intermediation ($t = 1$).[19]

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

6.2 Banks

Each economy has a representative bank that aims to maximize the present value of its franchise. There are two important features that distinguish emerging economies (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.[20]

EME-Banks. The banks in the emerging economies will intermediate funds in order to provide resources to local firms for capital acquisition. 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. 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

[19] This setup is very simplified as it abstracts from any stochastic features and from dynamics in the banks and policies effects once banks are allowed to intermediate in future periods (as in the main model). Those features are abstracted here as the policy mechanisms can be characterized with a static version of the same problem. For a discussion on the dynamic effects of these policies see Granados (2021). Notice however, that such features must remain in the main model where it is critical to make an accurate approximation of the welfare.

[20] In the main model all countries are allowed to have a friction, however the parameters are such that the extent of the friction is higher in emerging economies. This case is simpler, but it is still encompassed by the main model.

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 that takes the form of a default risk premium. This feature is modelled following the structure of Gertler and Kiyotaki (2010) and Céspedes, Chang, and Velasco (2017).

In the first and only period of intermediation the bank maximizes its franchise value by solving:

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

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

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

where the country index for emerging economies is e with $e = \{a, b\}$, $L_1 = Q_1 K_1$ is the total lending intermediated with the local firms, F_1 is the cross-border borrowing obtained from the Center, $R_{k,2}$ is the gross revenue rate of the banking services, paid by the firms, $R_{b,1}$ is the interbank borrowing rate for the banks that they pay to the Center intermediary, Q_1 is the price of capital, $\delta_B Q_1 K_0$ represents a start-up capital the bankers get from their owner households, and $\Lambda_{1,2}$ is the stochastic discount factor between periods 1 and 2.

The present value of the bank, will be given by the expected profits in the next period. The constraints are given by the balance sheet of the bank and an incentive compatibility constraint (ICC). 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, the latter of which in this simple case is only the start-up capital received from the households.

Finally, the ICC reflects the imposition that the value of the bank's franchise has to be equal or larger than the value of defaulting its creditors, which is given by a fraction κ of the intermediated assets.[21] For simplicity, this divertable fraction will be constant across locations and time.

This problem yields the following first-order conditions:

$$[F_1^e]: \quad \mathbb{E}_2 (1 + \mu^e)(R_{k,2}^e - R_{b,1}^e) = \kappa \mu^e,$$

Where μ^e is the lagrange multiplier of the ICC of bank in country e.

Similar to the previous sections, this condition shows that if the ICC binds, the credit spread is positive and increases in the absconded share of the assets κ. Moreover, as the friction is embodied in a positive spread, we can talk about κ and the extent of the distortion as analogous concepts.

[21] I 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., with the potential absconding occurring after the final goods firms repay their debt. In expectations, both cases are very similar, since the obtained gross rate times stochastic discount factor of the bank are equal to one.

Center-Banks. The Center representative intermeriary will solve a similar problem but without being subject to frictions. Therefore, the only constraints it faces are 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 maximizes it's value by solving:

$$J_1^c = \max_{F_1^a, F_1^b, L_1^c, D_1} \mathbb{E}_1 \left\{ \Lambda_{1,2}^c (R_{k,2}^c L_1^c + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b - R_{D,1} D_1) \right\},$$

$$s.t, \quad L_1^c + F_1^a + F_1^b = D_1 + \delta_B Q_1^c K_0^c. \qquad \text{[Balance sheet in t=1]}$$

The resulting first order conditions will just reflect that the expected credit spread is zero for all of the assets considered by the center (F_1, L_1, D_1). By using that result, and the perfect foresight assumption, we can drop the borrowing cross border rates $(R_{b,1})$ as they are all equal to the rate for deposits at the Center $(R_{D,1})$. Moreover, the Euler equations for the households with respect to the bonds and deposits allow to simplify further and replace the deposits rate with that of the bonds.

6.3 Production Sectors

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

Final Good Firm. There is a firm that maximizes their profits, given by the value of the production, plus the sales of undepreciated capital, minus the payment of banking loans. The only constraint it faces is the production technology. From the first order condition with respect to the capital, we can pin down the gross rate of return paid to the banks as $R_{k,2} = \frac{r_2 + (1-\delta)Q_2}{Q_1}$. Here , $r_2 = \frac{\alpha Y_2}{K_1}$ is the marginal product of capital and Q_t is the price of capital in period $t = \{1, 2\}$.

Capital Producers. There is a firm carrying 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 for future production. Moreover, the investment is subject to a cost of adjustment that depends on the investment growth with respect to the previous period.

6.4 Households

The households own the three types of firms (final goods, capital and banks), and use their profits for consumption, saving, and for supplying the bequests to their banks. They don't pay the banking taxes directly, instead, these are paid by the banks before distributing profits. However, they receive a lump sum transfer from the government 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 rent the capital to the firms directly.

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

$$\max_{C_1^e, C_2^e, B_1^e} u(C_1^e) + \beta u(C_2^e),$$

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

$$C_2^e = \pi_{f,2}^e + \pi_{bank,2}^e + B_1^e - T_2^e,$$

here B_1 denotes the bonds or net foreign assets position, R_1 the interest rate on bonds, and T_2 the lump sum taxes. As for the profits terms, $\pi_{f,t}$ are to the final goods firms profits, $\pi_{inv,1}$ the the capital firms profits, and $\pi_{bank,2}$ the banking profits. As usual, the superscript denotes the country.

I also assume that emerging households do 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 should be noted that this assumption is inconsequential for the saving decisions of the households as they can freely access the bonds market.

Center-households. The households at the Center solve a similar problem, with the differences that they access to local deposits, and their banking profits reflect that they are a global creditor:

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

$$s.t., \quad C_1^c + \frac{B_1^c}{R_1^c} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_B Q_1^c K_0^c$$

$$C_2^c = \pi_{f,2}^c + \pi_{bank,2}^c + B_1^c + R_{D,1} D_1 - T_2^c$$

The household optimality conditions for both economies consist of Euler equations and the budget constraints. These are used to simplify the rates structure and clearing the markets in equilibrium.

6.5 Macroprudential Policy

As before, I consider a policy consisting of a macroprudential policy tax that targets the banks. A government will tax the rate of return of the bankers in each period, and afterwards, rebates the tax income back to the households. As a result, the effective revenue rate perceived by the banks after paying their taxes is: $R_{k,2} = \frac{(1-\tau_2)r_2 + (1-\delta)Q_2}{Q_1}$, where τ_2 is the macroprudential tax.

With such structure, the following proposition holds:

Proposition 1: *An increase in the macroprudential tax decreases the leverage ratio of banks and its effect grows with the friction*

Proof: See appendix A. ■

Thus, in addition to the direct effect in smoothing the credit spread of a distorted economy, the macroprudential tax lowers the leverage of the banking sector. That is, implementing an optimal policy is equivalent to setting a leverate-ratio requirement in the banking sector.

6.6 Equilibrium

Market Clearing and International Links. The bonds market depicts a zero-net-supply:

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

In addition, I assume the uncovered parity holds which equals the bonds rates across countries ($R_t^a = R_t^b = R_t^c = R_t$). Furthermore, I make use of the Euler equation for the deposits and bonds from the first order conditions of the Center to determine that $R_{D,1} = R_1$.

On the other hand, the market clearing conditions for the goods market in $t = \{1, 2\}$ are:

$$\sum_i n_i Y_1^i = \sum_i n_i \left(C_1^i + C(I_1^i) \right),$$
$$\sum_i n_i Y_2^i = \sum_i n_i C_2^i,$$

where $C(I_1^i)$ is the gross cost of investing I_1^i (investment principal and adjustment cost).

Equilibrium. Given the policies $\tau_2 = \{\tau_2^a, \tau_2^b, \tau_2^c\}$, the equilibrium consists of prices $\{Q_t^i\}$, rates $\{R_1, R_{k,2}^e\}$, and quantities $\{B_1^i, K_1^i, F_1^e, D_1\}$ and $\{C_t^i, I_1^i\}$ for $t = \{1, 2\}$, with $i = \{a, b, c\}$ and $e = \{a, b\}$ such that: the households solve their utility maximization problem, the firms solve their profit maximization problems, the banks maximize their franchise value, the government runs a balanced budget, and the goods and bonds markets clear.

A summary of the final set of equilibrium conditions used for solving the model can be found in table 4. I solve this system of equations non-linearly and using a perfect foresight approximation.

6.7 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 expressions associated to a social planner problem and simplify them by using the private equilibrium conditions. Afterwards, I obtain the welfare effects via implicit differentiation.

A social planner will consider the following welfare expressions.

$$\begin{aligned} W_0^e = u\left(C_1^e\right) + \beta u\left(C_2^e\right) + \lambda_1^e \left\{ A_1^e K_0^{e\ \alpha} + Q_1^e I_1^e - C(I_1^e, I_0^e) - \delta_B Q_1^e K_0^e - C_1^e - \frac{B_1^e}{R_1} \right\} \\ + \beta \lambda_2^e \left\{ \varphi(\tau_2^e) A_2^e K_1^{e\ \alpha} + \kappa \frac{Q_1^e K_1^e}{\Lambda_{12}} + B_1^e - C_2^e \right\}, \end{aligned} \tag{21}$$

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

$$W_0^c = u(C_1^c) + \beta u(C_2^c) + \lambda_1^c \left\{ A_1^c K_0^{c\ \alpha} + Q_1^c I_1^c - C(I_1^c, I_0^c) - \delta_B Q_1^c K_0^c - C_1^c - \frac{B_1^c}{R_1} - D_1 \right\} \\ + \beta \lambda_2^c \{ A_2^c K_1^{c\ \alpha} + (1-\delta) Q_2^c K_1^c + R_{b1}^a F_1^a + R_{b1}^b F_1^b + B_1^c - C_2^c \} \tag{22}$$

To obtain these expressions I set the welfare as the present value of the life-stream of utility plus a budget constraints in each period (times their Lagrange multipliers). Then, I replace the profits and tax rebates. Notice that these expresions hold given the constraints are binding, and hence sum to zero, leaving the usual definition of welfare as result.

Setting the welfare in this fashion is convenient as the algebra is simplified because we can ignore the effect of the decision variables of the households as their first order conditions (zero in equilibrium) become a factor of the associated differential terms.

Next, we can obtain welfare effects from changing each type of tax. These are:[22]

For the EMEs:

$$\frac{dW_0^e}{d\tau_2^e} = \beta \lambda_2^e \left\{ \alpha_1(\kappa) \frac{dK_1^e}{d\tau_2^e} + \alpha_2(\kappa) \frac{dQ_1^e}{d\tau_2^e} + \frac{B_1^e}{R_1} \frac{dR_1}{d\tau_2^e} + \alpha Y_2^e \right\}, \text{ for } e = \{a, b\},$$

with $\alpha_1(\kappa) = \varphi(\tau_2^e) r_2^e + \kappa R_1 Q_1^e$, $\alpha_2(\kappa) = R_1(I_1^e + \kappa K_1^e)$, and $\varphi(\tau_2^e) = 1 - \alpha(1 - \tau_2^e)$. For the Center:

$$\frac{dW_0^c}{d\tau_2^c} = \beta \lambda_2^c \left\{ ((1-\delta) Q_2 + r_2^c) \frac{dK_1^c}{d\tau_2^c} + R_1 I_1^c \frac{dQ_1^c}{d\tau_2^c} + \frac{B_1^c}{R_1} \frac{dR_1}{d\tau_2^c} + \frac{dR_{b,1}^e}{d\tau_2^c} F_1^{ab} + R_{b,1}^e \frac{dF_1^{ab}}{d\tau_2^c} \right\},$$

with $F_t^{ab} = F_t^a + F_t^b$.

When interpreting these effects, we can see there are four drivers of the welfare effects of the tax: (i) effect from hindering the capital accumulation, (ii) effect from changes in the global interest rate, which are proportional to the net foreign asset position, (iii) effect from changes in the prices of capital, and in addition, for the Center, (iv) changes in the cross-border lending rates and quantities. The welfare effects (i) and (iv) are negative and capture a halting in banking intermediation, while the sign of (ii) and (iii) depends, respectively, on whether an economy is a net creditor or on the investment growth, in that sense, we expect (ii) to be positive for an emerging economy and negative for the Center as the latter acts as a global creditor. Finally, assuming that the investment in these economies is still growing after the tax change, (iii) is negative.

Noticeably, the aforementioned negative effects are reflective of the potential negative growth consequences of setting these taxes akin to putting sand in the wheels of the financial sector. That is what the literature refers to as the potential immiserizing growth effects of these prudential toolkit.[23] Of course, the policy trade-off here is that mitigating a financial friction may be worth such a cost.

[22] Here we show the direct welfare effects, i.e., effects on local (national) welfare from changing the domestic policy. Similar expressions follow for cross-country effects. We use the former to get the optimal tools for cooperative planners.

[23] See Boar, Gambacorta, Lombardo, and da Silva (2017) and Belkhir, Naceur, Candelon, and Wijnandts (2020) for a discussion on the growth effects of macroprudential policies

Finally, a critical feature we obtain is that the welfare effects from changes in capital accumulation and prices are augmented by the extent of the financial friction (κ). This indicates these taxes are potentially more effective for highly distorted economies.

Optimal taxes for nationally-oriented planners. From the analytical welfare effects it's possible to solve for the optimal taxes. The derivation procedure and other expressions are shown in appendix A. The optimal nationally-oriented policies are the following:

$$\begin{aligned}\tau_2^c &= \frac{Q_1^c}{r_2^c}\left\{((1-\delta)Q_2^c + r_2^c)\frac{dK_1^c}{dF_1^{ab}} + \Lambda_{1,2}^c B_1^c \frac{dR_1}{dF_1^{ab}} + F_1^{ab}\frac{dR_{b,1}^e}{dF_1^{ab}} + \frac{I_1^c}{\Lambda_{1,2}^c}\frac{dQ_1^c}{dF_1^{ab}}\right\} + 1 + (1-\delta)\frac{Q_2^c}{r_2^c} \\ \tau_2^e &= -\frac{1}{\alpha r_2^e}\left\{\frac{1}{\Lambda_{1,2}^e}(I_1^e + \kappa K_1^e)\frac{dQ_1^e}{dK_1^e} + \Lambda_{1,2}^e B_1^e \frac{dR_1}{dK_1^e} + \frac{\kappa}{\Lambda_{1,2}^e} Q_1^e\right\} + 1 - \frac{1}{\alpha},\end{aligned} \tag{23}$$

Notice these are the optimal local tools for maximizing domestic welfare. Thus, they are also the non-cooperative optimal taxes, and we can denote as $\tau_2^{e,nash}$ and $\tau_2^{c,nash}$ with $e = \{a, b\}$.

Two relevant features can be found in the optimal nationally-oriented taxes, first, the peripheral taxes grow in scale with the financial distortion, and second, the center depicts a substitution effect motive between local and foreign intermediation ($\frac{\partial K^c}{\partial F}$ term). This latter effect helps to understand how the tax setting of the Center differs from that of the periphery given its role of international creditor. In a nutshell, the regulators at the Center trade-off local intermediation for global lending which is useful for understanding the importance of the Center in generating gains from cooperation.

When obtaining the optimal toolkit under cooperation, we will see which of these drivers remain and which are removed after accounting for the additional policy incentives of the cooperative planner that internalizes the international welfare effects of setting any domestic regulation.

Optimal policy for cooperative planners The previous optimal taxes maximize national welfare, and thus correspond to the optimal taxes for non-cooperative planners. We can also obtain the optimal policies for cooperative planners analogously, except that we account by the fact that the cooperative planner maximizes centrally the weighted welfare of their coalition's participants.

In a nutshell, the procedure consists on equating the cooperative planners' welfare effects after a change in a tax to zero and solve for the policy involved. These welfare effects are given by the weighted average of the national effects shown before, and the cross-border welfare effects involving coalition participants.[24] The detailed derivation of these expressions is left in the appendix A

[24]For example, for the global cooperative planner the welfare effect of a tax change in country i is $\frac{dW_0^{Coop}}{d\tau^i} = n_a\frac{dW_0^a}{d\tau^i} + n_b\frac{dW_0^b}{d\tau^i} + n_c\frac{dW_0^c}{d\tau^i}$ where n_i is the welfare weight assigned to an economy $i = \{a, b, c\}$.

The optimal taxes of each type of economy for cooperative planners are given as follow,[25]

$$\tau_2^{c,coop} = \tau_2^{c,nash} + \frac{Q_1}{r_2}\frac{\lambda_2^e}{\lambda_2^c}\Bigg\{ \overbrace{\left(\varphi(\tau_2^e)r_2^e + \frac{\kappa}{\Lambda_{1,2}^e}Q_1\right)\frac{dK_1^e}{dF_1^{ab}} + \frac{I_1^e + \kappa K_1^e}{\Lambda_{1,2}^e}\frac{dQ_1^e}{dF_1^{ab}}}^{\text{substitution of Center capital accumulation for foreign intermediation (EMEs)}} \overbrace{-\Lambda_{1,2}^e B_1^c \frac{dR_1}{dF_1^{ab}}}^{\text{removal of NFA-value manipulation incentive}} \Bigg\}$$

$$\tau_2^{e,coop} = \tau_2^{e,nash} \underbrace{- \frac{1}{\alpha_2}\frac{\lambda_2^c}{\lambda_2^e}\left\{\left[\frac{I_1^c}{\Lambda_{1,2}^c}\frac{dQ_1^c}{dK_1^e} + \eta\frac{dK_1^c}{dK_1^e} + F_1^{ab}\frac{dR_{b,1}^e}{dK_1^e} + R_{b,1}^e\frac{dF_1^{ab}}{dK_1^e}\right] - \left[\Lambda_{1,2}^c B_1^e \frac{dR_1^c}{dK_1^e}\right]\right\}}_{\text{Additional policy mechanisms for cooperative planners}} \tag{24}$$

where $\eta = ((1-\delta)Q_2 + r_2^c)$, and $\{\tau_3^{c,nash}, \tau_3^{e,nash}\}$ with $e = \{a, b\}$ are respectively the optimal taxes to be set at each country by the non-cooperative planner shown in equations (23).

Crucially, the component that depends on changes in the global interest rates, that is proportional to the net foreign assets positions of the economies, cancels out between creditors and debtors that cooperate (i.e., the last term in each expression in (24) cancels with an analogous term, but with opposite sign within $\tau_3^{i,nash}$ with $i = \{e, c\}$).

On the other hand, for both types of instruments (i.e., regulations at Center and peripheries) a motive for augmenting the capital flows to emerging economies arises. In the Center it implies substituting local for global intermediation with higher taxes, while at the peripheries it implies increasing the subsidization, in both cases the effect grows with the scale of banking intermediation to the peripheries or the change in the emerging capital stock after the cross-border lending increases.

The additional motives for increasing intermediation toward the peripheries have two relevant nuances, first, in terms of the additional tightening in Center taxes, we obtain that such effect increases with the extent of the financial frictions (κ), and second, regarding the increased subsidization at the peripheries, we have that it will be subject to a dampening effect, proportional to how affected the capital accumulation at the Center is after their bankers substitute local for global intermediation in favor of the emerging economies. We interpret the latter as compensation mechanism that results from the internalization by the cooperative planner of the effects of the policies in all locations.

As one can expect, the only differences between regimes are their optimal policy prescriptions, and then, these additional features and policy incentives are the main factors explaining welfare differences between cooperative and non-cooperative settings. We analyze how they can generate cooperation gains in the following section.

[25] Here we focus on the mechanisms involved and thus analyze only the case of global cooperation. Similar expressions and insights follow from central planners of smaller coalitions.

7 Understanding the Sources of Welfare Gains From Cooperation

We are now equipped for understanding the welfare differences between the nationally-oriented and cooperative regimes in table 3. To begin, notice that the only difference between the regimes are the policies implemented. Also, the difference between cooperative and non-cooperative policies are given by the additional terms on the right-hand side of the optimal policies expressions shown in (24). These associate with new policy incentives under cooperation. We can summarize these as:

$$\begin{aligned}
\tau_2^{c,coop} &= \tau_2^{c,nash} - \overbrace{\varphi_2^{c,NFA}}^{\substack{\text{national NFA}\\ \text{manipulation motive}}} + \overbrace{\psi_2^{c,eme}(\kappa)}^{\substack{\text{local capital for foreign (EME)}\\ \text{intermediation substitution motive}}} \\
\tau_2^{e,coop} &= \tau_2^{e,nash} - \overbrace{\varphi_2^{e,NFA}}^{\substack{\text{national NFA}\\ \text{manipulation motive}}} - \overbrace{\psi_2^{e,eme}}^{\substack{\text{intermediation}\\ \text{substitution motive}}} + \overbrace{\chi_2^{c}}^{\substack{\text{Dampening of}\\ \text{substitution}}}
\end{aligned} \tag{25}$$

These equations are the same as in 24 but with the new policy terms grouped into the symbols with brackets. Here, NFA stands for net foreign assets, the taxes $\tau^{i,nash}$ refer to the non-cooperative taxes set in country i, and as before, the emerging tool equation applies for both peripheries ($e = \{a, b\}$).

The terms φ^{NFA} correspond to the national policy incentives to adjust the tools to boost the value of the net foreign assets portfolio through changes in the global lending rates. As we can see, they have a negative sign which denotes that such incentives are removed under cooperation. Such cancellation takes place as the same term is included in the non-cooperative tax with a positive sign.

The terms $\psi_2^c(\kappa)$ and ψ_2^e refer to the adjustments in each locations taxes (or subsidies) imposed to steer more financial lending towards the peripheries. In the case of the center, the effect will grow with the extent of the financial frictions, while for the emerging economies, the effect is dampened to account for how affected the capital accumulation at the Center is, the dampening effect is represented with χ_2^c. The signs of these terms denote how each implies higher taxes (positive) or subsidization (negative).

These arising policy incentives generate the following welfare-enhancing features:

Higher Smoothness of Cooperative Taxes: A Cooperative planner that can set the policy tools of the Center and of some or all peripheries finds that incentives to manipulate the global interest rate, in order to improve the net foreign assets position, disappear ($-\varphi_2^{NFA}$ cancels out with the same positive term in $\tau_3^{i,nash}$). This happens because in the cooperative welfare expressions, the net foreign assets terms of debtor and creditor (Center) countries offset with each other. As a result, there is one fewer source of fluctuations in the cooperative taxes which will make these instruments more stable. This cancellation effect works better with more peripheries in the policy coalition and exactly when the sum of the welfare weights of the participating EMEs equals that one of the Center, as in the global cooperation regime.

This mechanism is also present in the literature on cooperative capital controls, e.g., Davis and

Devereux (2022) describe this effect as the absence of terms of trade manipulation motives for cooperative planners. Here, however, I obtain an similar mechanism holds when regulating the banking sector, rather than when taxing capital flows (households) directly.

Substitution Motive of Local Capital for Foreign Intermediation: The cooperative planner has an additional motive for increasing taxes at the Center (or subsidies at peripheries). By doing so, it will discourage the local capital accumulation at the Center, which in turn protects the capital inflows to the emerging economies (EMEs).

This incentive, represented by φ_2^{NFA} in (25), increases with the financial friction (κ), and is proportional to the scale of the increase in the EMEs capital accumulation after a change in global lending. On the periphery's tool side, this effect is also subject to a dampening adjustment which accounts for effect of the lending destination substitution in the capital accumulation at the Center.

In summary, there are two main mechanisms at work: first, a cancellation effect that removes sources of variation from the taxes under cooperation (lowers their volatility), something that is welfare increasing and favors a more efficient pursuit of financial stability goals, as other potentially conflicting policy goals are removed, and second, a new policy incentive to encourage capital flows to the peripheries, even if it comes at the expense of the local capital accumulation at the Center.

Both motives add to the overall financial stability of the world economy. The first prevents unnecessary fluctuations in the taxes, leading to lower volatility in the international capital fluctuations, as the yield-seeking reactions of non-cooperative regulators are muted. The second one, on the other hand, encourages capital flows to the peripheries which can be useful in preventing capital retrenchment episodes, e.g., in presence of external shocks at the Center. Simultaneously, the second motive boosts the efficiency of the capital flows as these are allocated in the more productive destinations. In that spirit, the welfare gains from (center-led) cooperation are magnified as these regimes feature both a higher financial stability and increased efficiency in the use of capital.

Outlining the role of the Center in shaping cooperation gains. 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 countries in the cooperative coalition are debtors as in the emerging regional cooperation regime (CoopEMEs). The second one, is an effect that relies on the capacity of the Center, as a global creditor, to facilitate lending to different (domestic and foreign) destinations. The cooperative planners (in coalitions that include the Center) will recognize the capacity of the Center's banking sector for boosting global welfare; as a result, the instrument at the Center is not set to maximize the national welfare, which would imply increased domestic intermediation, but to maximize the world output by allocating the international flows optimally, which is beneficial to all destinations, including the Center as shown in the table 3.

Finally, another feature to notice in (24) is that the additional policy mechanisms are a factor of the relative ratio of marginal utilities in the second period (λ_2). Since we assume the Center is a larger economy, if follows that consumption is higher there and $\lambda_2^c < \lambda_2^e$. Thus, the strength of the additional policy mechanisms from cooperation affect more strongly the non-cooperative prescriptions of the Center. This acts as a type of automatically stabilizer in favor of the peripheries that balances out partially their unfavorable stance in the definition of global welfare where we assumed that the welfare weights are given by the relative population (and economies) sizes.

Role of the Welfare Weights. Both mechanisms generating welfare gains work better for regimes that assign higher weights to peripheries in the welfare objective of the cooperative planner. Here, I use the relative sizes of the economies (n_i for $i = \{a, b, c\}$) as the welfare weights for cooperative regimes. Furthermore, in the baseline we assume the sum of the peripheral sizes amount to that of the Center ($n_a + n_b = n_c$), i.e., the emerging block size is not negligible. With this, national incentives to manipulate the interest rate cancel out more evenly under cooperation, and, there is a stronger motive for facilitating the intermediation in the peripheries as these have a stronger effect in the global welfare.

By the same token, as the environment converges to that of a small open economy ($n_a, n_b \to 0$) the cancellation of incentives to manipulate the interest rate would no longer work as the planner would be biased to favor the Center. Also, the regulator would not find worthwhile to sacrifice capital accumulation at the Center to encourage peripheral intermediation as the latter, even if more efficient, would not contribute substantially to the global GDP.

Finally, it is relevant to remark that the difference in the welfare weights in favor of the Center is the reason explaining why the semi-cooperative regime "Coop(Center+EME-A)" does not perform as well as the global cooperation setup. A planner that is relatively biased to increase the welfare at the Center does not allow for a strong enough offsetting of the national NFA portfolio incentives.

Given these features, the inclusion of additional peripheral countries in the cooperative interactions, represents a way to balance the incentives of these economies in a welfare improving fashion. That is, to boost the social gains, we can either consider Center interactions with larger peripheries, or include more smaller economies into the cooperative arrangement.

8 Conclusions

We study whether the international macroprudential policy cooperation is beneficial for emerging economies and can be used to improve their macroeconomic performance and financial stability. We formulate two specific questions: (i) whether macroprudential cooperation is beneficial for these and other economies, and (ii) what mechanisms would be able to general such welfare gains. To address these questions, we propose an open economy setup with financially integrated economies that share interbank relationships but are subject to financial frictions. The latter justifies the presence of prudential regulations, however, these policies leak to other economies which may open the scope for policy coordination.

We test the outcomes of a wide menu of policy regimes that allow for different types and extents of cooperation. Importantly, we consider cases where subsets of countries form policy coalitions and enact cooperative regulations that other economies may retaliate to. This richer structure is part of our countribution and allows to determine which types of cooperation are beneficial, and which become counterproductive.

Our results confirm the existence of welfare gains for frameworks where peripheries collaborate with a center, thereby concluding that: cooperation is indeed useful, however, not every type of cooperation pays off, and the inclusion of a financial center in the coordinated arrangement is crucial. We rank our policy cases and obtain that the socially optimal regime will be the worldwide cooperation, followed by the cooperation between the financial center and a subset of the peripheries. This is explained by the fact that the welfare-increasing mechanisms work better when more peripheries are included in the coalitions. Therefore, the policy recommendation for an emerging economy would be that conditional on a participating center, it is advised to engage in cooperation.

As for the mechanisms inducing cooperation gains, we find that they are traced back to two policy incentives that arise for some cooperative planners. The first one, is the removal of national incentives to manipulate the value of the net foreign assets, and the second an incentive to increase capital flows to the emerging economies. These mechanisms can act with different strenghts across regimes depending on features such as the type of cooperative economies, the relative welfare weights of the planners, and the extent of the financial frictions.

Finally, although the potential gains of these coordinated regimes can be sizable, particularly for environments where the regulations' effects of on the balance sheets' are persistent, these cooperative efforts come with their own challenges, for example on the distributional front, where it may be hard to exert the best type of policy cooperation or to even maintain the participation of its coalition members. Thus, while we think this framework contributes in understanding the international role of the macroprudential policies, we acknowledge it still corresponds to a simplified framework that abstracts from relevant features, such as additional sources of risk (e.g., currency fluctuations), the presence of regulatory arbitrage or shadowbanking; all core concerns for financial regulators. The inclusion of these elements is left for future work.

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A Results from the Simplified Model

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

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

Table 4: Summary of equilibrium equations of the small scale model

Common to all countries:	
$Q_t = 1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \zeta\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - \Lambda_{t,t+1}\zeta\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2$	[Price of Capital, t={1,2}]
$K_1 = I_1 + (1-\delta)K_0$	[Capital Dynamics]
$R_{k,2} = \frac{(1-\tau_2)\alpha A_2 K_1^{\alpha-1} + (1-\delta)Q_2}{Q_1}$	[Banks rate of return]
$C_1^{-\sigma} = \beta R_1 C_2^{-\sigma}$	[Euler Equation, bonds]
for EMEs:	
$Q_1 K_1 = F_1 + \delta_B Q_1 K_0$	[bal. sheet of banks]
$\Lambda_{1,2}\left(R_{k,2}Q_1K_1 - R_1F_1\right) = kQ_1K_1$	[ICC]
$(1+\mu)\,\Lambda_{1,2}\left(R_{k,2} - R_1\right) = \mu \cdot \kappa$	[Credit spread]
$C_1 + \frac{B_1}{R_1} = r_1K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0$	[BC for t=1]
$C_2 = \pi_{f,2} + \pi_{b,2} + B_1 - T_2$	[BC for t=2]
for the Center:	
$Q_1^c K_1^c + F_1^a + F_1^b = D_1 + \delta_B Q_1^c K_0^c$	[Bal. sheet of banks]
$C_1^c + \frac{B_1^c}{R_1} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{1nv,1}^c - \delta_B Q_1^c K_0^c$	[BC for t=1]
$C_2^c = \pi_{f,2}^c + \pi_{b,2}^c + R_1D_1 + B_1^c - T_2^c$	[BC for t=2]
International Links:	
$n_a B_1^a + n_b B_1^b + n_c B_1^c = 0$	[Net Supply of Bonds]

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

Auxiliary definitions:

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

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

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

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

Profits of investors: $\pi_{inv,1} = Q_1I_1 - C(I_1, I_0) = Q_1I_1 - I_1\left(1 + \frac{\zeta}{2}\left(\frac{I_1}{I_0} - 1\right)^2\right)$,

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

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

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

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 value of the leverage.

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

The ICC is: $$J_1 = \Lambda_{1,2}(R_{k,2}L_1 - R_{b,1}F_1) = \kappa_1 L_1$$

By substituting the foreign lending $F_1 = L_1 - \delta_B Q_1 K_0$, where the second term on the right-hand side is the start-up capital of the bank (net worth), and solving for L_1:

$$L_1 = \overbrace{\frac{-\Lambda_{1,2}R_{b,1}}{\Lambda_{1,2}(R_{k,2} - R_{b,1}) - \kappa}}^{\phi}\delta_B Q_1 K_0$$

where ϕ denotes the leverage. Now, I substitute $R_{k,2}(\tau_2) = [(1-\tau_2)r_2 + (1-\delta)Q_2]/Q_1$ and differentiate with respect to the policy instrument:

$$\frac{\partial \phi}{\partial \tau_2} = -\frac{(\Lambda_{1,2})^2 R_{b,1} \cdot r_2}{(\Lambda_{1,2}(R_{k,2} - R_{b,1}) - \kappa)^2 Q_1} < 0$$

■

Table 5: 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	Captures large open economy effects in all countries
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 of each economy with respect of its own policy tool ($\frac{dW^i}{d\tau_2^i}$) to zero and then solving for the tax:

$$\frac{dW_0^e}{d\tau_2^e} = \beta\lambda_2^e \left\{ \alpha_1(\kappa)\frac{dK_1^e}{d\tau_2^e} + \alpha_2(\kappa)\frac{dQ_1^e}{d\tau_2^e} + \frac{B_1^e}{R_1}\frac{dR_1}{d\tau_2^e} + \alpha Y_2^e \right\} = 0,$$

where this equation is the same as in the section 6. We next simplify and substitute the coefficients $\alpha_1(\kappa)$, and $\alpha_2(\kappa)$:

$$\frac{dW_0^e}{d\tau_2^e} = \beta\lambda_2^e \left\{ (\varphi(\tau_2^e)r_2^e + \kappa R_1 Q_1)\frac{dK_1^e}{d\tau_2^e} + R_1(I_1^e + \kappa K_1^e)\frac{dQ_1^e}{d\tau_2^e} + \frac{B_1^e}{R_1}\frac{dR_1}{d\tau_2^e} + \alpha Y_2^e \right\} = 0,$$

from here we can solve for $\varphi(\tau_2^e)$, in doing so notice we are operating the differentials algebraically which is feasible as we're manipulating only first order differentials and in a total differentiation context (see Bartlett and Khurshudyan, 2019, for a discussion on this method).

$$\varphi(\tau_2^e) = -\frac{1}{r_2^e}\left\{ R_1(I_1^e + \kappa K_1^e)\frac{dQ_1^e}{dK_1^e} + \frac{B_1}{R_1}\frac{dR_1}{dK_1} + \kappa R_1 Q_1 \right\} - \frac{d\tau_2^e}{dK_1},$$

here, as a simplification, we assume the last term of the right-hand side of the equation to be zero, implying policies are not reacting strongly to the agents decisions on capital accumulation (but the reverse, agents react to the government policy strogly.

Finally, we replace $\varphi(\tau_2^e) = (1 - \alpha(1 - \tau_2^e))$, substitute the rates for the stochastic discount factors given their link through the households Euler equations, and solve for the policy tool which leads the second expression in (23):

$$\tau_2^{e,nash} = -\frac{1}{\alpha r_2^e}\left\{ \frac{1}{\Lambda_{1,2}^e}(I_1^e + \kappa K_1^e)\frac{dQ_1^e}{dK_1^e} + \Lambda_{1,2}^e B_1^e \frac{dR_1}{dK_1^e} + \frac{\kappa}{\Lambda_{1,2}^e}Q_1^e \right\} + 1 - \frac{1}{\alpha}, \quad \text{for } e = \{a, b\},$$

For the center we follow an analogous procedure, with the only difference that the taxes don't show up explicitely in the welfare effects (since they are not subject to an ICC). In that case we must use an additional first-order condition from the banks and replace the return on capital with the repayment rate to the banking sector: $R_{b,1}^e = R_{k,2}^c$; this is possible because in general equilibrium the credit spread at the Center is zero given in the small-scale version of the model it features no financial frictions.

$$\frac{dW_0^c}{d\tau_2^c} = \beta\lambda_2^c \left\{ ((1-\delta)Q_2 + r_2^c)\frac{dK_1^c}{d\tau_2^c} + R_1 I_1^c \frac{dQ_1^c}{d\tau_2^c} + \frac{B_1^c}{R_1}\frac{dR_1}{d\tau_2^c} + \frac{dR_{b,1}^e}{d\tau_2^c}F_1^{ab} + R_{b,1}^e \frac{dF_1^{ab}}{d\tau_2^c} \right\} = 0,$$

with $F_t^{ab} = F_t^a + F_t^b$.

We isolate $R_{b,1}^e$,

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

Next, we can replace $R^e_{b,1} = R^c_{k,2}(\tau^c_2) = \frac{(1-\tau^c_2)r^c_2+(1-\delta)Q^c_2}{Q_1}$, replace the gross rates for bonds for the stochastic discount factors as before, and then solve for the policy tool. After rearranging we obtain the first expression in (23):

$$\tau_2^{c,nash} = \frac{Q_1^c}{r_2^c}\left\{((1-\delta)Q_2^c + r_2^c)\frac{dK_1^c}{dF_1^{ab}} + \Lambda^c_{1,2}B^c_1\frac{dR_1}{dF_1^{ab}} + F_1^{ab}\frac{dR^e_{b,1}}{dF_1^{ab}} + \frac{I^c_1}{\Lambda^c_{1,2}}\frac{dQ^c_1}{dF_1^{ab}}\right\} + 1 + (1-\delta)\frac{Q^c_2}{r^c_2}$$

Notice that in each final step modified the super-index of the policy tool to denote this is also the optimal non-cooperative solution.

Optimal Taxes Under Cooperation. This section shows how to get the optimal Center tax under cooperation and the equation (25).

The procedure is analogous to the individual welfare case (non-cooperative), consisting of finding the welfare effect of setting τ^c_3 for the cooperative planner, i.e. $\frac{dW^{coop}}{d\tau^c_3}$, set it equal to zero and solve for the optimal policy $\tau^{c,coop}_3$. A crucial distinction here, is that the objective function of the planner is a weighted average of the national welfares and thus the welfare effect on this planner is an average of the national effects:

$$\frac{dW_0^{coop}}{d\tau_2^c} = n_a\frac{dW_0^a}{d\tau_2^c} + n_b\frac{dW_0^b}{d\tau_2^c} + (1-n_a-n_c)\frac{dW_0^c}{d\tau_2^c}$$

Now, given the perfect foresight assumption we consider as a simplification, the equilibrium allocation and welfare is symmetric between peripheries:

$$\frac{dW_0^{coop}}{d\tau_2^c} = (n_a+n_b)\frac{dW_0^a}{d\tau_2^c} + (1-n_a-n_c)\frac{dW_0^c}{d\tau_2^c}$$

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,

$$\frac{dW_0^{coop}}{d\tau_2^c} = \frac{1}{2}\frac{dW_0^e}{d\tau_2^c} + \frac{1}{2}\frac{dW_0^c}{d\tau_2^c},$$

where we use the index $e = \{a, b\}$ to denote the generic emerging economy (either). By substituting each of the individual welfare effects in the right hand side and equating to zero,

$$\beta\lambda_2^e\left\{(\varphi(\tau_2^e)r_2^e + \kappa R_1 Q_1^e)\frac{dK_1^e}{d\tau_2^c} + R_1(I_1^e + \kappa K_1^e)\frac{dQ_1^e}{d\tau_2^c} + \frac{B_1^e}{R_1}\frac{dR_1}{d\tau_2^c}\right\} +$$
$$\beta\lambda_2^c\left\{((1-\delta)Q_2 + r_2^c)\frac{dK_1^c}{d\tau_2^c} + R_1 I_1^c\frac{dQ_1^c}{d\tau_2^c} + \frac{B_1^c}{R_1}\frac{dR_1}{d\tau_2^c} + \frac{dR^e_{b,1}}{d\tau_2^c}F_1^{ab} + R^e_{b,1}\frac{dF_1^{ab}}{d\tau_2^c}\right\} = 0,$$

now we isolate the $R^c_{b,1}$ term,

$$-\lambda^c_2 R^e_{b,1}\frac{dF^{ab}_1}{d\tau^c_2} = \lambda^c_2\left((1-\delta)Q_2 + r^c_2\right)\frac{dK^c_1}{d\tau^c_2} + \lambda^c_2 R_1 I^c_1 \frac{dQ^c_1}{d\tau^c_2} + \lambda^e_2(\varphi\left(\tau^e_2\right) r^e_2 + \kappa R_1 Q^e_1)\frac{dK^e_1}{d\tau^c_2}$$
$$+\lambda^e_2 R_1\left(I^e_1 + \kappa K^e_1\right)\frac{dQ^e_1}{d\tau^c_2} + \lambda^c_2 F^{ab}_1\frac{dR^e_{b,1}}{d\tau^c_2} + \lambda^c_2\frac{B^c_1}{R_1}\frac{dR_1}{d\tau^c_2} + \lambda^e_2\frac{B^e_1}{R_1}\frac{dR_1}{d\tau^2_c},$$

Now, we can substitute $B^c_1 = -B^e_1$, multiply times $\frac{d\tau^c_2}{dF^{ab}_1}$, and multiply times $\frac{1}{\lambda^c_2}$, and isolate $R^e_{b,1}$,

$$-R^e_{b,1} = \left((1-\delta)Q_2 + r^c_2\right)\frac{dK^c_1}{dF^{ab}_1} + R_1 I^c_1\frac{dQ^c_1}{dF^{ab}_1} + \frac{\lambda^e_2}{\lambda^c_2}(\varphi\left(\tau^e_2\right) r^e_2 + \kappa R_1 Q^e_1)\frac{dK^e_1}{dF^{ab}_1}$$
$$+\frac{\lambda^e_2}{\lambda^c_2}R_1\left(I^e_1 + \kappa K^e_1\right)\frac{dQ^e_1}{dF^{ab}_1} + F^{ab}_1\frac{dR^e_{b,1}}{dF^{ab}_1} + \left(1 - \frac{\lambda^e_2}{\lambda^c_2}\right)\frac{1}{R_1}B^c_1\frac{dR_1}{dF^{ab}_1},$$

Now we substitute $R^e_{b,1} = R^c_{k,2}(\tau^c_2) = \frac{(1-\tau^c_2)r^c_2 + (1-\delta)Q^c_2}{Q_1}$ and solve for the policy tool,

$$\tau^{c,coop}_2 = \frac{Q_1}{r^c_2}\Bigg\{\left((1-\delta)Q_2 + r^c_2\right)\frac{dK^c_1}{dF^{ab}_1} + R_1 I^c_1\frac{dQ^c_1}{dF^{ab}_1} + \frac{\lambda^e_2}{\lambda^c_2}(\varphi\left(\tau^e_2\right) r^e_2 + \kappa R_1 Q^e_1)\frac{dK^e_1}{dF^{ab}_1}$$
$$+\frac{\lambda^e_2}{\lambda^c_2}R_1\left(I^e_1 + \kappa K^e_1\right)\frac{dQ^e_1}{dF^{ab}_1} + F^{ab}_1\frac{dR^e_{b,1}}{dF^{ab}_1} + \left(1 - \frac{\lambda^e_2}{\lambda^c_2}\right)\frac{1}{R_1}B^c_1\frac{dR_1}{dF^{ab}_1}\Bigg\} + 1 + (1-\delta)\frac{Q^c_2}{r^c_2},$$

Finallly, notice we can gather the terms corresponding to the exact expression for the individual optimal tax (non-cooperative) we derived before, and as in (23), yielding the first expression in (24),

$$\tau^{c,coop}_2 = \tau^{c,nash}_2 + \frac{Q_1}{r_2}\frac{\lambda^e_2}{\lambda^c_2}\Bigg\{\overbrace{\left(\varphi(\tau^e_2)r^e_2 + \frac{\kappa}{\Lambda^e_{1,2}}Q_1\right)\frac{dK^e_1}{dF^{ab}_1} + \frac{I^e_1 + \kappa K^e_1}{\Lambda^e_{1,2}}\frac{dQ^e_1}{dF^{ab}_1}}^{\text{substitution of Center capital accumulation for foreign intermediation (EMEs)}}\;\overbrace{-\Lambda^e_{1,2}B^c_1\frac{dR_1}{dF^{ab}_1}}^{\text{removal of NFA-value manipulation incentive}}\Bigg\}$$

An analogous procedure can be carried out with the welfare effects of the peripheral taxes under cooperation

$$\frac{dW^{coop}_0}{d\tau^c_2} = n_a\frac{dW^a_0}{d\tau^e_2} + n_b\frac{dW^b_0}{d\tau^e_2} + (1 - n_a - n_c)\frac{dW^c_0}{d\tau^e_2},$$

and as before, our assumptions and simplifications allow to rewrite this expression as:

$$\frac{dW^{coop}_0}{d\tau^e_2} = (n_a + n_b)\frac{dW^a_0}{d\tau^e_2} + (1 - n_a - n_c)\frac{dW^c_0}{d\tau^e_2} = \frac{1}{2}\frac{dW^e_0}{d\tau^e_2} + \frac{1}{2}\frac{dW^c_0}{d\tau^e_2}.$$

We replace the expressions and equate this to zero in order to look for the optimal policy,

$$\beta\lambda_2^e\left\{\left(\varphi\left(\tau_2^e\right)r_2^e+\kappa R_1 Q_1^e\right)\frac{dK_1^e}{d\tau_2^e}+R_1\left(I_1^e+\kappa K_1^e\right)\frac{dQ_1^e}{d\tau_2^e}+\frac{B_1^e}{R_1}\frac{dR_1}{d\tau_2^e}+\alpha Y_2^e\right\}+$$
$$\beta\lambda_2^c\left\{\left((1-\delta)Q_2+r_2^c\right)\frac{dK_1^c}{d\tau_2^e}+R_1 I_1^c\frac{dQ_1^c}{d\tau_2^e}+\frac{B_1^c}{R_1}\frac{dR_1}{d\tau_2^e}+\frac{dR_{b,1}^e}{d\tau_2^e}F_1^{ab}+R_{b,1}^e\frac{dF_1^{ab}}{d\tau_2^e}\right\}=0,$$

now we isolate the term with the policy variable ($\varphi(\tau_2^e)r_2^e$), multiply times $\frac{d\tau_2^e}{dK_1^e}$, replace $B_1^c=-B_1^e$ (as $B_1^a=B_1^b=B_1^e$, and $n_a=n_b=\frac{1}{4}$), remove the $\frac{d\tau_2^e}{dK_1^e}$ as it's assumed negligible, and rearrange,

$$-\varphi(\tau_2^e)=\frac{1}{r_2^e}\left\{R_1\left(I_1^e+\kappa K_1^e\right)\frac{dQ_1^e}{dK_1^e}+\frac{B_1^e}{R_1}\frac{dR_1}{dK_1^e}+\kappa R_1 Q_1^e\right\}+$$
$$\frac{1}{r_2^e}\frac{\lambda_2^c}{\lambda_2^e}\left\{R_1 I_1^c\frac{dQ_1^c}{dK_1^e}-\frac{B_1^e}{R_1}\frac{dR_1}{dK_1^e}+\left((1-\delta)Q_2+r_2^c\right)\frac{dK_1^c}{dK_1 e}+\frac{dR_{b,1}^e}{dK_1^e}F_1^{ab}+R_{b,1}^e\frac{dF_1^{ab}}{dK_1^e}\right\}=0,$$

Finally, we can replace $\varphi(\tau_2^e)=1-\alpha(1-\tau_2^e)$, replace the gross rates of the bonds for the stochastic discount factor given their link via the Euler equations, and rearrange to solve for the tool, which yields the expression shown in equation (24),

$$\tau_2^{e,coop}=\tau_2^{e,nash}-\underbrace{\frac{1}{\alpha_2}\frac{\lambda_2^c}{\lambda_2^e}\left\{\left[\frac{I_1^c}{\Lambda_{1,2}^c}\frac{dQ_1^c}{dK_1^e}+\eta\frac{dK_1^c}{dK_1^e}+F_1^{ab}\frac{dR_{b,1}^e}{dK_1^e}+R_{b,1}^e\frac{dF_1^{ab}}{dK_1^e}\right]-\left[\Lambda_{1,2}^c B_1^e\frac{dR_1^c}{dK_1^e}\right]\right\}}_{\text{Additional policy mechanisms for cooperative planners}},$$

where $\eta=((1-\delta)Q_2+r_2^c)$, and as before we included in the superindex of the solution "coop" to denote this is the optimal policy under cooperation.

Lastly, notice that the expressions in (25) are these same expressions but with the terms in brackets pooled into $\varphi_2^{j,NFA}$, $\psi_2^{j,eme}$, χ_2^c with $j=\{e,c\}$.

B Results from the Main Model

B.1 Effect of the macroprudential tool in the model

In the finite horizon version of this model with simple dynamics, I obtained that leverage is a function of the macroprudential instrument and that their relation is negative, i.e., an increase in the tax decreases the leverage ratio of banks. As a result, by implementing a tax, the planner would also enforce a leverage ratio in the banking sector, a commonly used prudential policy.

In the infinite horizon setup of this section, proving such result is less straightforward because the future effects of the policies show up 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, net worth, and two dynamic coefficients. Here I present the expressions for the emerging economies, but the same results hold for the advanced one that intermediates more types of assets. The value of the bank can be expressed as:

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

with,

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

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

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

$$\frac{Q^e_t K^e_t}{N^e_t} = \phi^e_t = \frac{\eta_t}{\kappa^e - \nu_t} \tag{26}$$

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 (26), it is difficult to pinpoint the actual change in leverage as the tax increases as in the simpler setup because the terms in the right hand side of the equations will depend on current and future values of the leverage themselves.

At the same time, notice that the effects on leverage occur only for values of κ^e that keep the ratio positive. This is the infinite horizon counterpart to the result indicating that the strenght of these effects grow with the financial friction.

B.2 Steady State of the Policy Models

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 steady state for the rest of the variables is obtained. A related question of utmost importance is: how to determine the instrument ($\bar{\boldsymbol{\tau}}$) for conditioning?.

For that, I 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: $\mathbf{x}$

2. replace $\mathbf{x}$ in the 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 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.3 Parameters of the Model

Table 6: Parameters used in the baseline 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

Summary of final model equations. To obtain a summarized version of the model equations I substitute the marginal product of capital, wages, tax rebates and the interest rates that are equalized due to the uncovered interest rate parity. The result is:

Table 7: Summary of private equilibrium equations of the baseline model

Common to all countries:	
$Q_t^i = 1 + \frac{\zeta}{2}\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)^2 + \zeta\left(\frac{I_t^i}{I_{t-1}^i} - 1\right)\frac{I_t^i}{I_{t-1}^i} - \Lambda_{t,t+1}^i \zeta \left(\frac{I_{t+1}^i}{I_t^i}\right)^2\left(\frac{I_{t+1}^i}{I_t^i} - 1\right)$	[Price of Capital]
$K_t^i = I_t^i + (1-\delta)\xi_t^i K_{t-1}^i$	[Capital Dynamics]
$R_{k,t}^i = \frac{(1-\tau_t^i)\alpha A_t^i H_t^{i\ (1-\alpha)} \xi_t^{i\alpha} K_{t-1}^{i\ (\alpha-1)} + (1-\delta)\xi_t^i Q_t^i}{Q_{t-1}^i}$	[Banks rate of return]
$R_t \Lambda_{t,t+1}^i = 1 + \eta\left(B_t^i\right)$	[Euler Equation, bonds]
$C_t^{i\ -\sigma} = \frac{H_t^{i\ \psi}}{(1-\alpha)A_t^i(\xi_t^i K_{t-1}^i)^\alpha H_t^{i\ (-\alpha)}}$	[Intra-temporal Euler Equation, labor]
$Y_t^i = A_t^i\left(\xi_t^i K_{t-1}^i\right)^\alpha H_t^{i\ 1-\alpha}$	[Output]
$\Lambda_{t,t+1}^i = \beta\left(\frac{C_{t+1}^i}{C_t^i}\right)^{-\sigma}$	[Stochastic Discount Factor]
$A_t^i = \rho_A A_{t-1}^i + \sigma_A \epsilon_{A,t}^i$	[Aggregate Productivity]
$\xi_t^i = \rho_\xi \xi_{t-1}^i + \sigma_\xi \epsilon_{k,t}^i$	[Capital Quality]
for EMEs:	
$Q_t^e K_t^e = N_t^e + F_t^e$	[Bal. sheet of banks]
$\mathbb{E}_t \Omega_{t+1\mid t}^i\left(R_{k,t+1}^i - R_{b,t}^i\right) = \mu_t^i \kappa^i$	[Credit Spread]
$j_t^e N_t^e = \kappa^e Q_t^e K_t^e$	[ICC]
$N_t^a = \theta\left[R_{k,t}^a Q_{t-1}^a K_{t-1}^a - R_{b,t-1}^a F_{t-1}^a\right] + \delta_B Q_t^a K_{t-1}^a \kappa$	[Net Worth Dynamics]
$j_t^e\left(1-\mu_t^e\right) = \mathbb{E}_t\left[\Omega_{t+1\mid t}^e R_{b,t}^e\right]$	[Envelope Condition for Net Worth]
$C_t^e + B_t^e + \frac{\eta}{2}\left(B_t^e\right)^2 = R_{t-1}B_{t-1}^e + (1-\alpha)A_t^e(\xi_t^e K_{t-1}^e)^\alpha H_t^{e\ (1-\alpha)} + \Pi_t^a$	[Budget Constraint, households]
for the Center:	
$Q_t^c K_t^c + F_t^a + F_t^b = N_t^c + D_t^c$	[Bal. sheet of banks]
$\mathbb{E}_t \Omega_{t+1\mid t}^c\left(R_{k,t+1}^c - R_{D,t}^c\right) = \mu_t^c \kappa^c$	[Credit Spread for Local Intermediation]
$\mathbb{E}_t \Omega_{t+1\mid t}^c\left(R_{b,t}^a - R_{D,t}^c\right) = \mu_t^c \kappa_{F_a}^c$	[Spread for Foreign Lending to EME-A]
$\mathbb{E}_t \Omega_{t+1\mid t}^c\left(R_{b,t}^b - R_{D,t}^c\right) = \mu_t^c \kappa_{F_b}^c$	[Spread for Foreign Lending to EME-B]
$j_t^c N_t^c = \kappa^c Q_t^c K_t^c + \kappa_{F_a}^c F_t^a + \kappa_{F_b}^c F_t^b$	[ICC]
$N_t^c = \theta\left[R_{k,t}^c Q_{t-1}^c K_{t-1}^c + R_{b,t-1}^a F_{t-1}^a + R_{b,t-1}^b F_{t-1}^b - R_{D,t-1}^c D_{t-1}^c\right] + \delta_B Q_t^c K_{t-1}^c$	[Net Worth Dynamics]
$j_t^c\left(1-\mu_t^c\right) = \mathbb{E}_t\left[\Omega_{t+1\mid t}^c R_{D,t}^c\right]$	[Envelope Condition for Net Worth]
$C_t^c + B_t^c + \frac{\eta}{2}\left(B_t^c\right)^2 + D_t^c + \frac{\eta}{2}\left(D_t^c - \bar{D}^c\right)^2 = R_{t-1}^c B_{t-1}^c + R_{D,t-1}^c D_{t-1}^c + w_t^c H_t^c + \Pi_t^c$	[Budget Constraint, households]
$R_{D,t}^c \Lambda_{t+1}^c = 1$	[Euler Equation, deposits]
International Links:	
$n_a B_t^a + n_b B_t^b + n_c B_t^c = 0$	[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 I use the following auxiliary definitions:

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

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

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

B.4 Welfare Accounting Supplementary Exercises

Table 8: Welfare cost in consumption equivalent compensation relative to no cooperation

	Consumption Equivalent Compensation		
	Cooperation (Center+EME-A)	Cooperation (EMEs)	Cooperation (All)
C	16.5	-1.7	8.8
A	24.7	-9.8	21.2
B	-10.9	-9.8	21.2
World	**12.0**	**-5.7**	**14.7**
EMEs	6.9	-9.8	21.4

Notes: Compensation using the Nash (no cooperation) as benchmark. The numbers in bold denote the departure from the benchmark, in terms of equivalent consumption variation.
In Cooperation symmetry between instruments rules is assumed for EMEs

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	-10.8	2.9	-12.1	-3.8	-93.9
A	-17.5	-0.4	-23.7	-2.3	-97.6
B	-17.5	-24.3	-23.7	-2.3	-97.6
World	**-14.2**	**-5.3**	**-18.1**	**-3.0**	**-96.1**
EMEs	-17.5	-12.8	-23.7	-2.3	-97.6

Notes: Compensation using the First Best as benchmark.
In Cooperation symmetry between instruments rules is assumed for EMEs

On Time Consistency. As part of the auxiliary exercises I 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 (see table 10). 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 I compute under the time consistent framework (timeless perspective). With this, I confirm the conveniency of working with the timeless perspective approximation for the main simulations of this study.

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	-4975.8	-4961.6	-4977.4	-4968.3	-5243.6
W^a	-5036.2	-5016.6	-5044.0	-5019.4	-5388.6
W^b	-5036.2	-5044.9	-5044.0	-5019.4	-5388.6
W	-5006.0	-4996.2	-5010.7	-4993.8	-5316.1
W^{ab}	-5036.2	-5030.7	-5044.0	-5019.4	-5388.6
Consumption Equivalent Compensation					
C	-11.7	2.9	-13.2	3.9	-286.1
A	-19.5	0.4	-27.4	-2.4	-377.5
B	-19.5	-28.3	-27.4	-2.4	-377.5
World	**-15.6**	**-5.5**	**-20.4**	**-3.2**	**-332.2**
EMEs	-19.5	-13.9	-27.4	-2.4	-377.1

Notes: Compensation using the First Best as benchmark.
In Cooperation symmetry between instruments rules is assumed for EMEs