Strategic Macro-prudential Policy Setting in Emerging Economies: The Role of Coordination in International Markets*

[Draft]

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Abstract

In order to understand the strategic interactions between financial regulators in open emerging economies we set a multicountry general equilibrium model with multiple peripheries, a long-lived banking sector and dynamic macro-prudential policies. This framework allows us to perform a welfare accounting exercise that accounts for the totality of policy effects over time and to rank a variety of policy frameworks that differ by their degree of international policy coordination. We obtain that not every type of policy coordination would generate welfare gains with respect to inward looking policies. Instead, only schemes where the financial center of reference is cooperative will generate gains, impliying that emerging countries coalitions can be counterproductive. Furthermore, we show that in relation to lower ranked models, the best performing policy frameworks implement a countercyclical macroprudential policy, while at the same time the policies can comove with the cycle in some scenarios, a result that helps reconcile literature debates on the cyclicality of optimal macroprudential tools. Finally, we study the dynamic path of the optimal financial instruments and describe the features characterizing cooperative policy settings.

JEL Codes: F38, F42, E44, G18

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1. Introduction

The emerging economies fragility to the global financial cycle is a core concern in international finance in recent times (Rey, 2013). Moreover, the financial resilience of these economies has gained even more importance after the global financial crisis as a larger fraction of the international capital flows has shifted in their direction McQuade and Schmitz (2017) which has been translated into a more frequent and intensive usage of these policies in the emerging economies (Alam et al., 2019). With that in mind, we study whether the international macroprudential policy cooperation is beneficial for these economies and can be used to improve their macroeconomic performance and financial resilience. We formulate two specific questions: (i) is macroprudential cooperation beneficial for these economies in general?, and (ii) are cooperative policies useful in protecting these economies from external shocks?.

Related Literature. TBA

2. Simple three-period model

Before analyzing the main dynamic model of this paper, we will lay out a simplified setup in finite horizon for building intuition about the main mechanisms at work. In that spirit, we will consider the simplest possible model that still features a dynamic decision making by banks and macroprudential regulators.[1] This model shares the essential features of the main one, and can be thought as a small scale version of the latter, with the advantage of allowing to analytically disentangle the welfare effects of forward looking policies, from the static ones. Clearly, there is a trade-off between the improved tractability, and the potential uses of a more quantitatively involved model, e.g., the smaller scale model would not allow for a complete study of the response of the economy to shocks, or a comprehensive welfare accounting comparison between models. We will leave such additional applications for subsequent sections of the paper based on the larger-scale, quantitative model.

On the other hand, when a sector is completely analogous to that of the main model explained in section 3 we will review it more briefly, and instead will focus more in the

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

sectors with more meaningful differences, the banks and the households.

2.1. Setup

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

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

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

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

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

Additionally, notice that with the homogeneous good assumption, and the identical preferences at the world level, we have that the law of one price and parity of purchasing power will hold. Consequently, we can abstract from the real exchange rate.

Finally, for this simple model we will work with a perfect foresight assumption.

2.2. Banks

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

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

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

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

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

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

The present value of the bank, will be given by the expected profits in the next period. For this, we include the posibility of exit from the banking business, with an associated probability of survival θ. [2] In that sense, with probability $(1-\theta)$ the bank will fail and report back its profits to the household, and with probability θ the bank will be able to continue its business and pursue future profits.

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

Finally, the incentive compatibility constraint, ICC, reflects the imposition that the value of the franchise has to equal or larger than the value the bank could divert after defaulting its creditors which is given by a fraction κ of the intermediated assets.[3] For simplicity, this divertable fraction will be constant across locations and time.

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

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

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

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

Where μ_t is the lagrange multiplier of the ICC in each period and $\Omega_1 = (1-\theta)\Lambda_{1,2} + \theta^2 R_{k,3}\Lambda_{1,3}$

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

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

With these results we can state an initial result:

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

Proof: See appendix A. ■

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

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

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

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

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

This problem will be dynamic, as it accounts for the potential profits and balance sheets of every intermediation period.

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

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

$$s.t$$

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

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

2.3. Production sectors

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

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

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

2.4. Macroprudential policy

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

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

With such structure, the following proposition holds:

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

Proof: See appendix A. ■

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

2.5. Households

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

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

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

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

$$s.t.$$

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

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

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

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

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

$$s.t.$$

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

$$C_2^c + \frac{B_2^c}{R_2^c} + D_2 = \pi_{f,2}^c + \pi_{inv}^c + \pi_{bank,2}^c - \delta_B Q_2^c K_1^c + B_2^c + R_{D,1} D_1 - T_2^c, \quad for$$

$$C_3^c = \pi_{f,3}^c + \pi_{bank,3}^c + B_2^c + R_{D,2} D_2 - T_3^c$$

2.6. Equilibrium

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

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

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

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

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

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

2.7. Welfare Effects of Policy

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

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

Table 1: Welfare effects in the 3-period model

		Change in tax				
		1%	**3%**	**5%**	**8%**	**10%**
Direct effect of τ_2	$\tau_2^a \rightarrow W^a$	0.1458	0.1437	0.1416	0.1382	0.1357
	$\tau_2^b \rightarrow W^b$	0.1458	0.1437	0.1416	0.1382	0.1357
	$\tau_2^c \rightarrow W^c$	-0.2421	-0.457	-0.1786	-0.0268	0.0211
Cross-border effect	$\tau_2^a \rightarrow W^b$	-0.0465	-0.0468	-0.0471	-0.0475	-0.0478
	$\tau_2^a \rightarrow W^c$	-0.0163	-0.0166	-0.0168	-0.0172	-0.0175
	$\tau_2^b \rightarrow W^a$	-0.0465	-0.0468	-0.0471	-0.0475	-0.0478
	$\tau_2^b \rightarrow W^c$	-0.0163	-0.0166	-0.0168	-0.0172	-0.0175
	$\tau_2^c \rightarrow W^a$	-0.162	-0.2257	-0.1803	-0.1548	-0.1446
	$\tau_2^c \rightarrow W^b$	-0.162	-0.2257	-0.1803	-0.1548	-0.1446
Direct effect of τ_3	$\tau_3^a \rightarrow W^a$	0.0573	0.0568	0.0564	0.0558	0.0554
	$\tau_3^b \rightarrow W^b$	5.73E-02	5.68E-02	5.64E-02	5.58E-02	5.54E-02
	$\tau_3^c \rightarrow W^c$	-0.0871	-0.1218	-0.243	-0.1341	-0.0809
Cross-border effect	$\tau_3^a \rightarrow W^b$	-0.0175	-0.0178	-0.0181	-0.0184	-0.0187
	$\tau_3^a \rightarrow W^c$	0.006	0.0049	0.0039	0.0025	0.0016
	$\tau_3^b \rightarrow W^a$	-0.0175	-0.0178	-0.0181	-0.0184	-0.0187
	$\tau_3^b \rightarrow W^c$	0.006	0.0049	0.0039	0.0025	0.0016
	$\tau_3^c \rightarrow W^a$	-5.05E-02	-5.87E-02	-8.73E-02	-7.41E-02	-6.62E-02
	$\tau_3^c \rightarrow W^b$	-0.0505	-0.0587	-0.0873	-0.0741	-0.0662

Note: the column denotes the size of the change applied in the taxes. The effect is obtained by the numerical approximation to the derivative of welfare with respect to a change in the tax ($\frac{\Delta W}{\Delta \tau}$)

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

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

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

Analytical Welfare Effects In order to understand the mechanisms that generate these spillovers we set a Social Planner Problem and obtain the welfare effects, following the methodology of Davis and Devereux (2019). What we do is to set the welfare equations and simplify them using the private equilibrium conditions. Then, we calculate the welfare effects with implicit differentiation.

A social planner will consider the following simplified welfare expressions.

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

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

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

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

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

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

The welfare effects of the taxes are:

For the EMEs:

$$
\begin{aligned}
\frac{dW^a}{d\tau_2^a} = \beta\lambda_2^a\left(\kappa R_1 Q_1^a + \varphi\left(\tau_2^a\right) r_2^a\right)\frac{dK_1^a}{d\tau_2^a} + \lambda_1^a\left(I_1^a + \kappa K_1^a\right)\frac{dQ_1^a}{d\tau_2^a} + \beta\lambda_2^a \frac{B_1^a}{R_1}\frac{dR_1}{d\tau_2^a} + \beta\lambda_2 \alpha Y_2^a \quad & \text{static effects} \\
+\beta\lambda_2^a\left(\kappa\left(1-\theta\Lambda_{23}\right)Q_2^a + \varphi\left(\tau_3^a\right)\Lambda_{12} r_3^a\right)\frac{dK_2^a}{d\tau_2^a} + \beta\lambda_2^a\left(I_2^a + \kappa\left(1-\theta\Lambda_{23}\right)K_2^a\right)\frac{dQ_2^a}{d\tau_2^a} \quad & \text{dynamic effects} \\
+\beta^2\lambda_3^a \frac{B_2^a}{R_2}\frac{dR_2}{d\tau_2^a} + \beta^2\lambda_3^a \alpha Y_3^a &
\end{aligned}
$$

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

and for the Center:

$$
\begin{aligned}
\frac{dW^c}{d\tau_2^c} = {} & \beta\lambda_2^c\left(\left(1-\alpha\theta\left(1-\tau_2^c\right)\right)r_2^c + (1-\theta)(1-\delta)Q_2^c\right)\frac{dK_1^c}{d\tau_2^c} + \beta\lambda_2^c\left(\tfrac{B_1^c}{R_1} - \theta D_1\right)\frac{dR_1}{d\tau_2^c} \\
& + \lambda_1^c K_1^c \frac{dQ_1^c}{d\tau_2^c} + \beta\lambda_2^c\alpha\theta Y_2^c + \beta\lambda_2^c(1-\theta)\left(\frac{dR_{b1}^{eme}}{d\tau_2^c}\left(F_1^a + F_1^b\right) + R_{b1}^{eme}\left(\frac{dF_1^a}{d\tau_2^c} + \tfrac{dF_1^b}{d\tau_2^c}\right)\right) \qquad \text{static effects} \\
& + \beta^2\lambda_3^c\left(r_3^c + (1-\delta)Q_3\right)\frac{dK_2^c}{d\tau_2^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_2^c} + \beta\lambda_2^c\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{d\tau_2^c} \\
& + \beta^2\lambda_3^c\left(\frac{dR_{b2}^{eme}}{d\tau_2^c}\left(F_2^a + F_2^b\right) + R_{b2}^{eme}\left(\frac{dF_2^a}{d\tau_2^c} + \frac{dF_2^b}{d\tau_2^c}\right)\right) \qquad \text{dynamic effects}
\end{aligned}
$$

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

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

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

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

It is also important to mention that the negative effects are reflective of the potentially negative growth consequences of setting these taxes as they are akin to putting sand in the wheels of the financial sector. That is what some literature refers to when pointing out the tentative immiserizing growth effects of these tools[4]. Of course, the policy trade-off here is that mitigating the friction may be well worth such cost.

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

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

There are two relevant features of both types of taxes (forward-looking or static), first, the peripheral taxes will grow in scale with the financial distortion and second, the center depicts a substitution effect motive between local and foreign intermediation that will push the tax down to favor local intermediation when the foreign lending grows ($\frac{\partial F_t^{eme}}{\partial K_1^c}$ terms). This latter effect helps to understand how the optimal tax setting of the Center differs from the periphery, given its role of international creditor. This particular feature will be important when understanding the importance of the Center in generating gains from the international coordination of policies in the main model of the section 3.

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

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

accumulation in the economy that is setting the tax.

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

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

With these new welfare expressions we can find the associated optimal cooperative taxes in an analogous fashion.

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

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

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

3. The Main Model

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

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

The agents will have access to an international bonds market where they can trade non-contingent bonds. Making this a model of incomplete markets.

In order to facilitate focusing on the main interactions between multiple countries an policy planners, we simplify a number of features of the model, while retaining the key characteristics we deem necessary for analyzing the open economy model with banking.

The main simplification we apply is that we limit the number of commodities and set the model in real terms, i.e., there is a single consumption good in the world, freely traded. Also, the preferences are identical between agents in each country and the law of one price holds. Thus, the purchasing power parity holds and the real exchange rate is one. In addition, the uncovered interest rate parity holds.

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

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

This has consequences in other sectors that will be visible in the budget constraint and menu of choice variables of the households as well as in the sources of capital (or funds to rent capital) for the firms.

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

Households

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

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

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 bond, D_t^i: domestic deposits, $W_t^i H_t^i$: labor income, Π_t^i : profits from banks and capital firms net of lump-sum taxes.

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

Only one good is produced worldwide and C^i is the corresponding consumption of it by the home household in the emerging country i.

Since only one good is produced, 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, for every economy the consumption baskets are expressed in terms of the same good and no departure from the law of one price is assumed, meaning that the relative prices across countries and real exchange rate are abstracted from.

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

$$\begin{aligned}
\mathbb{E}_t \left[R_t \Lambda_{t+1}^c \right] &= 1 + \eta(B_t^c) \\
\mathbb{E}_t \left[R_{D,t}^c \Lambda_{t+1}^c \right] &= 1 \\
C_t^{c\ -\sigma} &= \frac{H_t^{c\ \psi}}{(1-\alpha) A_t^c \xi_t^{c\ \alpha} K_{t-1}^{c\ (\alpha)} H_t^{c\ (-\alpha)}}
\end{aligned}$$

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

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

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

$$\mathbb{E}_t\left[R_t\Lambda_{t+1}^a\right] = 1 + \eta(B_t^a)$$
$$C_t^{a\ -\sigma} = \frac{H_t^{a\ \psi}}{(1-\alpha)A_t^a\xi_t^{a\ \alpha}K_{t-1}^{a\ (\alpha)}H_t^{i\ (-\alpha)}}$$

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

Final goods firms

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

$$Y_t^i = A_t^i\left(\xi_t^iK_{t-1}^i\right)^\alpha H_t^{i(1-\alpha)} \tag{3}$$

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

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

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

$$\max_{K_{t-1},H_t} \Pi_t^{i,prod} = Y_t + (1-\delta)\xi_tQ_tK_{t-1} - W_tH_t - \tilde{R}_{k,t}Q_{t-1}$$

$$\text{s.t.} \quad (3)$$

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

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

As we will see when describing the banking sector, the capital is funded by selling company securities to domestic banks in a one to one relationship, i.e., $Z_t^i = K_t^i$, where Z_t^i is the stock of securities from the representative 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.[5]

Capital goods firms

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

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

The capital dynamics will be given by:[6]

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

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

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

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

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

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

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

$$Q^i_t = 1 + \frac{\zeta}{2} \left(\frac{I^i_t}{I^i_{t-1}} - 1 \right)^2 + \zeta \left(\frac{I^i_t}{I^i_{t-1}} - 1 \right) \frac{I^i_t}{I^i_{t-1}} - \mathbb{E}_t \left[\Lambda^i_{t+1} \zeta \left(\frac{I^i_{t+1}}{I^i_t} \right)^2 \left(\frac{I^i_{t+1}}{I^i_t} - 1 \right) \right] \tag{5}$$

Banking sector

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

We consider a setup with entry and exit for banks. This prevents the banks from engaging in self-funding schemes that prevent the constraints that arise from the agency frictions to bind. The rate of exit of banks is given by $1 - \theta$. At the same time, the banks entering each period will receive a start-up capital from their household owners. Such capital will be proportional to the scale of the banking assets the preceding period. Each period the bank will re-invest its proceeds back in its business. However, when the bank fails and exit the market, it will give back its net worth in the form of profits to the owners.

In each case, we consider an incentive compatibility constraint (ICC) that will reflect the agency problem in the lending relationships of the bank. We will assume these constraints are binding.

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

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

EME Banks:

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

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

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

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

The aggregate net worth of the banking system is:

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

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

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

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

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

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

with τ^e_t representing a tax/subsidy.

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

The problem of the j banker is to maximize the value of the bank:[7]

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

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

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

This ICC condition states that the continuation value of the bank is larger than the potential profit of defaulting.[8]

The bank problem yields the following optimality conditions:

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

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

and envelope condition:

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

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

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

[8]There are several feasible choices for the right hand side term depending on the timing of the assets absconding. Here we assume they compare the value of the bank to absconding before the intermediated assets yield returns.

intermediated and proceeds from being a global creditor.

The balance sheet of the global country bank j is:

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

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

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

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

The bank j value function is:

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

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

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

with $\kappa^c_{F_i}, \kappa^c > 0$, i.e., the pledgeable fraction can be asymmetric across assets.

The optimality Conditions are:

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

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

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

and the envelope condition,

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

3.1. Macroprudential Policy

The policy tool considered is a tax on the return to capital. This is a general enough instrument that encompasses several variaties of macroprudential instruments.

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

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

The welfare objective of each policy maker is given by: W^i_0 as in (1).

In addition, each social planner could consider whether to coordinate or not with the planners of other economies. Clearly, its choice depends on which arrangement implies larger welfare gains for its economy.

Effect of the macroprudential tool in the model. In the finite horizon version of this model, with static banks and one shot policy (Granados (2020)) we obtained that leverage is a function of the macroprudential and that their relation is negative. That is, an increase in the tax will decrease the leverage ratio of banks. The implication of this is that, by implementing a given tax, the bank will also be enforcing a leverage ratio in the banking sector. This result is meaningful as it shows that the tool we analyze in this study encompasses a commonly used macroprudential tool.

In the dynamic framework used in this paper, it is not possible to prove such result in such a straightforward way. Particularly, because of the presence of continuation effects of policy in the net worth and lending, both, new features of this setup, relative to the static version.

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

$$J_{jt}^e = \nu_t Q_t^e K_{jt}^e + \eta_t N_{jt}^e$$

with,

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

Where $x_{t,t+i} = Q_{t+i}^e K_{j,t+i}^e / Q_t^e K_{j,t}^e$ and $z_{t,t+i} = N_{j,t+i}^e / N_{j,t}^e$

We now substitue J_{jt}^e from (8) when it binds and obtain the leverage as ϕ_t^e:

$$\frac{Q_t^e K_t^e}{N_t^e} = \phi_t^e = \frac{\eta_t}{\kappa^e - \nu_t} \tag{17}$$

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

It also follows that $z_{t,t+1} = [(R_{k,t+1}^e - R_{b,t})\phi_t^e + R_{b,t}^e]$ and $x_{t,t+1} = (\phi_{t+1}^e/\phi_t^e)z_{t,t+1}$.

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

3.2. Market Clearly Conditions

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

$$\text{Goods market:} \qquad \sum_i n_i Y_t^i = \sum_i n_i \left(C_t^i + I_t^i \left(1 + \frac{\zeta}{2} \left(\frac{I_t^i}{I_{t-1}^i} - 1 \right)^2 \right) + \frac{\eta}{2}(B_t^i)^2 + \frac{\eta}{2}(D_t^i - \bar{D}^i)^2 \right)$$

$$\text{Bonds market:} \qquad \sum_i n_i B_t^i = 0, \qquad \forall t$$

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

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

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

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

4. Ramsey Policy Problem

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

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

Table 2: Policy Cases Considered

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

Note: $j = a, b, c$

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

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

4.1. Planning problems

In every case we will consider the planning problem under commitment with a timeless perspective. [9] As explained by King and Wolman (1999) this implies we are assuming the policy makers were making optimal decisions in the past in a time consistent matter. This

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

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

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

$$\hat{W}_{coop,0} = \max_{\mathbf{x}_t, \boldsymbol{\tau}_t} [n_a \hat{W}_0^a + n_b \hat{W}_0^b + (1 - n_a - n_b)\hat{W}_0^c] \tag{18}$$

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

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

where $\mathbf{x}_t$ is the vector of endogenous variables, $\boldsymbol{\tau}_t = (\tau_t^a, \tau_t^b, \tau_t^c)'$ is the vector of instruments and φ_t is a vector of exogenous variables and shocks.

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

$$\hat{W}_{coop(C+A),0} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^c} [n_a \hat{W}_0^a + n_c \hat{W}_0^c] \tag{19}$$

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

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

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

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

$$\hat{W}_{coopEME,0} = \max_{\mathbf{x}_t, \tau_t^a, \tau_t^b} [n_a \hat{W}_0^a + n_b \hat{W}_0^b] \tag{20}$$

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

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

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

$$\hat{W}^{j}_{nash,0} = \max_{\mathbf{x}_t, \tau^j_t} \hat{W}^{j}_{0} \tag{21}$$

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

4.2. Gains from cooperation

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

$$Gain_{Coop/Nash} \equiv \hat{W}_{coop,0} - (n_a \hat{W}^{a}_{nash,0} + n_b \hat{W}^{b}_{nash,0} + (1 - n_a - n_b)\hat{W}^{c}_{nash,0})$$

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

$$\hat{W}_{coop,0}(\lambda) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{((1+\lambda)C_t)^{i(1-\sigma)}}{1-\sigma} - \frac{H_t^{i(1+\psi)}}{1+\psi} \right) = n_a \hat{W}^{a}_{nash,0} + n_b \hat{W}^{b}_{nash,0} + (1-n_a-n_b)\hat{W}^{c}_{nash,0}$$

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

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

5. Results

In this section, we discuss the solution of the main model under different policy schemes and how it helps us answer our two research questions, namely, (1) is international cooperation of macroprudential policies convenient for emerging economies in general, and (2) are cooperative policies useful in shielding the peripheric economies from external shocks and the global financial cycle.

For (1) we will compare the expected long run welfare that the policy frameworks in table 2 deliver. By construction, this will be a comparison of the long-run performance of the models. On the other hand, for (2) we will analyze how each policy setup fares when facing negative shocks that originate at the Center.

In terms of the solution, we will use the parametrization shown in table 8. In most cases we will borrow standard parameters from the literature that have the usual targets (e.g., discount factor and depreciation rate). However, there are other parameters that are chosen with the macroprudential litetarure on emerging markets in mind. This is particularly true for the divertable fraction of capital which we adopt from Aoki et al. (2018). In our case, nevertheless, we do care about the large open economy dimension of these policies, that will be reflected in the country sizes, which are set at 0.25 for each periphery.

Table 3: Steady State values for the policy tools

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

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

5.1. Welfare accounting comparison

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

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

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

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

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

[10] 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 **??** in the appendix D

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

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

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

Sources of Welfare Gains From Cooperation For identifying the origins and mechanishms that generate the welfare gains, we can resort to the analytical expression for the optimal tax in the Center under cooperation. Even if more complex, the structure of the taxes in the more comprehensive, but untractable model used to compute the table 4 would be similar.

What we find, after a number of simplifying steps, including the perfect foresight assumption of the previous section, is that the optimal tax in the financial center has the following form:

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

This equation is obtained in the appendix A, and $\tau_3^{c,nash}$ corresponds, exactly, to the optimal tax for the Center in the equation 23.

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

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

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

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

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

This mechanism is also present in the literature on cooperative capital controls, such as Davis and Devereux (2019) who describe this effect as the absence of terms of trade manipulation motives by cooperative planners.

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

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

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

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

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

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

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

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

Table 5: Correlations between the output and the macroprudential in each policy framework

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

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

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

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

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

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

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

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

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

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

On Time Consistency. As part of our exercises. We also solved a time variant version of this model to explore whether time consistency is relevant in this environment from a welfare perspective. We obtain potentially interesting results. On one hand, it is more difficult to solve the models, something relatively expected as a well known property of time inconsistent models is the presence of underterminacy and sunspot 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, overriding undeterminacy and non fundamental driven solutions. This may be relevant as the non-fundamental equilibria tend to be welfare decreasing.

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

5.2. Short Run and Cyclical Performance of the Policy Setups

This model also allows us to verify the short-run dynamics and optimal policy paths in presence of real and financial shocks originating at the Center. With that, we can answer the second question of this study, also stated at the beginning of this section: Are cooperative policies useful in protecting the emerging economies from external shocks?.

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

Financial shock. In the figure 1 we show the dynamic response in the real variables of these economies after a negative financial shock at the Center. We find that, indeed, the global cooperation model protects better the output dynamics of the emerging economies, with the semi-cooperative model where the Center cooperates with a periphery (Coop(A+C)) coming in second place, although in the latter case, as expected, the expansionary effect is concentrated in the periphery that form a policy coalition with the Center. On the other hand, the dynamics of the regional cooperation case (CoopEMEs) and the Nash are virtually the same, meaning they will not get any extra resilience from engaging in peripheral cooperation.

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

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

Noticeably, even with a better output response, the emerging consumption is hit the most under cooperation (second row panel in the figure). This occurs because the cooperative planners prioritize boosting the investment and intermediation to support the economic activity in these economies. This is reflective of the stronger institutional effort towards aiding the global welfare recovery, even if the shock is not domestic. Finally, the labor supply dynamics will be a by-product of the consumption and capital fluctuations. The former decreases at first, increasing the marginal utility of consumption, while the latter increases, pushing upwards the salaries. As a result, the hours supply increases significantly under cooperation. [11]

The financial variables tell a similar story. We show these in the the figure 2. Consistently with the evolution of capital, we obtain that the lending is boosted more strongly under cooperation, but in constrast, for every economy. The latter point is crucial, the Center is not accumulating more capital locally for production, however, increases its leanding to expand its banking sector international intermediation activities.

Additionally, we see a more persistent net-worth build-up in the peripheries under cooperative schemes.

On the other hand, the credit spread dynamics reflect a substantial effort to push up the interest rates in the hit country by cooperative planners (Center, third column panel, third row), whereas for the emerging ones, we see the opposite, indicating that the optimal stance under cooperation consists in compensating the effect of the shock (that would push the spread upwards in the peripheries) very fast and actively.

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

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

recovery.

Optimal taxes dynamics The policy response of the planners will be countercyclical on impact for all policy regimes (see fourth row panel in figure 2). That is, the peripheric planners will increase the taxes while planner at the Center will subsidize the banking sector. However, there are meaningful differences across regimes that explain the discrepancies between the cooperative and non-cooperative outcomes. First, the taxes will be smoother under cooperation and in particular during the first five to ten quarters after the shock. This reflects the comparative advantage of a coordinated policy scheme in avoiding unnecessary instrument fluctuations.

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

Figure 1: Response to a negative financial shock at the Center economy

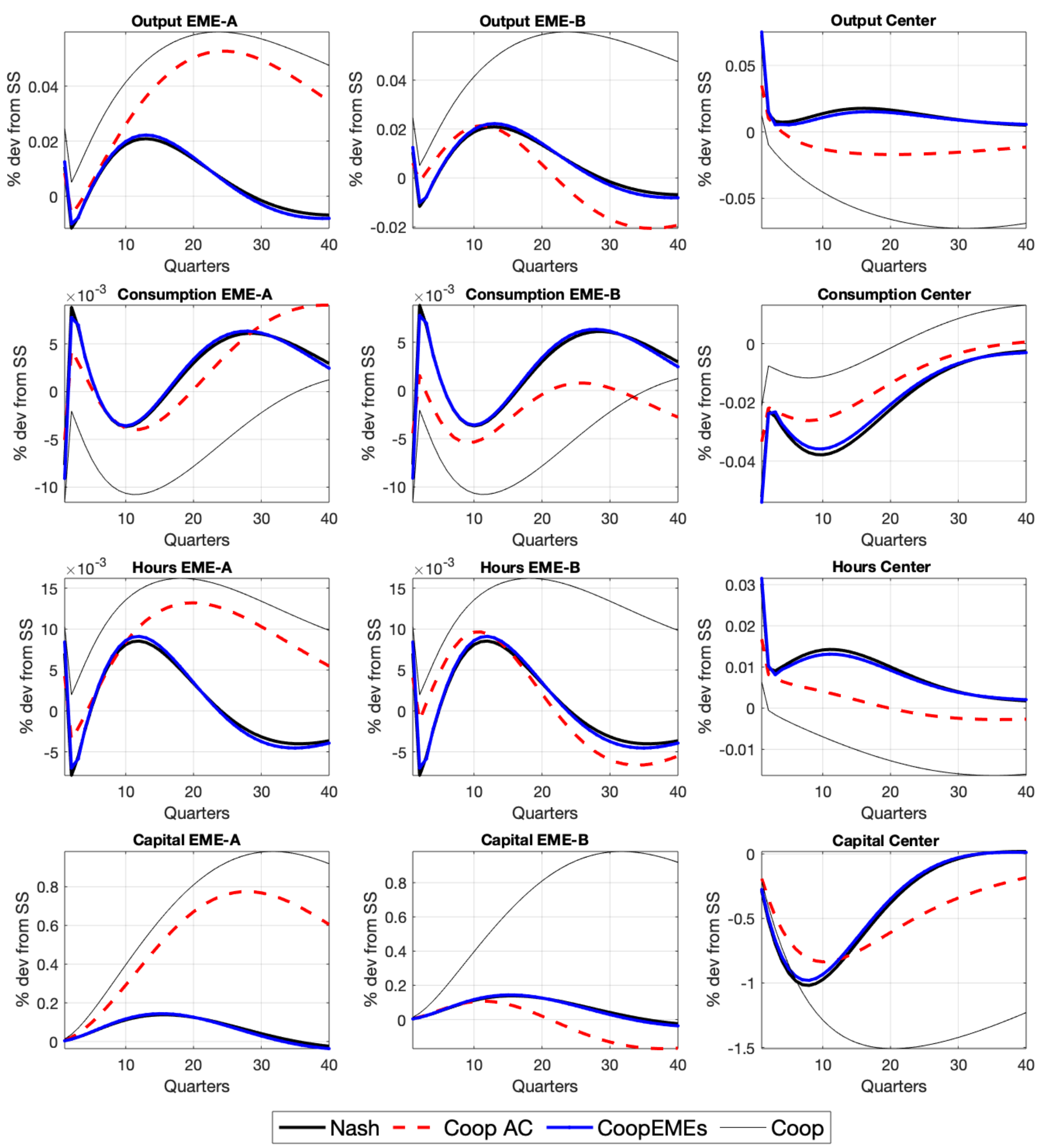
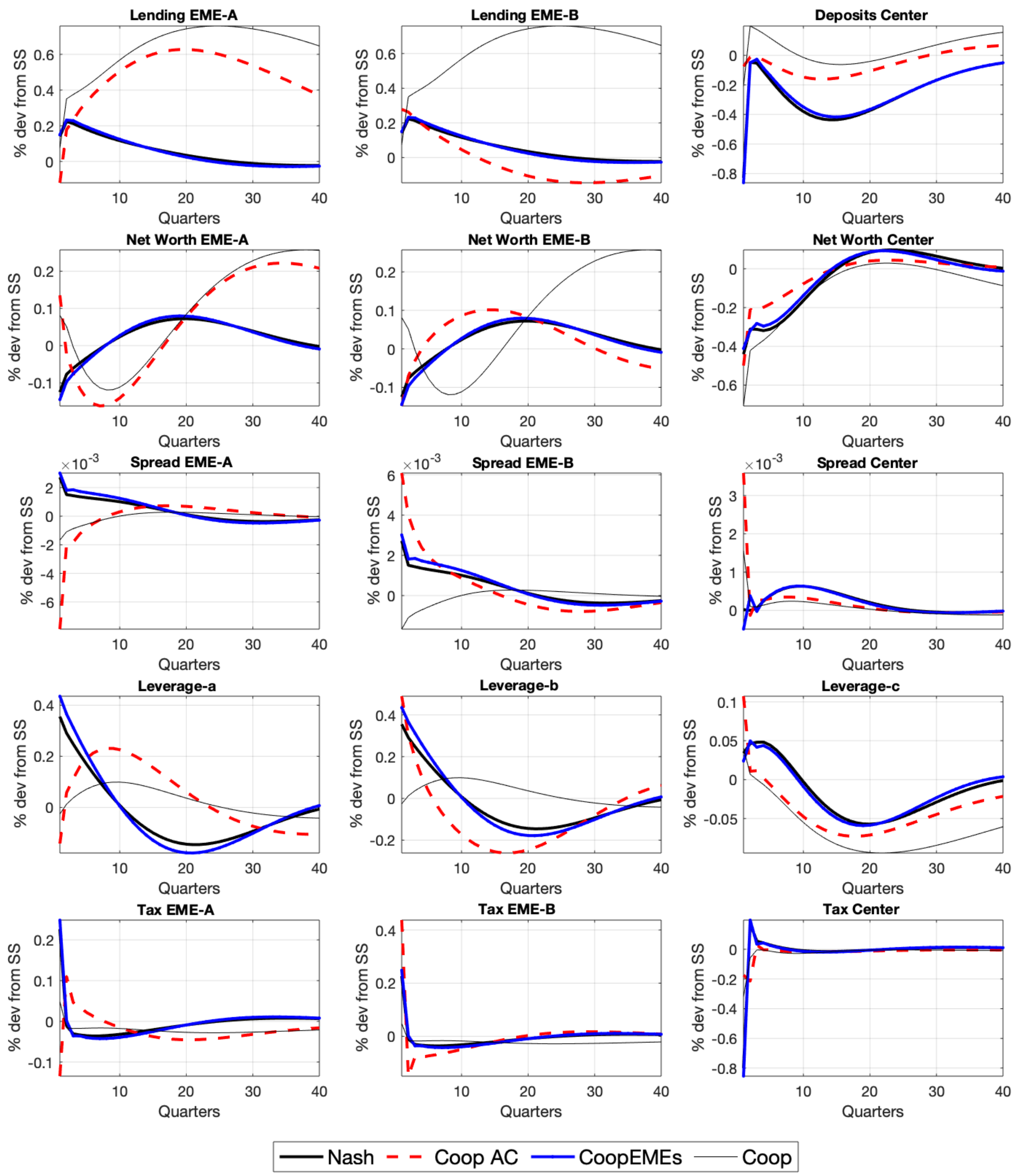


Figure 2: Response to a negative financial shock at the Center economy - Financial Variables and tools



Real Shock. We also report the dynamic response to a negative technological shock in the Center in figure 1. Similarly, we obtain a better output response in the emerging economies with a lengthier Center output recovery under cooperation. Likewise, the capital accumulation in the emerging countries will be larger in the centralized regimes. One difference, nevertheless, is that the increase in capital flows toward the EMEs will be delayed in comparison. The same will occur with the financial variables as these comove with the level of intermediation. This delayed response feature, characterized by hump shaped responses, for example in the consumption, has been previously documented in Fujiwara et al. (2011) and Steinsson (2008) and reflects the presence of financial frictions in the model.

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

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

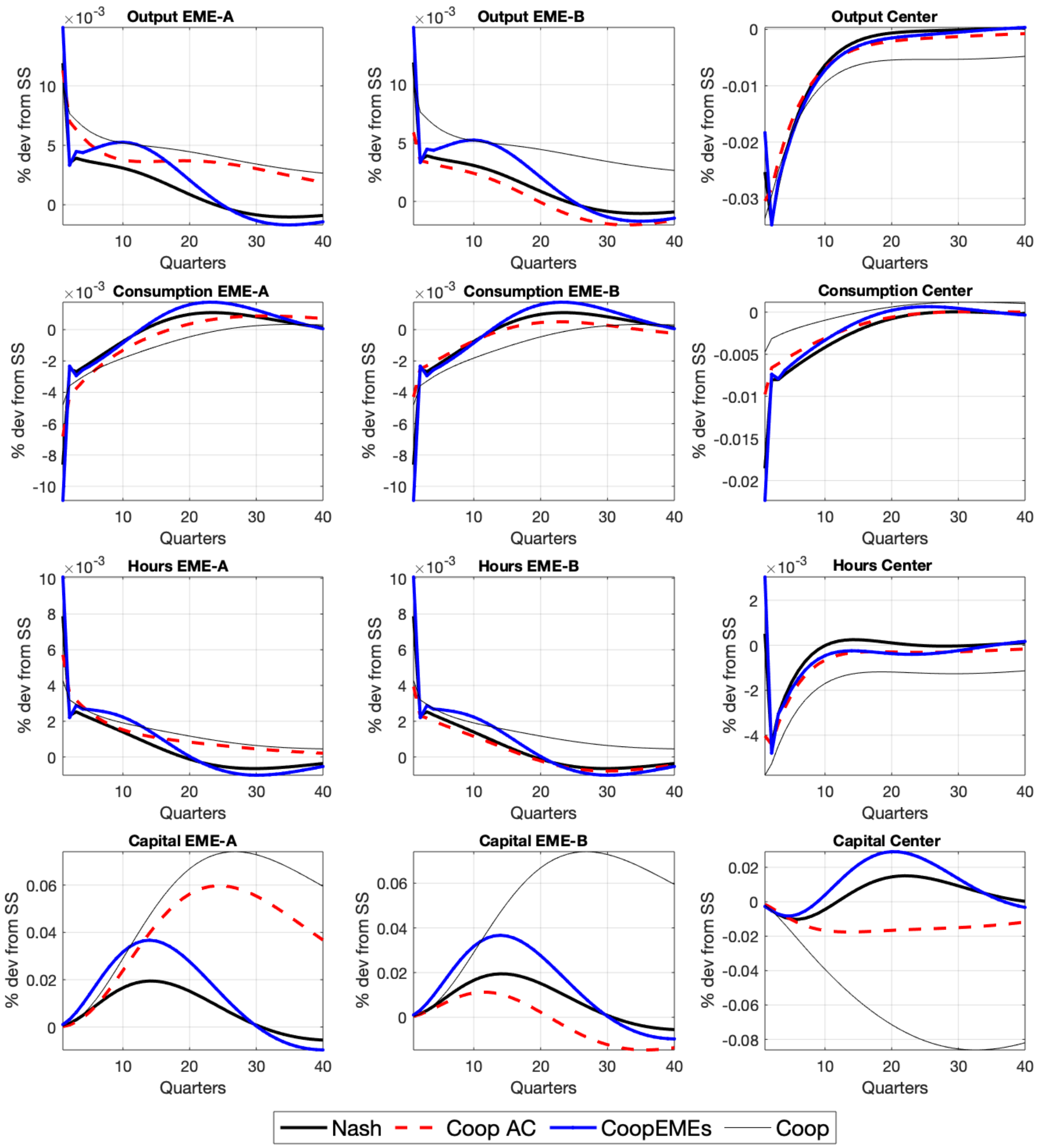
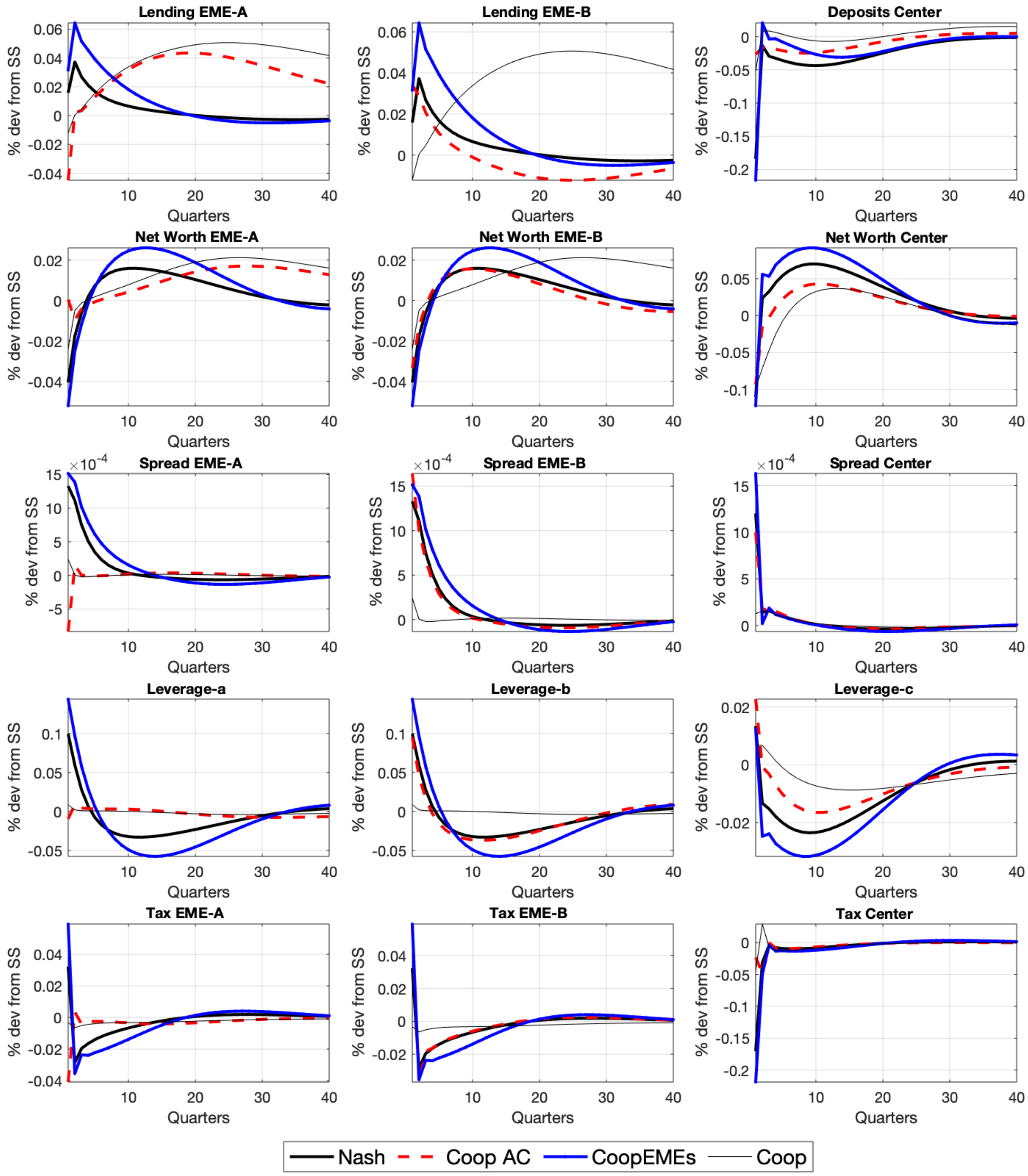


Figure 4: Response to a negative productivity shock at the Center economy - Financial Variables and tools



6. Conclusions

The emerging economies fragility to the global financial cycle is a core concern in international finance in recent times (Rey, 2013). Moreover, the financial resilience of these economies has gained even more importance after the global financial crisis as a larger fraction of the international capital flows has shifted in their direction McQuade and Schmitz (2017) which has been translated into a more frequent and intensive usage of these policies in the emerging economies (Alam et al., 2019). With that in mind, we study whether the international macroprudential policy cooperation is beneficial for these economies and can be used to improve their macroeconomic performance and financial resilience. We formulate two specific questions: (i) is macroprudential cooperation beneficial for these economies in general?, and (ii) are cooperative policies useful in protecting these economies from external shocks?.

To answer these questions, we study the policy mechanisms at work, the long run economic implications and the short run dynamics of these economies in an environment where there is a strong financial interdependency between the emerging markets and a financial center. For identifying the mechanisms we set a tractable, simplified, small scale model with dynamic banking and policies and for the long run and short run dynamics we set a larger scale quantitative model that allows us to take into account the total effects of these policies over time in a stochastic environment. Both can be seen as a dynamic extension of the static banking with one shot policy case of Granados (2020).

When exploring the general effects of these policies, that is, irrespective of the stance on cooperation, we find that forward-looking policies have stronger welfare effects, which will work through the retained profits of the bankers and how these build into the future net worth of the financial sector. In addition, the effects will grow with the financial distortion, suggesting the policy has a higher effectiveness scope for more distorted economies. At the same time, we find a feature that is unique to the financial center: in its role as global creditor it will be subject to a welfare substitution between the facilitation of local and global intermediation. The latter is a very important feature that becomes key when considering the potential benefits of cooperative policies.

On the other hand, on the mechanisms under cooperative policy regimes and the associated optimal taxes, we obtain that two new policy motives arise for a planner that sets the instrument at the financial center cooperatively. First, a new effect surges that offset the non-cooperative incentives for manipulating the global interest rate and gain from variations in the net foreign asset position, and second, there will be an incentive for increasing the financial intermediation and capital flows to the peripheries, at the expense of local capital accumulation.

We also study the long run performance of the policy regimes by carrying out a conditional welfare comparison. Our findings suggest there are gains from cooperation, but only for frameworks where the financial Center acts cooperatively, with the global gains maximized in the world-wide cooperation regime. In that vein, not every type of cooperation is beneficial, and in fact, a cooperative arrangement between peripheries can be detrimental. Although, it should be noted that this analysis excludes the presence of explicit policy implementation costs which could boost the gains from every cooperative setup. Simultaneously, the implementation of the best policy regime, global cooperation, can be challenging as the national distribution of gains are more favorable for the coalition participants under the second best framework, i.e., the cooperation between the financial center and a subset of the peripheries, in that case both countries in the coalition are better off than in the global cooperation equilibrium at the expense of the remaining economy, which in turn, ends up worse than at any other regime.

The main mechanisms generating the gains will be the new two features of the the optimal cooperative tax mentioned before, namely, the cancelation of national policy incentives for manipulating the global interest rate to improve the net foreign assets position and the new policy incentive for substituting the capital accumulation at the Center for foreign intermediation with the peripheries. The first mechanism improves the financial stability of these economies as a source of variation of the taxes is removed for all of the instruments, while the second facilitates a more efficient allocation of the international capital flows, which the cooperative planner will now direction towards the most productive destinations.

Both mechanisms work better when the aggregate welfare weights of the peripheries are closer to that of the Center. In fact, that is the reason why the gains are maximized when more peripheries collaborate with the Center. At the same time, the model with a stochastic component shows that this will translate in a countercyclical implementation of the Center tax for the regimes that deliver cooperation gains. The latter is important as it recognizes the generally procyclical features of these policies (Fernández et al. (2015) and Uribe and Stephanie (2017)) but also that among optimal regimes, the best performing ones will switch to become countercyclical as intuition would dictate (Bianchi (2011) and Jeanne and Korinek (2019)).

As for the short run dynamics of these regimes, we study the response in each case to negative shocks in the Center (financial and real). Our results suggest that the worldwide cooperation regime and the cooperation between the Center and a periphery will protect better the emerging economies from external negative shocks and will yield better output dynamics. We associate this to a higher accumulation of capital in the peripheries under cooperation at the expense of the Center capital stock, which results from the prioritization of the cooperative planner for a more effective and fast global output recovery. In addition the financial variables will be more stable under the best two regimes (worldwide and center-periphery cooperation) that also feature smoother policy dynamics that also tend to favor financial intermediation at the peripheries. All of these patterns are observed more markedly in the worldwide cooperation framework. In contrast, the underperforming regimes, i.e., the non-cooperative and the regional cooperation between peripheries, will feature more volatile policy tools and capital dynamics as well as substantial policy efforts towards boosting the capital accumulation at the Center.

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

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A. Results from the Simple Three Periods Model

Proof of proposition 1.

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

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

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

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

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

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

■

Proof of proposition 2.

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

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

For the last period:

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

we substitute the foreign lending $F_2 = L_2 - N_2$, where N_2 is the net worth in the last period (bequests plus retained previous profits).

We obtain,

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

where ϕ_2 denotes the leverage. We substitute $R_{k,3}(\tau_3) = [(1-\tau_3)r_3 + (1-\delta)Q_3]/Q_2$ an obtain:

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

For the first period:

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

After substitutions and some algebra the ICC becomes:

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

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

The leverage is given by:

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

We then have:

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

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

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

Common to all countries:	
$Q_t = 1 + \frac{\zeta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \zeta\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - \Lambda_{t,t+1}\zeta\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2$	[Price of Capital, t={1,2}]
$K_t = I_t + (1-\delta)K_{t-1}$	[Capital Dynamics, t={1,2}]
$R_{k,t} = \frac{(1-\tau_t)\alpha A_t K_{t-1}^{\alpha-1} + (1-\delta)Q_t}{Q_{t-1}}$	[Banks rate of return, t={2,3}]
$C_t^{-\sigma} = \beta R_t C_{t+1}^{-\sigma}$	[Euler Equation, bonds, t={1,2}]
for EMEs:	
$Q_1 K_1 = F_1 + \delta_B Q_1 K_0$	[bal. sheet of banks, t=1]
$Q_2 K_2 = F_2 + \delta_B Q_2 K_1 + \theta\left[R_{k,2} Q_1 K_1 - R_{b,1} F_1\right]$	[bal. sheet of banks, t=2]
$(1-\theta)\Lambda_{12}\left(R_{k,2} Q_1 K_1 - R_1 F_1\right) + \Lambda_{13}\theta\left(R_{k,3} Q_2 K_2 - R_2 F_2\right) = k Q_1 K_1$	[ICC, t=1]
$\Omega_1 (1+\mu_1)\left(R_{k,2} - R_1\right) = \mu_1 \kappa$	[Credit spread, t=2]
$\Lambda_{23}\left(R_{k,3} Q_2 K_2 - R_2 F_2\right) = k Q_2 K_2$	[ICC, t=2]
$(1+\mu_2)\Lambda_{23}\left(R_{k,3} - R_2\right) = \mu_2 \kappa$	[Credit spread, t=3]
$C_1 + \frac{B_1}{R_1} = r_1 K_0 + \pi_{f,1} + \pi_{inv,1} - \delta_B Q_1 K_0$	[BC for t=1]
$C_2 + \frac{B_2}{R_2} = \pi_{f,2} + \pi_{inv,2} + \pi_{b,2} - \delta_B Q_2 K_1 + B_1 - T_2$	[BC for t=2]
$C_3 = \pi_{f3} + T_{b3} + B_2 - T_3$	[BC for t=3]
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, t=1]
$Q_2^c K_2^c + F_2^a + F_2^b = D_2 + \delta_B Q_2^c K_1^c + \theta\left[R_{k,2}^c Q_1^c K_1^c + R_1^a F_1^a + R_1^b F_1^b - R_1 D_1\right]$	[Bal. sheet of banks, t=2]
$C_1^c + \frac{B_1^c}{R_1} + D_1 = r_1^c K_0^c + \pi_{f,1}^c + \pi_{1nv,1}^c - \delta_B Q_1^c k_0^c$	[BC for t=2]
$C_2^c + \frac{B_2^c}{R_1} + D_2 = \pi_{f,2}^c + \pi_{inv,2}^c + \pi_{b,2}^c - \delta_B Q_2^c K_1^c + R_1 D_1 + B_1^c - T_2^c$	[BC for t=2]
$C_3^c = \pi_{f,3}^c + \pi_{b,3}^c + B_2^c + R_2 D_2 - T_3^c$	[BC for t=3]
International Links:	
$n_a B_t^a + n_b B_t^b + n_c B_t^c = 0$	[Net Supply of Bonds, t = {1,2}]

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

Auxiliary definitions:

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

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

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

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

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

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

Profits of bankers in EMEs, t=2: $\pi_{b,2}^e = (1-\theta)\left(R_{k,2} Q_1^e K_1^e - R_1 F_1^e\right)$

Profits of bankers in EMEs, t=3: $\pi_{b,3}^e = R_{k,3}^e Q_2^e K_2^e - R_2 F_2^e,$ e = {a,b}

Profits of bankers in Center, t=2: $\pi_{b,2}^c = (1-\theta)\left(R_{k,2}^c Q_1^c K_1^c + R_1^a F_1^a + R_1^b F_1^b - R_1 D_1\right)$

Profits of bankers in Center, t=3: $\pi_{b,3}^c = R_{k,3}^c Q_2^c K_2^c + R_{b2}^a F_2^a + R_2^b F_2^b - R_2 D_2$

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

Table 7: Parameters in the 3-period model

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

Also, in the case of the Center, for the last period, there is no explicit τ_3^c terms in the welfare effect. We use the fact that $R_{k,3}(\tau_3)$ to back out the tax after substituting it for one of the taxes it will equate.

$$\tau_2^a = -\frac{1}{\alpha r_2^a}\Bigg\{(I_1 + \kappa K_1)\frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a} \qquad \text{contemporaneous component}$$

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

forward looking component

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

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

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

contemporaneous component

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

$$+\frac{1}{R_2}\left(r_3^c+(1-\delta)Q_3\right)\frac{dK_2^c}{dK_1^c}+\frac{B_2^c}{\left(R_2\right)^2}\frac{dR_2}{dK_1^c}+\left(I_2^c+(1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{dK_1^c}$$

forward looking component

$$+\frac{1}{R_2}\left(\frac{dR_{b2}^{eme}}{dK_1^2}\left(F_2^a+F_2^b\right)+R_{b2}^{eme}\left(\frac{dF_2^a}{dK_1^c}+\frac{dF_2^b}{dK_1^c}\right)\right)\Bigg\}+1-\frac{1}{\alpha\theta}$$

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

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

Optimal Taxes Under Cooperation In this section we show how to get the optimal Center tax under cooperation and the equation (22).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Steady State of the Policy Models

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

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

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

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

3. More equations than unknowns. Then solution is subject to an approximation error $\mathbf{u}$:

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

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

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

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

C. Parameters and other model simulation results

C.1. Parameters of the model

The table contains the parameter used in the baseline model.

Table 8: Parameters in the model

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

D. Welfare Accounting Supplementary Exercises

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

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

Notes: Compensation using the First Best as benchmark.

In Cooperation symmetry between instruments rules is assumed for EMEs

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

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

Notes: Compensation using the First Best as benchmark.

In Cooperation symmetry between instruments rules is assumed for EMEs