Macroprudential Policy Leakages in Open Economies: A Multiperipheral Approach

Camilo Granados

University of Texas at Dallas

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Introduction

Macroprudential Policies (MaP): Regulations aimed at preserving the stability of the financial system.

Why are needed?:

- First Best (FB): Financial Markets allow flow of resources to more productive destinations.

  SB: Distortions prevent productive countries from atracting K flows: Gourinchas, Fahri, Caballero (2008, 2016)

- First Best: Credit and Return Rates reflect actual risk of investment projects [No Financial Accelerator]

  SB: External Risk Premium, Overborrowing and Excessive Risk Taking.

$\Rightarrow$ Global Financial Cycle and too volatile credit dynamics (H. Rey, 2013) $\longrightarrow$ Financial Instability

What do we know about MaP policies?: Forbes (2019, AER P&P)

*"... accumulating evidence that it can be effective on its direct targets, **albeit often with unintended leakages and spillovers**. There has been less progress in terms of understanding the ramifications of these leakages".*

This paper inquires on these spillovers

How to "MacroPru"?:

If effective, should MaP be applied indiscriminately? ... Not necessarily:

- Trade-offs between other policy goals and Financial Stability (Rey and Coimbra, 2017)
- Aggresive limitations can curtail long term investment and growth (Richter, Shularick and Shim, 2019)
- Implementation (of regulation) is Costly (e.g., subsidies, acquiring FX reserves, etc.)
- MaP interdependency may lead to regulatory wars: Race to the Bottom.

Crossborder Leakages and Spillovers

In addition, the effects of Macroprudential policies **go beyond its jurisprudence borders**

$\Rightarrow$ All the effects above may stem from policies in other countries (or leak abroad)

If the Leakage is non-trivial $\longrightarrow$ Regulators would like to internalize these effects.

Research Questions

- What is the nature of the **International macroprudential policy spillovers**?
- Are these leakages shaped by the presence of financial frictions and the direction the policy change?
- Do Cooperative and Non-Cooperative (nationally-oriented) policies differ? how?

What we do in this paper

Set a **Multi-Country** Open Economy Model with Financial **Frictions**

⇒ verify (*domestic and international*) welfare spillovers of **Policies** stemming from different locations.

Countries: Center-Peripheries setup (3 Countries).

Center: Global Creditor

EMEs/Periphery: Country that depends on lending from Center.

Friction: Agency friction in financial lending that amplify credit spreads.

Policy: Macroprudential tax or leverage cap on banks.

In addition I verify how the policy changes by type of **regime:**

Regimes: 3 Countries ⇒ can study Cooperative, Semi-Cooperative (Coalitions) and Non-Cooperative cases.

Contribution: Study interactions of peripheries with general equilibrium effects but that still fragile to a center.

Explore different types of cross-border effects (Periphery-Periphery and Periphery-Center)

Related Literature

- **Financial Accelerator Channel:**

  Bernanke, Gertler and Gilchrist (1999), Gertler and Kiyotaki (1997), Bernanke and Gertler (1989)

- **Explicit banks modelling**:

  Gertler and Karadi (2011, JIE), Gertler and Kiyotaki (2010), Adrian and Shin (2010)

- **Macroprudential issues in EMEs:**

  Bianchi (2011, AER), Nuguer (2016), Nuguer and Cuadra (2016, RED), Benigno, Kiyotaki, Aoki (2018, wp), Cespedes, Chang and Velasco (2017, JIE)

- **Macroprudential Policy Leakages.**

  Empirical: Buch and Goldberg (2017, IJCB), Aiyar, Calomiris, and Wieladek (2017, JMCB), Forbes, Reindhart, and Wieladek (2017, JME), Forbes (2020), Tripathy (2020, JIE), Richter, Schularick, and Shim (2019, JIE)

  Modeling: Banerjee, Devereux, and Lombardo (2016), Agenor, et al. (2021, JMCB), Dennis and Ilbas (2023)

This paper: Multiperipheral environment with effects from Center and EMEs.

literature elements in model

Results Preview:

- Welfare Effects of MaP: Present on the target and **abroad**.
- **Policy Spillovers** Depend on Intermediation (production) disruption, Asset Positions (NFA), Global assets and rates (banking profits).
- Spillovers **grow with financial friction**
- General Equilibrium Effects (of MaP) $\longrightarrow$ **Interdependent Frictions** (Credit Spread)
- Centralized Policies are Conservative: **Prevent excessive interventionism**.
- More realistic features (e.g., **persistent policies**) **amplify welfare spillovers** of policy and differences across regimes (could increase scope for cooperation)

The Model: Simple two period economy with a Static Banking Sector

2 periods (t = 1,2 — finite horizon), three country model with two EMEs (a,b) and a Center (c)

LOE framework: size of each economy is n_i with $i = \{a, b, c\}$, $\sum_i n_i = 1$, and $n_c \geq \frac{1}{2}$.

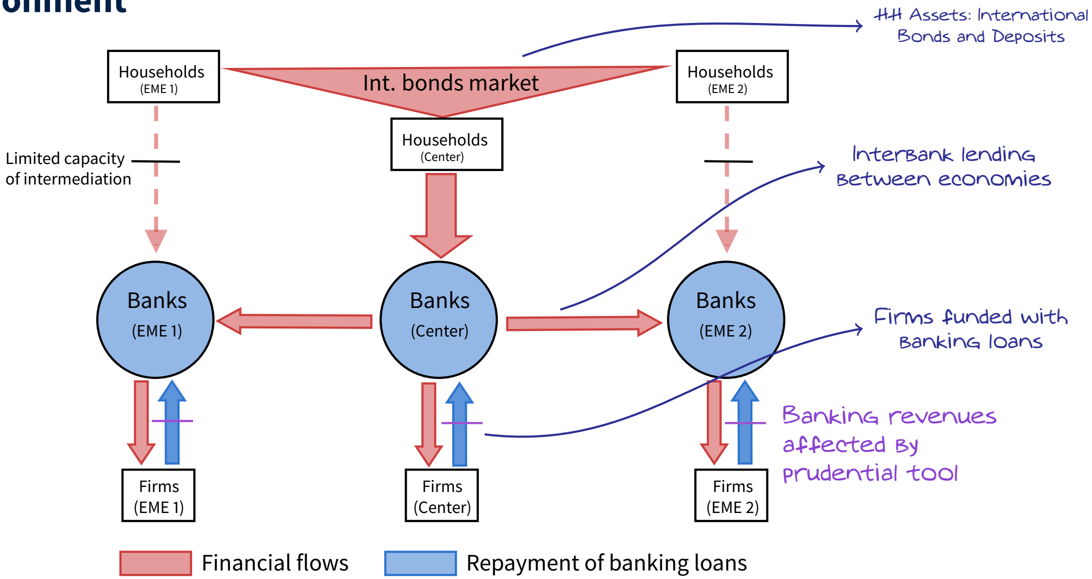
Capital: Used for production. Given at $t = 1$, funded with banking at $t = 2 \Rightarrow$ **1 period** of banking intermediation

Simplifications: LOP, PPP, UIP holds. Homogeneous (and freely traded) consumption good.

Agent	**Role**
Households	Buy consumption goods, assets (bonds, deposits), own firms, and pay lump sum tax (-)
Investors	Buy old capital and produce new capital goods to generate investment
Firms	Produce final good, sell undepreciated capital. **Funds capital with banking loans**
Government	Balanced budget, levies macroprudential tax on banks, rebates it to households
Banks	Lend to firms and participate in the interbank market (EMEs borrow from Center). Exist for only one period **Subject to a costly enforcement friction** $\Rightarrow$ **charged with a MaP Tax**

Households | Final Good Firms | Capital Firms | Banks | Government | Skip

Environment



Investors

Investment separated from the household decisions and subject to adjustment costs $\Rightarrow$ Capital Relative Price is dynamic.

The investor solves:

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

Where $\bar{I}$ is the reference level (we choose I_0).

the F.O.C is,

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

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

$$Q_2 = 1 + \frac{\zeta}{2}$$

back

Firms

Technology: The firm operates with a Cobb-Douglas technology that aggregates capital: $Y_t = A_t(\xi_t K_{t-1})^\alpha$.

A_t is the TFP, and ξ_t is a capital specific efficiency shock.

Capital:

- First period: given capital (K_0), rented directly to firms by households $\rightarrow$ Standard Firm PMP in $t = 1$
- Capital dynamics for accumulation period: $K_1 = I_1 + (1-\delta)\xi_1 K_0$
- Second period: **Firm relies on lending for funding capital accumulation** $\rightarrow$ firms fund K_1 with banks loans.

The problem of the firm in the second period is:

$$\max_{K_1} \pi_{f,2} = Y_2 + Q_2(1-\delta)\xi_2 K_1 \quad - \underbrace{\tilde{R}_{k,2} Q_1 K_1}_{\text{Repayment to bank}} \qquad s.t. \quad Y_2 = A_2(\xi_2 K_1)^\alpha$$

back

Gross Intermediation Returns

Solving from F.O.C., we get $R_{k,2}$, the gross **return from intermediation for the bank**

This rate will be variable targeted by the policy tool:

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

After tax rate

With $r_2 = \frac{\partial Y_2}{\partial K_1}$ and τ is the **macro-prudential policy tool**: a tax/subsidy on the bankers revenue rate.

The tax is NOT paid by the firms but by the banks directly.

This tool is analogous to a leverage ratio requirement..

Government

Setting and enforcing the rate is the only role of the government which will have a balanced budget constraint:

$$T + \tau r_2 K_1 = 0$$

back

Banks

- Target sector of MaP Policies. Set up based in Gertler and Karadi (2011).
- Financial intermediation sector in $t = 1$ that provides funding
  - At interbank and firms level.

Financial under-development of the EMEs will be reflected:

- **Financial Friction**: Banks subject to Incentive Compatibility Constraint $\rightarrow$ can divert a portion of assets intermediated.

  After realizing the return on capital holdings
- Limited capacity of intermediation

  Not able to hold local deposits from households

  Relies on foreign lending from the center bank in order to supply capital to the firms.

data

Banks

Agency problem: debtor bank can default and divert a portion κ of the assets.

The EME bank solves:

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

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

$$J_1 \geq \kappa \, \mathbb{E}_1 \Lambda_{1,2} R_{k,2} L_1 \qquad \text{[ICC]}$$

$L_1 = Q_1 K_1$: total lending intermediated, F_1: foreign borrowing and $\delta_B Q_1 K_0$: household bequest.

The F.O.C. implies a positive credit spread when the ICC binds:

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

μ: Lagrange multiplier of the ICC.

κ: Financial Friction Parameter.

back

Banks

The center economy bank is frictionless and solves:

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

$$s.t. \quad F^a_1 + F^b_1 + L^c_1 = D_1 + \delta_b Q^c_1 K^c_0$$

the associated F.O.C. are:

$$\begin{aligned} [F^a_1]: &\quad \mathbb{E}_1 (R^a_{B,1} - R_{D,1}) = 0 \\ [F^b_1]: &\quad \mathbb{E}_1 (R^b_{B,1} - R_{D,1}) = 0 \\ [L^c_1]: &\quad \mathbb{E}_1 (R^c_{k,2} - R_{D,1}) = 0 \end{aligned}$$

Here the problem and conditions are simpler given there is No agency problem in the Center

back

But: Notice the FOCs imply that by regulating banks (via $R^c_{k,2}$) the Center affects the frictions at EMEs (via $R_{B,1}$) $\rightarrow$ General Equilibrium Effect

Leverage and Credit Spread Implications from banking setup

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

From EME Banks F.O.C.:

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

$\Phi > 1$ guarantees the credit spread is positive. The larger Φ the greater the spread ($R_{k,2} - R_1 \propto \Phi$).

$\mu > 0$ (def. of binding ICC). It follows that,

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

and,

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

Relevant result to understand the role of the friction $\longrightarrow$ can exogenously increase financial friction by $\uparrow \kappa$

Macroprudential policy tool

Several MaP policies available. We consider one of the general types, a **tax targeted at the banks**. This can encompass other types of policies (leverage constraints, capital controls, among others).

We can map the leverage with the MaP Tax:

Proposition 2: *An increase in the tax lowers the leverage ratio of banks*

$$L_1 = \underbrace{\frac{R^e_{b,1}}{R^e_{b_1} - (1-\kappa^e)R_{k,2}}}_{\phi_L:\ \text{leverage ratio}} \delta_B Q^e_1 K^e_0$$

We can substitute $R^e_{k,2} = \frac{(1-\tau^e)r^e_2 - (1-\delta)\xi^e_2 Q_2}{Q_1}$ and differentiate with respect to τ^e:

$$\frac{\partial \phi_L}{\partial \tau^e} = -\frac{(1-\kappa^e)R^e_{b,1}(r^e_2)}{(R^e_{b,1} - (1-\kappa^e)R^e_{k,2})^2 Q^e_1} < 0$$

A higher tax
lowers the leverage

Skip

Households

The household lifetime utility is given by $U = u(c_1) + \beta u(c_2)$ with $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$.

The budget constraints in each period are:

Start-up capital for Banks

Emerging markets:

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

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

Banking profits

Advanced Economy:

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

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

HH (F.O.C.)

Market Clearing

- Int. Bonds: given at zero-net-supply

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

- Goods:

$$n_a \left(C_1^a + C(I_1^a)\right) + n_b \left(C_1^b + C(I_1^b)\right) + n_c \left(C_1^c + C(I_1^c)\right) = n_a Y_2^a + n_b Y_2^b + n_c Y_2^c$$

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

where $C(I_1) = I_1(1 + (I_1/\bar{I} - 1)^2)$

Finally, given that there is only one final good and the law of one price holds ($RER = 1$), we have by the UIP:

$$R_1^a = R_1^b = R_1^c = R_1$$

where R denotes the world interest rate on bonds.

Simplified Equations used for solving the model (summary)

Common to all countries:

$$Q_1 = 1 + \frac{\zeta}{2}\left(\frac{I_1}{\bar{I}} - 1\right)^2 + \zeta\left(\frac{I_1}{\bar{I}} - 1\right)\frac{I_1}{\bar{I}} \quad \text{[Price of Capital]}$$

$$K_1 = I_1 + (1-\delta)K_0 \quad \text{[Capital Dynamics]}$$

$$R_{k,2} = \frac{(1-\tau)\alpha A_2 K_1^{\alpha-1} + (1-\delta)Q_2}{Q_1} \quad \text{[Banks rate of return]}$$

$$C_1^{-\sigma} = \beta R_1 C_2^{-\sigma} \quad \text{[Euler Equation w.r.t. Bonds]}$$

for EMEs:

$$R_{k,2}Q_1K_1 - R_1Q_1K_1 + R_1\delta_B Q_1 K_0 = \kappa R_{k,2}Q_1K_1 \quad \text{[ICC]}$$

$$R_{k,2} - R_1 = \mu\left(\kappa R_{k,2} - (R_{k,2} - R_1)\right) \quad \text{[Credit Spread]}$$

$$C_1 + \frac{B_1}{R_1} = A_1K_0^{\alpha} + Q_1I_1 - C(I_1) - \delta_b Q_1 K_0 \quad \text{[BC for t=1]}$$

$$C_2 = (1-\alpha)A_2K_1^{\alpha} + R_{k,2}Q_1K_1 - R_1Q_1K_1 + R_1\delta_B Q_1K_0 + B_1 + \tau r_2 K_1 \quad \text{[BC for t=2]}$$

for the Center:

$$Q_1^aK_1^a - \delta_B Q_1^a K_0^a + Q_1^bK_1^b - \delta_B Q_1^b K_0^b + Q_1^cK_1^c = D_1 + \delta_B Q_1^c K_0^c \quad \text{[Bal. Sheet of Banks]}$$

$$C_1 + \frac{B_1}{R_1} + D_1 = A_1K_0^{\alpha} + Q_1I_1 - C(I_1) - \delta_B Q_1 K_0 \quad \text{[BC for t=1]}$$

$$C_2^c = (1-\alpha)A_2^cK_1^{c\,\alpha} + R_1Q_1^aK_1^a - R_1\delta_B Q_1^aK_0^a + R_1Q_1^bK_1^b - R_1\delta_B Q_1^bK_0^b + R_1Q_1^cK_1^c + B_1^c + \tau^c r_2^c K_1^c \quad \text{[BC for t=2]}$$

International Links:

$$n_aB_1^a + n_bB_1^b + n_cB_1^c = 0 \quad \text{[Zero Net Supply of Bonds]}$$

Analytical Welfare Analysis

We set a Social Planner Problem (SPP) and analyze welfare expressions (following Davis and Devereux, 2022):

Welfare set as $W = U + \lambda_1 BC_1 + \beta\lambda_2 BC_2$:

$$W^s = U^s + \lambda_1^s\left(r_1^s K_0^s + \pi_{f,1}^s + \pi_{inv,1}^s - \delta_B Q_1^s K_0^s - C_1^s - \frac{B_1^s}{R_1^s}\right) + \beta\lambda_2^s\left(\pi_{f,2}^s + \pi_{b,2}^s + B_1^s - T^s - C_2^s\right) \quad \text{for } s = \{a, b\} \qquad \text{(For EMEs)}$$

$$W^c = U^c + \lambda_1^c\left(r_1^c K_0^c + \pi_{f,1}^c + \pi_{inv,1}^c - \delta_B Q_1^c K_0^c - C_1^c - \frac{B_1^c}{R_1^c} - D_1\right) + \beta\lambda_2^c\left(\pi_{f,2}^c + \pi_{b,2}^c + B_1^c + R_{D,1} D_1 - T^c - C_2^c\right) \qquad \text{(For the Center)}$$

A (non-cooperative) planner will maximize the welfare of her country W^j.

Alternatively, welfare optimization could be centralized.

▸ Welfare Analysis Method steps

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

$$W^s = u(C_1^s) + \beta u(C_2^s) + \lambda_1^s \left(A_1^s K_0^{s\ \alpha} + Q_1^s I_1^s - C(I_1^s) - C_1^s - \frac{B_1^s}{R_1^w} \right) \quad \text{EMEs}$$

$$+ \beta\lambda_2^s \left(\phi(\tau^s) A_2^s K_1^{s\ \alpha} + \kappa^s (1-\delta) Q_2^s K_1^s + B_1^s - C_2^s \right) \quad \text{for } s = \{a, b\}$$

$$W^c = u(C_1^c) + \beta u(C_2^c) + \lambda_1^c \left(A_1^c K_0^{c\ \alpha} + Q_1^c I_1^c - C(I_1^c) - C_1^c - D_1^c - \frac{B_1^c}{R_1^w} \right)$$

$$+ \beta\lambda_2^c \left(A_2^c K_1^{\alpha} + R_{b,1}^a F_1^a + R_{b,1}^b F_1^b + (1-\delta) Q_2^c K_1^c + B_1^c - C_2^c \right) \quad \text{Center}$$

with $\phi(\tau) = 1 - \alpha(1-\kappa)(1-\tau)$

From this welfare expressions we will **obtain the effects of taxes via implicit differentiation** and simplify them further with the Competitive Equilibrium FOCs.

Welfare Effects

SPP + Private Eq. FOCs $\longrightarrow$ simplified welfare expressions (Davis and Devereux, 2022)

Each nationally-oriented planner takes W^i as their welfare function ($W^i = u(C_1^i) + \beta u(C_2^i)$)

Direct Effects (of tax change on its location)

Welfare effect of the tax for EMEs:

Effect grows with friction and tax

$$\frac{dW^a}{d\tau^a} = \beta\lambda_2^a\{\underbrace{\alpha_1(\kappa^a)\frac{dK_1^a}{d\tau^a}}_{①} + \underbrace{\frac{B_1^a}{R_1^w}\frac{dR_1^w}{d\tau^a}}_{②} + \underbrace{R_1^w I_1^a\frac{dQ_1^a}{d\tau^a}}_{③} + \underbrace{\alpha(1-\kappa^a)Y_2^a}_{\text{Direct effect of } \tau}\}$$

Debt position changes effect

with $\alpha_1(\kappa^a) = (\phi(\tau^a)\alpha A_2^a K_1^{a\ \alpha-1} + \kappa^a(1-\delta)Q_2^a)$ and $\alpha_1'(\kappa^a) > 0$

①: Halting of K Accumulation. [Negative welfare effect].

②: Net Foreign Assets (NFA) variation effect: Sign changes for borrower/lender.

③: Variation in investment profits.

Welfare Effects

Direct effect for Center:

$$\frac{dW^c}{d\tau^c} = \beta\lambda_2^c \left\{ R_1^w I_1^c \frac{dQ_1^c}{d\tau^c} + \frac{B_1^c}{R_1^w}\frac{dR_1^w}{d\tau^c} + \alpha_2 \frac{dK_1^c}{d\tau^c} + \underbrace{\left[R_{b,1}^{eme}\left(\frac{dF_1^a}{d\tau^c} + \frac{dF_1^b}{d\tau^c}\right) + \frac{dR_{b,1}^{eme}}{d\tau^c}\left(F_1^a + F_1^b\right)\right]}_{\text{welfare effect of changes in intermediation profits } (4)} \right\}$$

Reflects position as global creditor

with $\alpha_2 = \left(\alpha A_2^c K_1^{c\ \alpha-1} + (1-\delta)Q_2^c\right)$

New: (4): Change in Global Intermediation Profits [Sign: ambiguous] (and also (1), (2), (3))

Then: Policy Trade-off at Center $\longrightarrow$ Cooling financial sector (frictions) vs. Boosting intermediation profits.

Cross-country effects: similar structure, but without direct effects for peripheries.

Cross-country Effects

Optimal tax

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

$$\tau^{a\,*} = -\frac{1}{\alpha(1-\boldsymbol{\kappa^a})}\left\{\frac{1}{\boldsymbol{r_2^a}}\left[\left(R_1 I_1^a \frac{dQ_1^a}{dK_1^a} + \frac{B_1^a}{R_1}\frac{dR_1}{dK_1^a}\right) + \boldsymbol{\kappa^a}(1-\delta)\xi_2^a Q_2\right] + 1 + \alpha(\boldsymbol{\kappa^a} - 1)\right\}$$

Relevant features:

- Scale of instrument: **amplified with the friction** (κ)

- Tax decreases with Marginal Productivity of K

- whether Investment $\lessgtr \bar{I}$

- country being a saver of borrower and change in international bonds rate

Similar process for obtaining an expression for the optimal tax in the center.

▶ Center tax

Gauging the Effects from Policy

The model can be solved numericallly for different combination of taxes for gauging the effects of policy:

Capital Accumulation effects

		Baseline	Increased frictions everywhere (by 25%)	Increased friction in country a (by 25%)
		Effect on capital		
Direct effect	$\tau^a \rightarrow K_1^a$	-0.168	-0.121	-0.120
	$\tau^b \rightarrow K_1^b$	-0.168	-0.121	-0.169
	$\tau^c \rightarrow K_1^c$	-0.441	-0.437	-0.439
Cross-border effect	$\tau^a \rightarrow K_1^b$	0.004	0.002	0.002
	$\tau^a \rightarrow K_1^c$	-0.012	-0.009	-0.008
	$\tau^b \rightarrow K_1^a$	0.004	0.002	0.003
	$\tau^b \rightarrow K_1^c$	-0.012	-0.009	-0.014
	$\tau^c \rightarrow K_1^a$	0.012	0.009	0.009
	$\tau^c \rightarrow K_1^b$	0.012	0.009	0.012
		Effect on financial intermediation		
Direct effect	$\tau^a \rightarrow Int_1^a$	-0.049	-0.040	-0.038
	$\tau^b \rightarrow Int_1^b$	-0.049	-0.040	-0.052
	$\tau^c \rightarrow Int_1^c$	-0.035	-0.044	-0.039
Cross-border effect	$\tau^a \rightarrow Int_1^b$	0.012	0.006	0.008
	$\tau^a \rightarrow Int_1^c$	-0.008	-0.010	-0.010
	$\tau^b \rightarrow Int_1^a$	0.012	0.006	0.009
	$\tau^b \rightarrow Int_1^c$	-0.008	-0.010	-0.010
	$\tau^c \rightarrow Int_1^a$	0.036	0.031	0.027
	$\tau^c \rightarrow Int_1^b$	0.036	0.031	0.041

Stricter Center's regulations generates a substitution of intermediation towards EMEs

Trade-off between macro perfomance and financial stability: Lower for EMEs with stronger frictions

Extension: Role of Dynamic Policymaking

A Model with Dynamic Policymaking

Simplified baseline assumes a single period of banking intermediation $\Rightarrow$ policy only have static effects

What if we allow policy to have **persistent effects**?

Planner internalizes this and decision making becomes dynamic $\rightarrow$ What difference does this make?

Extended model: Analogous setup to previous baseline but now there are three periods $t = \{1, 2, 3\}$

Agents have analogous roles to before.

Capital is given initially but afterwards is funded with loans $\rightarrow$ **Two periods of intermediation**

Banking environment (decisions and policy implications) change substantially (due to profits retaining)

Main change:

τ_2 has contemporaneous and future effects via retained banking profits $\longrightarrow$ it is a **forward-looking tool**

τ_3 only affects the contemporaneous profits of the terminal period $\longrightarrow$ it is a **static tool** (as before)

Households Final Good Firms Capital Firms Bank-EMEs Bank-Center Government Skip

Households

The household lifetime utility is given by $U = u(c_1) + \beta u(c_2) + \beta^2 u(c_3)$ with $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$.

Budget constraints:

Emerging markets:

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

$$C_2^s + \frac{B_2^s}{R_2^s} = \pi_{f,2}^s + \pi_{inv} + \pi_{bank,2}^s - \delta_B Q_2^s K_1^s + B_2^s - T_2^s, \quad for\ s = \{a, b\}$$

$$C_3^s = \pi_{f,3}^s + \pi_{bank,3}^s + B_2^s - T_3^s, \quad for\ s = \{a, b\}$$

Advanced Economy:

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

$$C_2^c + \frac{B_2^c}{R_2^c} + \boldsymbol{D_2} = \pi_{f,2}^c + \pi_{inv,2}^c + \boldsymbol{\pi_{bank,2}^c} - \delta_B Q_2^c K_1^c + R_{D,1} D_1 + B_1^c - T_2^c$$

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

back to summary

Investors

The investment decision is made intertemporal to emphasize on the dynamic effects.

How? $\rightarrow$ adjustment costs penalize the growth in investment (and not only departure from SS).

The investor solves:

$$\max_{I_1} \mathbb{E}_t \sum_{i=0}^{2} \Lambda_{t,t+i} \left\{ Q_{t+i} I_{t+i} - I_{t+i} \left(1 + \frac{\zeta}{2} \left(\frac{I_{t+i}}{I_{t+i-1}} - 1 \right)^2 \right) \right\}$$

the F.O.C is,

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

For the first period, we take as I_0 the Steady state value. We will abstract from the last term for $t = 3$.

back to summary

Firms

Technology: The firm operates with a Cobb-Douglas technology that aggregates capital: $Y_t = A_t(\xi_t K_{t-1})^\alpha$

Capital:

- The capital dynamics for an accumulation period: $K_t = I_t + (1-\delta)\xi_t K_{t-1}$
- First period: given (K_0), rented directly to firms by households => Standard Competitive Firm PMP in $t = 1$
- Other periods: **the EME relies on lending for funding capital accumulation** $\rightarrow$ firms fund K_1 with banks loans.

The problem of the firm for $t = 2, 3$ is:

$$\max_{K_t} \pi_{f,t} = Y_t + \underbrace{Q_t(1-\delta)\xi_t K_1}_{\text{sales of leftover capital}} - \underbrace{R_{k,t}Q_{t-1}K_{t-1}}_{\text{repayment to banks}} \qquad s.t. \quad Y_t = A_t(\xi_t K_{t-1})^\alpha$$

back to summary

Intermediation Returns & The Government

From the F.O.C. we get $R_{k,t}$, the gross **return from intermediation for the bank**. This is the variable targeted by the policy tool:

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

After tax rate

for $t = \{2, 3\}$ and with $r_t = \alpha \frac{Y_t}{K_{t-1}}$

τ_t is the macro-prudential policy tool: a tax/subsidy on the bankers revenue rate.

Notice:

τ_2 has contemporaneous and future effects via retained banking profits $\longrightarrow$ it is a **forward-looking tool**

τ_3 only affects the contemporaneous profits of the terminal period $\longrightarrow$ it is a **static tool**

Government:

Setting and enforcing the rate is the only role of the government which will have a balanced budget constraint:

$$T_t + r_t K_{t-1} = 0$$

back to summary

Banks

The EME bank's problem in $t = 1$: maximize the expected franchise present value

$$J_1 = \max_{F_1, L_1} \mathbb{E}_1 \Big\{ \overbrace{(1-\theta)\Lambda_{1,2}(R_{k,2}L_1 - R_{B,1}F_1)}^{\text{Pr(Exit)*profits}_{t=2}} + \overbrace{\Lambda_{1,3}\theta(R_{k,3}L_2 - R_{B,2}F_2)}^{\text{Pr(Survive)*profits}_{t=3}} \Big\}$$

$$\begin{aligned} s.t \quad & L_1 = F_1 + \delta_B Q_1 K_0 && \text{[Balance sheet } t=1\text{]} \\ & L_2 = F_2 + \delta_B Q_2 K_1 + \theta[R_{k,2}L_1 - R_{B,1}F_1], && \text{[Balance sheet } t=2\text{]} \\ & J_1 \geq \kappa \cdot Q_1 K_1, && \text{[ICC } t=1\text{]} \end{aligned}$$

where the $L_1 = Q_1 K_1$ is the total lending intermediated. F_1 is the foreign lending, θ is the survival rate of the banks. $\Lambda_{t,t+j}$ is a Stochastic Discount Factor j periods apart.

Future (Bal. sheet) profits' changes are internalized now

The F.O.C. implies a positive credit spread when the ICC binds:

$$[F_1]: \qquad \Omega_1(1-\mu_1)(R_{k,2} - R_{B,1}) = \mu \cdot \kappa$$

μ: lagrange multiplier of the ICC $\qquad \Omega_1 = (1-\theta)\Lambda_{1,2} + \theta^2 R_{k,3}\Lambda_{1,3}$ (effective SDF of banks)

Banks

Bank's problem for $t = 2$: Max. value of the bank **but with NO continuation value**.

$$J_2 = \max_{F_2, L_2} \mathbb{E}_2 \left\{ \Lambda_{2,3} (R_{k,3} L_2 - R_{B,2} F_2) \right\}$$

Problem still different from baseline due to retained profits

$s.t.$

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

$$J_2 \geq \kappa Q_2 \cdot K_2 \qquad \text{[ICC } t = 2\text{]}$$

where the $L_1 = Q_1 K_1$ is the total lending intermediated.

the F.O.C. implies a positive credit spread when the ICC binds:

$$[F_2]: \qquad \mathbb{E}_2 (R_{k,3} - R_{B,2}) = \mu_2 \cdot [\kappa - \mathbb{E}_2 (R_{k,3} - R_{B,2})]$$

back to summary

Banks

In $t = 1$ the center economy bank solves:

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

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

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

Future balance sheet with expected retained profits

the associated F.O.C. are:

$$[F_1^a] : \qquad \mathbb{E}_1\Omega_1(R_{B,1}^a - R_{D,1}) = 0$$

$$[F_1^b] : \qquad \mathbb{E}_1\Omega_1(R_{B,1}^b - R_{D,1}) = 0$$

$$[L_1^c] : \qquad \mathbb{E}_1\Omega_1(R_{k,2}^c - R_{D,1}) = 0$$

With no agency problem in the Center FOC just reflect an zero credit spread in expectation.

Banks

In $t = 2$ the center economy bank solves:

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

$$s.t$$

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

the associated F.O.C. are:

$$[F_2^a]: \qquad \mathbb{E}_2(R_{B,2}^a - R_{D,2}) = 0$$

$$[F_2^b]: \qquad \mathbb{E}_2(R_{B,2}^b - R_{D,2}) = 0$$

$$[L_2^c]: \qquad \mathbb{E}_2(R_{k,3}^c - R_{D,2}) = 0$$

back to summary

Analytical Welfare Effects

Similar to before we can set the SPP and find the welfare effects with **dynamic policymaking**

The structure analogous but the additional terms help explain the magnified effects.

Example:

$$\frac{dW_0^a}{d\tau_2^a} = \beta\lambda_2^a \left\{ \overbrace{\alpha_1(\kappa)\frac{\mathbf{dK_1^a}}{\mathbf{d\tau_2^a}} + \alpha_2(\kappa)\frac{\mathbf{dQ_1^a}}{\mathbf{d\tau_2^a}} + \frac{B_1^a}{R_1}\frac{\mathbf{dR_1}}{\mathbf{d\tau_2^a}} + \alpha Y_2^a}^{\text{static effects}} + \overbrace{\alpha_3(\kappa)\frac{\mathbf{dK_2^a}}{\mathbf{d\tau_2^a}} + \alpha_4(\kappa)\frac{\mathbf{dQ_2^a}}{\mathbf{d\tau_2^a}} + \frac{B_2^a}{(R_2)^2}\frac{\mathbf{dR_2}}{\mathbf{d\tau_2^a}}}^{\text{dynamic effects}} \right\}$$

The effects grow with the financial distortion: $\frac{\partial \alpha_s(\kappa)}{\partial \kappa} > 0$ for $s = \{1, 2, 3, 4\}$.

Other expressions

Similar Drivers of Welfare effects:

(i) Hindering K accumulation **(-)**

(ii) Changes in global rates ($\propto$ NFA)

(iii) Changes in prices of capital

(iv) Changes in cross-border rates and quantities **(for Center)**

Implications for Policy Design

Welfare effects for different regimes

The policy leakages from the prudential tool can have distinct design implications for different policy choices:

Nationally oriented regimes: The planners maximize domestic welfare at each location (set τ^j to max. W^j)

Alternative: (full and semi) Centralized regimes would account for effects in multiple locations:

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

Note: $j = a, b, c$

Implied Optimal Choices by Regime

Table: Ramsey-Optimal taxes under each policy setup

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

Units: proportional tax on banking rate of return

- Frequent Policy: set a **Tax to undo the friction** ($\downarrow$ Credit Spread)
- Taxes are **lower under cooperation**
- **Taxes by Center**: larger ($\approx 3 \times \tau^{eme}$)
- Center tax is set with different aims: to foster trade of assets and intermediation ($\downarrow$ price of bonds and implicit subsidy to demand of EME Banks)

Policy trade-off:
$\uparrow$ Production vs. Undoing Friction

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Units: proportional tax on banking rate of return

Policy trade-off:
↑ Production vs. Undoing Friction

- Frequent Policy: set a Tax to undo the friction (↓ Credit Spread)
- Taxes are **lower under cooperation** $\longrightarrow$ [More effective regulation]
- **Taxes by Center**: larger ($\approx 3 \times \tau^{eme}$)
- Center tax is set with different aims: to foster trade of assets and intermediation
  (↓ price of bonds and implicit subsidy to demand of EME Banks)

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  (↓ price of bonds and implicit subsidy to demand of EME Banks)

Policy trade-off:
↑ Production vs. Undoing Friction

Effects of policies

Natural question: How the outcomes of these regimes differ?

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

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

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

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

- World level: friction mitigated, **FB mimicked** by all Ramsey Equilibria $\Rightarrow$ No Cooperation Gains
- Substantial **Welfare Improvement wrt No Policy** setup
- Equivalent to 4% Consumption increase
- Policy is helpful but regime choice is not relevant: Even with divergent Interventionism!
- This is due to frictionless policy environment **and can change**.

Results with $\sigma = 1.5$

Changed policy environment: Policy Implementation Costs

Now we break the flexibility of the policy tool. Can no longer be set without costs:

The welfare for the planner now is:

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

with: $\boldsymbol{\Gamma(\tau^j) = \psi(\tau^j)^2}$

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

Outcomes by Regimes: Policy Implementation Costs

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

- Large Cost $\rightarrow$ Significantly lower taxes everywhere

- **Gains from Coordination for all countries and at the world level**

- **FB at world level is achieved by all policies but Nash**

Conclusions

- I study the presence and determinants of **international macroprudential policy spillovers** in an open economy framework with several emerging economies integrated to a center.
- Question of interest: Does Macroprudential policy leak? What is the nature of the policy spillovers?
- An additional periphery is included to determine value of modeling regional interactions
  - Given the 2nd EME: Can verity Policy Spillovers from different directions and multiple regimes
- Policy tool: **taxes on banking** sector revenues OR Leverage Requirement
- Non-trivial **prudential policy leakages that are magnified** if policy effects are lasting.
- Toolkit scale and effects are also amplified by the **extent of financial frictions**.
- Centralized policies imply less interventionism: **Higher regulatory efficiency**
- **Welfare differences across regime may appear** when policy frictions are assumed.

Thank You!

Questions and feedback are welcome!

camilo.granados@utdallas.edu

Appendix

Ramsey Planner Problem

Policy problem that allows us to recover the optimal tool levels.

The Ramsey planner maximizes an objective function subject to the private decisions of agents.

Generally:

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

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

$F(\cdot)$: System of equations that characterize private equilibrium (e.g., FOC, BC and MC Conds)

$\mathbf{x_t}$: Endogenous (decision) variables to agents. θ: Other parameters.

I set 4 possible setups: Nash and 3 types of cooperation.

Nash

In each country a planner solves:

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

for $t = 1$.

In this case we compute an *Open Loop Nash Equilibrium*: Each planner j will only take the tools of the other players (τ^{-j}) as given and decide on optimal actions ($\mathbf{x^j_t}, \tau^j_t$) at the start of the game.

Cooperative cases

Table: Cooperative Cases

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

Note: $j = a, b, c$

In all cases the constraints are the same: $\mathbb{E}_t F(\mathbf{x_{t-1}}, \mathbf{x_t}, \mathbf{x_{t+1}}, \tau_t, \theta)$

Results: Baseline - No policy setup and First Best

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

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Country	First Best	Nash	Coop (All)	Coop (EMEs)	Coop (Center and EME-A)
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Units: **Proportional steady state consumption increase** in the baseline (No Policy) model

- World level: friction mitigated, **FB mimicked** by all Ramsey Equilibria $\Rightarrow$ No Cooperation Gains

- Country level: Distributional issues (against EMEs)

  No scope for Pareto improvements

Results with $\sigma = 1.5$

Results: Baseline - No policy setup and First Best

Country	Nash	Coop (All)	Coop (EMEs)	Coop (Center and EME-A)
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World	1.00	1.00	1.00	1.00
EME Block	0.99	0.99	0.99	0.99

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EME Block	1.03	1.02	1.03	1.02	1.02

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- World level: friction mitigated, FB mimicked by all Ramsey Equilibria $\Rightarrow$ No Cooperation Gains
- Country level: Distributional issues (against EMEs)

  No scope for Pareto improvements
- Substantial **Welfare Improvement wrt No Policy** setup
- Equivalent to 4% Consumption increase

Results with $\sigma = 1.5$

Explained results

- Baseline model shows No gains from cooperation.

- Experiments can generate gains, but small.

experiments

Explained results

- Baseline model shows No gains from cooperation.

- Experiments can generate gains, but small. experiments

Can we rationalize this based on Korinek (2020, REStud)?

Cooperation Gains exist only if Nash Eq. is Pareto Inefficient and fails to achieve FB

First Welfare Theorem of Open Economies: The Nash Eq. is Pareto Efficient IF conditions 1-3 hold.

1. *Competition:* Policy makers act as **price takers** by not manipulating international assets prices.
2. *Sufficient Instruments:* The policy tool is **flexible and effective** enough.
3. *Frictionless International Markets:* International market for assets is free of imperfections and frictions.

In my model **2-3** hold.

1 not necessarily (LOE assumption), hence the **small gains** $\longrightarrow$ but the effect is not strong enough.

We can exacerbate the effects by breaking down 2,3 Cases: Policy Costs Frictions in All Countries

References followed for the model setup

Article	**Feature used in the model**
Gertler and Karadi (2011, JME), *A model of unconventional monetary policy*	framework for modelling the balance sheet of banks and financial constraint.
Banerjee, Devereux and Lombardo (2016, JIMF) *Self-oriented monetary policy, global financial markets and excess volatility of international capital flows*	General equilibrium model structure for center and periphery.
Cespedes, Chang and Velasco (2017, JIE): *Financial Intermediation, Real Exchange Rates, and Unconventional Policies in an Open Economy*	Modelling of banks in finite horizon
Davis and Devereux (2019, NBER wp): *Capital Controls as Macro-prudential Policy in a Large Open Economy*	Analytical welfare analysis method (and coordination gains framework)

Back to Literature

Welfare Analysis Methodology Description

The welfare analysis method is borrowed from Davis and Devereux (2019, NBER wp)

0. Characterize Competitive Equilibrium Conditions.
1. Set a Social Planner Problem: individual welfare is $W^j = U^j + \lambda_1^j BC_1^j + \beta\lambda_2^j BC_2^j$ or jointly as the weighted sum.
2. Substitute from CEq conditions variables/equations characterizing optimal behaviour of non-household decision variables (profits of bankers and constraints, production, taxes rebate, etc.)
3. Obtain welfare effects **via implicit differentiation**: here we recognize that the CEq-derived variables are a function of the taxes (taken as exogenous by agents). $\rightarrow$ *Tax distorted equilibrium*
4. Based on numerical/calibrated estimation of CEq, obtain approximated values of welfare effects and optimal taxes.

Back to Welfare Analysis

Cross-country Effects

The welfare effect between emergent countries is,

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

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

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

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

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

Optimal tax (cont.)

For c:

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

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

- prevalent **role for cross-border lending** variables.

- Quantities role is analogous to physical capital effects on EMEs.

In both expressions: Inside brackets sign may not coincide: policy trade-off.

back

Simulation choices

The model is solved using non-linear methods. For private model must provide the taxes.

Parameter choices

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)
Fraction of capital that can be diverted	$\kappa^a = \kappa^b$	0.399	Aoki, Benigno and Kiyotaki (2019)
Discount factor	β	0.99	
Risk Aversion parameter	σ	2	
Country size	$n_a = n_b$	0.25	
Depreciation rate	δ	0.6	Targets a longer than quarterly period duration ~ 5 years
Capital share	α	0.333	

Predetermined variables: $K_0^a,\ K_0^b,\ K_0^c,\ \bar{I}^a,\ \bar{I}^b,\ \bar{I}^c$

back

Welfare gains computation

I compute the welfare gains as a proportional change in the consumption stream of the agents.

Thus, if I want to compare the welfare gains of a policy that leads to 'welfare 1' given by $W_1 = u(c_{1,1}) + \beta u(c_{1,2})$ relative to a benchmark $W_0 = u(c_{0,1}) + \beta u(c_{0,2})$ we just find the proportional change in average consumption ϕ such that:

$$W_0 = u(\boldsymbol{\phi}\bar{c}_0) + \beta u(\boldsymbol{\phi}\bar{c}_0) = W_1$$

Where $\bar{c}_0$ would be the equivalent constant stream of consumption that would yield the welfare (W_0) delivered by the baseline model.

For the CRRA we get ϕ as:

$$\begin{aligned} \frac{(\phi\bar{c}_0)^{1-\sigma}}{1-\sigma} + \beta\frac{(\phi\bar{c}_0)^{1-\sigma}}{1-\sigma} &= W_1 \\ \phi^{1-\sigma}W_0 &= W_1 \\ \phi &= \left(\frac{W_1}{W_0}\right)^{\frac{1}{1-\sigma}} \end{aligned}$$

Back to policy comparison

Welfare Effects: Consumption Equivalent Units

Table: Welfare effect of 1% increase in taxes

Direct Effects	
$\tau_a \to W^a$	-1.560
$\tau_b \to W^b$	-1.560
$\tau_c \to W^c$	-0.847
Cross-country Effects	
$\tau_a \to W^b$	-0.078
$\tau_a \to W^c$	-0.039
$\tau_b \to W^a$	-0.078
$\tau_b \to W^c$	-0.039
$\tau_c \to W^a$	-0.308
$\tau_c \to W^b$	-0.308

Table: Welfare effect - Proportional Consumption Equivalent

Direct Effects	
$\tau_a \to W^a$	0.9958
$\tau_b \to W^b$	0.9958
$\tau_c \to W^c$	0.9972
Cross-country Effects	
$\tau_a \to W^b$	0.9998
$\tau_a \to W^c$	0.9999
$\tau_b \to W^a$	0.9998
$\tau_b \to W^c$	0.9999
$\tau_c \to W^a$	0.9992
$\tau_c \to W^b$	0.9992

The welfare effect is approximated as: $\frac{\partial W^j}{\partial \tau^k} = \frac{W^j_{\tau^k=0.01} - W^j_{\vec{\tau}=0}}{\tau^k - 0}$

This is the marginal effect around the zero taxes vector, the magnitude of the effect can change depending of the benchmark point

Cooperative effects - numerical example

The cooperative welfare effects will be given by population weighted averages of the individual counterparts:

Table: Welfare effect of 1% increase in taxes: Cooperative Planners

World Planner		EME Planner		AC Coalition Planner	
$\tau_a \to W$	-0.429	$\tau_a \to W^{eme}$	-0.819	$\tau_a \to W^{ac}$	-0.546
$\tau_b \to W$	-0.429	$\tau_a \to W^{eme}$	-0.819	$\tau_a \to W^{ac}$	-0.668
$\tau_c \to W$	-0.578				

back

Households (cont.)

In the first period each household will maximize the present value of its life-time utility subject to the budget constraints for the first and second period.

The associated F.O.C.s for the three types of households are:

$$u'(C_1) = \beta R_1 u'(C_2)$$
$$u'(C_1^c) = \beta R_{D,1} u'(C_2^c)$$

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

Back to HH-UMP

Alternative microfoundation for policy cost

Change Government structure

Current: balanced budget $T + \tau r_2 K_1 = 0$

Alternative: MaP Subsidy funded by other sectors: $\tau_w W_2 L_2 + \tau_r r_2 K_1 = 0$

In that way a subsidy to the banks imply taxing the workers sector.

In the case of a Ramsey tax, wages will be pushed upwards increasing production which may be inefficient.

back

Baseline model with $\sigma = 1.5$

Table: Welfare comparison

Country	Bechmark: Nash Coop (All)	Coop (EMEs)	Coop (C+EME-A)	Bechmark: First Best Nash	Coop (All)	Coop (EMEs)	Coop (C+EME-A)
C (Center)	1.00	1.00	1.00	1.02	1.02	1.02	1.02
A	1.00	1.00	1.00	0.99	0.99	0.99	0.99
B	1.00	1.00	1.00	0.99	0.99	0.99	0.99
World	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EME Block	1.00	1.00	1.00	0.99	0.99	0.99	0.99

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

Country	Policy Scheme Nash	Coop (All)	Coop (EMEs)	Coop (Center+EME-A)
τ^a	0.86	0.37	0.75	0.83
τ^b	0.86	0.37	0.75	0.84
τ^c	1.71	1.55	1.69	1.68

Units: proportional tax on banking rate of return

Higher financial friction in one emerging economy ($\kappa^a = 0.399$, $\kappa^b = \frac{1}{2}$)

$\sigma = 1.5$

Table: Welfare comparison

	Bechmark: Nash			Bechmark: First Best			
Country	Coop (All)	Coop (EMEs)	Coop (C+EME-A)	Nash	Coop (All)	Coop (EMEs)	Coop (C+EME-A)
C (Center)	1.00	1.00	1.00	1.01	1.02	1.02	1.02
A	1.00	1.02	1.02	0.96	0.97	0.99	0.99
B	1.02	1.02	1.02	0.96	0.98	0.99	0.99
World	1.01	1.01	1.01	0.99	1.00	1.00	1.00
EME Block	1.01	1.02	1.02	0.96	0.98	0.99	0.99

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

	Policy Scheme			
Country	Nash	Coop (All)	Coop (EMEs)	Coop (Center+EME-A)
τ^a	0.68	0.49	0.60	0.83
τ^b	0.37	0.09	0.28	0.57
τ^c	1.72	1.57	1.66	1.68

Units: proportional tax on banking rate of return

back

Smaller periphery $(n_a, n_b, n_c) = (\frac{1}{3}, \frac{1}{6}, \frac{1}{2})$

$\sigma = 1.5$

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

Country	Policy Scheme Nash	Coop (All)	Coop (EMEs)	Coop (Center + EME-A)
τ^a	0.84	0.58	0.72	0.84
τ^b	0.65	0.24	0.09	0.83
τ^c	1.70	1.55	1.61	1.68

Units: proportional tax on banking rate of return

Policy Implementation Costs: $\kappa^a = \kappa^b = 0.399$ and $\kappa^c = 0.1$ and $\psi = 1$ $\sigma = 1.02$

Table: Welfare comparison

Country	Bechmark: Nash Coop (All)	Coop (EMEs)	Coop (C+EME-A)	Bechmark: First Best Nash	Coop (All)	Coop (EMEs)	Coop (C+EME-A)
C (Center)	0.96	0.94	1.00	1.05	1.01	0.99	1.04
A	1.09	1.08	1.07	0.91	0.99	0.99	0.98
B	1.09	1.08	1.06	0.91	0.99	0.99	0.96
World	1.02	1.01	1.03	0.98	1.00	0.99	1.01
EME Block	1.09	1.08	1.06	0.91	0.99	0.99	0.97

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

Country	Policy Scheme Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center and EME-A)
τ^a	0.01	-0.01	1.20	1.25
τ^b	0.01	-0.01	1.20	-0.01
τ^c	2.00	0.02	0.02	1.98

Units: proportional tax on banking rate of return

back

Experiments: changes in baseline model

I explore whether the results change with variations in a number of parameters.

Q: How important is the **friction** in shaping the results? Does the **population size** structure matters?

Cases:

- Changes in Financial Friction
  - Stronger Friction (both EMEs) $\longrightarrow$ No Gains from Cooperation; larger gains wrt No Policy go
- Changes in population size
  - Larger Center $\longrightarrow$ No Gains, no model matches FB go

Skip

Experiments: changes in baseline model

I explore whether the results change with variations in a number of parameters.

Q: How important is the **friction** in shaping the results? Does the **population size** structure matters?

Cases:

- Changes in Financial Friction
  - Stronger Friction (both EMEs) $\longrightarrow$ No Gains from Cooperation; larger gains wrt No Policy go
  - Stronger Friction in one EME $\longrightarrow$ **Small Gains** from World Cooperation; Nash won't match the FB go
- Changes in population size
  - Larger Center $\longrightarrow$ No Gains, no model matches FB go
  - Asymmetric EMEs: Smaller EME2 $\longrightarrow$ **Small Gains** in SemiCoop1 (between EMEs) go

Interesting patterns arise with **asymmetryc changes** in EMEs Skip

Experiment 1: higher financial friction in both EMEs ($\kappa^a = \kappa^b = \frac{1}{2}$)

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

Country	Policy Scheme Nash	Cooperation (All)	Cooperation (EMEs)	Cooperation (Center+EME-A)
τ^a	0.20	-0.30	-0.04	0.15
τ^b	0.20	-0.30	-0.04	0.16
τ^c	1.29	1.09	1.23	1.25

Units: proportional tax on banking rate of return

- No gains from Cooperation
- Larger gain wrt No Policy (expected)
- Consistent w increased Welfare Effects given $\uparrow \kappa$:

Stronger taxes in Center

Experiment 2: higher financial friction in EME-A ($\kappa^a = \frac{1}{2}$, $\kappa^b = 0.399$)

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

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

Units: proportional tax on banking rate of return

- Small gains from World Cooperation
- EME with lower distortion is benefited from cooperation.
- Cooperative Planners match the FB
- Country with larger distortion: Sets Subsidy or lower tax when cooperating
- Consistent w increased Welfare Effects given $\uparrow$ κ:

EMEs: Less aggressive policy setting ($\tau^{eme} < \tau^{eme}_{base}$)

Results with $\sigma = 1.5$

Experiment 3: Larger financial center $(n_a, n_b, n_c) = (\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

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

Units: proportional tax on banking rate of return

- No Gains from Cooperation
- Larger welfare (expected)
- Planners no longer can match FB

  Guess: lower effect of τ^{eme} $\rightarrow$ less effective tools
- Smallest departure from FB: World Cooperation

Experiment 4: Smaller periphery $(n_a, n_b, n_c) = (\frac{1}{3}, \frac{1}{6}, \frac{1}{2})$

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

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

Units: proportional tax on banking rate of return

- Small gains from Cooperation for smaller EME
- For both EMEs in Regional Cooperation
- CoopEMEs: Better-off EMEs $\Rightarrow$ Small gains from Cooperation (World)
- Smaller EME wants to subsidize in more setups

Results with $\sigma = 1.5$ Back

Generating gains from cooperation

First modification: Every country suffers from Agency frictions.

Before, a Center without frictions implied important simplifications in equilibrium (equalization of rates).

The Center bank now solves:

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

$$s.t. \quad F^a_1 + F^b_1 + L^c_1 = D_1 + \delta_b Q^c_1 K^c_0$$

$$J_1 \geq k^c \mathbb{E}_1 \Lambda^c_{1,2} \left[R^a_{a,1} F^a_1 + R^b_{b,1} F^b_1 + R^c_{k,2} L^c_1 \right]$$

F.O.C.:

$$[F^a_1] : \qquad \mathbb{E}_1 (R^a_{b,1} - R_{D,1}) = \mu^c_1 \left[\kappa^c R^a_{b,1} - (R^a_{b,1} - R_{D,1}) \right]$$

$$[F^b_1] : \qquad \mathbb{E}_1 (R^b_{b,1} - R_{D,1}) = \mu^c_1 \left[\kappa^c R^b_{b,1} - (R^b_{b,1} - R_{D,1}) \right]$$

$$[L^c_1] : \qquad \mathbb{E}_1 (R^c_{k,2} - R_{D,1}) = \mu^c_1 \left[\kappa^c R^c_{k,2} - (R^c_{k,2} - R_{D,1}) \right]$$

Thus, the credit spread is > 0 for the center as well.

Generating gains from coordination

Table: Welfare comparison

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

Units: Proportional steady state consumption increase in the benchmark model

Table: Ramsey-Optimal taxes

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

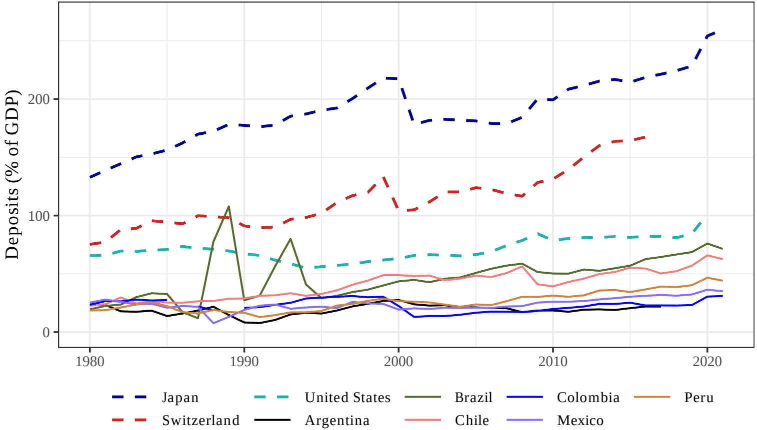
Units: proportional tax on banking rate of return

- No Gains from Cooperation
- FB achieved at world level. Same distributional issues as baseline
- **Lower Gains wrt No Policy**

  with $\kappa^c > 0$ the Cr.Spread in EMEs will be lower by default
- Smaller tax in Center wrt baseline
- Now EMEs subsidize in all cases

  Offsetting frictions (between countries) already mitigate distortion $\Rightarrow$ they can subsidize

Relative Importance of Local Deposits



Back

Figure: Deposits as percentage of GDP (AE vs. EMEs)

Other effects from taxes

For the EMEs:

$$\frac{dW_0^a}{d\tau_3^a} = \beta\lambda_2^a \left\{ \alpha_5(\kappa)\frac{dK_2^a}{d\tau_3^a} + \alpha_4(\kappa)\frac{dQ_2^a}{d\tau_3^a} + \frac{B_2^a}{(R_2)^2}\frac{dR_2}{d\tau_3^a} + \alpha\frac{Y_3^a}{R_2} \right\}$$

with $\alpha_4(\kappa) = I_2^a + \kappa\left(1-\theta\Lambda_{23}\right)K_2^a, \alpha_5(\kappa) = \kappa\left(1-\theta\Lambda_{23}\right)Q_2^a + \varphi\left(\tau_3^a\right)\Lambda_{23}r_3^a,$

and for the Center:

$$\frac{dW_0^c}{d\tau_2^c} = \overbrace{\beta\lambda_2^c \left\{ \gamma_1\frac{dK_1^c}{d\tau_2^c} + \left(\frac{B_1^c}{R_1} - \theta D_1\right)\frac{dR_1}{d\tau_2^c} + \frac{K_1^c}{R_1}\frac{dQ_1^c}{d\tau_2^c} + \alpha\theta Y_2^c + (1-\theta)\left(F_1^{ab}\frac{dR_{b,1}^{eme}}{d\tau_2^c} + R_{b,1}^{eme}\frac{dF_1^{ab}}{d\tau_2^c}\right)\right\}}^{\text{static effects}}$$

$$\underbrace{+\beta^2\lambda_3^c \left\{ \gamma_2\frac{dK_2^c}{d\tau_2^c} + \frac{B_2^c}{R_2}\frac{dR_2}{d\tau_2^c} + \gamma_3\frac{dQ_2^c}{d\tau_2^c} + F_2^{ab}\frac{dR_{b,2}^{eme}}{d\tau_2^c} + R_{b,2}^{eme}\frac{dF_2^{ab}}{d\tau_2^c} \right\}}_{\text{dynamic effects}}$$

$$\frac{dW_0^c}{d\tau_3^c} = \beta^2\lambda_3^c \left\{ \gamma_2\frac{dK_2^c}{d\tau_3^c} + \frac{B_2^c}{R_2}\frac{dR_2}{d\tau_3^c} + \gamma_3\frac{dQ_2^c}{d\tau_3^c} + F_2^{ab}\frac{dR_{b,2}^{eme}}{d\tau_3^c} + R_{b,2}^{eme}\frac{dF_2^{ab}}{d\tau_3^c} \right\}$$

$\gamma_1 = \left(1-\alpha\theta\left(1-\tau_2^c\right)\right)r_2^c + (1-\theta)(1-\delta)Q_2^c, \gamma_2 = \left(r_3^c + (1-\delta)Q_3\right), \gamma_3 = R_2\left(I_2^c + (1-\theta)(1-\delta)K_1^c\right),$
$F_t^{ab} = F_t^a + F_t^b$

back