

The Synthetic Dollar Funding Channel of US Monetary Policy

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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:

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

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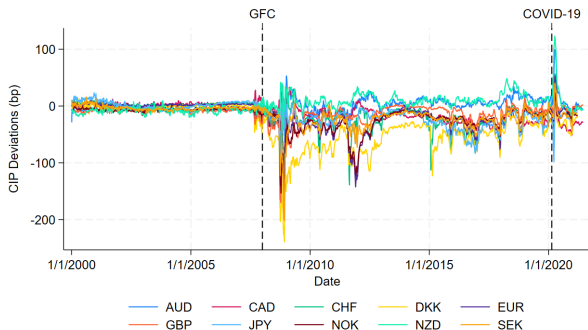
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Motivation

Importance of synthetic dollar funding

- Synthetic dollar funding/Total dollar funding: 15-20% past 5 years
- Emergence of **CIP deviations** since the GFC (∴ regulation on arbitrage)
 - 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

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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 (*cid*): 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 due to the widening of *cid*
 - Central bank swap lines: dampen the amplification by preventing the widening of CIP deviations

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Related Literature

Contribution

- 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
- 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
- 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

$$cid_{j,t} = r_{\$,t} - (r_{j,t} - \rho_{j,t}) \quad \text{▶ definition}$$

- $r_{j,t}$: 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)

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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
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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
 - $\Delta cid < 0 \Leftrightarrow$ widening of cid ($\because cid < 0$ on average) ▶ summary
- 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

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Estimation Results

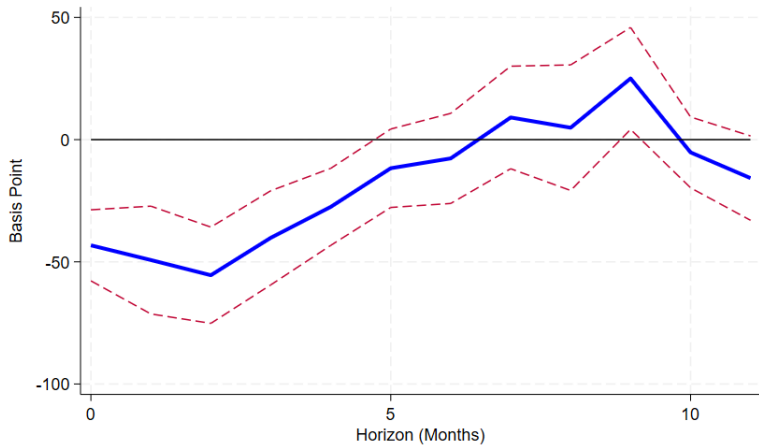
	(1)		(2)
NS	-35.34*** (13.40)	Target	-28.33*** (6.386)
		Path	-7.006* (3.626)
R^2	0.135		0.203
N	1047		1047

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 \Rightarrow This paper's focus: *Target* shock

Local Projection



Note: 95% confidence interval

► long version

Theoretical Model

Structure of FX Swap Market

- **Arbitrageur**: US bank
 - CIP deviations < 0 : arbitrage strategy is “borrow in \$, lend in €”
 - US bank can approach large and stable pool of \$
 - Arbitrage implies **sell \$ and buy € spot** \Rightarrow **supplier** of synthetic dollar funding
- **Demander**: non-US bank
 - Banks: highly penalized for currency mismatches
 - **buy \$ and sell € spot** \Rightarrow **demander** of synthetic dollar funding
- Supported by CLS data (Kloks et al., 2024)

US Bank: Balance Sheet

US Bank i 's Portfolio

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

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)

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

US bank: Value Function

Value function: $V_{i,t} = E_t [\Lambda_{t,t+1} \{(1 - \sigma)N_{i,t+1} + \sigma V_{i,t+1}\}]$

- $\Lambda_{t,t+1}$: 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,

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

- 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

Non-US Bank: Balance sheet

Non-US Bank i 's Portfolio

- Non-US capital assets: $K_{F,i,t}^* \Rightarrow$ gross return rate in € : $R_{F,t+1}^*$
- US capital assets: $K_{H,i,t}^* \Rightarrow$ gross return rate in $\text{\$}$: $R_{K,t+1}$
 - Assumption: cannot issue $\text{\$}$ deposits \Rightarrow all deposits are in €
 - Currency mismatch between $K_{H,i,t}^*$ and liabilities
 - Different degree of regulation on currency matching/mismatches
 \Rightarrow hedge ratio (χ^*) is optimally chosen

Non-US Bank: Demand for FX Swap

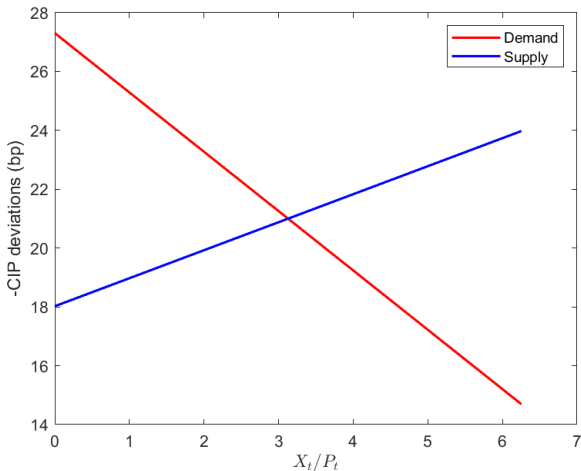
Optimality condition:

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

- Effective cost of dollar funding: $R_t^* S_t / F_t$ (\because no direct dollar funding)
- Downward-sloping inverse demand function in $-cid_t$ \triangleright eqm
- cid_t : **intermediation fee** for **currency matching**
 - If non-US banks can fund USD directly, then excess return is $R_{K,t+1} - R_t$

Equilibrium: 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

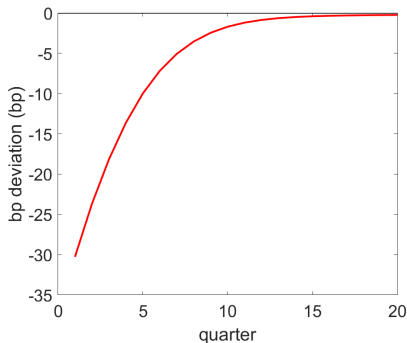
Frequency: quarterly

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)
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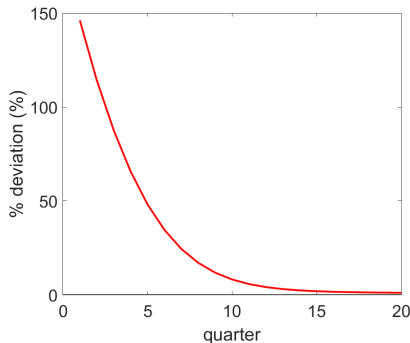
► calibration ► sensitivity

IRFs: CIP Deviations

Shock: 1pp US monetary policy shock



(a) CIP Deviations (*cid*)

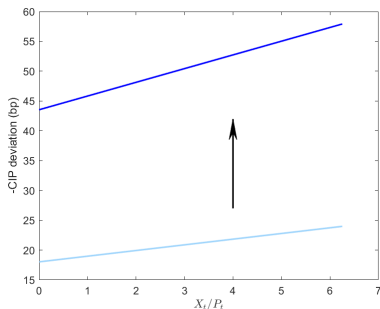


(b) Lagrange Multiplier (μ)

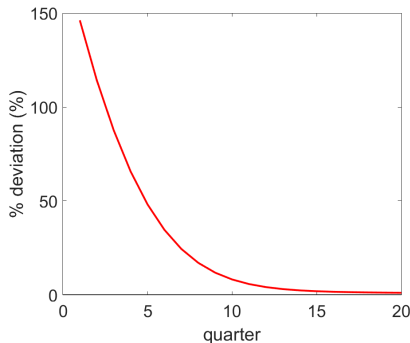
- $R \uparrow \Rightarrow N \downarrow \Rightarrow$ Tighter limit on CIP arbitrage $\Rightarrow \mu \uparrow$
- Supply of synthetic dollar funding \downarrow

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(a) CIP Deviations (*cid*)

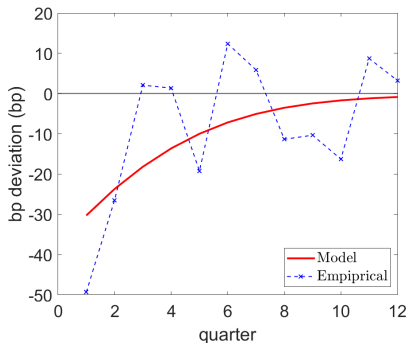


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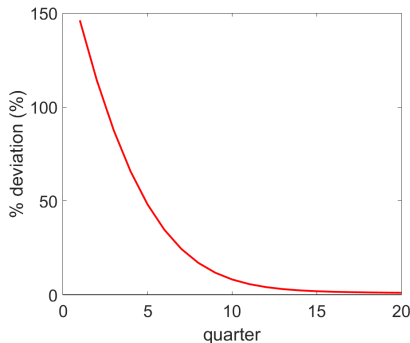
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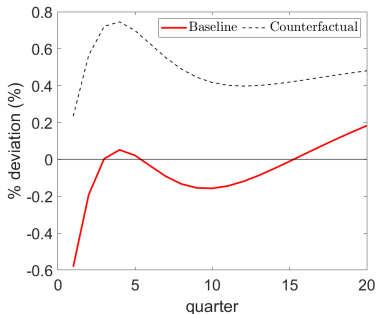


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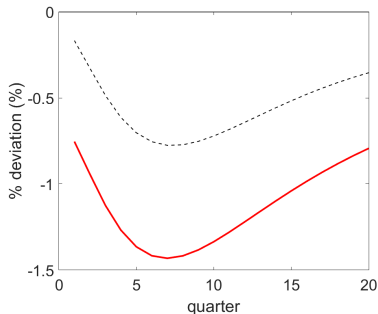
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IRFs: Synthetic Dollar Funding

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



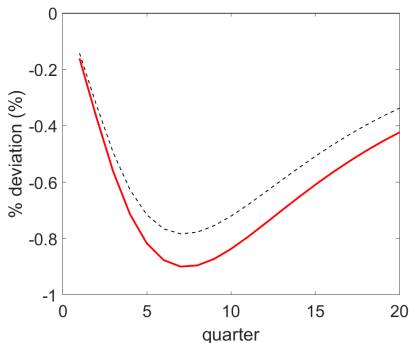
(a) Synthetic Dollar Funding (X/P)



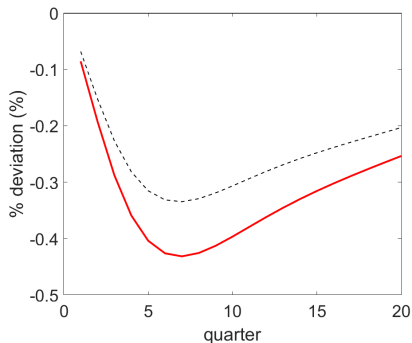
(b) US Capital Holdings by non-US (K_H^*)

- 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



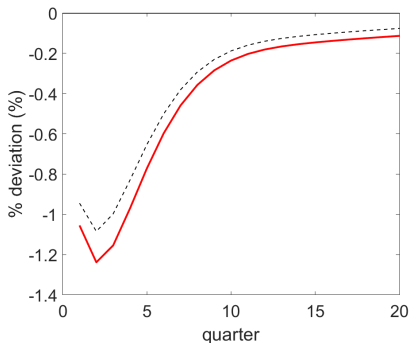
(a) US Capital (K)



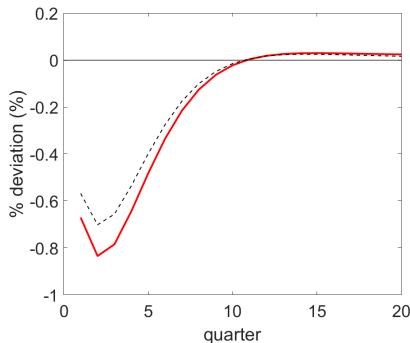
(b) Non-US Capital (K^*)

- 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) Non-US Output (Y^*)

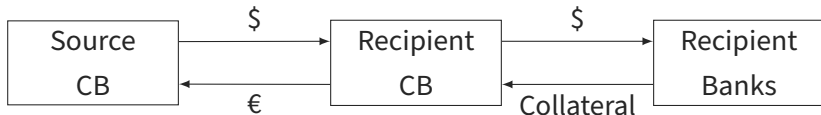
► investment ► consumption ► inflation ► exchange rate ► price of capital

- Amplification effects of 15-20% with persistence

Central Bank Swap Lines and Synthetic Dollar Funding Channel

Central Bank Swap Lines

Lender of last resort: collateralized public liquidity line



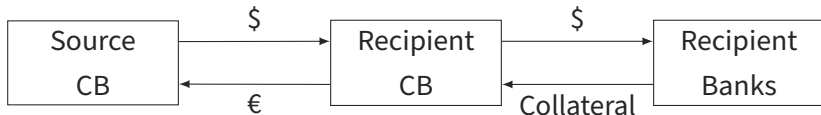
- Policy instrument: swap spread ss_t over a risk-free rate
- $-cid_t \leq ss_t$: ceiling on CIP deviations (Bahaj and Reis, 2022)
 - International version of discount window policy

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

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Modelling Swap Line Policy

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

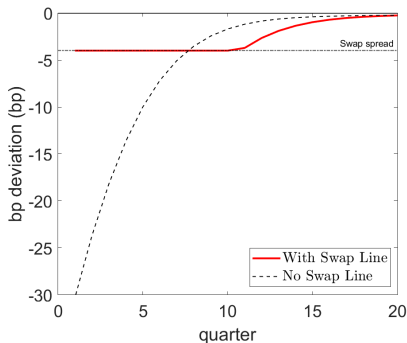
- Policy instrument: occasionally binding constraint

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

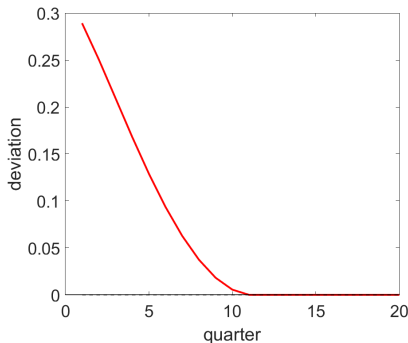
- $ss_t = 25\text{bp}$: swap spreads of standing facilities
- Market clearing condition: $X_t + X_t^{SL} = x_t^* Q_t K_{H,t}^*$
- Complementary slackness condition:

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

Transmission Channel: With v.s. Without Swap Lines



(a) CIP Deviations (cid)

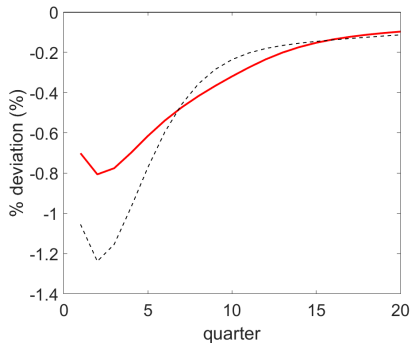


(b) Swap Lending (χ^{SL})

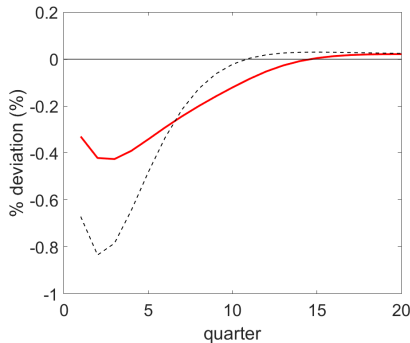
- $R \uparrow \Rightarrow$ Downward pressure on $cid \Rightarrow$ Ceiling binds: less widening
- $\chi_t^{SL} > 0$ when ceiling binds

Transmission Channel: With v.s. Without Swap Lines

Change in impulse responses:



(a) US Output



(b) Non-US Output

- Synthetic dollar funding channel: dampened
 - Swap line policy affects monetary transmission

Conclusion

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		3Y	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
Mean	-2.48	-20.93	0.25	-17.82	0.49	-16.31	0.60	-15.11
Median	-2.40	-17.87	0.18	-15.94	0.56	-15.01	0.74	-13.97
S.D.	5.42	20.99	2.11	14.29	1.99	12.79	2.10	12.43
Autocorr.	0.52	0.75	0.72	0.78	0.72	0.79	0.72	0.79
	5Y		7Y		10Y			
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC		
Mean	0.76	-13.29	0.58	-12.02	0.34	-10.13		
Median	1.06	-12.08	1.03	-10.70	0.75	-8.70		
S.D.	2.51	12.63	2.79	12.89	3.12	13.14		
Autocorr.	0.72	0.79	0.72	0.79	0.73	0.79		

Note: This table presents summary statistics of CIP deviations for each maturity of 3-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year. For each maturity, each statistic of CIP deviations is a simple average of the statistics across G10 currencies. The pre-GFC period is from 1/1/2000 to 12/31/2007 while the post-GFC period is from 1/1/2008 to 4/30/2021.

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Estimation Results: All Maturities

	3M	1Y	2Y	3Y	5Y	7Y	10Y
NS	-35.34*** (13.40)	-5.095 (3.505)	-0.526 (1.330)	-0.303 (0.713)	0.602 (1.021)	1.267 (0.793)	0.445 (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*** (6.386)	-3.471* (1.785)	-0.289 (1.051)	0.031 (0.674)	0.998 (0.936)	1.658 (1.042)	0.256 (0.312)
Path	-7.006* (3.626)	-1.662 (1.776)	-0.297 (0.865)	-0.397 (0.584)	-0.459 (0.846)	-0.445 (0.836)	0.148 (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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Decomposition

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

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

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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 (1.925)		-5.991** (2.309)	
Target		-0.405 (1.297)		-4.939*** (1.059)
Path		-0.952 (1.413)		-0.979 (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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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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](#)

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Robustness Check: Two-day Window

	3M		1Y		2Y		3Y	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NS	-25.32** (10.55)		-13.13** (6.474)		-5.939* (3.291)		-5.592* (3.228)	
Target		-36.63*** (7.775)		-10.00 (6.278)		-4.261 (3.094)		-3.902 (2.821)
Path		10.54** (4.422)		-3.174 (2.214)		-1.748 (1.627)		-1.765 (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 (1.500)		-0.160 (1.799)		0.575 (1.292)			
Target		-1.442 (0.802)		-0.080 (1.465)		0.329 (0.847)		
Path		-1.303 (0.881)		-0.137 (1.324)		0.183 (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** (7.399)		6.082* (3.233)		2.104** (0.793)		1.496 (1.059)	
Target		17.36** (5.367)		4.047* (1.876)		1.628* (0.858)		1.743** (0.707)
Path		1.503 (3.302)		2.047 (1.688)		0.519 (0.679)		-0.202 (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 (0.906)		-0.054 (0.823)		0.339 (0.385)			
Target		1.580* (0.870)		1.096 (1.285)		0.117 (0.258)		
Path		-0.345 (0.805)		-1.123 (0.956)		0.243 (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 (0.004)	-0.011* (0.006)	0.001 (0.005)	$i = -1$	-0.000 (0.007)	-0.009 (0.010)	0.006 (0.010)
$i = 0$	0.014 (0.009)	0.014 (0.014)	0.015 (0.010)	$i = 0$	0.007 (0.010)	0.006 (0.015)	0.007 (0.014)
$i = 1$	0.007 (0.013)	-0.009 (0.024)	0.017 (0.015)	$i = 1$	0.022 (0.015)	0.021 (0.027)	0.024 (0.019)
$i = 2$	-0.005 (0.011)	0.026 (0.019)	-0.027* (0.015)	$i = 2$	0.008 (0.015)	-0.017 (0.025)	0.024 (0.019)
Inflation forecasts				Δ Inflation forecasts			
$i = -1$	0.002 (0.007)	-0.023** (0.011)	0.019** (0.008)	$i = -1$	0.002 (0.011)	0.012 (0.023)	-0.002 (0.011)
$i = 0$	0.018* (0.010)	0.032* (0.019)	0.007 (0.011)	$i = 0$	-0.002 (0.017)	-0.009 (0.030)	0.006 (0.017)
$i = 1$	0.001 (0.015)	-0.031 (0.031)	0.026 (0.016)	$i = 1$	-0.011 (0.021)	0.037 (0.040)	-0.044* (0.024)
$i = 2$	-0.012 (0.022)	0.024 (0.036)	-0.035 (0.029)	$i = 2$	0.041 (0.029)	0.006 (0.045)	0.063* (0.035)
Unemployment forecasts				Constant			
$i = 0$	0.001 (0.003)	-0.002 (0.005)	0.002 (0.004)		-0.045 (0.054)	-0.042 (0.087)	-0.050 (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		

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:

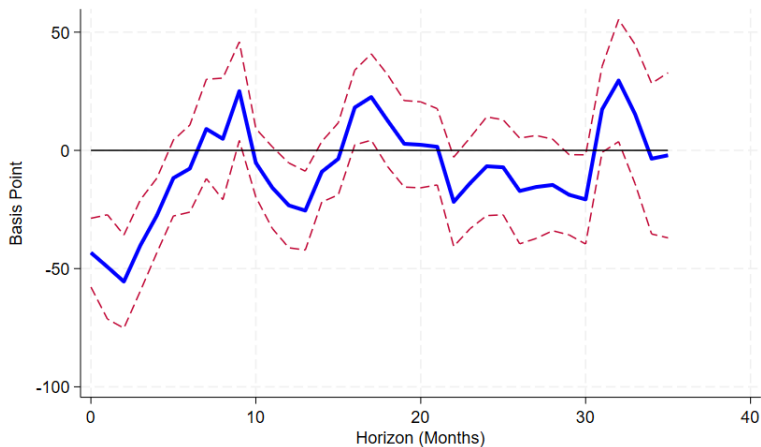
$$\Delta mp_t = \alpha + \gamma' X_t + \Delta mpn_t$$

- 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*** (12.20)	-6.300 (4.238)	-0.623 (1.631)	0.645 (0.663)	1.837 (1.285)	2.038 (1.162)	-0.247 (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

Local Projection



Note: 95% confidence interval

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	$t + 1$
$Q_t K_{H,i,t}$	$D_{i,t}$	$-\$Q_t K_{H,i,t}$	$+\$R_{K,t+1} Q_t K_{H,i,t}$
$X_{i,t}$	$N_{i,t}$	$-\$X_{i,t}$ $+\text{€}S_t X_{i,t}$ $-\text{€}S_t X_{i,t}$ $+\$D_{i,t}$	$+\$R_t^* (S_t/F_t) X_{i,t}$ $-\text{€}R_t^* S_t X_{i,t}$ $+\text{€}R_t^* S_t X_{i,t}$ $-\$R_t D_{i,t}$

Linearity of Bank Value Function

Guess: $V_{i,t} = v_t N_{i,t}$

\Rightarrow Bellman equation:

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

for

$$v_{H,t} \equiv E_t \left[\Omega_{t,t+1} (R_{K,t+1} - R_t) \right]$$

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

$$v_{N,t} \equiv E_t \left[\Omega_{t,t+1} \right] R_t$$

Linearity of Bank Value Function

First-order conditions

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

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

Verify:

$$v_t = \frac{v_{N,t}}{1 - \mu_t}$$

$\Rightarrow v_t$: 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.

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

- 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. $-cid_t \uparrow$

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

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

Balance Sheet and Flow of Funds

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

Non-US Bank: Law of Motion of Net Worth

Law of motion for net worth:

$$N_{i,t+1}^* = \left[(R_{K,t+1}^* - R_t^*) \Phi_{F,i,t}^* + \frac{S_{t+1}}{S_t} \left(R_{K,t+1} - R_t^* \frac{S_t}{S_{t+1}} \right) (1 - x_{i,t}^*) \Phi_{H,i,t}^* \right. \\ \left. + \frac{S_{t+1}}{S_t} \left(R_{K,t+1} - R_t^* \frac{S_t}{F_t} \right) x_{i,t}^* \Phi_{H,i,t}^* + R_t^* \right] N_{i,t}^*$$

- 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^* ,

$$E_t \left[\Omega_{t,t+1}^* \frac{S_{t+1}}{S_t} \underbrace{\left(R_{K,t+1} - R_t^* \frac{S_t}{F_t} \right)}_{R_{K,t+1} - (R_t - cid_t)} \right] = \mu_t^* \left(\theta_{x1}^* + \theta_{x2}^* \frac{x_t^* S_t Q_t K_{H,t}^*}{P_t^*} \right)$$

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

Household

Optimization Problem

$$\begin{aligned} \max_{\{C_t, L_t, D_t\}_{t=0}^{\infty}} \quad & E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\gamma} - 1}{1-\gamma} - \kappa \frac{L_t^{1+\varphi}}{1+\varphi} \right] \\ \text{s.t.} \quad & P_t C_t + D_t = W_t L_t + R_{t-1} D_{t-1} + TR_t + \Pi_t \end{aligned}$$

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

Investment adjustment cost

$$\Psi\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

Tobin's Q

$$Q_t = P_t \left[1 + \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \psi_I \frac{I_t}{I_{t-1}} \left(\frac{I_t}{I_{t-1}} - 1\right) \right] - E_t \left[\Lambda_{t,t+1} P_{t+1} \psi_I \left(\frac{I_{t+1}}{I_t}\right)^2 \left(\frac{I_{t+1}}{I_t} - 1\right) \right]$$

Law of motion for the capital

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

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 ,

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

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: $I_t \left(1 + \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) \equiv \left[\omega^{\frac{1}{\nu}} I_{H,t}^{\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} I_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$

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

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

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

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

$$I_{F,t} = (1-\omega) \left(\frac{P_{F,t}}{P_t} \right)^{-\nu} I_t \left(1 + \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) \quad \text{back}$$

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 $\epsilon_{m,t} \sim N(0, 1)$.

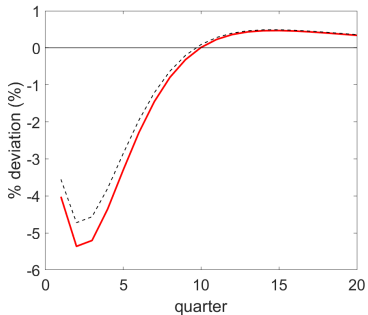
Fiscal Policy

$$TR_t + s(P_{H,t}Y_{H,t} + S_t P_{H,t}^* Y_{H,t}^*) = 0 \quad \text{back}$$

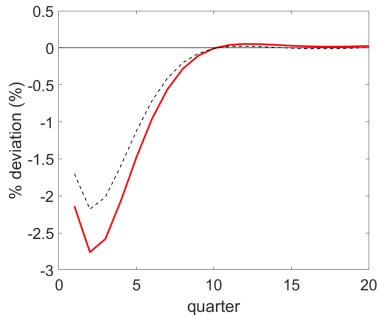
Calibration

Parameter	Value	Description	Source or Target
γ	2	Inverse of intertemporal elasticity of substitution	Standard literature
ω	0.8	Home bias	Standard literature
ν	3.8	Elasticity of substitution across country	Bajzik et al. (2020)
ϵ	6	Elasticity of substitution within country	Standard literature
φ	1	Inverse of Frisch elasticity	Standard literature
$s = s^*$	0.2	Subsidy to firms	$s = 1/(\epsilon - 1)$
κ	13.97	Disutility of labor (US)	Steady-state L of 1/3
κ^*	11.83	Disutility of labor (Non-US)	Steady-state L^* of 1/3
α	1/3	Capital share	Standard literature
ψ_P	155.88	Rotemberg price adjustment cost	Calvo parameter of 0.84
δ	0.04	Capital depreciation rate	Standard literature
ψ_I	0.7	Investment adjustment cost	Standard literature
ξ	0.12	Transfer to new US banks	Steady-state leverage of 6
ξ^*	0.09	Transfer to new non-US banks	Steady-state leverage of 6
ϕ_π	1.5	Taylor coefficient on inflation	Standard literature
ρ_r	0.7	Interest rate smoothing parameter	Standard literature
ρ_m	0.25	Persistence of US MP shock	Standard literature

Investments

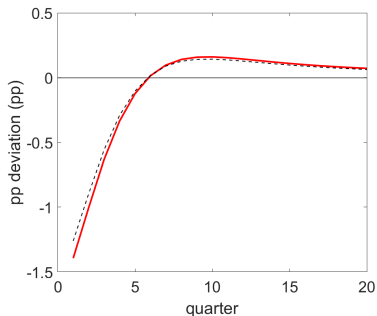


(a) US Investment

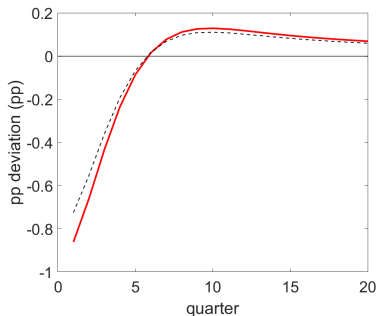


(b) Non-US Investment

Inflation Rates

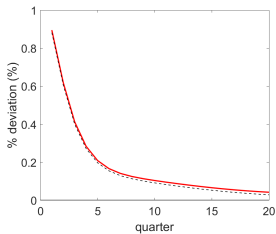


(a) US Inflation Rate

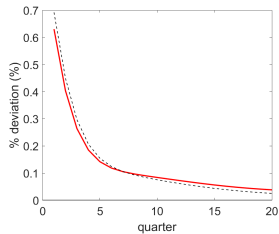


(b) Non-US Inflation Rate

Exchange Rates

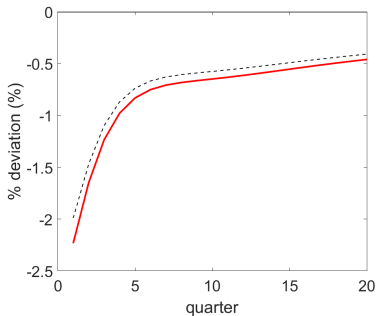


(a) Real Exchange Rate

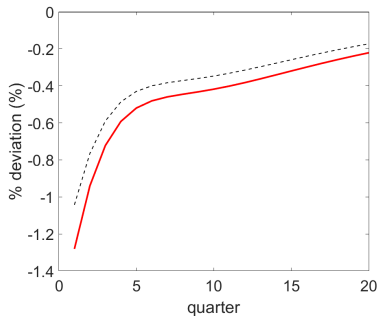


(b) Real Forward Rate

Capital Asset Prices

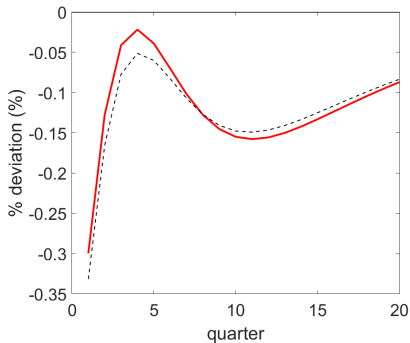


(a) US Price of Capital

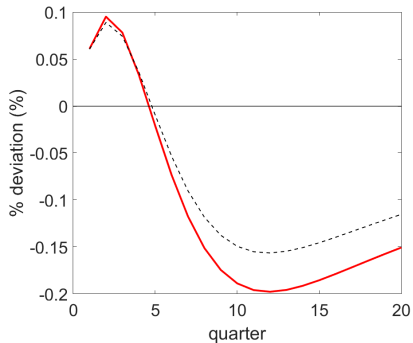


(b) Non-US Price of Capital

Consumption



(a) US Consumption

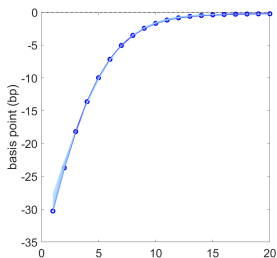


(b) Non-US Consumption

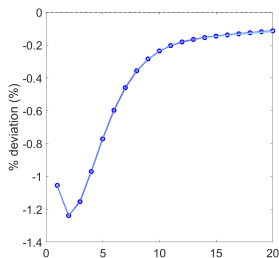
Sensitivity Analysis

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

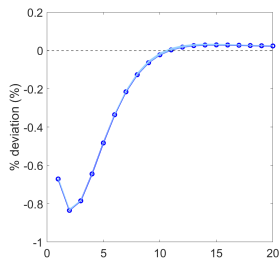
- Pick 100 number of $\theta_{X2} \in (0.0001, \theta_{X1}/\bar{x})$
 - To guarantee positive value of leverage constraint $\theta_{X1} + \theta_{X2}(x_t - \bar{x})$
 - $\theta_{H2}, \theta_{F2}^*, \theta_{H2}^*, \theta_{X2}^*$: fixed



(a) CIP Deviations



(b) US Output



(c) Non-US Output