The Synthetic Dollar Funding Channel of US Monetary Policy

Jongho Lee

Department of Economics, Columbia University

October 10, 2024

Motivation

Synthetic dollar funding: dollar funding through the FX swap market

1. Borrowing local currency at R_t^*
2. Exchanging into USD at spot exchange rate S_t
3. Covering exchange rate risk at forward exchange rate F_t

- Synthetic dollar funding cost:

$$R_t^* \frac{S_t}{F_t} = \underbrace{R_t^\$}_{\text{direct funding cost}} - \underbrace{\left(R_t^\$ - R_t^* \frac{S_t}{F_t} \right)}_{\text{CIP deviation: gap}}$$

Motivation

Synthetic dollar funding: dollar funding through the FX swap market

1. Borrowing local currency at R_t^*
2. Exchanging into USD at spot exchange rate S_t
3. Covering exchange rate risk at forward exchange rate F_t

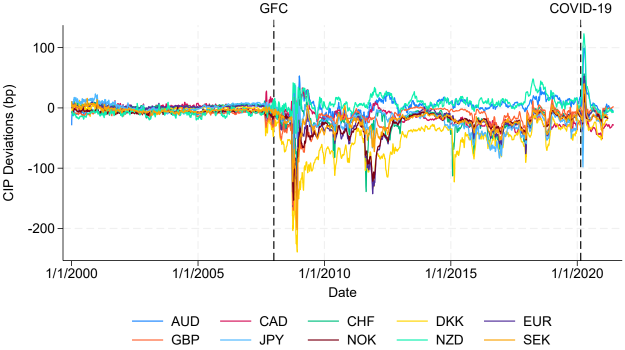
- Synthetic dollar funding cost:

$$R_t^* \frac{S_t}{F_t} = \underbrace{R_t^\$}_{\text{direct funding cost}} - \underbrace{\left(R_t^\$ - R_t^* \frac{S_t}{F_t} \right)}_{\text{CIP deviation: gap}}$$

Motivation

Importance of synthetic dollar funding

- Rising share of the synthetic dollar funding
- Emergence of CIP deviations (*cid*) since the GFC
  - CIP deviations < 0 $\Leftrightarrow$ synthetic cost > direct cost



Research Question

Synthetic dollar funding channel of US monetary policy: transmission channel of US monetary policy through FX swap markets

1. What are the effects of US monetary policy on CIP deviations?
2. How do the effects amplify spillovers and spillbacks of US monetary policy?

- Related to credit channel of monetary policy (Bernanke & Gertler, 1995)
  - Monetary policy affects CIP deviations through balance sheets
  - CIP deviations: wedge in the dollar funding market amplifying transmission channel

Research Question

Synthetic dollar funding channel of US monetary policy: transmission channel of US monetary policy through FX swap markets

1. What are the effects of US monetary policy on CIP deviations?
2. How do the effects amplify spillovers and spillbacks of US monetary policy?

- Related to credit channel of monetary policy (Bernanke & Gertler, 1995)
  - Monetary policy affects CIP deviations through balance sheets
  - CIP deviations: wedge in the dollar funding market amplifying transmission channel

Key Takeaways

Empirical findings: From high-frequency data,

- US monetary contraction $\Rightarrow$ CIP deviations widen

Theoretical model: Two-country NK model + FX swap market

- CIP deviations: price of the FX swap market
  - Supply: US banks with limit on CIP arbitrage
  - Demand: Non-US banks' currency matching for the USD assets
- Synthetic dollar funding channel:
  - *cid* widens since US banks' leverage constraints become tighter
  - Amplification of spillover and spillback (output, investment, inflation..)
  - Central bank swap lines: dampen the amplification by preventing the widening of CIP deviations

Key Takeaways

Empirical findings: From high-frequency data,

- US monetary contraction $\Rightarrow$ CIP deviations widen

Theoretical model: Two-country NK model + FX swap market

- CIP deviations: price of the FX swap market
  - Supply: US banks with limit on CIP arbitrage
  - Demand: Non-US banks' currency matching for the USD assets
- Synthetic dollar funding channel:
  - *cid* widens since US banks' leverage constraints become tighter
  - Amplification of spillover and spillback (output, investment, inflation..)
  - Central bank swap lines: dampen the amplification by preventing the widening of CIP deviations

Related Literature

Empirical: Keerati (2020), Viswanath-Naraj (2020), Cerutti et al. (2021), Jiang et al. (2021)

- High-frequency identification with more up-to-date dataset

Theoretical:

- CIP deviations and banks: Ivashina et al. (2015), Iida et al. (2018), Liao and Zhang (2020), Bahaj and Reis (2022), Bacchetta et al. (2024)
  - Infinite horizon & GE model to analyze the transmission channel
- UIP deviation and macro model: Kollmann (2005), Gabaix and Maggiori (2015), Itskhoki and Mukhin (2021), Akinci et al. (2022), Schmitt-Grohé and Uribe (2022), Devereux et al. (2023)
  - Focus on CIP deviations as barometers for dollar funding costs
- Convenience yield and macro model: Jiang et al. (2020), Kekre and Lenel (2021), Bianchi et al. (2022)
  - Focus on limit to arbitrage rather than safety or liquidity of USD

Empirical Evidence

Measurement of CIP Deviations

CIP deviations: cross-currency bases measured by ▸ summary

$$cid_{j,t} = r_{\$,t} - (r_{j,t} - \rho_{j,t})$$

- $r_{j,t}$: 3-month risk-free rate of currency j
  - Risk-free rate: IBORs
  - 3-month: business cycle frequency & no quarter-end effects
- $\rho_{j,t}$: forward premium $(= F_{j,t}/S_{j,t} - 1)$
  - Mid price of bid & ask rates
- Source: Updated dataset of Du, Im, and Schreger (2018)

Identification of US Monetary Policy Shock

Identification problem: endogeneity of policy rate

- *cid*: market price of synthetic dollar funding
  - *cid* and policy rate: jointly affected by macro-conditions

Identification strategy: high-frequency method

- 30-minute changes in FF1, FF4, ED2, ED3, ED4 around each FOMC
  - Key identifying assumption: all the information on monetary policy are priced just before the FOMC
- Factors extracted from the surprises in 5 interest rate futures
  - Single factor (Nakamura and Steinsson, 2018): NS
  - Two factors (Gürkaynak et al., 2005): target and path factor
  - Normalized to have 1-1 relationship with 1-year treasury rate
- Source: Acosta (2023)

Identification of US Monetary Policy Shock

Identification problem: endogeneity of policy rate

- *cid*: market price of synthetic dollar funding
  - *cid* and policy rate: jointly affected by macro-conditions

Identification strategy: high-frequency method

- 30-minute changes in FF1, FF4, ED2, ED3, ED4 around each FOMC
  - Key identifying assumption: all the information on monetary policy are priced just before the FOMC
- Factors extracted from the surprises in 5 interest rate futures
  - Single factor (Nakamura and Steinsson, 2018): NS
  - Two factors (Gürkaynak et al., 2005): target and path factor
  - Normalized to have 1-1 relationship with 1-year treasury rate
- Source: Acosta (2023)

High-Frequency Estimation: Estimation Strategy

Fixed-effect regression in the post-GFC period:

$$\Delta cid_{j,t} = \alpha_j + \beta \Delta mp_t + \epsilon_{j,t}$$

- $\Delta cid_{j,t}$: one-day change in CIP deviations (unit: basis points)
  - Time-zone differences? OTC markets with 24-hour trading
  - Interpretation: $\Delta cid < 0 \Leftrightarrow$ widening of *cid* ($\because$ $cid < 0$ on average)
- Δmp_t: US monetary policy shock (unit: percentage points)
- Sample:
  - G10 currencies (AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD, SEK)
  - Jan 2008 - Apr 2021 / Frequency: FOMC announcement

High-Frequency Estimation: Estimation Strategy

Fixed-effect regression in the post-GFC period:

$$\Delta cid_{j,t} = \alpha_j + \beta \Delta mp_t + \epsilon_{j,t}$$

- $\Delta cid_{j,t}$: one-day change in CIP deviations (unit: basis points)
  - Time-zone differences? OTC markets with 24-hour trading
  - Interpretation: $\Delta cid < 0 \Leftrightarrow$ widening of cid ($\because$ $cid < 0$ on average)
- Δmp_t: US monetary policy shock (unit: percentage points)
- Sample:
  - G10 currencies (AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD, SEK)
  - Jan 2008 - Apr 2021 / Frequency: FOMC announcement

High-Frequency Estimation: Estimation Strategy

Fixed-effect regression in the post-GFC period:

$$\Delta cid_{j,t} = \alpha_j + \beta \Delta mp_t + \epsilon_{j,t}$$

- $\Delta cid_{j,t}$: one-day change in CIP deviations (unit: basis points)
  - Time-zone differences? OTC markets with 24-hour trading
  - Interpretation: $\Delta cid < 0 \Leftrightarrow$ widening of cid ($\because$ $cid < 0$ on average)
- Δmp_t: US monetary policy shock (unit: percentage points)
- Sample:
  - G10 currencies (AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD, SEK)
  - Jan 2008 - Apr 2021 / Frequency: FOMC announcement

High-Frequency Estimation: Results

	(1)		(2)
NS	-35.34***	Target	-28.33***
	(13.40)		(6.386)
		Path	-7.006*
			(3.626)
R^2	0.135		0.203
N	1047		1047

Note: Units of the estimates are in basis points. Driscoll-Kraay standard errors are reported in the parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

▸ all maturities ▸ decomposition ▸ term structure ▸ robustness

- $\beta < 0$: US monetary contraction $\Rightarrow$ widening of CIP deviations
  - Synthetic cost rises by 35bp more than direct cost
  - Effects: target > path

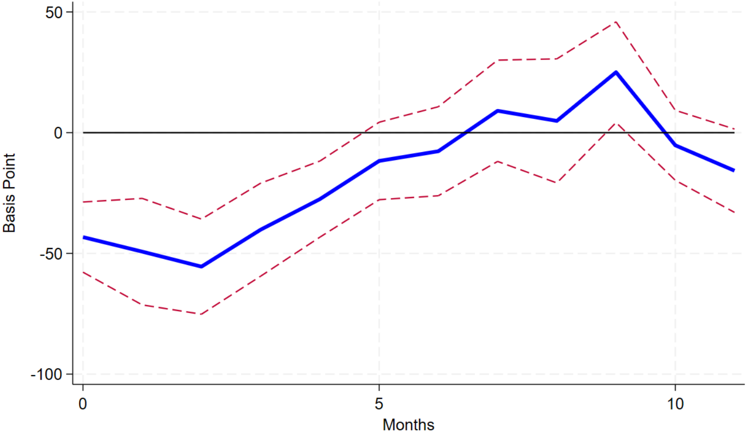
Local Projection: Estimation Strategy

Local projection (monthly frequency):

$$\Delta cid_{j,t+h} = \alpha_j + \beta_h \Delta mp_t + \gamma' X_t + \epsilon_{j,t+h}$$

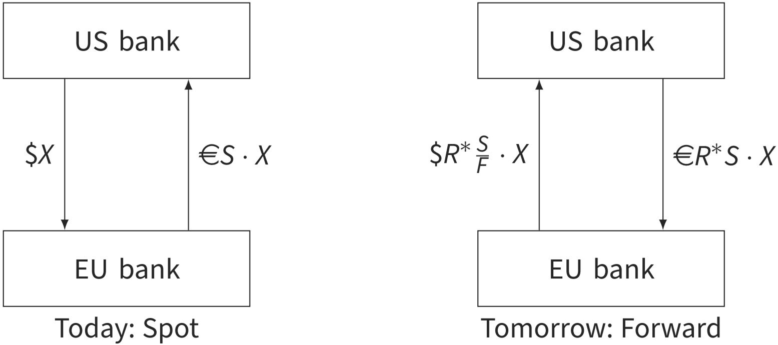
- $\Delta cid_{j,t}$: changes in monthly average of CIP deviations
- X_t: control variables
  - Lagged variables of $\Delta cid_{j,t}$ and Δmp_t
  - Lag: up to 4 months (Stock & Watson, 2018)

Local Projection: Results



Theoretical Model

Structure of a FX Swap Contract



- US bank: sell \$ and buy € spot, buy \$ and sell € forward
  - Supplier of synthetic dollar funding
- EU bank: buy \$ and sell € spot, sell \$ and buy € forward
  - Demander of synthetic dollar funding

US Bank: Balance Sheet

US Bank i's Portfolio

- US capital assets: $K_{H,i,t} \Rightarrow$ gross return rate in \$: $R_{K,H,t+1}$
- Risk-less arbitrage: $X_{i,t} \Rightarrow$ gross return rate in \$: $R_t^* S_t / F_t$
  - $\$X_{i,t} \rightarrow €S_t X_{i,t} \rightarrow €R_t^* S_t X_{i,t} \rightarrow \$R_t^* (S_t/F_t) X_{i,t}$

Law of motion of net worth $N_{i,t}$:

$$N_{i,t+1} = R_t N_{i,t} + (R_{K,t+1} - R_t) K_{H,i.t} + \underbrace{\left(R_t^* \frac{S_t}{F_t} - R_t\right)}_{=-cid_t} X_{i.t}$$

- $-cid_t$: return on supplying synthetic dollar funding ($\because$ sell USD spot)

US Bank: Balance Sheet

US Bank i's Portfolio

- US capital assets: $K_{H,i,t} \Rightarrow$ gross return rate in \$: $R_{K,H,t+1}$
- Risk-less arbitrage: $X_{i,t} \Rightarrow$ gross return rate in \$: $R_t^* S_t / F_t$
  - $\$X_{i,t} \to €S_t X_{i,t} \to €R_t^* S_t X_{i,t} \to \$R_t^* (S_t/F_t) X_{i,t}$

Law of motion of net worth $N_{i,t}$:

$$N_{i,t+1} = R_t N_{i,t} + (R_{K,t+1} - R_t) K_{H,i.t} + \underbrace{\left(R_t^* \frac{S_t}{F_t} - R_t \right)}_{= -cid_t} X_{i.t}$$

- $-cid_t$: return on supplying synthetic dollar funding ($\because$ sell USD spot)

US bank: Value Function

<u>Value function</u>: $V_{i,t} = E_t\left[\Lambda_{t,t+1}\{(1-\sigma)N_{i,t+1} + \sigma V_{i,t+1}\}\right]$

- $\Lambda_{t,t+1}$: SDF of households (holding banks)
- σ: continuation probability (revealed at the beginning of t)
  - Exiting banks: pay out net worth to households
- $V_{i,t} = \nu_t N_{i,t}$: shown by guess and verify method proof
  - $\nu_t = E_t[\Lambda_{t,t+1}(1-\sigma+\sigma\nu_{t+1})(N_{i,t+1}/N_{i,t})] \equiv E_t[\Omega_{t,t+1}(N_{i,t+1}/N_{i,t})]$
  - $\Omega_{t,t+1}$: SDF of US bank
  - $\Omega_{t,t+1} \neq \Lambda_{t,t+1}$ if $\nu_{t+1} \neq 1$

US Bank: Financial Friction

Leverage constraint (Gertler & Kiyotaki, 2011):

$$V_{i,t} \geq \left(\theta_{H1} + \theta_{H2}\frac{Q_t K_{H,t}}{P_t}\right) Q_t K_{H,i,t} + \left(\theta_{X1} + \theta_{X2}\frac{X_t}{P_t}\right) X_{i,t}$$

- θ: parameters for the degree of regulation on each asset
- θ_{X1}, θ_{X2}: limit on CIP arbitrage
  - Pre-GFC: $\theta_{X1} = \theta_{X2} = 0$
- θ_{H2}, θ_{X2}: introduced for closing the model (Devereux et al., 2023)
  - External stationarity device (Schmitt-Grohé and Uribe, 2003)
  - State-dependent regulation

US Bank: Supply of FX Swap

Optimality condition for $X_{i,t}$: For Lagrangian multiplier μ_t of the leverage constraint,

$$\underbrace{E_t\left[\Omega_{t,t+1}\right]}_{\text{Bank SDF}}\underbrace{\left(R_t^*\frac{S_t}{F_t}-R_t\right)}_{=-cid_t} = \mu_t\left(\theta_{X1}+\theta_{X2}\frac{X_t}{P_t}\right)$$

- Upward-sloping inverse supply function in $-cid_t$
- cid_t: non-zero even up to first-order unless $\theta_{X1}=\theta_{X2}=0$
  - Pre-GFC ($\theta_{X1}=\theta_{X2}=0$): $cid_t=0$ (perfectly elastic)
- As $\mu_t\uparrow$, CIP deviations widen, *i.e* $-cid_t\uparrow$
  - CIP deviations reflect bank balance sheet costs

EU Bank: Balance sheet

<u>EU Bank *i*'s Portfolio</u>

- EU capital assets: $K^*_{F,i,t}$ $\Rightarrow$ gross return rate in €: $R^*_{F,H,t+1}$
- US capital assets: $K^*_{H,i,t}$ $\Rightarrow$ gross return rate in \$: $R_{K,H,t+1}$
  - Assumption 1: **cannot** issue \$ deposits $\Rightarrow$ all deposits are in €
  - Currency mismatch between $K^*_{H,i,t}$ and liabilities
  - Assumption 2: Tighter regulation (higher θ) on currency mismatch $\Rightarrow$ hedge ratio (x^*) is optimally chosen

EU Bank: Demand for FX Swap

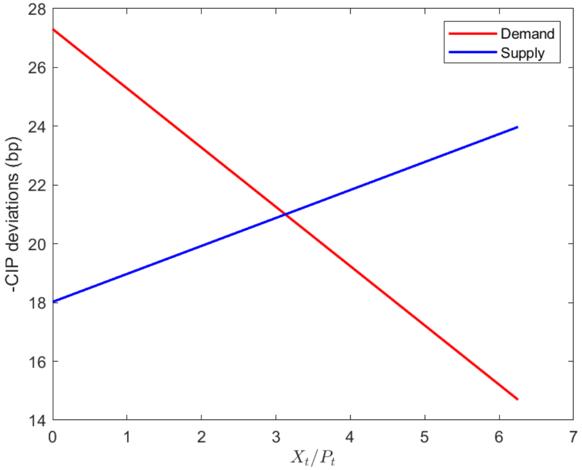
Optimality condition:

$$E_t\left[\Omega^*_{t,t+1}\frac{S_{t+1}}{S_t}\underbrace{\left(R_{K,t+1} - R^*_t\frac{S_t}{F_t}\right)}_{R_{K,t+1}-(R_t-cid_t)}\right] = \mu^*_t\left(\theta^*_{X1} + \theta^*_{X2}\frac{x^*_t S_t Q_t K^*_{H,t}}{P^*_t}\right)$$

- Downward-sloping inverse demand function in $-cid_t$ ▸ eqm
- cid_t: intermediation fee for currency matching
  - If EU banks can fund USD directly, then excess return is $R_{K,t+1} - R_t$

Equilibrium for the FX Swap Market

Market clearing condition: $X_t = x_t^* Q_t K_{H,t}^*$ ▸ supply ▸ demand



Other Sectors

- Household: chooses consumption, labor, and deposits ‣ household
- Capital-good producer: installs capital ‣ capital-good producer
  - Subject to quadratic capital adjustment cost
  - Price of capital (Tobin's Q) $\neq$ price of investment-good
- Firm: produces each variety using labor and capital ‣ firm
  - Price rigidity à la Rotemberg (1982) and local currency pricing
- Wholesalers: assemble varieties into a final good ‣ wholesaler
  - Demand functions faced by monopolistically competitive firms
- Retailers: assemble domestic and imported goods ‣ retailer
  - Home-bias and elasticity of substitution between domestic and imported goods
- Monetary policy and fiscal policy ‣ policy

Results

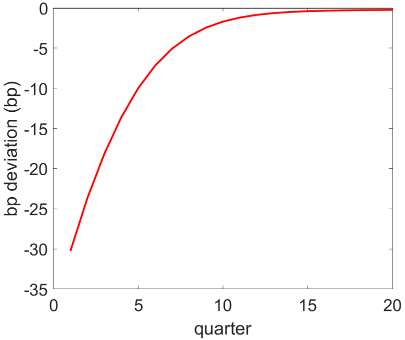
Calibration: Banking Sector

Frequency: quarterly

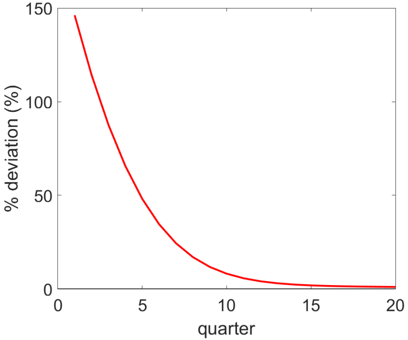
Parameter	Value	Target
$\sigma = \sigma^*$	0.95	Average survival horizon of 5 years
θ_{X1}	0.11	CIP deviation of -21bp
θ^*_{X1}	0.19	RoW capital excess return of 100bp
θ_{X2}	0.005	Devereux et al. (2023)
θ^*_{X2}	0.005	Devereux et al. (2023)

‣ calibration ‣ sensitivity

IRFs: CIP Deviations



(a) CIP Deviations (*cid*)

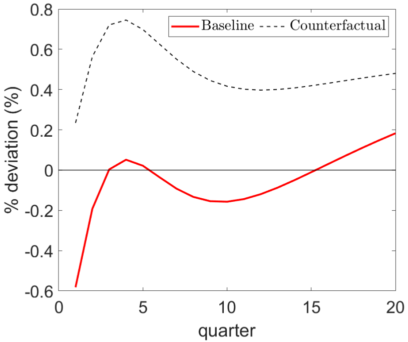


(b) Lagrange Multiplier (μ)

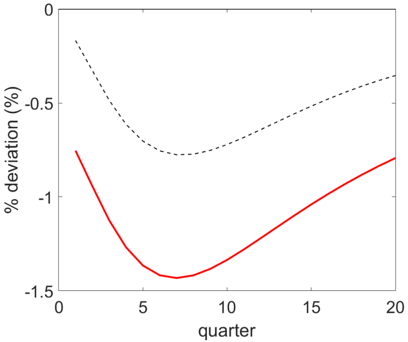
- $R \uparrow \Rightarrow N \downarrow \Rightarrow$ Tighter limit on CIP arbitrage $\Rightarrow \mu \uparrow$
- Supply of synthetic dollar funding $\downarrow$

IRFs: Synthetic Dollar Funding

Baseline vs Counterfactual ($\theta_{X1} = \theta_{X2} = 0$)



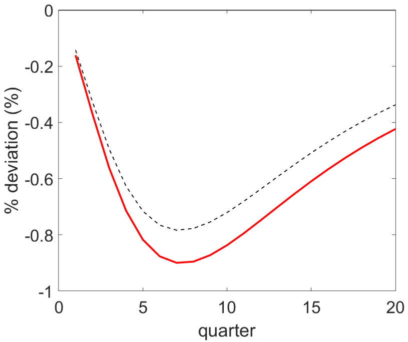
(a) Synthetic Dollar Funding (X/P)



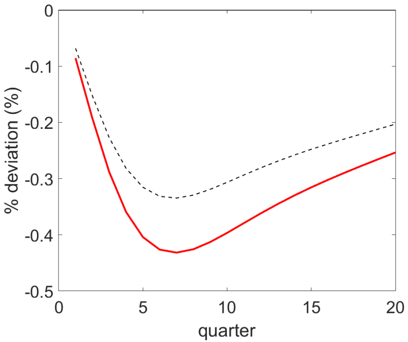
(b) US Capital Holdings by EU (K_H^*)

- Lower X/P: due to the decrease in supply schedule
- Lower K_H^*: due to larger *cid* and lower X/P
  - Cost of hedging currency risks in K_H^*: CIP deviations

Amplification of Spillover and Spillback



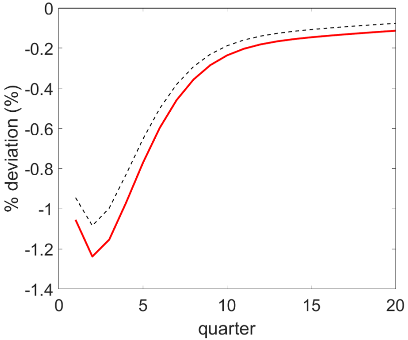
(a) US Capital (K)



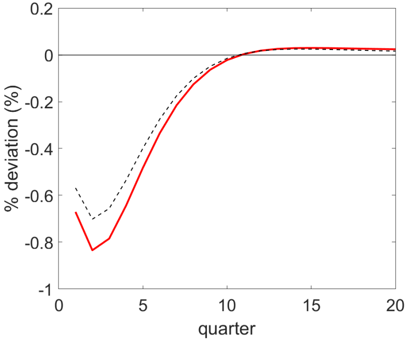
(b) EU Capital (K^*)

- Decrease in K: X/P and $K_H^* \downarrow$
- Decrease in K^*: Larger *cid* $\Leftrightarrow$ higher intermediation fees $\Rightarrow$ $N^* \downarrow$

Amplification of Spillover and Spillback



(a) US Output (Y)

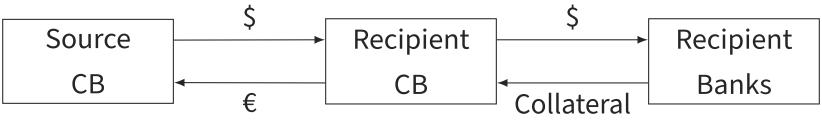


(b) EU Output (Y^*)

▸ investment ▸ inflation ▸ exchange rate ▸ price of capital

Central Bank Swap Lines

<u>Lender of last resort</u>: collateralized public liquidity line



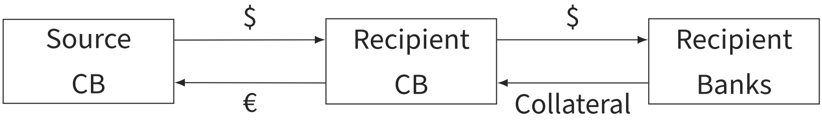
- Interest rate: swap spread ss_t over a risk-free rate
- $-cid_t \leq ss_t$: ceiling on CIP deviations (Bahaj and Reis, 2022)
  - International version of discount window policy

<u>Question</u>: what does this imply for the synthetic dollar funding channel?

- Effect on CIP deviations and synthetic dollar funding costs?
- Implication for the amplification effects?
- Caveat: Focusing on positive rather than normative analysis

Central Bank Swap Lines

Lender of last resort: collateralized public liquidity line



- Interest rate: swap spread ss_t over a risk-free rate
- $-cid_t \leq ss_t$: ceiling on CIP deviations (Bahaj and Reis, 2022)
  - International version of discount window policy

Question: what does this imply for the synthetic dollar funding channel?

- Effect on CIP deviations and synthetic dollar funding costs?
- Implication for the amplification effects?
- Caveat: Focusing on positive rather than normative analysis

Modelling Swap Line Policy

Swap Line Policy: described by (ss_t, X_t^{SL}) ▸ Eqm

- Policy instrument: occasionally binding constraint

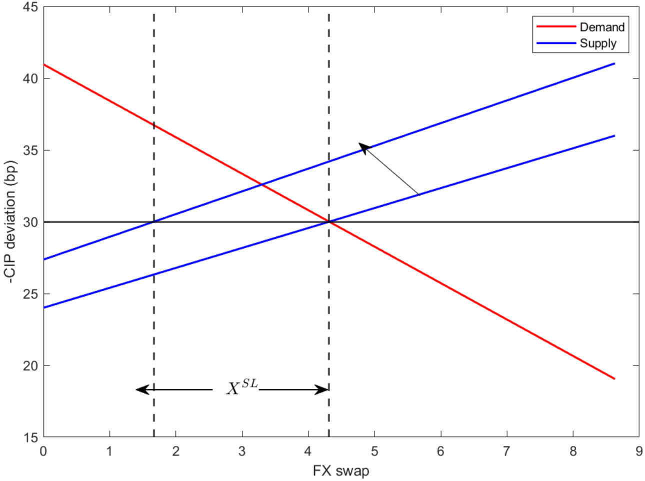
$$-cid_t \equiv R_t - R_t^* \frac{S_t}{F_t} \leq ss_t$$

  - $ss_t = 25$bp: swap spreads of standing facilities

- Market clearing condition: $X_t + X_t^{SL} = x_t^* Q_t K_{H,t}^*$
- Complementary slackness condition:

$$(cid_t + ss_t) X_t^{SL} = 0$$

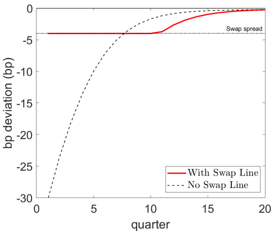
FX Swap Market with Swap Line Policy



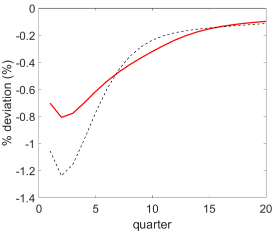
back

Transmission Channel: With v.s. Without Swap Lines

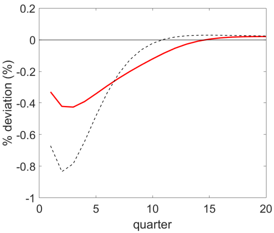
Change in impulse responses:



(a) CIP Deviations



(b) US Output



(c) EU Output

- No widening of CIP deviations due to swap lines
- Synthetic dollar funding channel: dampened
  - Swap line policy affects monetary transmission

Conclusion

Empirical findings: In the post-GFC periods,

- US monetary contraction: larger deviations from CIP

Theoretical model: 2-country NK model + FX swap market

- CIP deviations: price in the FX swap market
  - Supply: US banks with limit on CIP arbitrage
  - Demand: Non-US banks' currency matching for the USD assets
- Finding 1: Net worth $\downarrow \Rightarrow$ Tighter limit on CIP arbitrage
- Finding 2: Dollar funding costs $\uparrow$ & Capital inflows to US $\downarrow$
- Central bank swap lines: dampen the synthetic dollar funding channel

Appendix

Summary Statistics of CIP Deviations

	3M			1Y			2Y		
	90-99	00-07	08-	90-99	00-07	08-	90-99	00-07	08-
Mean	-3.75	-2.48	-20.93	-2.03	-0.45	-16.74	-2.14	-0.29	-15.63
Median	-2.68	-2.40	-17.87	-1.49	-0.52	-14.80	-2.09	-0.24	-14.21
S.D.	15.36	5.42	20.99	2.63	1.80	13.00	3.20	1.67	11.53
Autocorr.	0.39	0.52	0.75	0.33	0.64	0.71	0.39	0.64	0.71
	3Y			5Y			10Y		
	90-99	00-07	08-	90-99	00-07	08-	90-99	00-07	08-
Mean	-2.56	-0.25	-14.74	-2.46	0.76	-13.29	-4.05	-0.75	-10.63
Median	-2.53	-0.21	-13.55	-2.56	1.06	-12.08	-4.42	-0.45	-9.22
S.D.	3.20	1.76	11.21	4.31	2.51	12.63	3.22	2.64	12.19
Autocorr.	0.41	0.64	0.71	0.39	0.72	0.79	0.35	0.65	0.71

Note: This table presents summary statistics of CIP deviation for each maturity of 3-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year. CIP deviation is measured as an average of cross-currency bases across G10 currencies. For each maturity, summary statistics for subperiods of 1990-1999, 2000-2007, and post-2008 are displayed. Row of this table refers to each summary statistic: mean, median, standard deviation, and autocorrelation.

back

Estimation Results: All Maturities

	3M	1Y	2Y	3Y	5Y	7Y	10Y
NS	-35.34***	-5.095	-0.526	-0.303	0.602	1.267	0.445
	(13.40)	(3.505)	(1.330)	(0.713)	(1.021)	(0.793)	(0.597)
R^2	0.135	0.021	0.001	0.000	0.001	0.003	0.001

	3M	1Y	2Y	3Y	5Y	7Y	10Y
Target	-28.33***	-3.471*	-0.289	0.031	0.998	1.658	0.256
	(6.386)	(1.785)	(1.051)	(0.674)	(0.936)	(1.042)	(0.312)
Path	-7.006*	-1.662	-0.297	-0.397	-0.459	-0.445	0.148
	(3.626)	(1.776)	(0.865)	(0.584)	(0.846)	(0.836)	(0.476)
R^2	0.203	0.027	0.001	0.001	0.006	0.011	0.001
N	1047	1022	1028	1030	1031	1039	1024

Note: Units of the estimates are in basis points. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Decomposition

	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid	-35.34***	-5.095	-0.526	-0.303	0.602	1.267	0.445
	(13.40)	(3.505)	(1.330)	(0.713)	(1.021)	(0.793)	(0.597)
$\Delta r^{\$}$	6.602**	62.48***	79.87***	84.59***	83.06***	42.52***	65.55***
	(3.221)	(0.299)	(6.324)	(0.017)	(0.138)	(0.057)	(14.87)
$-\Delta r^{j}$	-2.063*	-9.465**	-12.30***	-12.75**	-12.35*	-11.75*	-10.95**
	(2.576)	(3.846)	(4.180)	(4.147)	(3.943)	(3.558)	(2.782)
$\Delta \rho^{j}$	-39.88**	-58.52***	-67.65***	-71.35***	-70.42***	-30.30***	-54.20***
	(15.71)	(4.729)	(4.744)	(4.920)	(6.026)	(5.770)	(11.80)

Note: Units of the estimates are in basis points. Driscoll-Kraay standard errors are reported in the parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Cumulative Explained Variance of Δcid

Δcid	PC1	PC2	PC3
AUD	0.5619	0.7057	0.8214
CAD	0.6540	0.7931	0.8694
CHF	0.6450	0.8091	0.8848
DKK	0.4929	0.6478	0.7882
EUR	0.7088	0.8761	0.9287
GBP	0.6045	0.7832	0.8625
JPY	0.6730	0.8411	0.9085
NOK	0.4275	0.5852	0.7076
NZD	0.5778	0.7269	0.8519
SEK	0.5829	0.7596	0.8568

Note: For each currency, principal components of Δcid with maturities of 3-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year are extracted for the post-GFC (08-) periods. Three principal components are displayed in this table for simplicity.

Factor Loadings on PC1 and PC2

PC1	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
3m	0.0455	0.2110	0.2350	0.0906	0.2558	0.2013	0.2212	0.2025	0.0618	0.1593
1y	0.4122	0.3551	0.3600	0.3747	0.3421	0.3177	0.3688	0.3137	0.3264	0.3495
2y	0.4182	0.4015	0.4123	0.4050	0.4131	0.4225	0.4140	0.4211	0.4228	0.3887
3y	0.4698	0.4212	0.4302	0.4227	0.4211	0.4376	0.4353	0.4624	0.4537	0.4208
5y	0.4535	0.3975	0.3983	0.4432	0.4110	0.4426	0.4191	0.4365	0.4492	0.4316
7y	0.3341	0.4037	0.4015	0.3975	0.3967	0.3816	0.3928	0.4047	0.4012	0.4225
10y	0.3393	0.4121	0.3745	0.3927	0.3785	0.3835	0.3524	0.3394	0.3773	0.3995
PC2	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
3m	0.9714	0.8115	0.6376	0.1987	0.6790	0.6854	0.6777	0.5256	0.8273	0.6488
1y	0.1122	0.3449	0.4304	0.3776	0.5064	0.5162	0.3793	0.5214	0.3882	0.4093
2y	0.0552	0.1276	0.2240	0.4569	0.0894	0.1269	0.2062	0.2126	0.1545	0.3167
3y	-0.0205	-0.0893	0.0128	0.3072	-0.0862	-0.0540	0.0284	0.0957	0.0205	0.0636
5y	-0.0196	-0.1977	-0.2951	-0.2034	-0.2257	-0.1940	-0.2483	-0.2209	-0.1332	-0.2574
7y	-0.1481	-0.3089	-0.3573	-0.4724	-0.3236	-0.3120	-0.3614	-0.3807	-0.2399	-0.3433
10y	-0.1339	-0.2525	-0.3783	-0.5003	-0.3339	-0.3313	-0.4015	-0.4516	-0.2555	-0.3507

Note: This table presents factor loadings on the first two principal components for each currency during the post-GFC (08-) periods. The first panel shows the factor loadings on the first principal component while the second panel displays those on the second principal component. Each column indicates factor loadings for each G10 currency.

Principal Components and US Monetary Policy

	PC1		PC2	
	(1)	(2)	(3)	(4)
NS	-1.231		-5.991**	
	(1.925)		(2.309)	
Target		-0.405		-4.939***
		(1.297)		(1.059)
Path		-0.952		-0.979
		(1.413)		(0.564)
R^2	0.001	0.001	0.082	0.131
N	1002	1002	1002	1002

Note: This table presents the regression results of principal components of Δcid on 1%p contractionary US monetary policy shock. For each principal component, there are two columns: the left column is the estimation result when *NS* is used as the US monetary policy shock whereas the right column is the one when *Target* and *Path* are used as proxies for the shock. Standard errors clustered across currencies are reported in the parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Robustness Check

Different choices of the dependent variable

- Two-day changes in CIP deviations results
- Changes in absolute values of CIP deviations results

Different choices of the explanatory variable

- Information-robust monetary policy shocks results
- Monetary policy shocks robust to Fed response to news channel

  results

back

Robustness Check: Two-day Window

	3M		1Y		2Y		3Y	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NS	-25.32**		-13.13**		-5.939*		-5.592*	
	(10.55)		(6.474)		(3.291)		(3.228)	
Target		-36.63***		-10.00		-4.261		-3.902
		(7.775)		(6.278)		(3.094)		(2.821)
Path		10.54**		-3.174		-1.748		-1.765
		(4.422)		(2.214)		(1.627)		(1.271)
R^2	0.018	0.080	0.053	0.075	0.025	0.034	0.029	0.038
N	1047	1047	1018	1018	1027	1027	1027	1027

	5Y		7Y		10Y	
	(7)	(8)	(9)	(10)	(11)	(12)
NS	-2.686		-0.160		0.575	
	(1.500)		(1.799)		(1.292)	
Target		-1.442		-0.080		0.329
		(0.802)		(1.465)		(0.847)
Path		-1.303		-0.137		0.183
		(0.881)		(1.324)		(1.158)
R^2	0.009	0.010	0.000	0.000	0.001	0.001
N	1026	1026	1036	1036	1023	1023

Robustness Check: Absolute Value of CIP Deviations

	3M		1Y		2Y		3Y	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NS	18.78**		6.082*		2.104**		1.496	
	(7.399)		(3.233)		(0.793)		(1.059)	
Target		17.36**		4.047*		1.628*		1.743**
		(5.367)		(1.876)		(0.858)		(0.707)
Path		1.503		2.047		0.519		-0.202
		(3.302)		(1.688)		(0.679)		(0.640)
R^2	0.045	0.084	0.030	0.038	0.010	0.014	0.006	0.016
N	1047	1047	1022	1022	1028	1028	1030	1030

	5Y		7Y		10Y	
	(7)	(8)	(9)	(10)	(11)	(12)
NS	1.213		-0.054		0.339	
	(0.906)		(0.823)		(0.385)	
Target		1.580*		1.096		0.117
		(0.870)		(1.285)		(0.258)
Path		-0.345		-1.123		0.243
		(0.805)		(0.956)		(0.322)
R^2	0.004	0.013	0.000	0.008	0.000	0.001
N	1031	1031	1039	1039	1024	1024

Robustness Check: Information Effect

Signaling channel (Romer and Romer 2000; Nakamura and Steinsson 2018)

- Asymmetric information between the central bank and the market
- High-frequency surprises may reflect revision of market expectation

Slow absorption of information (Coibion and Gorodnichenko 2015)

- Market prices may not reflect fundamental shocks instantaneously
- High-frequency surprises may contain past fundamental shocks

Signalling Channel of Monetary Policy

Test for the signalling channel

- Greenbook forecasts: Fed's private information
- Project monetary policy indicators (NS, Target, Path) on Greenbook forecasts (Miranda-Agrippino and Rico, 2021) results

$$\Delta mp_t = \alpha + \sum_{i=-1}^{2} \beta_i' x_{t,i}^f + \sum_{i=-1}^{2} \gamma_i' (x_{t,i}^f - x_{t-1,i}^f) + \Delta \widetilde{mp}_t$$

  - Greenbook Sample: Feb 1984 - Dec 2017
  - $x_{t,i}^f$: vector of Greenbook forecasts of horizon i for GDP growth rate, inflation, and unemployment rate
    - ★ Unemployment rate: only contemporaneous forecast is included (Romer and Romer 2004)

Results: Signalling Channel of Monetary Policy

	NS	Target	Path		NS	Target	Path
GDP forecasts				Δ GDP forecasts			
i = –1	-0.004	-0.011*	0.001	i = –1	-0.000	-0.009	0.006
	(0.004)	(0.006)	(0.005)		(0.007)	(0.010)	(0.010)
i = 0	0.014	0.014	0.015	i = 0	0.007	0.006	0.007
	(0.009)	(0.014)	(0.010)		(0.010)	(0.015)	(0.014)
i = 1	0.007	-0.009	0.017	i = 1	0.022	0.021	0.024
	(0.013)	(0.024)	(0.015)		(0.015)	(0.027)	(0.019)
i = 2	-0.005	0.026	-0.027*	i = 2	0.008	-0.017	0.024
	(0.011)	(0.019)	(0.015)		(0.015)	(0.025)	(0.019)
Inflation forecasts				Δ Inflation forecasts			
i = –1	0.002	-0.023**	0.019**	i = –1	0.002	0.012	-0.002
	(0.007)	(0.011)	(0.008)		(0.011)	(0.023)	(0.011)
i = 0	0.018*	0.032*	0.007	i = 0	-0.002	-0.009	0.006
	(0.010)	(0.019)	(0.011)		(0.017)	(0.030)	(0.017)
i = 1	0.001	-0.031	0.026	i = 1	-0.011	0.037	-0.044*
	(0.015)	(0.031)	(0.016)		(0.021)	(0.040)	(0.024)
i = 2	-0.012	0.024	-0.035	i = 2	0.041	0.006	0.063*
	(0.022)	(0.036)	(0.029)		(0.029)	(0.045)	(0.035)
Unemployment forecasts				Constant			
i = 0	0.001	-0.002	0.002		-0.045	-0.042	-0.050
	(0.003)	(0.005)	(0.004)		(0.054)	(0.087)	(0.067)
R^2	0.223	0.133	0.215	p-value	0.001	0.569	0.000
F-statistic	2.71	0.91	3.67	N	192	192	192

Information-robust Monetary Policy Shock

Construction

1. $\Delta\widetilde{mp}$: robust to signaling effect
   - Orthogonal to the Fed's information set
2. Run AR(1) regression on $\Delta\widetilde{mp}$:

$$\Delta\widetilde{mp}_t = \alpha_0 + \alpha_1 \Delta\widetilde{mp}_{t-1} + \Delta mpi_t$$

   - Removing the serially correlated part in surprises
   - Δmpi_t: information-robust monetary policy shock

Estimation with *MPI*

	3M		1Y		2Y		3Y	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NS	-24.51**		-1.581		1.000		1.823*	
	(9.894)		(2.086)		(1.478)		(0.992)	
Target		-24.96***		-2.267*		-0.487		0.252
		(7.581)		(1.151)		(1.282)		(0.777)
Path		1.663		1.084		2.228*		1.909***
		(3.162)		(1.255)		(1.260)		(0.382)
R^2	0.045	0.098	0.001	0.007	0.002	0.012	0.006	0.011
N	879	879	862	862	869	869	871	871

	5Y		7Y		10Y	
	(7)	(8)	(9)	(10)	(11)	(12)
NS	2.614*		2.441		0.680	
	(1.226)		(1.553)		(0.867)	
Target		1.068		1.779		-0.040
		(1.123)		(1.352)		(0.431)
Path		1.706***		0.877		0.966
		(0.465)		(0.803)		(0.796)
R^2	0.012	0.014	0.009	0.012	0.001	0.003
N	873	873	879	879	866	866

back

Robustness Check: Fed Response to News Channel

Fed response to news channel: imperfect information for the Fed's monetary policy rule (Bauer & Swanson, 2023)

- Correlation between Δmp_t and macroeconomic and financial data available before FOMC announcements
- Orthogonalize Δmp_t with respect to available data:

$$\Delta mp_t = \alpha + \gamma' X_t + \Delta mpn_t$$

  - X_t: vector of macroeconomic and financial data
  - Δmpn_t: monetary policy shock robust to the Fed Response to news channel

Results

	3M	1Y	2Y	3Y	5Y	7Y	10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
NS	-34.06***	-6.300	-0.623	0.645	1.837	2.038	-0.247
	(12.20)	(4.238)	(1.631)	(0.663)	(1.285)	(1.162)	(0.877)
R^2	0.053	0.014	0.000	0.001	0.004	0.004	0.000
N	959	942	949	951	951	959	946

US Bank: Balance Sheet

Balance sheet ▸ chart

$$\underbrace{Q_t K_{H,i,t} + X_{i,t}}_{\text{Assets}} = \underbrace{D_{i,t} + N_{i,t}}_{\text{Liabilities}}$$

- $X_{i,t}$: risk-less lending to non-US banks (CIP arbitrage)
- Hedge exchange rate risks by FX swap contract (off-balance)

Budget constraint ▸ chart

$$Q_{t+1}K_{H,i,t+1} + X_{i,t+1} + R_t D_{i,t} = R_{K,t+1}Q_t K_{H,i,t} + R_t^* \frac{S_t}{F_t} X_{i,t} + D_{i,t+1}$$

$$\Rightarrow \frac{N_{i,t+1}}{N_{i,t}} = (R_{K,t+1} - R_t)\phi_{H,i.t} + \underbrace{\left(R_t^* \frac{S_t}{F_t} - R_t\right)}_{=-cid_t} \phi_{X,i.t} + R_t$$

- $-cid_t$: fee for supplying synthetic dollar funding ($\because$ sell USD spot)

Balance Sheet and Flow of Funds

Balance Sheet		Flow of Funds	
Asset	Liability	t	$t+1$
$Q_t K_{H,i,t}$	$D_{i,t}$	$-\$Q_t K_{H,i,t}$	$+\$R_{K,t+1} Q_t K_{H,i,t}$
$X_{i,t}$	$N_{i,t}$	$-\$X_{i,t}$	$+\$R_t^*(S_t/F_t)X_{i,t}$
		$+€S_t X_{i,t}$	$-€R_t^* S_t X_{i,t}$
		$-€S_t X_{i,t}$	$+€R_t^* S_t X_{i,t}$
		$+\$D_{i,t}$	$-\$R_t D_{i,t}$

back

Linearity of Bank Value Function

Guess: $V_{i,t} = \nu_t N_{i,t}$

$\Rightarrow$ Bellman equation:

$$\nu_t = \max_{\phi_{H,i,t},\phi_{X,i,t}} \nu_{H,t}\phi_{H,i,t} + \nu_{X,t}\phi_{X,i,t} + \nu_{N,t}$$
$$\text{s.t. } \nu_t \geq \left(\theta_{H1} + \theta_{H2}\frac{Q_t K_{H,t}}{P_t}\right)\phi_{H,i,t} + \left(\theta_{X1} + \theta_{X2}\frac{X_t}{P_t}\right)\phi_{X,i,t}$$

for

$$\nu_{H,t} \equiv E_t\left[\Omega_{t,t+1}\left(R_{K,t+1} - R_t\right)\right]$$
$$\nu_{X,t} \equiv E_t\left[\Omega_{t,t+1}\right]\left(R_t^*\frac{S_t}{F_t} - R_t\right)$$
$$\nu_{N,t} \equiv E_t\left[\Omega_{t,t+1}\right]R_t$$

Linearity of Bank Value Function

First-order conditions

$$\nu_{H,t} = \mu_t \left(\theta_{H1} + \theta_{H2} \frac{Q_t K_{H,t}}{P_t} \right)$$

$$\nu_{X,t} = \mu_t \left(\theta_{X1} + \theta_{X2} \frac{X_t}{P_t} \right)$$

Verify:

$$\nu_t = \frac{\nu_{N,t}}{1 - \mu_t}$$

$\Rightarrow \nu_t$: same for all banks and not dependent on an individual bank's net worth back

US bank: Leverage Constraint

Key financial friction: limited commitment constraint (GK 2011)

$$V_{i,t} \geq \left(\theta_{H1} + \theta_{H2}\frac{Q_t K_{H,t}}{P_t}\right) Q_t K_{H,i,t} + \left(\theta_{X1} + \theta_{X2}\frac{X_t}{P_t}\right) X_{i,t}$$

- $\theta(\cdot)$: fraction of each asset that US banks can divert
  - Limited commitment constraint: induce self-enforcement
  - θ_{H2}, θ_{X2}: introduced for closing the model (Devereux et al., 2023)
    - ★ External stationarity device (Schmitt-Grohé and Uribe, 2003)
- Also interpreted as a leverage constraint ($\because V_{i,t}$ is linear in net worth)
  - θ_{H2}, θ_{X2}: state-dependent regulation
- θ: parameters for the degree of regulation on leverage
  - θ_{X1}, θ_{X2}: limit on CIP arbitrage (pre-GFC: $\theta_{X1} = \theta_{X2} = 0$)

US bank: Supply of FX Swap

Supply for FX swap: value func. opt. + LoM for net worth + leverage const.

$$\underbrace{E_t\left[\Omega_{t,t+1}\right]}_{\text{Bank SDF}}\underbrace{\left(R_t^*\frac{S_t}{F_t}-R_t\right)}_{=-cid_t}=\mu_t\left(\theta_{X1}+\theta_{X2}\frac{X_t}{P_t}\right)$$

- Upward-sloping inverse supply function in $-cid_t$ eqm
- μ_t: Lagrangian multiplier (tightness of the leverage constraint)
  - $\mu_t > 0$ guaranteed by the calibration
- cid_t: non-zero even up to first-order unless $\theta_{X1} = \theta_{X2} = 0$
  - Pre-GFC ($\theta_{X1} = \theta_{X2} = 0$): $cid_t = 0$ (perfectly elastic)
- As $\mu_t \uparrow$, CIP deviations widen, *i.e* $-cid_t \uparrow$

back

Non-US Bank: Balance Sheet

Balance sheet ‣ chart

$$Q_t^* K_{F,i,t}^* + S_t Q_t K_{H,i,t}^* = D_{i,t}^* + S_t \tilde{X}_{i,t}^* + N_{i,t}^*$$

- $Q_t X_{i,t}^*$ (\$ value of US capital holdings): s.t. currency mismatch
  - $x_{i,t}^* Q_t K_{H,i,t}^*$ for $x_{i,t}^* \in [0,1]$: demand for *currency matching* (off-balance)
  - Motive for currency matching: regulation (leverage constraint)
  - Assumption: direct dollar funding *not available* to non-US banks

Budget constraint ‣ chart

$$Q_{t+1}^* K_{F,i,t+1}^* + S_{t+1} Q_{t+1} K_{H,i,t+1}^* + R_t^* (D_{i,t}^* + S_t \tilde{X}_{i,t}^*) + S_{t+1} R_t^* \frac{S_t}{F_t} x_{i,t}^* Q_t K_{H,i,t}^*$$

$$= R_{K,t+1}^* Q_t^* K_{F,i,t}^* + S_{t+1} R_{K,t+1} Q_t K_{H,i,t}^* + (D_{i,t+1}^* + S_{t+1} \tilde{X}_{i,t+1}^*) + R_t^* S_t x_{i,t}^* Q_t K_{H,i,t}^*$$

Balance Sheet and Flow of Funds

Balance Sheet		Flow of Funds	
Asset	Liability	t	$t+1$
$Q_t^* K_{F,i,t}^*$	$D_{i,t}^*$	$-€Q_t^* K_{F,i,t}$	$+€R_{K,t+1}^* Q_t^* K_{F,i,t}^*$
$S_t Q_t K_{H,i,t}^*$	$S_t \tilde{X}_t^*$	$-\$Q_t K_{H,i,t}$	$+\$R_{K,t+1} Q_t K_{H,i,t}^*$
	$N_{i,t}^*$	$\boxed{+\$x_{i,t}^* Q_t K_{H,i,t}^*}$	$\boxed{-\$R_t^*(S_t/F_t) x_{i,t}^* Q_t K_{H,i,t}^*}$
		$\boxed{-€S_t x_{i,t}^* Q_t K_{H,i,t}^*}$	$\boxed{+€R_t^* S_t x_{i,t}^* Q_t K_{H,i,t}^*}$
		$+€S_t \tilde{X}_{i,t}^*$	$-€R_t^* S_t \tilde{X}_{i,t}^*$
		$+€D_{i,t}^*$	$-€R_t^* D_{i,t}^*$

▸ back

Non-US Bank: Law of Motion of Net Worth

Law of motion for net worth:

$$N^*_{i,t+1} = \left[(R^*_{K,t+1} - R^*_t)\phi^*_{F,i,t} + \frac{S_{t+1}}{S_t}\left(R_{K,t+1} - R^*_t\frac{S_t}{S_{t+1}}\right)(1 - x^*_{i,t})\phi^*_{H,i,t} + \frac{S_{t+1}}{S_t}\left(R_{K,t+1} - R^*_t\frac{S_t}{F_t}\right)x^*_{i,t}\phi^*_{H,i,t} + R^*_t\right]N^*_{i,t}$$

- Excess return on $x^*_{i,t}\phi^*_{H,i,t}$: $R_{K,t+1} - (R_t - cid_t)$
  - $-cid_t$: intermediation fee for currency matching

Non-US bank: Leverage Constraint

Leverage constraint:

$$V^*_{i,t} \geq \left[\left(\theta^*_{F1} + \theta^*_{F2} \frac{Q^*_t K^*_{F,t}}{P^*_t} \right) \phi^*_{F,i,t} + \left(\theta^*_{H1} + \theta^*_{H2} \frac{(1 - x^*_t) S_t Q_t K^*_{H,t}}{P^*_t} \right) (1 - x^*_{i,t}) \phi^*_{H,i,t} \right.$$
$$\left. + \left(\theta^*_{X1} + \theta^*_{X2} \frac{x^*_t S_t Q_t K^*_{H,t}}{P^*_t} \right) x^*_{i,t} \phi^*_{H,i,t} \right] N^*_{i,t}$$

- $\theta^*_{H1} > \theta^*_{X1}$: stricter regulation on currency mismatch
  - Reflecting heavy penalty on currency mismatch in practice

Non-US Bank: Demand for FX Swap

Optimality condition for $X_{i,t}$:: For the Lagrangian multiplier μ_t^*,

$$E_t\left[\Omega^*_{t,t+1}\frac{S_{t+1}}{S_t}\underbrace{\left(R_{K,t+1}-R_t^*\frac{S_t}{F_t}\right)}_{R_{K,t+1}-(R_t-cid_t)}\right]=\mu_t^*\left(\theta^*_{X1}+\theta^*_{X2}\frac{x_t^*S_tQ_tK^*_{H,t}}{P_t^*}\right)$$

- Downward-sloping inverse demand function in $-cid_t$ eqm

back

Household

Optimization Problem

$$\max_{\{C_t, L_t, D_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\gamma} - 1}{1-\gamma} - \kappa \frac{L_t^{1+\varphi}}{1+\varphi} \right]$$

$$\text{s.t. } P_t C_t + D_t = W_t L_t + R_{t-1} D_{t-1} + TR_t + \Pi_t$$

First-order conditions

$$\kappa C_t^{\gamma} L_t^{\varphi} = \frac{W_t}{P_t}$$

$$E_t[\Lambda_{t,t+1}] R_t = 1$$

for the SDF given by $\Lambda_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \left(\frac{P_t}{P_{t+1}} \right)$ back

Capital-good Producer

Perfectly competitive capital-good producers purchasing investment goods at P_t and selling to banks at Q_t

Capital adjustment cost

$$\Psi\left(\frac{I_t}{K_{t-1}}\right) \equiv \frac{\psi_K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2$$

Tobin's Q

$$Q_t = P_t\left(1 + \psi_K\left(\frac{I_t}{K_{t-1}} - \delta\right)\right) - E_t\left[\Lambda_{t,t+1}P_{t+1}\psi_K\left(\frac{I_{t+1}}{K_t} - \delta\right)\frac{I_{t+1}}{K_t}\right]$$

Law of motion for the capital

$$K_t = I_t + (1 - \delta)K_{t-1}$$ back

Firm

Monopolistic competitive firm $j \in [0,1]$: $Y_t(j) = Z_t L_t(j)^{1-\alpha} K_{t-1}(j)^{\alpha}$

Cost minimization

$$W_t = (1-\alpha) MC_t \frac{Y_t(j)}{L_t(j)}$$

$$\tilde{R}_{K,t} = \alpha MC_t \frac{Y_t(j)}{K_{t-1}(j)}$$

$$MC_t = \frac{1}{Z_t} \frac{W_t^{1-\alpha} \tilde{R}_{K,t}^{\alpha}}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}}$$

Price rigidity: Following Rotemberg (1982), for price adjustment cost ψ_P,

$$(1+s)(\epsilon - 1) = \epsilon \frac{MC_t}{P_{H,t}} - \psi_P \left(\frac{P_{H,t}}{P_{H,t-1}} - 1 \right) \frac{P_{H,t}}{P_{H,t-1}}$$
$$+ E_t \left[\Lambda_{t,t+1} \psi_P \left(\frac{P_{H,t+1}}{P_{H,t}} - 1 \right) \left(\frac{P_{H,t+1}}{P_{H,t}} \right)^2 \left(\frac{Y_{H,t+1}}{Y_{H,t}} \right) \right]$$

back

Wholesaler

Perfectly competitive wholesalers aggregating varieties into a single good

- Domestic wholesalers: $Y_{H,t} \equiv \left[\int_{0,1} Y_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}$
- Export wholesalers: $Y^*_{H,t} \equiv \left[\int_{0,1} Y^*_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}$

Demand functions for each variety

$$Y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y_{H,t}, \quad Y^*_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y^*_{H,t}$$

where price indices for domestic and exported goods are given by

$$P_{H,t} = \left[\int_0^1 P_{H,t}^{1-\epsilon}(j) dj \right]^{\frac{1}{1-\epsilon}}, \quad P^*_{H,t} = \left[\int_0^1 P_{H,t}^{*1-\epsilon}(j) dj \right]^{\frac{1}{1-\epsilon}}$$

Retailer

Perfectly competitive retailer aggregating domestic and foreign goods

- Consumption: $C_t \equiv \left[\omega^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$
- Investment: $I_t + K_{t-1}\frac{\psi_K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 \equiv \left[\omega^{\frac{1}{\nu}} I_{H,t}^{\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} I_{F,t}^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$

<u>Demand functions</u>: For $P_t = \left[\omega P_{H,t}^{1-\nu} + (1-\omega) P_{F,t}^{1-\nu}\right]^{\frac{1}{1-\nu}}$

$$C_{H,t} = \omega\left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t$$

$$C_{F,t} = (1-\omega)(\frac{P_{F,t}}{P_t})^{-\nu} C_t$$

$$I_{H,t} = \omega\left(\frac{P_{H,t}}{P_t}\right)^{-\nu}\left[I_t + K_{t-1}\frac{\psi_K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2\right]$$

$$I_{F,t} = (1-\omega)(\frac{P_{F,t}}{P_t})^{-\nu}\left[I_t + K_{t-1}\frac{\psi_K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2\right]$$

back

Monetary and Fiscal Policy

Monetary Policy

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R} \left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi(1-\rho_R)} \epsilon_{R,t}$$

where $\bar{R}$ is the steady-state value for R_t, ρ_R is the interest rate smoothing parameter, and

$$\log \epsilon_{R,t} = \rho_m \log \epsilon_{R,t-1} + \sigma_m \epsilon_{m,t}$$

for the monetary policy shock $\epsilon_{m,t} \sim N(0, 1)$.

Fiscal Policy

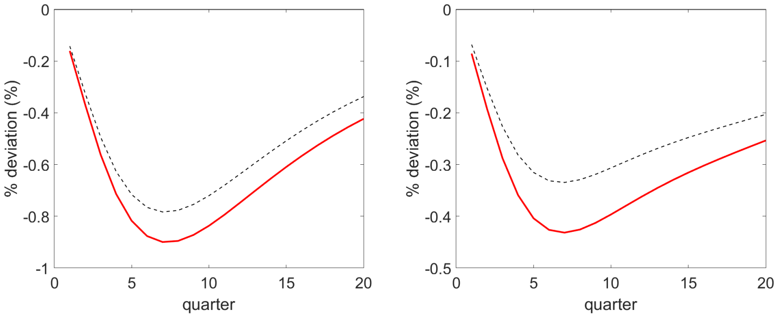
$$TR_t + s(P_{H,t}Y_{H,t} + S_t P^*_{H,t} Y^*_{H,t}) = 0$$ back

Calibration

Parameter	Value	Description	Source or Target
γ	2	Inverse of intertemporal elasticity of substitution	Devereux et al. (2023)
ω	0.8	Home bias	Devereux et al. (2023)
ν	3.8	Elasticity of substitution across country	Feenstra et al. (2018)
ϵ	6	Elasticity of substitution within country	Devereux et al. (2023)
φ	1	Inverse of Frisch elasticity	Gopinath et al. (2020)
$s = s^*$	0.2	Subsidy to firms	$s = 1/(\epsilon - 1)$
κ	13.936	Disutility of labor (Home)	Steady-state L of 1/3
κ^*	11.841	Disutility of labor (Foreign)	Steady-state L^* of 1/3
α	0.333	Capital share	Capital share of 1/3
ψ_P	155.88	Rotemberg price adjustment cost	Calvo parameter of 0.84
δ	0.04	Capital depreciation rate	Itskhoki & Mukhin (2021)
ψ_K	10	Investment adjustment cost	
ξ	0.114	Transfer to US new banks	Steady-state US leverage of 6
ξ^*	0.091	Transfer to RoW new banks	Steady-state RoW leverage of 6
ϕ_π	1.5	Taylor coefficient on inflation	Gali (2015)
ρ_r	0.5	Interest rate smoothing parameter	Gopinath et al. (2020)
ρ_m	0.5	Persistence of US monetary policy shock	Devereux et al. (2023)

back

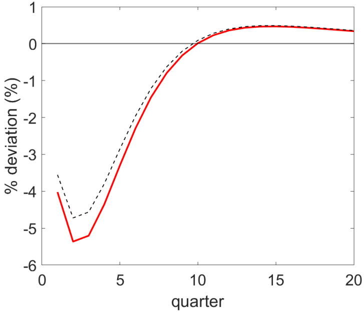
Capital



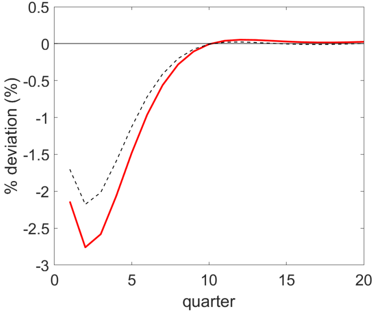
(a) US Capital (b) EU Capital

back

Investments



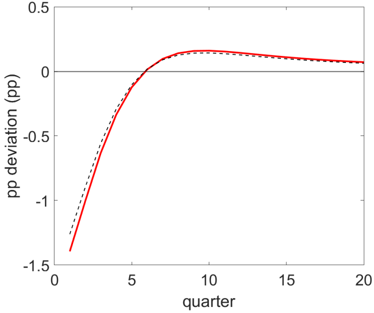
(a) US Investment



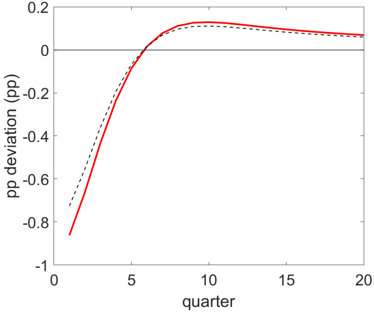
(b) EU Investment

back

Inflation Rates



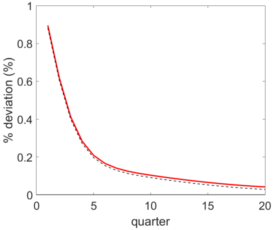
(a) US Inflation Rate



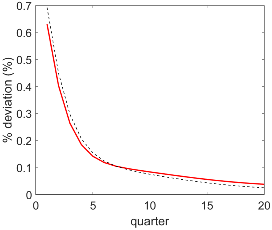
(b) EU Inflation Rate

back

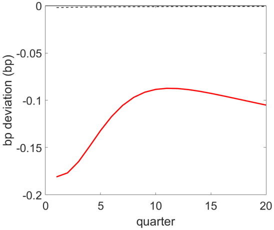
Exchange Rates



(a) Real Exchange Rate



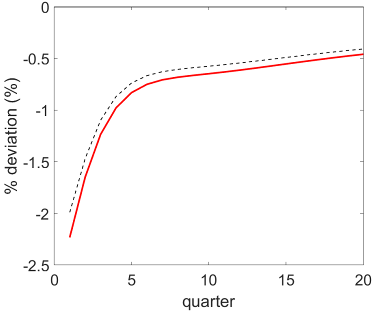
(b) Real Forward Rate



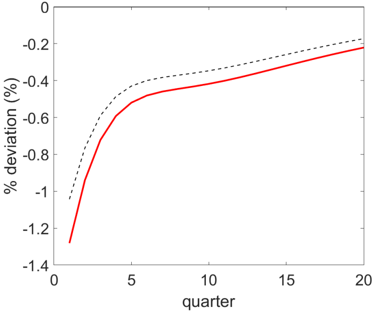
(c) UIP Deviations

back

Capital Asset Prices



(a) US Price of Capital



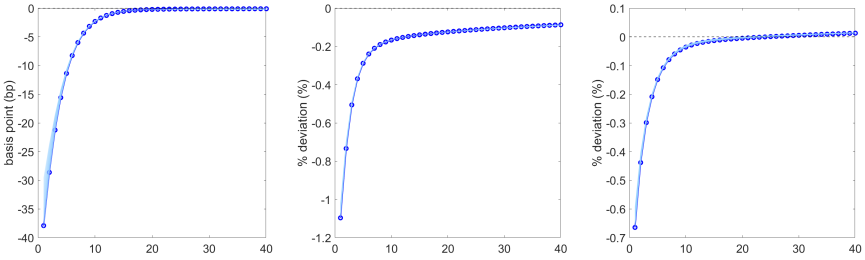
(b) EU Price of Capital

back

Sensitivity Analysis

Choice of θ_{X2}: do impulse responses for each θ_{X2} vary substantially?

- Pick 100 number of $\theta_{X2} \in (0.0001, \theta_{X1}/\bar{x})$
  - To guarantee positive value of leverage constraint $\theta_{X1} + \theta_{X2}(x_t - \bar{x})$
  - $\theta_{H2}, \theta^*_{F2}, \theta^*_{H2}, \theta^*_{X2}$: fixed



(a) CIP Deviations (b) US Output (c) Non-US Output

back