Monetary and Exchange Rate Policies in a Global Economy

Naoki Yago

The University of Cambridge

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Introduction

- Foreign exchange intervention (FXI)
- Central banks buy/sell foreign currency reserves
    - ex. Bank of China buys yuan, sells dollar reserves $\Rightarrow$ yuan expensive
- Mundell-Fleming vs. exchange rate stabilization (Rey'15)
- I construct a theory with both monetary policy and FXI.

Introduction

- Large open economies with huge foreign exchange reserves use FXI.

  ▸ Example

- Literature: separate objectives
  - Monetary policy $\Rightarrow$ inflation, FXI $\Rightarrow$ exchange rate

- During the pandemic & war,
  - Central banks set low interest rates despite high inflation.
  - They intervened by selling the dollar.

What I do

- A large two-country model with monetary policy and FXI based on:
  - Monetary policy in large open economies (Corsetti/Dedola/Leduc'23)
  - FXI in small open economies (Itskhoki/Mukhin'23)
- **Result:** the two policies are interdependent for large countries.
  - FXI affects inflation by dampening/stimulating foreign demand
- Opens up a discussion on which policies to use.

Literature

Table | Relationship with Literature

- Theory on foreign exchange intervention
  - Gabaix/Maggiori'15, Fanelli/Straub'21: FXI independently of MP
  - Cavallino'19, Amador/etal'20, Basu/etal'21, Itskhoki/Mukhin'23: MP and FXI in a small open economy

$\Rightarrow$ Two-country model with both monetary policy and FXI

- Empirical evidence on the effectiveness of FXI
  - Fatum/Hutchison'10, Kuesteiner/Phillips/Villamizar-Villegas'18, Fratzscher/etal'19, Adler/Mano'21, Rodnyansky/Timmer/Yago'24, Dao/Gourinchas/Mano/Yago'24

$\Rightarrow$ Normative implication of FXI

- Non-fundamental volatility of exchange rates
  - Itskhoki/Mukhin'21, Jiang/Krishnamurthy/Lustig'21,23, Devereux/Engel/Wu'23, Engel/Wu'22, Kekre/Lenel'23, Fukui/Nakamura/Steinsson'23

$\Rightarrow$ Role of FXI in stabilizing exchange rates

Roadmap

Step-by-step construction of a large two-country model

1. Optimal monetary policy under cooperation (Corsetti/Dedola/Leduc'23)
2. Optimal monetary policy & FXI under cooperation
3. Extension 1: Dollar pricing
4. Extension 2: Non-cooperative equilibrium

Roadmap

Step-by-step construction of a large two-country model

1. Optimal monetary policy under cooperation (Corsetti/Dedola/Leduc'23)
    - Define international risk-sharing
    - Characterize policy trade-offs due to the lack of risk-sharing
2. Optimal monetary policy & FXI under cooperation
3. Extension 1: Dollar pricing
4. Extension 2: Non-cooperative equilibrium

Monetary Policy under Cooperation (Corsetti/Dedola/Leduc'23)

- Two large countries: US and local
- **Households** consume local & US goods, supply labor

$$U(C_t) = \log(C_t), \qquad C_t = \left[a^{\frac{1}{\phi}} C_{Lt}^{\frac{\phi-1}{\phi}} + (1-a)^{\frac{1}{\phi}} C_{Ut}^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{1-\phi}}$$

  - Cannot trade state-contingent asset internationally
- **Firms** produce goods, price rigidity (Calvo'83)
  - Shocks: productivity and markup
  - Export in own currency
- **Global planner** sets local and US monetary policy rates

Households detail Firms detail

International Risk Sharing

- Cooperation: central banks in the two countries target **risk-sharing.**

- **Concept:** Exchange rate adjusts to smooth consumption
  - China supply $\Uparrow$ $\rightarrow$ China consumption $\Uparrow$
  - Cheap yuan $\rightarrow$ US import price $\Downarrow$, consumption $\Uparrow$

- **Definition:** Risk-sharing wedge = Difference in marginal utilities

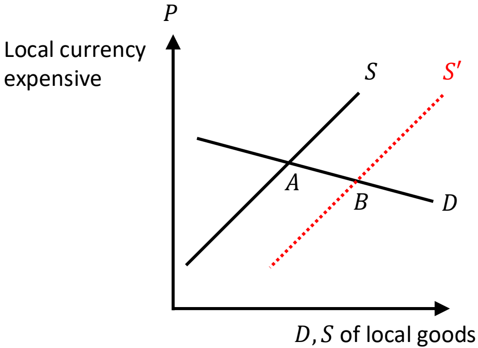
$$\tilde{\mathcal{W}}_t \equiv \widetilde{U'(C_t^*)} - \widetilde{U'(C_t)} - \widetilde{RER}_t$$
$$= \tilde{C}_t - \tilde{C}_t^* - \widetilde{RER}_t \quad \text{(with log utility)}$$

  - $\tilde{C}_t$: China, $\tilde{C}_t^*$: US, RER_t $\Uparrow$: strong dollar, RER_t $\Downarrow$: strong yuan
  - $\tilde{\mathcal{W}}_t = 0$: risk-sharing, $\tilde{\mathcal{W}}_t > 0$: China strong demand

International Risk Sharing

Consider an increase in local productivity.

- **Trade elasticity** $= 1$: Risk-sharing holds ($\tilde{W}_t = 0$) (Cole/Obstfeld'91)
- **Trade elasticity** > 1: Local excess demand ($\tilde{W}_t > 0$) (substitutes)



Price Setting

Intuition

- New Keynesian Phillips Curve:

$$\pi_{Lt} = \beta E_t \pi_{Lt+1} + \kappa \Big[\tilde{Y}_{Lt} - \underbrace{2a(1-a)(\phi-1)\tilde{\mathcal{T}}_t}_{\text{Terms-of-trade gap}} + \underbrace{(1-a)\tilde{\mathcal{W}}_t}_{\text{Risk-sharing wedge}} + \underbrace{\mu_t}_{\text{Markup shock}} \Big]$$

- π_{Lt}: inflation rate for local goods consumed by local households
- $\tilde{Y}_{Lt}$: output gap for local goods
- Terms of trade: import − export price
  - Import price $\tilde{\mathcal{T}}_t \Downarrow \rightarrow$ consumption $\Uparrow$, inflation $\Uparrow$ (if substitutes)
- Local excess demand $\tilde{\mathcal{W}}_t \Uparrow \rightarrow$ inflation $\Uparrow$

Central Banks' Objective

- Assume cooperation and commitment.
  - Central banks maximize the sum of households' welfare in two countries.
- Central banks minimize the weighted sum of:
  - Inflation rate for goods produced in each country
  - Output gap in each country
  - Terms-of-trade gap and risk-sharing wedge across countries

Details

Optimal Monetary Policy Rule

Lemma 1 (Optimal MP without FXI)

When FXI is not available, the optimal monetary policy rule is:

$$0 = \theta\pi_{Lt} + \left(\tilde{Y}_{Lt} - \tilde{Y}_{Lt-1}\right) + \psi_D(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1}).$$

Intuition:

- Local supply $\Uparrow$ $\rightarrow$ deflationary $\rightarrow$ interest rate $\Downarrow$
- If trade elasticity $= 1$, no trade-off
- If substitutes, local excess demand $\Rightarrow$ inflationary
  - Interest rate $\Uparrow$, output $\Downarrow$
  - Lack of risk-sharing generates monetary-policy trade-off

Details

Roadmap

Step-by-step construction of a large two-country model

1. Optimal monetary policy under cooperation (Corsetti/Dedola/Leduc'23)
2. Optimal monetary policy & FXI under cooperation
   - FXI is effective under segmented currency market

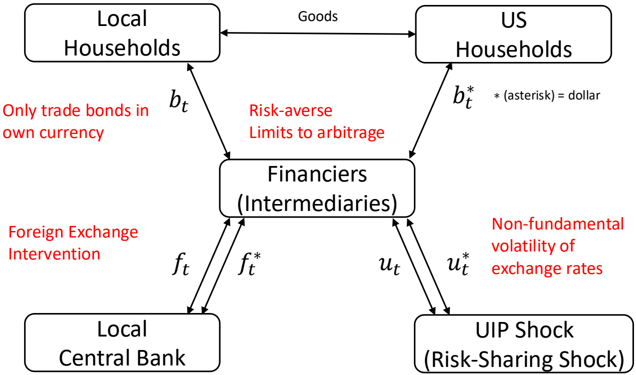
     (Gabaix/Maggiori'15, Itskhoki/Mukhin'23)
   - Characterize optimal policy trade-offs and transmission channels
   - Calibrate the model and quantify the effect of FXI
3. Extension 1: Dollar pricing
4. Extension 2: Non-cooperative equilibrium

Introduce FXI: Basic Idea

- Global planner chooses local MP, local FXI, and US MP
- FXI is effective under frictions in international asset trade.
- **Data:** unhedged returns on savings are different across currencies
  - Deviation from Uncovered Interest Parity (UIP) (Fama'94) Details
- Assume households can only borrow/lend in their own currency.

  (Gabaix/Maggiori'15, Itskhoki/Mukhin'21)
- **Example:** CB of China buys yuan / sells dollar
  - Yuan expensive, return on yuan $\Downarrow$, dollar $\Uparrow$
  - However, Chinese households cannot lend in dollars

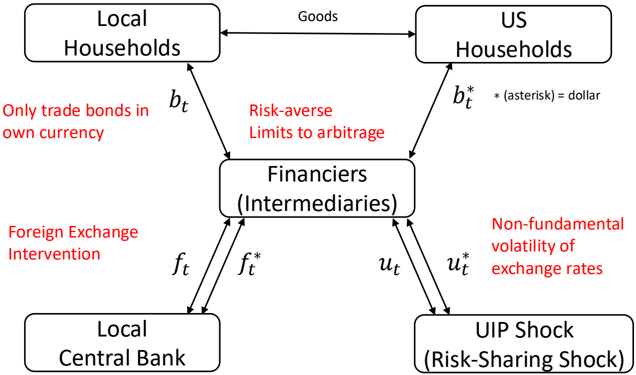
Introducing FXI: Details



Example:

- Investors lend \$, borrow yuan ($u_t^* \Uparrow$) $\Rightarrow$ financiers borrow \$, lend yuan
- Yuan return $>$ \$ return due to risk premium (UIP deviation)
- However, Chinese households cannot borrow \$ / lend yuan despite higher return

Introducing FXI: Details



Example:

- CB of China buys yuan bonds ($f_t \Uparrow$) $\Rightarrow$ same return (UIP holds) when $f_t = u_t^*$
- Same consumption-savings decisions
- Consumption smoothing (risk-sharing) across countries

Financiers' Problem (Itskhoki/Mukhin'21,23)

Asset market clearing

- Financiers trade both local and US bonds but they are risk-averse.

$$\max_{d_t} E_t \left\{ -\frac{1}{\omega} \exp\left(-\omega \bar{R}_t d_t\right) \right\}$$

  - $\omega > 0$: risk aversion
  - $\bar{R}_t = R_t - R_t^* \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}$: local $-$ \$ bond return ($\neq 0$ when risk-averse)
  - d_t: local bond purchase (\$ sales)

International Asset Market

$$\underbrace{E_t\tilde{\mathcal{W}}_{t+1} - \tilde{\mathcal{W}}_t}_{\Delta \text{ Risk-sharing wedge}} = \underbrace{\tilde{r}_t - \tilde{r}_t^* - (E_t\tilde{e}_{t+1} - \tilde{e}_t)}_{\substack{\text{UIP deviation} \\ \text{(local} - \text{dollar return)}}} = \underbrace{\chi(u_t^* - f_t)}_{\substack{\text{Traders buy \$ } (u_t^*) \\ - \text{ CB buys local } (f_t)}}$$

- Investors' \$ demand ($u_t^* \Uparrow$) $\Rightarrow$ China consumes less ($\tilde{\mathcal{W}}_t < 0$)
  - Strong \$ $\Rightarrow$ higher import prices
  - High return on yuan $\Rightarrow$ save more

- Bank of China buys yuan ($f_t = u_t^*$) $\Rightarrow$ same return, $E_t\tilde{\mathcal{W}}_{t+1} = \tilde{\mathcal{W}}_t$

- If trade elasticity $= 1$, $\tilde{\mathcal{W}}_t = 0$ for every state.
- If trade elasticity $\neq 1$, $\tilde{\mathcal{W}}_t \neq 0$ in general. $\Rightarrow$ non-trivial trade-offs

Optimal MP and FXI

Details

Proposition 1 (Optimal Monetary Policy and FXI)

The optimal monetary policy rule is:

$$0 = \theta\pi_{Lt} + (\tilde{Y}_{Lt} - \tilde{Y}_{Lt-1}) + \xi_\pi(\pi_{Lt} - \pi^*_{Ut}) + \xi_D(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1}).$$

The optimal FXI rule is:

$$f_t = u^*_t + \xi_f E_t(\pi_{Lt+1} - \pi^*_{U,t+1})$$

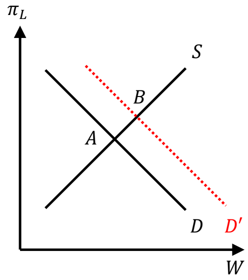
- Optimal FXI has two objectives.
  1. Offset UIP shock, risk-sharing
  2. Local $>$ US inflation $\Rightarrow$ Buy the local currency, sell dollars
- $f = u^*$ is only optimal when $\pi_L = \pi^*_U$.

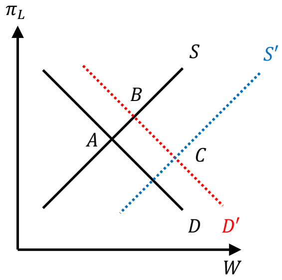
Case 1: Separate Objectives (Trade Elasticity = 1)

Monetary policy and FXI have two separate objectives when there are only productivity shocks and trade elasticity = 1.

- Monetary policy: inflation = output gap = 0 in both countries
- FXI: UIP = risk sharing wedge = 0
  - Offsets non-fundamental volatility in capital flows
- No trade-offs, first-best allocation

Case 2: Interdependent Objectives (Trade Elasticity $\neq 1$)





- Buy local $\Rightarrow$ local currency strong $\Rightarrow$ local demand $\mathcal{W} \Uparrow$ ($D \to D'$)
- US households shift demand from local to US goods
  $\rightarrow$ Local output $Y_L \Downarrow$, inflation $\pi_L \Downarrow$ ($S \to S'$)
- The second effect is large when the trade elasticity is high.

Case 2: Interdependent Objectives (Trade Elasticity $\neq 1$)

- What is optimally traded off depends on the source of shocks.
- **Productivity shock:**
  - FXI stabilizes inflation in both countries.
  - FXI widens the output gap in both countries and the risk-sharing wedge.
- **Cost-push (markup) shock:**
  - FXI stabilizes inflation and the output gap in both countries.
  - FXI widens the risk-sharing wedge.

Quantification

Countries / Summary statistics · Parameters · Identification · Regression

- Estimate the effect of FXI on UIP deviation
  - 2000-23, quarterly, 11 major currencies against the dollar
  - UIP deviation: exchange rate forecast & interbank rate (Bloomberg)
  - FXI (Central bank website, FRED, Adler/etal'23)
- Identify FXI via deviation from estimated policy rules

  (Fratzscher/etal'19, Rodnyansky/Timmer/Yago'24)
- Result: sell \$ (1% of GDP) $\rightarrow$ UIP $\Downarrow$ by 0.51pp (local return $\Downarrow$)

Quantification

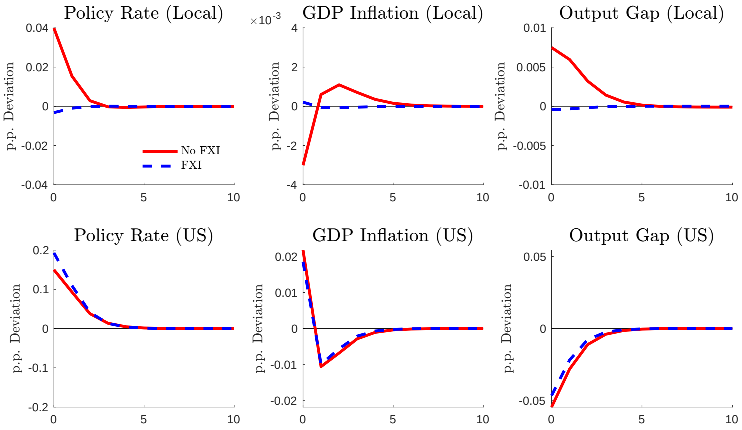
IRF (Cost-push) IRF (Cost-push, high elasticity)

The optimal volume of FXI is:

- Larger with markup shocks than productivity shocks
- Larger when local and US goods are highly substitutable
  - 1 stddev US markup $\Uparrow \rightarrow$ sell \$ of 0.1% over GDP[1]
  - FXI allows nearly full stabilization of local inflation & output gap with little changes in the local policy rate

[1] 1 stddev US markup = 2% (Bodenstein/etal'23). Median \$ sales = 0.18% over GDP.

Impulse Response to an Inflationary US Cost-push Shock



▸ IRF (Cost-push) ▸ IRF (Cost-push, high elasticity)

Roadmap

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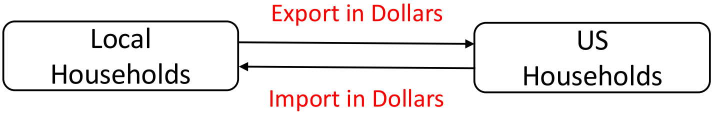
   - Optimal FXI volume is large under dollar pricing
   - Transmission is asymmetric: FXI stabilizes local inflation more
4. Extension 2: Non-cooperative equilibrium

Dollar Pricing

- Bridge the gap between:
  - Dollar dominance in international trade (Gopinath/etal'20)
  - Capital flow management in international finance (Itskhoki/Mukhin'23)

- Assume both exports and imports are invoiced in dollars



Dollar Pricing

NKPC and loss function

When exports and imports are both invoiced in dollars,

1. Identical local goods have different prices in different currencies despite the same marginal cost of production
   - Strong \$ $\Rightarrow$ Chinese goods are more expensive in \$ than yuan
   - $\Delta_{Lt} \equiv \mathcal{E}_t P^*_{Lt}/P_{Lt}$: Price of local goods in \$ / local currency
   - $\Delta_{Lt} \neq 1$: price dispersion wedge
   - Central banks target Δ_{Lt} (Corsetti/Dedola/Leduc'20)
2. Exchange rate has limited effect on US import prices

Dollar Pricing

Optimal MP Optimal MP and FXI

Consider an inflationary US cost-push shock.

- Optimal FXI is increasing in the price-dispersion wedge (Δ_{Lt}).
  - \$ appreciates $\rightarrow$ local good is expensive in \$ ($\Delta_{Lt} \Uparrow$) $\rightarrow$ optimal FXI is to buy local currency
- Optimal FXI volume is larger under dollar pricing.
- Transmission is asymmetric.
  - Optimal FXI decreases the local consumer-price inflation more and increases the US consumer price inflation less.

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   - Strategic interaction between local FXI and US monetary policy
   - Larger risk-sharing wedge than cooperation

Nash Equilibrium

- In reality, central banks can follow non-cooperative (Nash) policies.
  - Maximize households' welfare in own country
- Focus on the open-loop Nash equilibrium (Bodenstein et al., 2019, 2024)
  - In period 0, each player specifies his/her state-contingent plans for every possible future state.
  - Each player's action is the best response to the other player's best response.

  ▸ Formal Definition
- Strategic interaction between local FXI and US monetary policy
  - Higher-order perturbation (Bodenstein/etal'19,24)
  - Remark: the toolbox supports one strategic instrument per player.

Nash Equilibrium

IRF IRF (Difference)

The risk-sharing wedge is larger under the Nash equilibrium.

US inflationary cost-push shock:

- US: interest rate $\Uparrow$
- Local: sell \$, stabilize local inflation $\Rightarrow$ \$ cheap, US interest rate $\Uparrow$
- Beggar-thy-neighbor: local excess demand

US deflationary cost-pull shock:

- US: interest rate $\Downarrow$
- Local: buy \$ (competitive devaluation)
- Beggar-thy-self: US excess demand

Conclusion

- A two-country framework with monetary policy and FXI
- Trade-off between internal (inflation-output) and external objectives (risk-sharing)
- Opens up a discussion on how to combine different policies
- Challenges:
  - Identification of FXI, empirical analysis (Rodnyansky/Timmer/Yago'24)
  - How to combine FXI with capital control and macroprudential policy (IMF's integrated policy framework) (Basu/etal'20)

Appendix

Monetary Policy and FXI: Recent Examples

Back

- Low interest rate policy during the pandemic and war:
  - China and India set a record low of 4% interest rate.
  - Brazil lowered the rate to 2%.
  - Japan set a negative interest rate.

- FXI by large open economies:
  - China and Japan have 3.5 trillion and 1.4 trillion dollars of foreign exchange reserves
    - 40% of the world's reserves, 20-30% of Chinese/Japanese GDP
  - US monitoring list for gaining unfair competitive advantage in trade
  - World foreign exchange reserves fell by 1 trillion dollars in 2021-22.
  - China and Brazil sold 38 billion and 25 billion dollars in 2020.
  - India and Japan sold 32 billion and 63 billion dollars in 2022.

Evidence for Limits to Arbitrage: UIP Deviation

Back

Country	Currency	α_0	(s.e.)	β_1	(s.e.)	$\chi^2(\alpha_0 = \beta_1 = 0)$	R^2
Australia	AUD	-0.001	(0.002)	-1.63***	(0.48)	16.3***	0.014
Austria	ATS	0.002	(0.002)	-1.75***	(0.58)	9.5***	0.023
Belgium	BEF	-0.0002	(0.002)	-1.58***	(0.39)	17.5***	0.025
Canada	CAD	-0.003	(0.001)	-1.43***	(0.38)	19.1***	0.013
Denmark	DKK	-0.001	(0.001)	-1.51***	(0.32)	25.4***	0.025
France	FRF	-0.001	(0.002)	-0.84	(0.63)	1.9	0.007
Germany	DEM	0.002	(0.001)	-1.58***	(0.57)	7.9**	0.015
Ireland	IEP	-0.002	(0.002)	-1.32***	(0.38)	12.3***	0.020
Italy	ITL	-0.002	(0.002)	-0.79**	(0.33)	7.0**	0.013
Japan	JPY	0.006***	(0.002)	-2.76***	(0.51)	28.9***	0.038
Netherlands	NLG	0.003	(0.002)	-2.34***	(0.59)	16.0***	0.041
Norway	NOK	-0.0003	(0.001)	-1.15***	(0.39)	10.4***	0.013
New Zealand	NZD	-0.001	(0.002)	-1.74***	(0.39)	28.3***	0.038
Portugal	PTE	-0.002	(0.002)	-0.45**	(0.20)	5.9*	0.019
Spain	ESP	0.002	(0.003)	-0.19	(0.46)	2.8	0.001
Sweden	SEK	0.0001	(0.001)	-0.42	(0.50)	0.9	0.002
Switzerland	CHF	0.005***	(0.002)	-2.06***	(0.55)	13.9***	0.026
UK	GBP	-0.003**	(0.001)	-2.24***	(0.60)	14.2***	0.028
Panel, pooled		0.0002	(0.001)	-0.79***	(0.15)	22.3***	
Panel, fixed eff.				-1.01***	(0.21)	19.1***	

Source: Valchev (2015).

- If households can invest freely in two currencies, the excess return is zero (uncovered interest rate parity holds). However, UIP does not hold in data.
- Fama (1985) regression: $e_{t+1} - e_t - (i_t - i_t^*) = \alpha_0 + \beta_1(i_t - i_t^*) + \epsilon_t$
- When $\beta_1 < 0$, high interest rate currency appreciates in future = positive return

Literature on MP and FXI in Open Economy

Back

	(1) Monetary Policy	(2) FX Intervention	(3) Both MP and FXI
(a) Small Open Economy	Gali & Monacelli (2005) Clarida, Gali & Gertler (2001) Kollmann (2002) Corsetti & Pesenti (2005) Faia & Monacelli (2008) Egorov and Mukhin (2023)	Fanelli & Straub (2021) Davis, Devereux & Yu (2023) Ottonello, Perez & Witheridge (2024)	Cavallino (2019), Amador et al. (2020) Basu et al. (2020) Itskhoki & Mukhin (2023)
(b) Large Open Economies (Two-country)	Clarida, Gali & Gertler (2002) Benigno & Benigno (2003, 2006) Devereux & Engel (2003), Engel (2011) Corsetti, Dedola & Leduc (CDL) (2010, 2020, 2023)	Gabaix & Maggiori (2015) Maggiori (2022)	**This Paper**

Literature on MP & FXI in a Small Open Economy

Back

- Cavallino (2019)
  - Cost for central banks: FX purchase lowers the FX return
  - Profit for intermediaries: opposite carry trade position against central banks
  - Domestic intermediaries share $\beta = 1$: loss = profit, $\beta < 1$: loss > profit
- Basu et al. (2020) (IMF Integrated Policy Framework)
  - Sudden stop $\Rightarrow$ a monetary easing relaxes banks' domestic borrowing constraint but depreciation tightens their external borrowing constraint
  - FX sales limit the depreciation and improves the trade-off
- Itskhoki and Mukhin (2023)
  - MP and FXI eliminate nominal and financial frictions separately
  - Without FXI, MP trades off inflation and exchange rate stabilization
- My paper:
  - FXI trades off the internal (inflation) & external objectives (exchange rate, purchasing power)
  - Cooperative MP & FXI in two large countries

Risk-Sharing Wedge and Inflation: Details

- Substitutes ($\phi > 1$): when output increases $(\tilde{Y}_{Lt} - \tilde{Y}_{Ut}) \Uparrow$, import price increases by less than one-to-one $(\tilde{\mathcal{T}}_t \Downarrow = \tilde{P}_{Ut} - \tilde{P}_{Lt})$
- Local HHs' income increases relative to the US $(P_{Lt} Y_{Lt} > P_{Ut} Y_{Ut})$ $=$ consistent with $\tilde{W}_t > 0$ (local excess demand).
- More generally, inflation is non-zero unless $\phi \neq 1$.

Back

Households (Details)

- CRRA, CES bundle of local and US goods

$$U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \iota_l \frac{L_t^{1+\eta}}{1+\eta}, \quad C_t = \left[a^{\frac{1}{\phi}} C_{Lt}^{\frac{\phi-1}{\phi}} + (1-a)^{\frac{1}{\phi}} C_{Ut}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{1-\phi}}$$

$$C_{Lt} = \left[\int_0^1 C_t(l)^{\frac{\zeta-1}{\zeta}} dj \right]^{\frac{\zeta}{1-\zeta}}, \quad C_{Ut} = \left[\int_0^1 C_t(u)^{\frac{\zeta-1}{\zeta}} du \right]^{\frac{\zeta}{1-\zeta}}$$

- $\sigma = \phi = 1$: log and Cobb-Douglas utility (Cole/Obstfeld '91)
- Budget constraint:

$$P_{Lt} C_{Lt} + P_{Ut} C_{Ut} + \frac{B_t}{R_t} = B_{t-1} + W_t L_t + \Pi_t + T_t$$

▸ Households (simple) ▸ Households (general) ▸ Full quantitative model

Solution to Households' Problem

- Euler equation for the local bond: $\beta R_t E_t \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} = 1$
- Labor supply equation: $C_t^{\sigma} L_t^{\eta} = \frac{W_t}{P_t}$
- Demand for local and US goods:

$$C_{Lt} = a \left(\frac{P_{Lt}}{P_t} \right)^{-\phi} C_t, \quad C_{Ut} = (1-a) \left(\frac{P_{Ut}}{P_t} \right)^{-\phi} C_t$$

- Demand for differentiated goods produced within each country:

$$C_t(l) = \left(\frac{P_t(l)}{P_{Lt}} \right)^{-\zeta} C_{Lt}, \quad C_t(u) = \left(\frac{P_t(u)}{P_{Lt}} \right)^{-\zeta} C_{Ut}$$

Back

Firms' Maximization Problem

- Producer currency pricing (PCP): law of one price $P_t(l) = \mathcal{E}_t P_t^U(l)$
- Firms set prices subject to price adjustment cost (Rotemberg '82)

$$\max \sum_{t=0}^{\infty} \beta^t \frac{U'(C_{t+k})}{U'(C_t)} \left[P_t(l) \left(\frac{P_t(l)}{P_{Lt}} \right)^{-\zeta} Y_{Lt} - \frac{W_t}{A_t} \frac{1}{1-\tau_t} \left(\frac{P_t(l)}{P_{Lt}} \right)^{-\zeta} Y_{Lt} \right.$$
$$\left. - \frac{AC_p}{2} \left(\frac{P_t(l)}{P_{t-1}(l)} - 1 \right)^2 P_{Lt} Y_{Lt} \right]$$

- New Keynesian Phillips Curve:

$$\pi_{Lt} = \beta E_t \pi_{Lt+1} + \kappa \{ \underbrace{(\sigma+\eta)\tilde{Y}_{Lt}}_{\text{Output gap}} + \underbrace{2a(\sigma\phi - 1)(\tilde{P}_{Lt} - \tilde{P}_{Ut})}_{\text{Relative price}} + \underbrace{(1-a)\tilde{\mathcal{W}}_t}_{\text{Demand gap}} + \underbrace{\mu_t}_{\text{Cost-push}} \}$$

- Productivity: $\log(A_t) = \rho_a \log(A_{t-1}) + \epsilon_{at}, \ \epsilon_{at} \sim N(0, \sigma_a^2)$
- Markup shock: $\mu_t = \frac{\zeta}{(\zeta-1)(1-\tau_t)}$

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Intuition on NKPC

Back

Effects of terms-of-trade gap: (Clarida/Gali/Gertler'02)

- Consider US output $\tilde{Y}_{Ut} \Uparrow$, local appreciation, import price $\Downarrow$ ($\tilde{\mathcal{T}}_t \Downarrow$)
- $\phi > 1$: Local and US goods are substitutes
  - Import price $\Downarrow$, local consumption $C_t \Uparrow$ via risk sharing
  - Marginal cost $w_t = \frac{V'(L_t)}{U'(C_t)} \Uparrow$, inflation $\pi_{Lt} \Uparrow$
- $\phi < 1$: Local and US goods are complements
  - Export price $\Uparrow \rightarrow$ marginal cost $\Downarrow$, inflation $\pi_{Lt} \Downarrow$

Effect of demand gap: (Corsetti/Dedola/Leduc'10)

- $\mathcal{W}_t \Uparrow = U'(C_t) \Downarrow \rightarrow$ marginal cost $w_t = \frac{V'(L_t)}{U'(C_t)} \Uparrow$, inflation $\pi_{Lt} \Uparrow$

Loss Function (PCP, Details)

Back

- Loss function:

$$\mathcal{L} = -E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{2} \left[\begin{array}{l} \left(\tilde{Y}_{Lt}^2 + \tilde{Y}_{Ut}^2\right) + \frac{\theta}{\kappa}\left(\pi_{Lt}^2 + \pi_{Ut}^{*2}\right) \\ -\frac{2a(1-a)(\phi-1)}{4a(1-a)(\phi-1)+1}\left(\tilde{Y}_{Lt} - \tilde{Y}_{Ut}\right)^2 \\ +\frac{2a(1-a)\phi}{4a(1-a)(\phi-1)+1}\tilde{\mathcal{W}}_t^2 \end{array} \right],$$

where $\tilde{Y}_{Lt} - \tilde{Y}_{Ut} = [\{4a(1-a)(\phi-1)+1\}\tilde{\mathcal{T}}_t + (2a-1)\tilde{\mathcal{W}}_t]$.

- The coefficient on the risk-sharing wedge in optimal policy (log utility):

$$\psi_D = \frac{4a(1-a)\phi}{\sigma + \eta\{4a(1-a)(\phi-1)+1\}} \frac{2a(\phi-1)+1-\sigma}{2a(\phi-1)+1}$$

- When $\phi = 1$, $\psi_D = 0$ & same optimal policy as the closed economy:

$$0 = \theta\pi_{Lt} + \left(\tilde{Y}_{Lt} - \tilde{Y}_{Lt-1}\right),$$

Asset Market Clearing

- B_t, N_t, D_t, F_t: aggregate demand for local bond
- Zero net position:

$$B_t/R_t + \mathcal{E}_t B_t^*/R^* = 0, \quad N_t/R_t + \mathcal{E}_t N_t^*/R^* = 0$$
$$D_t/R_t + \mathcal{E}_t D_t^*/R^* = 0, \quad F_t/R_t + \mathcal{E}_t F_t^*/R^* = 0$$

- Market clearing for local and US bonds:

$$B_t + N_t + D_t + F_t = 0, \quad B_t^* + N_t^* + D_t^* + F_t^* = 0$$

Back to maximization

UIP condition (General Case)

UIP simple case Quantitative model

- The maximization problem for intermediaries implies:

$$\underbrace{E_t\tilde{W}_{t+1} - \tilde{W}_t}_{\Delta \text{ Demand gap}} = \underbrace{\tilde{r}_t - \tilde{r}_t^* - E_t\Delta\tilde{e}_{t+1}}_{\substack{\text{UIP deviation} \\ (\text{LC} - \$ \text{ return})}} = \underbrace{\chi_1(n_t^* - f_t)}_{\substack{\text{Noise trader buys } \$ \ (n_t^*) \\ - \text{ CB buys LC } (f_t)}} - \underbrace{\chi_2 b_t}_{\text{HHs' savings}}$$

where $\chi_1 \equiv m_n(\omega\sigma_e^2/m_d)$, $\chi_2 \equiv \bar{Y}(\omega\sigma_e^2/m_d)$ for finite $(\omega\sigma_e^2/m_d)$.

- Itskhoki and Mukhin (2021, 2023) scale the risk aversion ω so that $\omega\sigma_e^2$ is finite and nonzero and risk premium is first-order.[2]
- When deriving analytical result, I assume $\chi_2 = 0$ for tractability. Assume financial sector (m_d financiers and m_n noise traders) is larger than households.

[2] See Hansen and Sargent (2011).

Optimal MP and FXI: Details

Optimal Rules

Optimal monetary policies for local and US central banks are:

$$0 = \zeta\pi_{Lt} + (\tilde{Y}_{Lt} - \tilde{Y}_{Lt-1}) + \xi_\pi(\pi_{Lt} - \pi^*_{Ut}) + \xi_D(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1})$$

$$0 = \zeta\pi_{Ut} + (\tilde{Y}_{Ut} - \tilde{Y}_{Ut-1}) - \xi_\pi(\pi_{Lt} - \pi^*_{Ut}) - \xi_D(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1})$$

where

$$\xi_\pi = (1-a)\frac{2a(\sigma\phi - 1) + 1}{\sigma + \eta\{4a(1-a)(\sigma\phi - 1) + 1\}}\frac{2a(\sigma\phi - 1) + 1 - \sigma}{2a(\phi - 1) + 1}\zeta$$

$$\xi_D = \frac{2a(1-a)\phi}{\sigma + \eta\{4a(1-a)(\sigma\phi - 1) + 1\}}\frac{2a(\sigma\phi - 1) + 1 - \sigma}{2a(\phi - 1) + 1}.$$

Optimal FXI is:

$$f_t = n^*_t + \xi_f E_t(\pi_{Lt+1} - \pi^U_{U,t+1})$$

where

$$\xi_f = \frac{1-a}{\chi}\frac{2a(\sigma\phi - 1) + 1}{2a(1-a)\phi} \text{ and } \chi = \frac{\omega\sigma_e^2}{\beta} \quad \left(\xi_f > 0 \text{ if } \sigma\phi > 1 - \frac{1}{2a}\right).$$

NKPC and Loss Function under Dollar Pricing

Back

- NKPCs for local goods in LC (π_{Lt}) and \$ (π^*_{Lt}), US goods in \$ (π^*_{Ut})
  - Local good inflation depends on the LOOP deviation (Δ_{Lt})

$$\pi_{Lt} = \beta\pi_{Lt+1} + \kappa\{(\sigma+\eta)\tilde{Y}_{Lt} - (1-a)[2a(\sigma\phi-1)(\tilde{\mathcal{T}}_t + \tilde{\Delta}_{Lt}) + (\tilde{D}_t + \tilde{\Delta}_{Lt})] + \mu_t\}$$
$$\pi^*_{Lt} = \beta\pi^*_{Lt+1} + \kappa\{(\sigma+\eta)\tilde{Y}_{Lt} - (1-a)[2a(\sigma\phi-1)(\tilde{\mathcal{T}}_t + \tilde{\Delta}_{Lt}) + (\tilde{D}_t + \tilde{\Delta}_{Lt})] - \tilde{\Delta}_{Lt} + \mu^*_t\}$$
$$\pi^*_{Ut} = \beta\pi^*_{Ut+1} + \kappa\{(\sigma+\eta)\tilde{Y}_{Ut} + (1-a)[2a(\sigma\phi-1)\tilde{\mathcal{T}}_t - \tilde{D}_t] + \mu^*_t\}$$

- Loss function depends on the LOOP deviation (Δ_{Lt}):

$$\mathcal{L} = -E_0\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\left[\begin{array}{l}(\sigma+\eta)\left(\tilde{Y}^2_{Lt}+\tilde{Y}^2_{Ut}\right)+\frac{\zeta}{\kappa}\left(a\pi^2_{Lt}+(1-a)\pi^{*2}_{Lt}+\pi^{*2}_{Ut}\right)\\ -\frac{2a(1-a)(\sigma\phi-1)\sigma}{4a(1-a)(\sigma\phi-1)+1}\left(\tilde{Y}_{Lt}-\tilde{Y}_{Ut}\right)^2\\ +\frac{2a(1-a)\phi}{4a(1-a)(\sigma\phi-1)+1}\left(\tilde{\mathcal{W}}_t+\Delta_{Lt}\right)^2\end{array}\right]$$

Dollar Pricing: Optimal Monetary Policy

Back

Optimal monetary policy under DCP when FXI is not available:

$$0 = \theta a \pi_{Lt} + (\tilde{C}_t - \tilde{C}_{t-1}) + \frac{2a(1-a)\phi}{2a(\phi-1)+1}\frac{\sigma-1}{\sigma}(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1} + \tilde{\Delta}_t - \tilde{\Delta}_{t-1})$$

$$0 = \theta[(1-a)\pi^*_{Lt} + \pi^*_{Ut}] - (\tilde{C}^*_t - \tilde{C}^*_{t-1}) - \frac{2a(1-a)\phi}{2a(\phi-1)+1}\frac{\sigma-1}{\sigma}(\tilde{\mathcal{W}}_t - \tilde{\mathcal{W}}_{t-1} + \tilde{\Delta}_t - \tilde{\Delta}_{t-1})$$

- Local: trades off local inflation and demand growth.
- US: trades off international dollar price inflation and demand growth.
- When $\sigma \neq 1$, MP also trades off the LOOP deviation.

Dollar Pricing: Optimal Monetary Policy and FXI

Back

Optimal monetary policy and FXI under DCP:

$$
\begin{aligned}
0 &= \tilde{Y}_{Lt} + \theta[a\pi_{Lt} + (1-a)\pi^*_{Lt}], \\
0 &= \tilde{Y}_{Ut} + \theta\pi^*_{Ut} + \gamma_{\Delta_{Lt}} - \gamma_{\Delta_{Lt-1}}, \\
\gamma_{\Delta_{Lt}} &= -\frac{4a(1-a)}{2a-1}(\tilde{\Delta}_{Lt} + \tilde{\mathcal{W}}_t) + \theta\frac{1}{2a-1} \\
&\quad \times [a\pi_{Lt} - ((1-a)\pi^*_{Lt} + \pi^*_{Ut})] - (2a-1)[a\pi_{Lt} + (1-a)\pi^*_{Lt} + \pi^*_{Ut}] \\
f_t &= n^*_t + \frac{\theta}{2a\chi_1}E_t[a\pi_{Lt+1} + (1-a)\pi^*_{Lt+1} + \pi^*_{Ut+1}] \\
&\quad + \frac{2a-1}{2a(1-a)\chi_1}(E_t\gamma_{\Delta t+t} - \gamma_{\Delta t}).
\end{aligned}
$$

- Local: MP trades off local inflation and output growth.
- US: MP trades off US inflation, output growth, LOOP deviation, and demand gap.
- FXI responds to the LOOP deviation.

Countries / Summary Statistics

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Countries:

- Australia, Brazil, Canada, China, Euro area, India, Japan, Korea, Russia, Switzerland, United Kingdom
  - **Robustness:** exclude small-open economies (Australia, Canada, Korea, Switzerland) and managed exchange rate regime (China)

Summary Statistics of FXI:

	Mean	Median	SD	p25	p75	p90	Max	Obs
Sell Dollars (Billions)	10.19	2.09	24.65	0.74	7.73	22.10	179.88	262
Buy Dollars (Billions)	14.66	5.53	25.71	1.59	13.21	33.79	164.17	448

	Mean	Median	SD	p25	p75	p90	Max	Obs
Sell Dollars (% GDP)	0.48	0.18	0.92	0.06	0.52	1.09	9.11	262
Buy Dollars (% GDP)	0.91	0.35	1.79	0.13	1.02	2.08	19.86	448

Parameter Values

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Table 1: Parameter Values

Value	Description	Notes
$\beta = 0.995$	Discount factor (local)	Annual interest rate $= 2\%$
$\sigma = 2$	Relative risk aversion	Itskhoki and Mukhin (2021)
$\eta = 0.35$	Inverse Frisch elasticity	Bodenstein et al. (2023)
$\zeta_l = 13.3$	Labor disutility (local)	Steady-state labor $= 1/3$
$a = 0.88$	Home bias of consumption	Bodenstein et al. (2023)
$\phi = 1.5$	CES Local & US goods	Itskhoki and Mukhin (2021)
$\theta = 10$	CES differentiated goods	Price markup $= 11\%$
$\xi_p = 0.75$	Calvo price stickiness	Duration of four quarters
$\bar{\pi} = 1$	Steady-state inflation	
$\chi = 1.42$	UIP coefficient on FXI	$\Delta(UIP)/\Delta(FXI/GDP) = 0.47$
$\rho_a = 0.97$	Persistence of productivity shock	Itskhoki and Mukhin (2021)
$\rho_\mu = 0.2$	Persistence of markup shock	Bodenstein et al. (2023)
$\sigma_a = 0.015$	SD of productivity shock	Bodenstein et al. (2023)
$\sigma_\mu = 0.019$	SD of markup shock	Bodenstein et al. (2023)

Identification of FXI

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- Identify direct effect of FXI by deviations from an FXI policy rule

$$FXI_{i,t} = \alpha + \beta X_{i,t-1} + \gamma_i + \epsilon_{i,t}$$

- $FXI_{c,t}$: FXI in country i, quarter t (> 0: sell \$, % over GDP)
- $X_{i,t-1}$: Controls (lagged)
  - Past FXI over GDP ratio, spot exchange rate (trend, volatility), UIP deviation, VIX, policy rate (local, US), consumer price inflation, unemployment rate, current account over GDP ratio
- γ_i: country fixed effect

First-step Regression

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Dependent Variable	FXI / GDP (%)	
	(1)	(2)
Lagged FXI / GDP (%)	0.129***	0.283***
	(0.040)	(0.056)
Lagged Exchange Depreciation (%)	0.005	0.006
	(0.014)	(0.011)
Lagged Exchange Volatility (%)	0.089	0.006
	(0.062)	(0.044)
Lagged UIP Deviation (p.p.)	0.010	0.012**
	(0.007)	(0.006)
Lagged log(VIX)	-0.135	-0.065
	(0.203)	(0.162)
Lagged Policy Rate (Local)	-0.078*	-0.030
	(0.046)	(0.032)
Lagged Policy Rate (US)	0.041	-0.077*
	(0.048)	(0.040)
Lagged CPI Inflation (%)	0.041	0.026
	(0.039)	(0.026)
Lagged Unemployment Rate (%)	0.004	-0.003
	(0.055)	(0.035)
Lagged Current Account / GDP (%)	-0.115***	-0.069*
	(0.031)	(0.038)
R^2	0.176	0.259
N	627	309
Country Fixed Effect	✓	✓
Exclude Small Economy		✓
Exclude Managed Exchange Rate		✓

- 74-82% of variation in intervention cannot be explained.

Estimating the Effect of FXI on UIP Deviation

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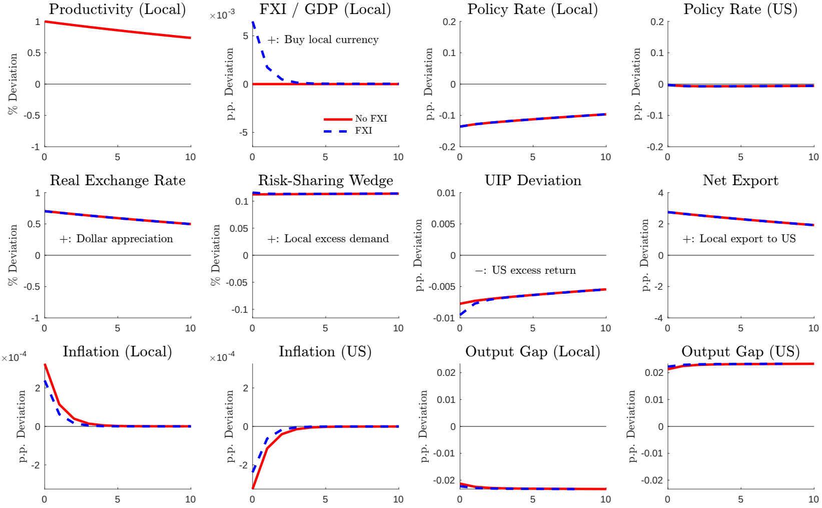
Dependent Variable	$UIP_t - UIP_{t-1}$			
	(1)	(2)	(3)	(4)
Net \$ Sales / GDP (%)	-0.589**	-0.509**	-1.599***	-1.106***
	(0.264)	(0.212)	(0.182)	(0.178)
R^2	0.004	0.013	0.009	0.020
N	706	392	367	212
Country Fixed Effect	✓	✓	✓	✓
Identified		✓		✓
Exclude Small Economy			✓	✓
Exclude Fixed Exchange Rate			✓	✓

- Sell dollars (1% of GDP) $\rightarrow$ UIP $\Downarrow$ by 0.5-0.6 pp (local return $\Downarrow$)
- More effective without small economies (liquid currencies: Swiss franc)

Impulse Response to a Local Productivity Increase



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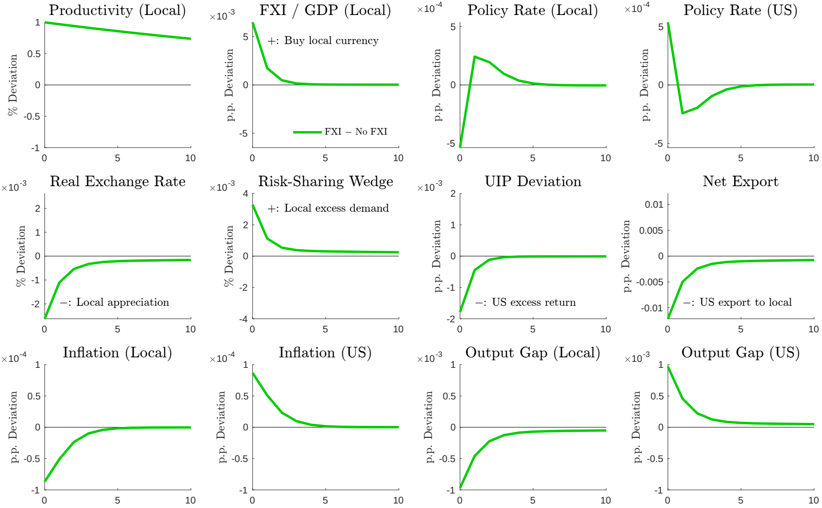
Impulse Response to a Local Productivity Increase



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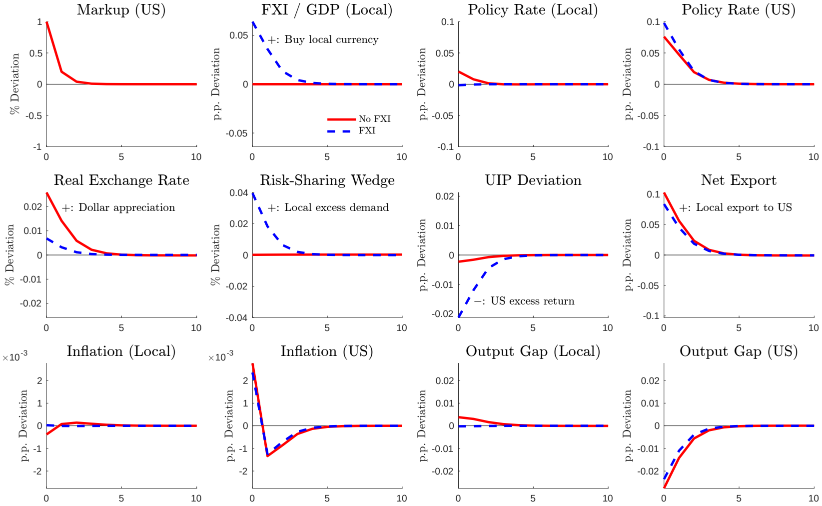
Impulse Response to a US Cost-Push Shock ($\phi = 1.5$)



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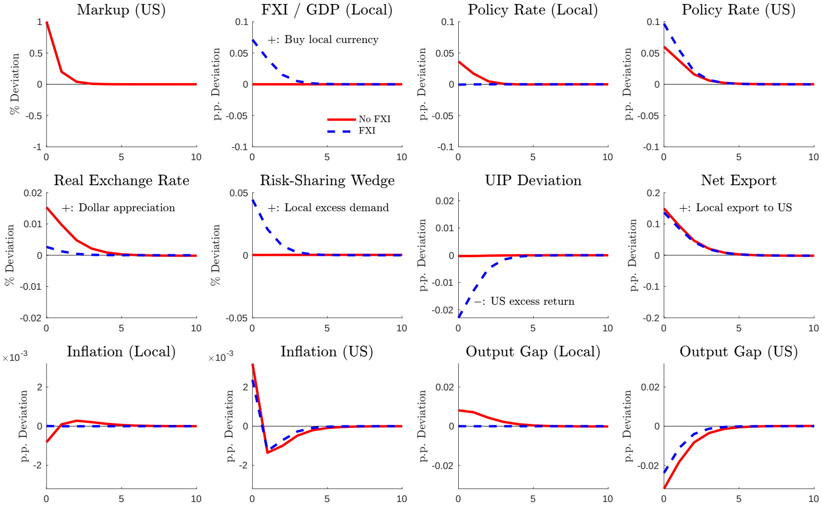
Impulse Response to a US Cost-Push Shock ($\phi = 4$)



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Definition of Open-Loop Nash Equilibrium

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- $x_t = (\tilde{x}_t, i_{1,t}, i_{2,t})$: endogenous variables, ζ_t: exogenous variables
- $i_{1,t}, i_{2,t}$: policy instrument of player $j = [1, 2]$

Definition 1

An open-loop Nash equilibrium is a sequence $\{i^*_{j,t}\}_{t=0}^{\infty}$ such that, for all period t^*, i^*_{j,t^*} maximizes player j's objective function subject to the constraints for given sequences of $\{i^*_{j,t,-t^*}\}_{t=0}^{\infty}$ (own action except for period t^*) and $\{i^*_{-j,t}\}_{t=0}^{\infty}$ (the other player's action).

- Each player j maximizes for given $\{i^*_{j,-t}\}_{t=0}^{\infty}$,

$$\max_{\tilde{x}_t, \{i_{j,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U_j(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t) \quad \text{s.t.} \quad E_t g(x_{t-1}, x_t, x_{t+1}, \zeta_t) = 0.$$

- Timeless perspective: the Lagrange multiplier λ_{-1} is chosen so that agents face the same FOCs for all $t \geq 0$.

Cost-Push Shock (Nash and Cooperation)

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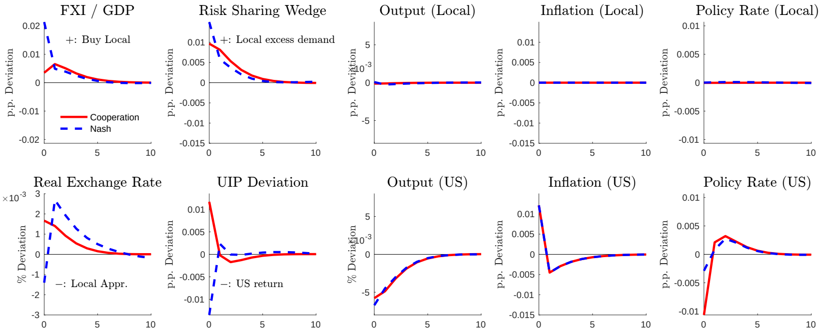
Figure 1: US Cost-Push Shock, Nash and Cooperation



Cost-Push Shock (Nash Equilibrium)

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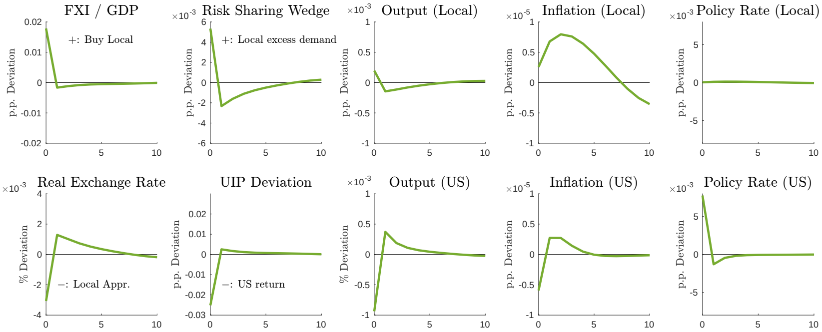
Figure 2: US Cost-Push Shock, Difference Nash − Cooperation



- Excess accumulation of local currency reserves → local appreciation
  - US import price ⇑ → US monetary tightening, under-production
  - Local excess demand, risk-sharing distortion (beggar-thy-neighbor)

Cost-Push Shock (Nash Equilibrium)

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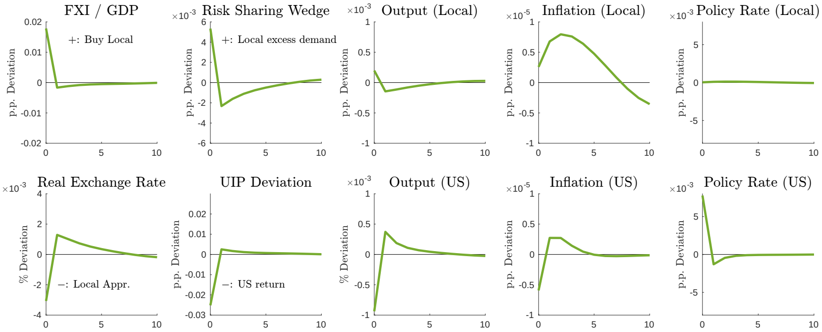
Figure 2: US Cost-Push Shock, Difference Nash − Cooperation



- Excess accumulation of local currency reserves → local appreciation
  - US tightening → $ appreciation, local import price ⇑
  - Local CB buys the local currency more (feedback loop)

Cost-Push Shock (Nash Equilibrium)

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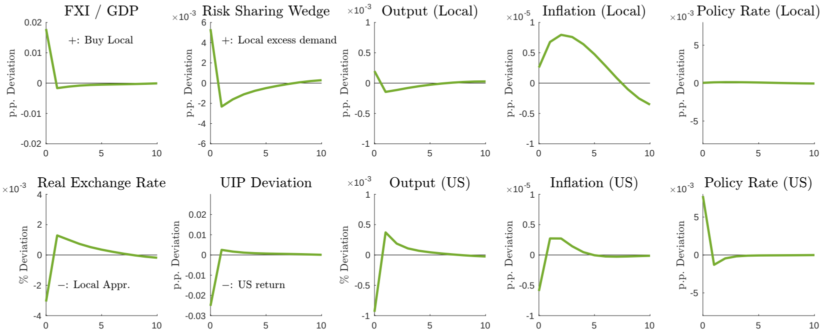
Figure 2: US Cost-Push Shock, Difference Nash − Cooperation



- Conversely, US cost-pull shock → competitive devaluation
  - Excess accumulation of $ reserves and monetary easing
  - Over-production, risk-sharing distortion in favor of the US