Enhancing Economic Resiliency Through Prudential Cooperation *

[Work in Progress / Preliminary]

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Abstract

I analyze the short-run resilience and financial stability properties of an array of cooperative policy regimes relative to nationally-oriented regulations. I show that countries that rely on internationally coordinated policies are more insulated to the negative effects of international financial downturns like the global financial crisis. Additionally, cooperative policies allow countries to increase the countercyclicality of the prudential policies, to lower the required level of interventionism to deal with crises, and to mitigate the deleveraging processes after a financial crisis. All of these properties imply that smoother and less volatile policy responses can be compatible with improved economic performance after external shocks which makes a case for the implementation of coordinated policy schemes that go beyond the potential welfare gains involved in these initiatives.

JEL Codes: F38, F42, E44, G18

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

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1 Introduction

The Global Financial Crisis experience generated lessons with regards to the importance of keeping track of the cross-border economic and financial spillovers in open economy and financially integrated environments. The practical consequence has been a strenghtening of the banking regulations both from a multilateral perspective (Basel accords revisions) and from a national perspective, especially in advanced economies.

The main point of these regulatory previsions is related to the mitigation of excessive risk taking and the promotion of coordinated regulations to allow for financial stability increases both at the regional and national levels. Behind this, rests the idea that there are unclaimed welfare gains from macroprudential regulation in countries that abstract from the international spillovers of their regulations when setting their policy toolkit.

Now, with a new crisis in motion, the COVID-19 lockdown, the role of the financial sector in facilitating the well-functioning of the economies at any possible extent has become more evident, and with that, the need to understand whether there are short run benefits from coordinating the financial regulations internationally. What is the best policy type of implementation for dealing with specific downturns? Are there financial stability gains from coordinating the prudential policies internationally? With these questions in mind, I study whether the international macroprudential policy cooperation is beneficial for emerging economies and could be used to improve their economics and financial resilience. In particular, I address a specific question: (i) are cooperative policies useful in protecting emerging economies from external shocks?, (ii) What are the resilience inducing properties of cooperative policy regimes?.

Similarly, the policy regimes' short-run performance reflects these features, implying that the worldwide cooperation regime is the best at protecting the emerging economies from external shocks. This result stems from higher and smoother capital accumulation at the peripheries that grows at the expense of local capital dynamics elsewhere. Noticeably, the reliance on capital flows to peripheries results from a cooperative planner that internalizes the center tool effect in the peripheral output while prioritizing the global economic recovery over the national welfare.

Furthermore, I find that the policies under the welfare-improving coordination regimes imply a more modest regulatory response by the policymakers; that is, the associated taxes will be smoother and conservative relative to their nationally-oriented counterparts. This result is consistent with the portfolio cancellation policy effect and captures a desirable property of cooperative (with the center) regimes: they limit the scope for excessive regulatory interventions and the potential detrimental effect on the macroeconomic performance.[1]

On the other hand, I find another benefit of cooperation (with the center) in the short run exercise: the deleveraging processes, documented in studies like Bianchi (2011) and Jeanne and Korinek (2010, 2019) to hinder the economic recoveries after financial shocks, are noticeably mitigated by the centralized policies, thereby making a stronger case for coordinating regulatory efforts.

Finally, the cyclical component of these policy frameworks suggests that unlike in any other regime (or economies), cooperative efforts at the center leads to a countercyclical implementation of its instruments. Thus, this model recognizes the general procyclicality of these policies, documented in the literature in studies like Fernández, Rebucci, and Uribe (2015) and Uribe and Schmith-Grohe (2017), but also that among optimal regimes, the best performing policies tend to adopt countercyclical features, as intuition dictates and as stated by other studies (Bianchi (2011) and Jeanne and Korinek (2019)).

2 The Main Model

In this section I 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, I take elements from Banerjee, Devereux, and Lombardo (2016), Agénor, Kharroubi, Gambacorta, Lombardo, and da Silva (2017) and Gertler and Karadi (2011) and incorporate them into a three country center-periphery framework with incomplete markets.

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

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

This implies that the only friction present in this model is the financial agency friction in

[1]See Richter, Schularick, and Shim (2019) for a discussion on the macroeconomic effects of the macroprudential policies.

borrower-lending relationships. In that regard, this is a costly-enforcement framework like Gertler and Kiyotaki (2010).

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

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

2.1 Households

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

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

s.t.,

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

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

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

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

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

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

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

Emerging Economy Households. One difference between the advanced economy and the emerging ones is that, at the former, households are able to freely purchase deposits from the Center banks while the emerging economy banks will have a limited local intermediation capacity. This implies the banks in these countries hold less deposits. As a simplification, I drop the deposits for these countries altogether (i.e., D^a_t and D^b_t are zero). Note that this feature is not explicitely reflected in the household budget constraint above.

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

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

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

2.2 Final Goods Firms

A single final good is produced with a CD technology:

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

H^i, K^i are labor and capital, A^i is a 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 $\delta^i_t(\xi^i_t) = 1-(1-\delta)\xi^i_t$.

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

$$\max_{K^i_{t-1},H^i_t} \Pi^{i,prod}_t = Y^i_t + (1-\delta)\xi^i_t Q^i_t K^i_{t-1} - w^i_t H^i_t - \tilde{R}^i_{k,t} Q^i_{t-1}$$
$$\text{s.t.} \quad (3)$$

I define the marginal product of capital as $r^i_t \equiv \alpha A^i_t \xi^{i\ \alpha}_t K^{i\ \alpha-1}_{t-1} H^{i\ 1-\alpha}_t$, and obtain the wages and gross rate of returns paid to the banking sector from the FOCs with respect to labor and capital:

$$w^i_t = (1-\alpha) A^i_t H^{i(-\alpha)}_t \xi^{i\ \alpha}_t K^{i(\alpha)}_{t-1}$$
$$\tilde{R}^i_{k,t} = \frac{r^i_t + (1-\delta)\xi^i_t Q^i_{t-1}}{Q^i_{t-1}}$$

The physical capital is funded by selling company securities to domestic banks in a one to one relationship, i.e., $Z^i_t = K^i_t$, where Z^i_t is the stock of securities from the representative final goods firm in the country i. In that spirit, the marginal product of capital r^i_t can also be interpreted as the return from the firm securities.[2]

2.3 Capital Goods Firms

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

$$C(I^i_t) = I^i_t \left(1 + \frac{\zeta}{2}\left(\frac{I^i_t}{I^i_{t-1}} - 1\right)^2\right)$$

The capital dynamics are:[3]

$$K^i_t = I^i_t + (1-\delta)\xi^i_t K^i_{t-1} \tag{4}$$

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

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

After production takes place, these firms buy the old capital stock from the final goods firms at price Q_t^i and produce new capital subject to the adjustment cost.

Finally, the problem of the capital goods firm choosing their investment level is:

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

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

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

2.4 Banking Sector

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

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

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

The structure of the sector in each country and the decisions they face are explained in detail in the following subsections. However, it can be said that in general, the problem of the j-th 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), its balance sheet and the ICC.

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

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

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

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

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

The aggregate net worth of the banking system is:

$$N^e_t = \overbrace{\theta N^e_{j,t}}^{\substack{\text{surviving banks'}\\ \text{net worth}}} + \overbrace{\delta_T Q^e_t K^e_{t-1}}^{\substack{\text{new banks'}\\ \text{start-up capital}}}$$

Here, the bequests provided by the households to the banks are proportional to the pre-existing level of intermediation (capital) times the current price of capital. At the same time, $N^e_{j,t}$ is the net-worth of surviving banks and have 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, $R^e_{k,t}$, accounts for the payment of the macroprudential tax:

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

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

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

The problem of the j-th banker is to maximize the franchise value of the bank:[4]

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

[4] An analogous sequential problem is: $J^e(N^e_{j,t}) = \max_{\{N_t, Z^e_t, F^e_{j,t}\}^\infty_{t=0}} \mathbb{E}_t (1-\theta) \sum_{s=0}^\infty \Lambda^e_{t,t+1+s} [\theta^s N^e_{j,t+1+s}]$

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

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

This incentive compatibility constraint states that the continuation value of the bank is larger than the potential profit of defaulting.[5]

The bank's 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 $\Omega^e_{t+1|t} = \Lambda^e_{t,t+1}\big(1 - \theta + \theta J^{e'}_{t+1}\big)$ is the effective stochastic discount factor of the bank.

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

The balance sheet of the global country bank j is:

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

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

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

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

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

The bank j value function is:

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

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

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

The optimality Conditions are:

$$[Z^c_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t} (R^c_{k,t+1} - R^c_{D,t}) = \kappa^c \mu^c_t \tag{13}$$
$$[F^a_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t} \left(R^a_{b,t} - R^c_{D,t} \right) = \kappa^c_{F_1} \mu^c_t \tag{14}$$
$$[F^b_{j,t}]: \quad \mathbb{E}_t \Omega^c_{t+1|t} \left(R^b_{b,t} - R^c_{D,t} \right) = \kappa^c_{F_2} \mu^c_t \tag{15}$$

and the envelope condition,

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

2.5 Macroprudential Policy

The policy tool I consider is a tax on the return to capital. This is a general enough tool that encompasses several varieties of macroprudential instrumets. For example, and as I showed in the proposition 2, it has leverage-ratio implications.

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

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

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

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

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

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

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

with,

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

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

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

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

Where I removed the j sub-index as the components of the leverage will not depend on firm-specific factors. It also follows that $z_{t,t+1} = [(R^e_{k,t+1} - R_{b,t})\phi^e_t + R^e_{b,t}]$ and $x_{t,t+1} = (\phi^e_{t+1}/\phi^e_t)z_{t,t+1}$.

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

2.6 Market Clearing Conditions

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

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

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

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

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

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

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

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

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

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

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

In the table 9 in the appendix B, I show the final system of equations that characterizes the equilibrium. These structural equations will be used as the set of constraints for the policy makers that decide the optimal level of the tools in each of the regimes considered.

3 Ramsey Policy Problem

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

Table 1: Policy Cases Considered

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

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

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

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

3.1 Planning Problems

In every case I consider the planning problem under commitment with a timeless perspective. [6] As explained by King and Wolman (1999) this implies I am assuming the policy makers were making optimal decisions in the past in a time consistent manner. This formulation is the standard in the literature given its property of avoiding indeterminacy issues in the model solution.

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

Definition 1. *Open-loop Nash equilibrium*

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

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

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

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

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

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

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

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

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

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

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

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

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) solves the same problem as in the Nash case.

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

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

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

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

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

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

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

3.2 Gains From Cooperation

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

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

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

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

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

Clearly, an overperforming model, or in this example a model with gains from cooperation, would depict a negative λ. In that case, a negative λ would indicate that consumption in the cooperative regime would have to decrease in order to match the non-cooperative equilibrium, implying the cooperative regime is better from a welfare perspective. I approximate λ by normalizing the welfare gain (in utility units) by the increase in steady-state welfare that would be obtained from a 1% increment in consumption. [7]

4 Results

In this section, I discuss the solution of the main model under different policy schemes and what are the resiliency properties of the regimes under consideration.

For this, the stategy I follow a two step strategy, first, I analyze a number of resilience

[7] In the results (table 7) I show the consumption compensation variation that agents in the First Best model (with no frictions) would undergo in order to match each one of the considered regimes.

indicators of the policy regimes over-the-cycle, that is, in terms of their solution around the deterministic steady state and in the long-run. Then, as a second step I analyze the policy and economic dynamics of the system in presence of different types of shocks, with special attention paid to a financial downturn originating at the Center such as the one observed during the Global Financial Crisis.

I use the parametrization shown in table 6 in the appendix B. In most cases I follow the calibration used in the literature that have the usual targets (e.g., discount factor and depreciation rate). However, there are other parameters that are calibrated specifically with the emerging markets in mind. This is particularly true for the divertable fraction of capital. At the same time, given the focus on the large open economy dimension of these policies, I set the population sizes of each emerging economy at 0.25 each ($n_a = n_b = 0.25$).

Steady State of the Policy Instruments. The table 2 shows the steady states of the policy taxes for each policy regime considered. The algorithm used implies computing an instrument conditional steady state and follows the steps outlined in Christiano, Motto, and Rostagno (2007) and Bodenstein, Guerrieri, and LaBriola (2019). A detailed explanation can be found in the appendix A. I obtain that the Center always applies subsidies to its banking sector in the long run, while planners of the EMEs subsidize its banking sector only when cooperating with the Center, and instead, set a tax to the financial intermediaries in the non-cooperative case or under the emerging coalition. Thus, at least in the long-run, cooperation with the center consists on setting higher subsidies (lower taxes).

Table 2: Steady State values for the policy tools

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

both a higher financial stability and increased efficiency in the use of capital.

Finally, an additional factor in favor of emerging capital accumulation that is reflected in this model is the fact that, unlike in every other regime and country, a cooperative planner sets the macroprudential taxes at the Center in a countercyclical fashion.

Table 3: Correlations between output and macroprudential tools in each policy regime

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

Cyclicality of the Optimal Policies. In table 3 I report the correlations of the output with the macroprudential tax. Given this tax limits intermediation (capital accumulation), we would have a countercyclical tax when the covariance between the output and the policy tool is positive ($Cov(Y_t, \tau_t) > 0$), i.e., a higher tax is implemented during booms in a way that cools down business cycle.

From the table we can see that under the welfare-improving cooperation regimes (center-cooperative schemes) the planner implements a countercyclical tax at the Center. This result is relevant, first it captures that the Center tool is set to favor the stream of capital flows to emerging economies, and second, it is deemed as a desirable, yet difficult to achieve property of the macroprudential tools.

Regarging the first point, during a boom at the Center, the planner discourages 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, studies as Bianchi (2011) and Jeanne and Korinek (2019) that find 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, Rebucci, and Uribe (2015) find that actual macroprudential policies are procyclical. Here, by exploiting another dimension of these policies, i.e., the degree of cooperation, I find a result that is consistent with both views: although taxes tend to be pro-cylical, the best regimes adopt counter-cyclical features.

Conversely, the emerging economies' taxes become more pro-cyclical under cooperation. This is explained by the feature of this regimes that favor capital flows to the peripheries when these are more productive and is also consistent with a higher effort, in those cases, for curbing down the local intermediation at the Center.

Role of the Welfare Weights. How the resilience features are heightened with higher EM welfare weights.

By the same token, as the environment converges to that of a small open economy ($n_a, n_b \to 0$) the features are muted and we return to a case analogous to that of a single economy environment where the policy manipulation motive is activated again, leading to policy efficiency losses in line as what is found in Korinek (2020).

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

Given these features, the inclusion of additional peripheral countries in the cooperative interactions, represents a way to balance the policy incentives of these economies ...

4.1 Short Run and Cyclical Performance of the Policy Setups

It is possible to verify the short-run dynamics and policy paths after financial and real shocks that originate at the Center. I do it here, thereby answering whether cooperative policies can be useful in protecting the emerging economies from external shocks.

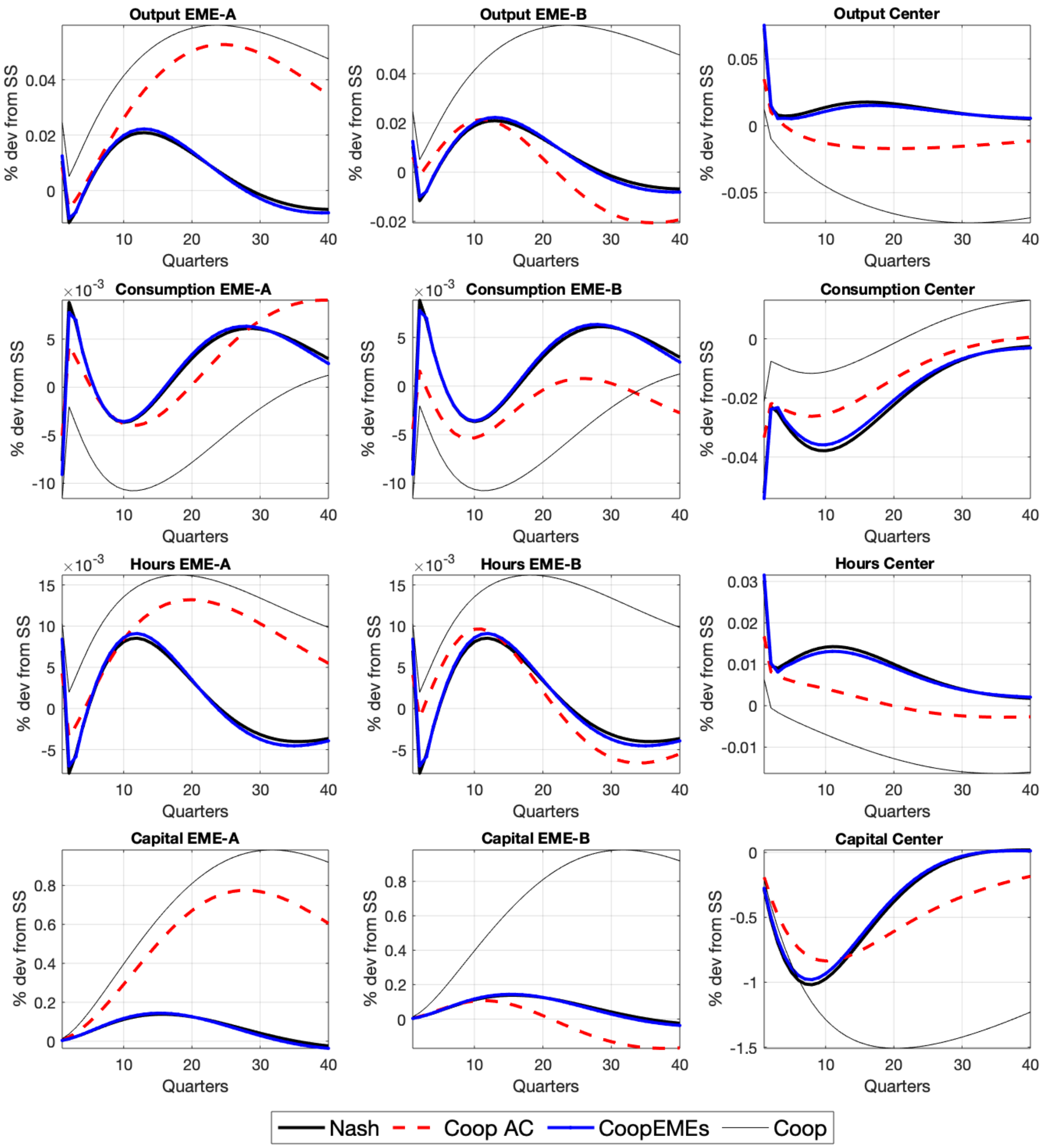
The type of situation in mind when formulating this question is one like the crisis of 2008, where a recessionary shock with origins in the advanced economies ended up having international consequenses as part of the global financial cycle.

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

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

For this protection to happen, we see that the cooperative planners increase the capital acumulation by EMEs in a much greater scale than non-cooperative planners (fourth row in figure 1). This comes at the expense of the acumulation in the Center, however, this is deemed appropriate by the planners as their priority now becomes the global output recovery and not only that of the Center. Clearly, such effect relies on the fact that the relative sizes of the peripheries in our setup are sizable.

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



Noticeably, even with a better output response, the emerging economies 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 are 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. [8]

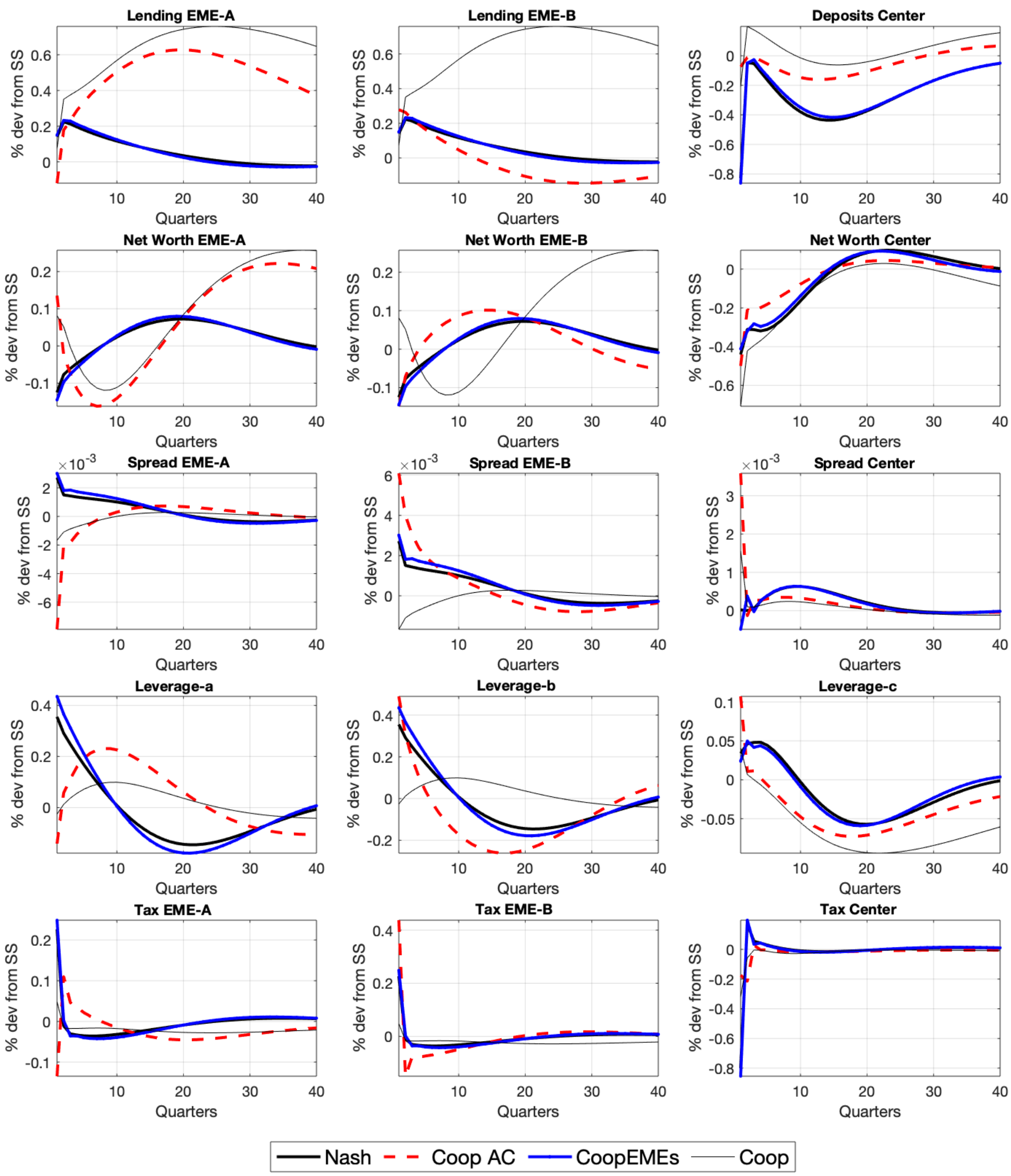
The financial variables tell a similar story. I show these in the figure 2. Consistently with the evolution of capital, the lending is boosted more strongly under cooperation, and for every economy. The latter point is crucial, the Center is not accumulating more capital locally for production, however, increases its lending to expand its international financial intermediation. Additionally, we see a more persistent build-up of net-worth for the peripheries under the Center-compliant cooperative schemes.

On the other hand, the credit spread dynamics reflect a substantial effort by cooperative planners to push up the interest rates in the country hit by the shock (Center, third column panel, third row), whereas for the emerging ones we see the opposite, i.e., when cooperating with the Center, they implement lower spreads (with higher taxes). Thus, the optimal stance under cooperation consists in a fast and active multilateral compensation of the shock, a desirable stance that also goes in the direction of mitigating the financial friction. This contrasts with non-cooperative regimes where the peripheral planners would take advantage of the momentum and push the spread upwards.

Finally, the leverage will goes up over time in the EMEs by construction (in all regimes). However, it is salient 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 of their policies and as a result will know better where to focus (on EMEs) to facilitate a global economic recovery.

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

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



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 increase the taxes while the planner at the Center subsidizes the banking sector. However, there are meaningful differences across regimes that explain the discrepancies between the cooperative and non-cooperative outcomes. First, the taxes are smoother under cooperation and in particular during the first five to ten quarters after the shock. This reflects the comparative advantage of a coordinated policy scheme in avoiding unnecessary instrument fluctuations.

Secondly, the non-cooperative Center planner (Nash and Coop(EMEs) regimes) will exert a substantial effort towards increasing the local intermediation by implementing a stronger 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.

In the same spirit, it can be noticed the dynamics of the optimal taxes are very similar between the non-cooperative and emerging cooperation regime (specially for the financial shock). This reflects how the critical feature for a coordinated regime to be beneficial, and internalize the cross-border spillovers of policy, is that a Center complies with cooperation.

Real Shock. The dynamic response to a negative technological shock in the Center is shown in figure 3. Similarly, we can see 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 occurs 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, is documented in Fujiwara, Hirose, and Shintani (2011) and Steinsson (2008) and reflects the presence of financial frictions in the model.

Simultaneously, the financial variables and the policy instruments vary within a narrower range in the regimes where the center cooperates (Coop and Coop(A+C)), reflective of the financial stability gains from smoother taxes.

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

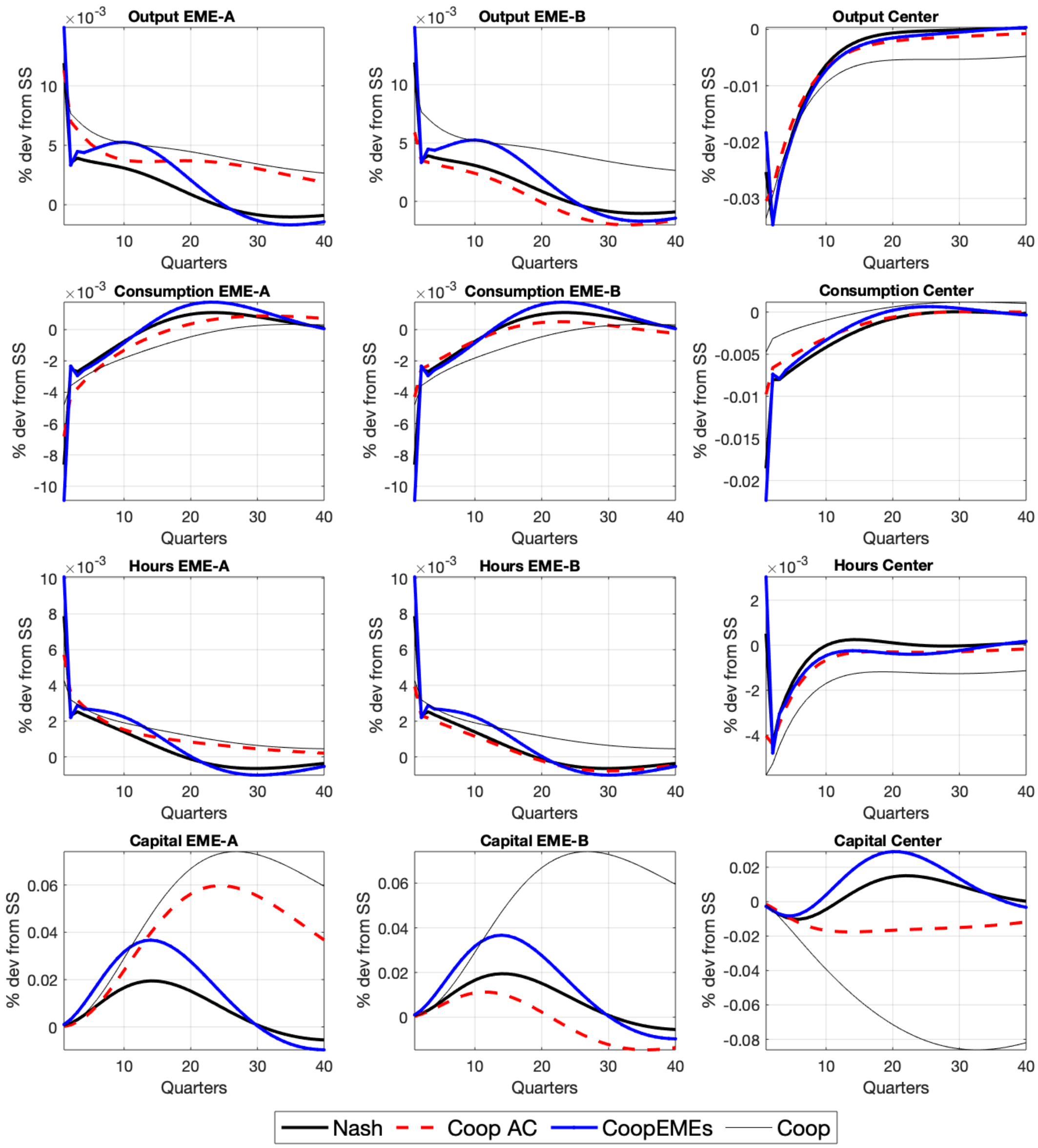
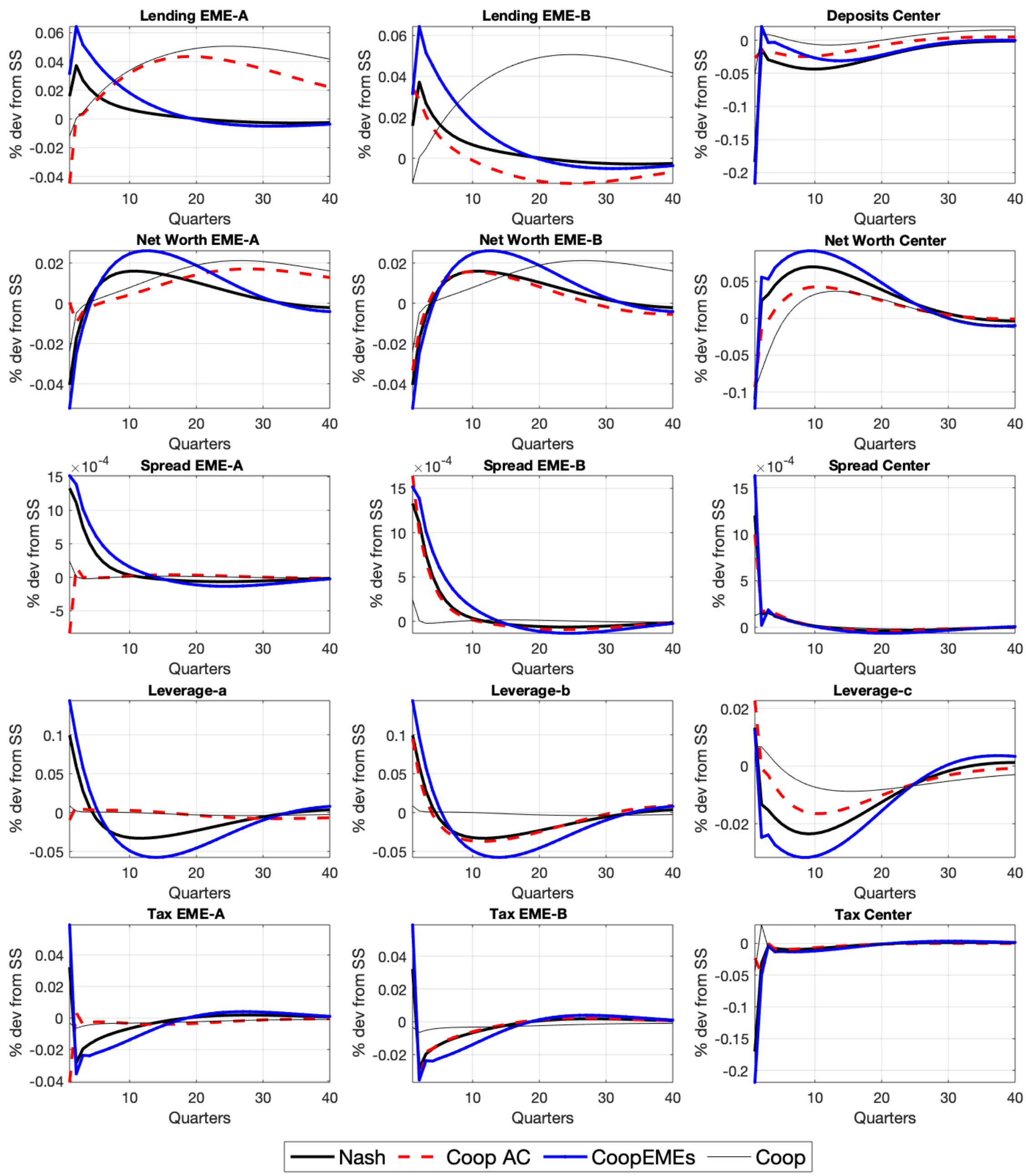


Figure 4: Response to a negative productivity shock at the Center economy - Financial Variables and tools



5 Conclusions

I study whether the international macroprudential policy cooperation is beneficial for emerging economies and can be used to improve their macroeconomic and financial resilience. I formulate two specific questions: (i) are cooperative policies useful in protecting these economies from external shocks? and (ii) What are the resilience-inducing properties of cooperative policy regimes.

I perform a welfare evaluation in an stochastic environment and confirm the existence of welfare gains for frameworks where peripheries collaborate with a Center, thereby concluding that: cooperation is indeed useful, however, not every type of cooperation pays off, and the inclusion of a financial center in the coordinated arrangement is crucial.

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

An advantage of this study with respect to the rest of the literature is that it is based on a clear identification of the two main sources of the welfare gains while also accounting for different types of cooperative and semi-cooperative policies.

Finally, while I think this framework represents a contribution in understanding the macroeconomic resilience features of the macroprudential policies in open economies, other realistic features could complement this analysis in potentially insightful directions, such as the inclusion of currency risk in the debt flows, shadowbanking, or even allowing for a scenario of repeated policy interactions or revisions such that countries could reassess their choices on cooperation or competition. I leave the inclusion of these elements for future work.

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A Results from the Simple Three Periods Model

Proof of proposition 1.

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

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

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

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

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

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

■

Proof of proposition 2.

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

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

For the last period:

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

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

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

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

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

For the first period:

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

After substitutions and some algebra the ICC becomes:

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

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

The leverage is given by:

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

Then,

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

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

Table 4: 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]
$(1-\theta)\Lambda_{1,2}\left(R_{k,2} Q_1 K_1 - R_1 F_1\right) + \Lambda_{1,3}\theta\left(R_{k,3} Q_2 K_2 - R_2 F_2\right) = k Q_1 K_1$	[ICC, t=1]
$\Omega_1 (1+\mu_1)\left(R_{k,2} - R_1\right) = \mu_1 \kappa$	[Credit spread, t=2]
$\Lambda_{2,3}\left(R_{k,3} Q_2 K_2 - R_2 F_2\right) = k Q_2 K_2$	[ICC, t=2]
$(1+\mu_2)\Lambda_{2,3}\left(R_{k,3} - R_2\right) = \mu_2 \kappa$	[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]
$C_3 = \pi_{f3} + T_3 + B_2 - T_3$	[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: $\Omega_1 = (1-\theta)\Lambda_{1,2} + \theta^2 R_{k,3}\Lambda_{1,3}$

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

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

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

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

Profits of bankers in EMEs, t=2: $\pi^e_{b,2} = (1-\theta)\left(R_{k,2}Q^e_1 K^e_1 - R_1 F^e_1\right)$

Profits of bankers in EMEs, t=3: $\pi^e_{b,3} = R^e_{k,3}Q^e_2 K^e_2 - R_2 F^e_2, \qquad$ e = {a,b}

Profits of bankers in Center, t=2: $\pi^c_{b,2} = (1-\theta)\left(R^c_{k,2}Q^c_1 K^c_1 + R^a_1 F^a_1 + R^b_1 F^b_1 - R_1 D_1\right)$

Profits of bankers in Center, t=3: $\pi^c_{b,3} = R^c_{k,3}Q^c_2 K^c_2 + R^a_{b2} F^a_2 + R^b_2 F^b_2 - R_2 D_2$

Table 5: Parameters in the 3-period model

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

A.1 Optimal Taxes

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

In the case of the Center and for the last period, there is no explicit τ^c_3 terms in the welfare effect. Then, to pintpoint the tax I use the fact that banking returns show the tax explicitely ($R_{k,3}(\tau_3)$) to back out the tax after substituting it for one of the rates it equates.

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

$$\underbrace{+\left(1-\frac{\Lambda_{1,2}}{\Lambda_{2,3}}\right)\alpha_4(\kappa)\frac{dQ_2^a}{dK_1^a}+(1-\Lambda_{1,2})\frac{B_2^a}{R_2}\frac{dR_2}{dK_1^a}+\kappa\left(1+\theta\left(\Lambda_{1,2}-\Lambda_{2,3}\right)-\frac{\Lambda_{1,2}}{\Lambda_{2,3}}\right)Q_2^a\frac{dK_2^a}{dK_1^a}\bigg\}}_{\text{forward-looking component}}$$

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

$$\tau_2^c=\overbrace{-\frac{1}{\theta\alpha r_2^c}\bigg\{(1-\theta)(1-\delta)Q_2^c+\left(\tfrac{B_1^c}{R_1}-\theta D_1\right)\frac{dR_1}{dK_1^c}+R_1K_1^c\frac{dQ_1^c}{dK_1^c}+(1-\theta)\left(\frac{dR_{b,1}^{eme}}{dK_1^c}F_1^{ab}+R_{b1}^{eme}\frac{dF_1^{ab}}{dK_1^c}\right)}^{\text{contemporaneous component}}$$

$$\underbrace{+\frac{1}{R_2}\left[\gamma_2\frac{dK_2^c}{dK_1^c}+\frac{B_2^c}{R_2}\frac{dR_2}{dK_1^c}+\gamma_3\frac{dQ_2^c}{dK_1^c}+\left(\frac{dR_{b2}^{eme}}{dK_1^2}F_2^{ab}+R_{b2}^{eme}\frac{dF_2^{ab}}{dK_1^c}\right)\right]\bigg\}}_{\text{forward looking component}}+\frac{\alpha\theta-1}{\alpha\theta}$$

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

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

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

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

$$\frac{dW_0^{coop}}{d\tau_3^c}=n_a\frac{dW_0^a}{d\tau_3^c}+n_b\frac{dW_0^b}{d\tau_3^c}+\left(1-n_a-n_c\right)\frac{dW_0^c}{d\tau_3^c}$$

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

$$\frac{dW_0^{coop}}{d\tau_3^c}=(n_a+n_b)\frac{dW_0^a}{d\tau_3^c}+\left(1-n_a-n_c\right)\frac{dW_0^c}{d\tau_3^c}$$

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

$$\frac{dW_0^{coop}}{d\tau_3^c} = \frac{dW_0^a}{d\tau_3^c} + \frac{dW_0^c}{d\tau_3^c}$$

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

$$\begin{aligned}\frac{dW_0^{coop}}{d\tau_3^c} = &\left[\beta\lambda_2^a\left(\kappa\left(1-\theta\Lambda_{2,3}\right)Q_2^a + \varphi\left(\tau_3^c\right)\Lambda_{2,3}r_3^a\right)\frac{dK_2^a}{d\tau_3^c} + \beta\lambda_2^a\left(I_2^a + \kappa\left(1-\theta\Lambda_{2,3}\right)K_2^a\right)\frac{dQ_2^a}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\left(r_3^c + (1-\delta)Q_3\right)\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \beta\lambda_2^c\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right)\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\left(\frac{dR_{b2}^{eme}}{d\tau_3^c}\left(F_2^a + F_2^b\right) + R_{b_2}^{eme}\left(\frac{dF_2^a}{d\tau_3^c} + \frac{dF_2^b}{d\tau_3^c}\right)\right)\right]\end{aligned}$$

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

$$\begin{aligned}\frac{dW_0^{coop}}{d\tau_3^c} = &\left[\alpha_1\frac{dK_2^a}{d\tau_3^c} + \alpha_2\frac{dQ_2^a}{d\tau_3^c} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\alpha_3\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \alpha_4\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\frac{dR_{b2}^{eme}}{d\tau_3^c}F_2^{ab} + \beta^2\lambda_3^c R_{b_2}^{eme}\frac{dF_2^{ab}}{d\tau_3^c}\right]\end{aligned}$$

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

$$\begin{aligned}\frac{dW_0^{coop}}{d\tau_3^c} = &\left[\alpha_1\frac{dK_2^a}{d\tau_3^c} + \alpha_2\frac{dQ_2^a}{d\tau_3^c} + \beta^2\lambda_3^a\frac{B_2^a}{R_2}\frac{dR_2}{d\tau_3^c}\right] + \left[\beta^2\lambda_3^c\alpha_3\frac{dK_2^c}{d\tau_3^c} + \beta^2\lambda_3^c\frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \alpha_4\frac{dQ_2^c}{d\tau_3^c}\right.\\ &\left.+\beta^2\lambda_3^c\frac{dR_{b2}^{eme}}{d\tau_3^c}F_2^{ab} + \beta^2\lambda_3^c\frac{(1-\tau_3^{c,coop})r_3^c + (1-\delta)Q_3}{Q_2^c}\frac{dF_2^{ab}}{d\tau_3^c}\right] = 0\end{aligned}$$

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

$$\tau_3^{c,coop} = \frac{Q_2^c}{\Lambda_{2,3} r_3^c} \frac{\lambda_2^a}{\lambda_2^c} \left\{ (\kappa(1-\theta\Lambda_{2,3})Q_2 + \varphi(\tau_3^a)\Lambda_{2,3} r_3^a) \frac{dK_2^a}{dF_2^{ab}} + (I_2^a + \kappa(1-\theta\Lambda_{2,3}K_2^a)) \frac{dQ_2^a}{dF_2^{ab}} \right\}$$
$$+ \frac{Q_2^c}{\Lambda_{2,3} r_3^c} \left(\Lambda_{2,3} \left(r_3^c + (1-\delta)Q_3 \right) \frac{dK_2^c}{\partial F_2^{ab}} + (I_2^c + (1-\theta)(1-\delta)K_1^c) \frac{dQ_2^c}{dF_2^{ab}} + \Lambda_{2,3} F_2^{ab} \frac{dR_{b2}^{eme}}{dF_2^{ab}} \right)$$
$$+ \frac{(1-\delta)Q_3^c}{r_3^c} + 1 + \frac{Q_2^c}{r_3^c} \left(\frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}} - \frac{\lambda_2^a}{\lambda_2^c} \frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}} \right)$$

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

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

$$\tau_3^{c,coop} = \overbrace{\frac{Q_2^c}{\Lambda_{2,3} r_3^c} \frac{\lambda_2^a}{\lambda_2^c} \left\{ (\kappa(1-\theta\Lambda_{2,3})Q_2 + \varphi(\tau_3^a)\Lambda_{2,3} r_3^a) \frac{dK_2^a}{dF_2^{ab}} + (I_2^a + \kappa(1-\theta\Lambda_{2,3}K_2^a)) \frac{dQ_2^a}{dF_2^{ab}} \right\}}^{\text{New substitution of Center capital accumulation for foreign intermediation (EMEs) motive under cooperation}}$$
$$+ \tau_3^{c,nash} - \frac{\lambda_2^a}{\lambda_2^c} \underbrace{\frac{Q_2^c}{r_3^c} \frac{B_2^c}{R_2} \frac{dR_2}{dF_2^{ab}}}_{\substack{\text{NFA-led interest rate} \\ \text{manipulation motive} \\ \text{at Center}}}$$

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

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

We can make a further simplification[9], for a clearer argument and assume the $\lambda_2^a = \lambda_2^c$ which leads to the equation (**??**).

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

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

taxes under cooperation which would generate the following optimal tax:

$$\tau_3^{a,coop} = \overbrace{\frac{\alpha-1}{\alpha} - \frac{1}{\alpha\Lambda_{2,3}r_3^a}\left\{\left(\alpha_4(\kappa)\frac{dQ_2^a}{dK_2^a} + \kappa\left(1-\theta\Lambda_{2,3}\right)Q_2^a\right) + \left(\frac{B_2^a}{(R_2)^2}\right.}^{\tau_3^{a,nash}} \left. - \frac{\lambda_2^c}{\lambda_2^a}\frac{B_2^a}{(R_2)^2}\right)\frac{dR_2}{dK_2^a}$$
$$\left.\left(\gamma_2\Lambda_{2,3}\frac{dK_2^c}{dK_2^a} + \gamma_3\frac{dQ_2^c}{dK_2^a} + \Lambda_{2,3}F_2^{ab}\frac{dR_{b,2}^{\text{eme}}}{dK_2^a} + R_{b,2}^{\text{eme}}\frac{dF_2^{ab}}{dK_2^a}\right)\right\}$$

with $\alpha_4 = I_2^a + \kappa(1-\theta\Lambda_{2,3})K_2$, $\gamma_2 = r_3^c + (1-\delta)Q_3$, and $\gamma_3 = I_2^c + (1-\theta)(1-\delta)K_1^c$

In terms of the interpretation in section 4 we can express the tax in terms of a wedge with respect to the non-cooperative one as:

$$\tau_3^{a,coop} = \tau_3^{a,nash} - \varphi_3^{a,NFA} - \omega_3$$

Although not refered to explicitely in the main sections, it can be noticed ω_3 is consistent the fact a cooperative planner sets higher subsidies with the EMEs instruments.

B Results from the Main Model

B.1 Steady State of the Policy Models

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

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

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

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

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

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

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

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

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

B.2 Parameters of the Model

Table 6: Parameters used in the baseline model

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

B.3 Welfare Accounting Supplementary Exercises

Table 7: 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, i.e., the equivalent variation in consumption agents undergo if they transition from the FB to the column's regime.

In Cooperation symmetry between instruments rules is assumed for EMEs

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

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

Notes: Compensation using the Nash (no cooperation) as benchmark. The numbers in bold denote the departure from the benchmark, in terms of equivalent consumption variation.

In Cooperation symmetry between instruments rules is assumed for EMEs

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

Table 9: Summary of private equilibrium equations of the baseline model

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

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

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

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

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

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