Dollar Shortages and Central Bank Swap Lines*

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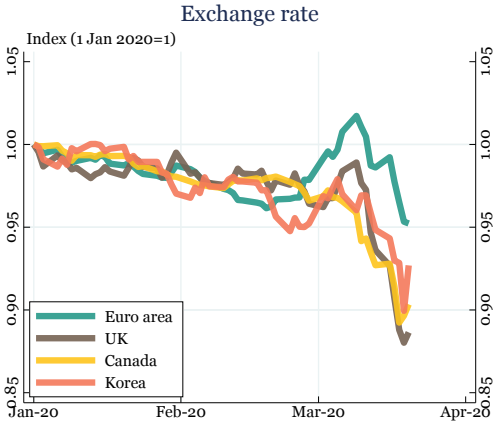
The Fed & The March 2020 dollar shortage

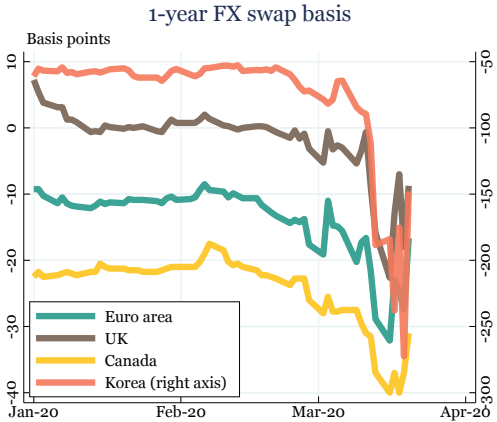
Fed sets up scheme to meet booming foreign demand for dollars

Central bank meets global shortage of greenbacks after scramble for safety

The March 2020 dollar shortage

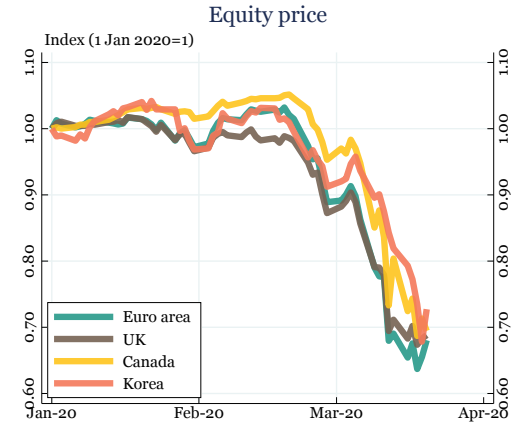
FX markets





The March 2020 dollar shortage

Other asset prices



Dollar shortages and central bank swap lines

- Dollar shortages are a recurring feature of global crises
  - Not limited to Covid, but seen in the global financial crisis and euro area crisis
- Fed introduced and expanded US dollar swap lines with major central banks
  - Evolved from temporary measures to standing network, expanded further in scope during Covid
- **Question** What are the macro and financial effects of central bank swap lines?

What we do, what we find

- **Empirics** High-frequency event study panel local projections
  - Construct a novel series of swap lines shocks
  - Estimate causal effects of swap lines shocks on aggregate financial variables
- **Model** Open economy DSGE
  - Introduce swap lines in a model with international intermediation frictions and bank runs
  - Quantify effects of dollar shortage shock and role of swap lines

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still in progress...

- **Results**
  - Swap line shock appreciates currency, boosts equities, reduces spreads and CIP deviations
  - Swap lines mitigate adverse macro-financial effects of dollar shortage shock

Empirics

Empirical evidence

- **Question** What is the effect of swap lines on the economy?
- **Challenges** Identification of swap line 'shocks' non-trivial
  - Role of confounding factors (stress periods, contemporaneous policies)
  - Very few events, scattered irregularly over time
  - Role of expectations

Construction of swap line surprises

- **New Approach** Construct a surprise measure from Fed swap line announcements
  - Event study high-frequency identification strategy [Gurkaynak et al., 2015]
- **Raw sample** 23 episodes where Fed provided new information on its network of swap lines
  - New lines, expansions, maturity extensions, pricing changes, expiry extensions (no FIMA)
  - 14 affected currencies from 2007 to 2021
- **Surprise** Log-change of USD exchange rate in 30-minute window around event (t, k):

$$\epsilon_{it}^{SL} = ln(e_{it,k+20'}) - ln(e_{it,k-10'})$$

- **Key assumption** Only swap line news affects exchange rates in tight 30-minute window

Identification

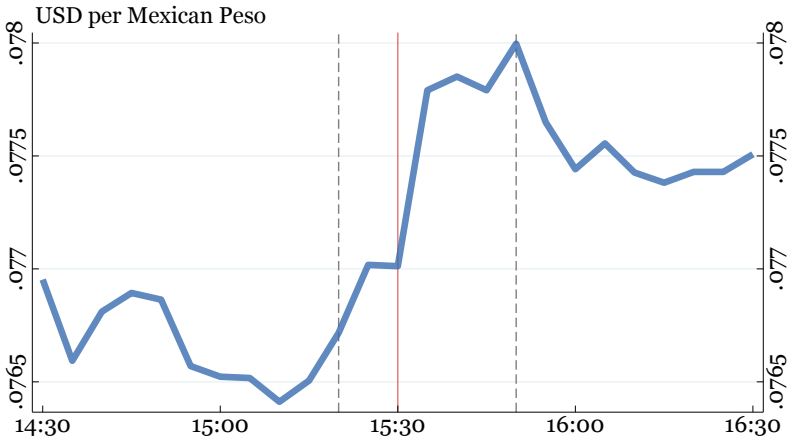
- As usual, some threats to identification:
  - Joint Fed announcements (QE, rate cuts) → Cannot isolate swap line effect
  - Same-day non-US policy shocks → Outcome responses dominated by larger shocks
- **Solution** Keep only 'clean' announcements Details
  - Prioritize internal validity over sample size for causal identification
- **Final sample** 11 clean events, 14 affected currencies, sample period covering 2008 to 2021

Swap line announcements: Selected list of events

Date	Time (EST)	Description	Affected currencies
18-Sep-2008	03:00	Major $180B expansion + 3 new CBs [link]	EUR, CHF, JPY, GBP, CAD
24-Sep-2008	01:00	Addition of 4 Nordic/Oceanic CBs [link]	AUD, SEK, DKK, NOK
26-Sep-2008	11:00	$13B boost to ECB/SNB swap lines [link]	EUR, CHF
13-Oct-2008	02:00	Swap lines uncapped for major CBs [link]	EUR, CHF, JPY, GBP
28-Oct-2008	17:00	NZ joins swap network [link]	NZD
29-Oct-2008	15:30	New swaps with 4 EM CBs [link]	BRL, MXN, KRW, SGD
09-May-2010	21:15	Swap lines reestablished with 4 major CBs [link]	CAD, GBP, EUR, CHF
21-Dec-2010	09:00	Swap lines extended thru Aug 2011 [link]	CAD, GBP, EUR, CHF, JPY
29-Jun-2011	09:00	Extension of swap lines to Aug 2012 [link]	CAD, GBP, EUR, CHF
31-Oct-2013	02:00	Swap lines become standing arrangements [link]	CAD, GBP, EUR, CHF, JPY
16-Jun-2021	14:00	Swap lines extended through Dec 2021 [link]	AUD, BRL, DKK, KRW, MXN, NOK, NZD, SGD, SEK

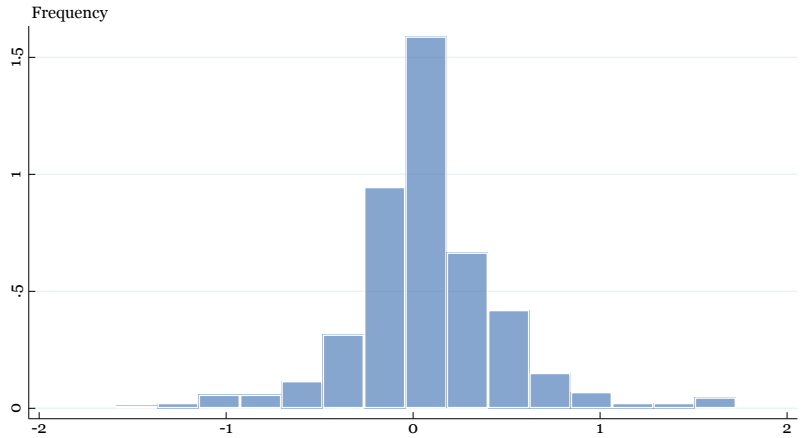
Swap line surprises: Example

- On 29 Oct 2008 at 15:30 (NY time) the Fed announced a new swap line with Banco the Mexico



Swap line surprises

- Distribution of swap line surprises in our sample



Panel event-study local projections

- Estimate the following specification

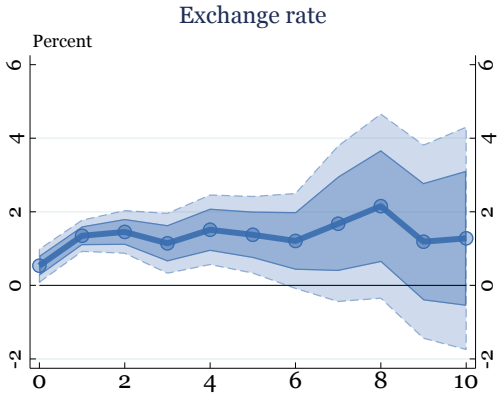
$$y_{i,t+h} - y_{t-1} = \alpha_i^h + \beta^h \cdot \epsilon_{it}^{SL} + u_{i,t+h}$$

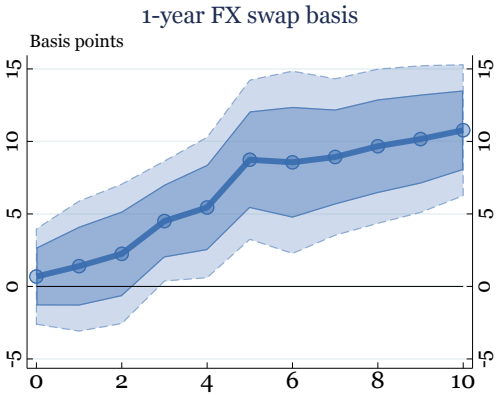
  where

  - $y_{i,t+h}$ is the (log) level of asset price y in country i, h trading days after the swap line announcement
  - α_i is a country/currency fixed effect
  - ϵ_{it}^{SL} is the swap line surprise (standardized)

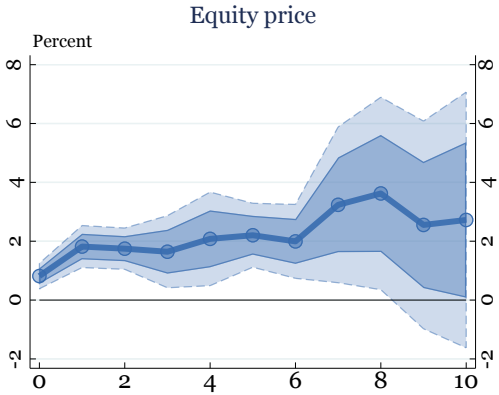
- Asset prices:
  - Exchange rate, Equity index, Corporate bond spread, FX swap basis

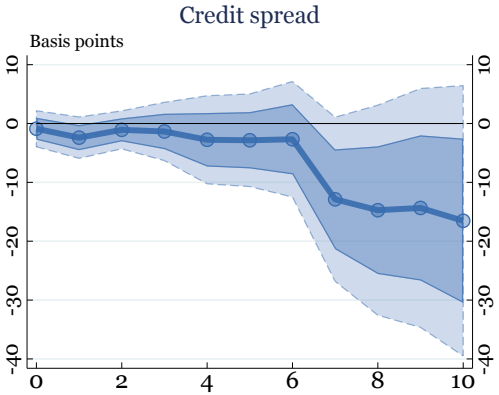
The Effect of Swap Line Shocks





The Effect of Swap Line Shocks





Robustness

- Keep events with confounding non-US policy shocks Go
- Drop safe haven currencies (Japan, Swiss franc) Go
- Add controls (economic surprise index, VIX index, gold) Go
- Different event window ($[-30', +30']$) Go

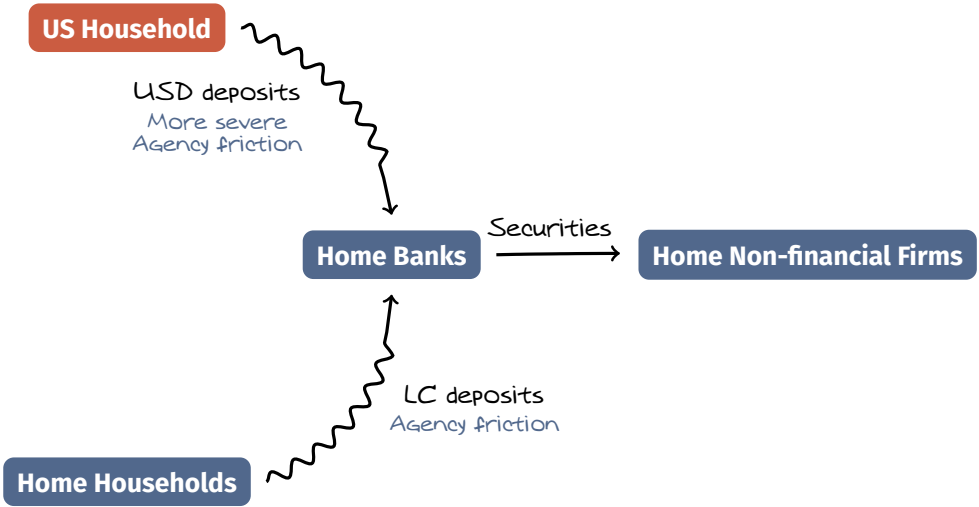
An Open Economy Model of Central Bank Swap Lines

Overview of the model

- Two-country New Keynesian model with financial frictions
  - Foreign is the United States
  - Home is a small open economy

- Key ingredients
  - Frictions between depositors and banks as in Gertler-Karadi-Kiyotaki
  - Home banks borrow in both home currency and USD to finance purchases of securities from firms
  - Agency friction more severe for USD borrowing as in Akinci and Queralto (2023)

Financial flows



Home (i.e. non-US) banks

- Banks:
  - Have limited net worth (N_{it})
  - Borrow from Home and US households (D_{it}, D^*_{it})
  - Purchase claims on capital (S_{it})

Banks	
Assets	*Liabilities*
Capital, $q_t S_{it}$	USD Deposits, $\mathcal{Q}_t D^*_{it}$ LC Deposits, D_{it} Net Worth, N_{it}

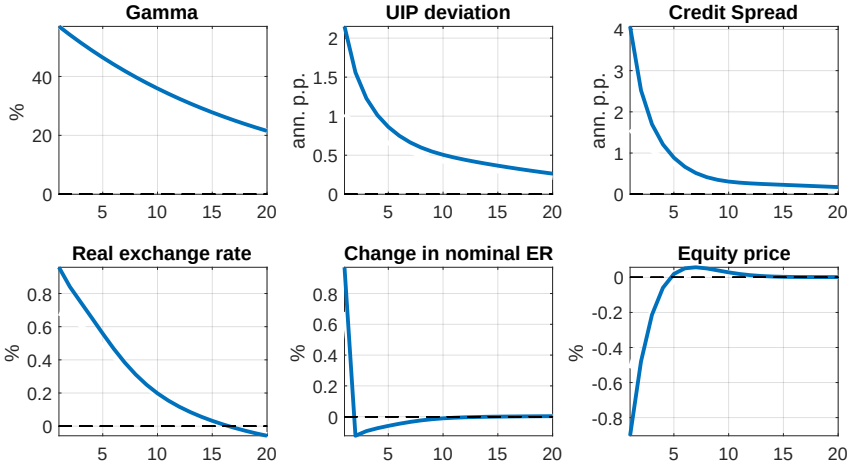
- Bank can default and abscond with a fraction of funds

$$\theta\left(D_{it} + (1+\gamma)\mathcal{Q}_t D^*_{it} + N_{it}\right)$$

- Foreign funds are harder for creditors to recover ($\gamma > 0$) $\rightarrow$ Endogenous UIP deviations (μ^*)

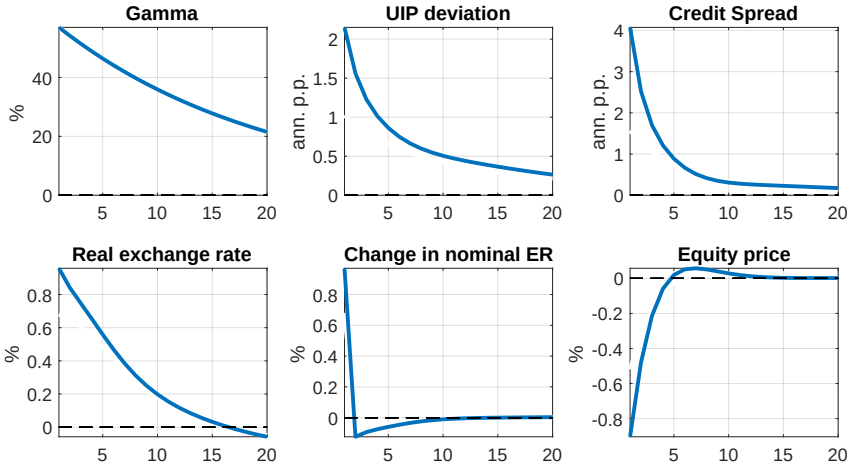
A dollar shortage shock

- **Narrative device** Increase in monitoring cost of USD debt ($\gamma \uparrow$)

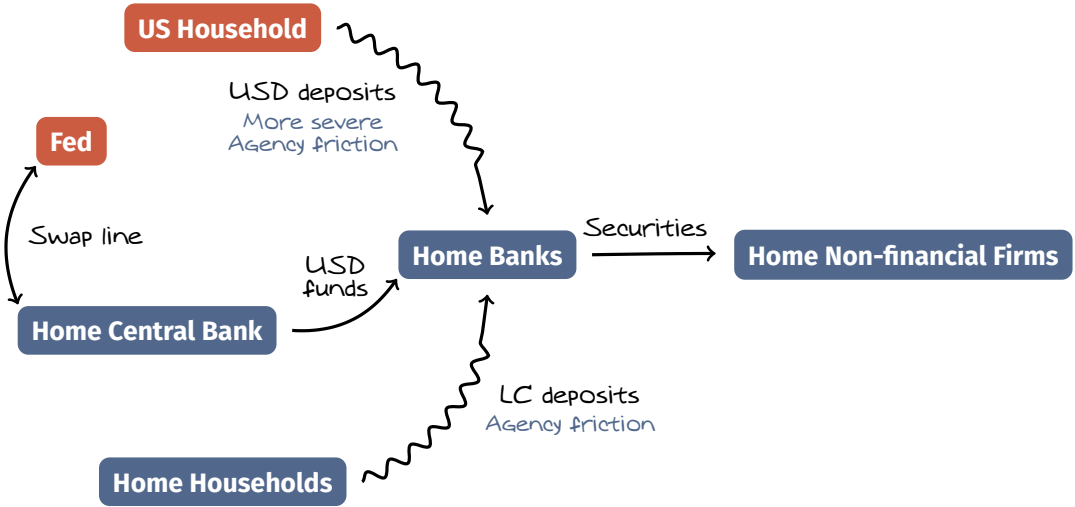


A dollar shortage shock

- Response of financial variables in line with stylized facts



Swap lines


US Household
USD deposits
More severe
Agency friction
Fed
Swap line
Home Central Bank
USD
funds
Home Banks
Securities
Home Non-financial Firms
LC deposits
Agency friction
Home Households

Swap policy rule

- Similar to Del Negro, Eggertsson, Ferrero, and Kiyotaki (2017):

$$F_t = \phi^F(\mu_t^* - \bar{\mu}^*)$$

  - Home central bank can draw up to F_t in USD from Fed at cost R_t^*
  - UIP deviation μ_t^* as barometer of worsening of underlying friction in model

- Home banks' balance street constraint becomes

$$q_t S_{it} = D_{it} + \mathcal{Q}_t D_{it}^* + \mathcal{Q}_t F_{it} + N_{it}$$

- Home central bank requires same collateral for USD funding as for local currency funding

$$\theta\left[D_{it} + \mathcal{Q}_t F_{it} + (1+\gamma)\mathcal{Q}_t D_{it}^* + N_{it}\right]$$

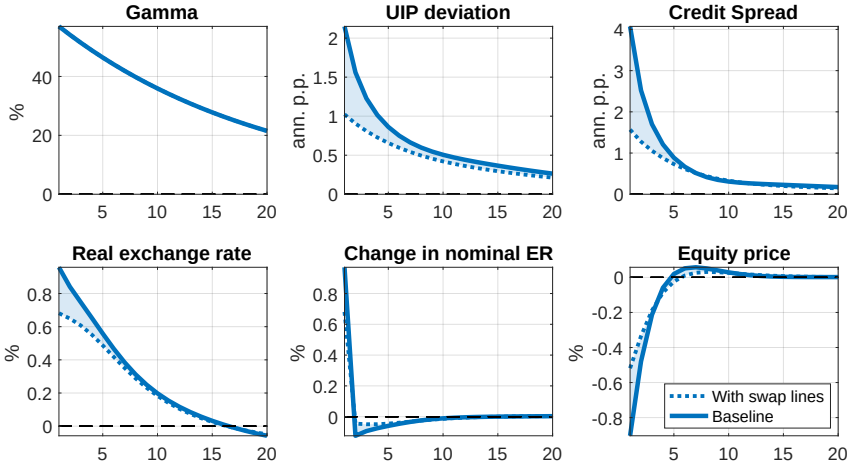
- Swap lines allow Home banks to get USD without tightening their financial constraint

The effect of swap lines: A counterfactual experiment

- **Calibration** Calibrate swap line policy rule (ϕ^F) and shock (ε_t^γ) jointly to match
  - Korean won (KRW/USD) CIP deviations in Covid-19 distress period
  - Size of swap line allowed between Fed and Bank of Korea
- **Baseline** IRFs to a dollar shortage shock without policy response ($\phi^F = 0$)
- **Counterfactual** Same shock with active swap line rule

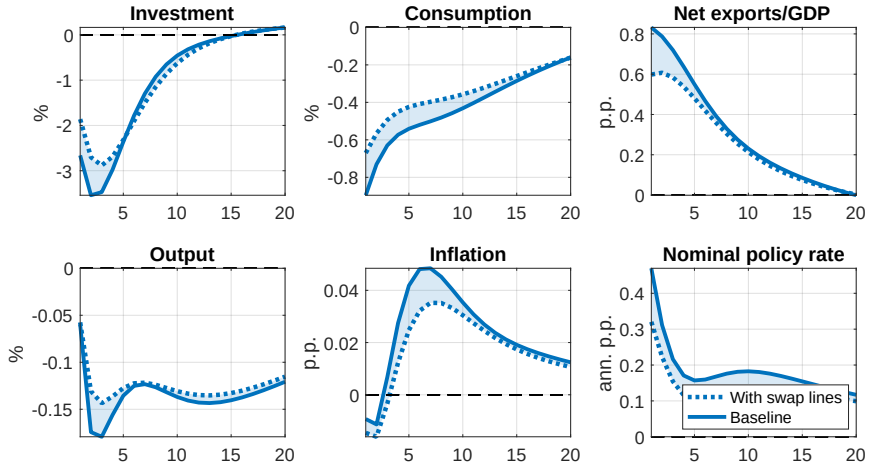
The effect of swap lines

- Difference between baseline and counterfactual in line with empirical estimates



The effect of swap lines

- Significant but transitory effects on real variables



Taking stock & Work in progress

- Model captures both unconditional and conditional dynamics well
- But some dimensions can be strengthened
  - Swap lines can be effective even without being drawn → Missing role of expectations
  - As a liquidity backstop, swap lines can rule out bad equilibrium → Missing multiple equilibria
  - Effects appear larger in the data → Need additional amplification
- Our (work in progress) solution
  - Introduce financial panics (as in Gertler and Kiyotaki, 2015) in our two-country set up

International banking panics

- Banking panics ('runs') in closed economy
  - Banks cannot liquidate their assets at full value in a crisis $\tilde{q}_t < q_t$
  - If $\tilde{q}_t$ is low enough, banks cannot repay everyone in a run → Panic equilibrium exists
  - Depositors recognize run-risk and price it in, even in normal times → Risk premia
- In open economy, the risk of banking panics amplifies impact of dollar shortages
  - Depositors fear that the dollar shortage could cause a banking collapse
- The role of swap lines
  - Contain risk premia by anchoring expectations on the 'no panic' equilibrium
  - Ease pressure on local currency and on bank funding costs

Conclusions

Conclusions

- Our contributions
  - Conditional evidence on the dynamic effects of swap lines on asset prices
  - Open-economy framework to assess broader macro implications
- Swap lines are a standing Fed tool, important to improve our understanding of their workings

References I

Akinci, O. and A. Queralto (2023): "Exchange Rate Dynamics and Monetary Spillovers with Imperfect Financial Markets," *The Review of Financial Studies*, 37, 309–355.

Del Negro, M., G. Eggertsson, A. Ferrero, and N. Kiyotaki (2017): "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities," *American Economic Review*, 107, 824–857.

Gertler, M. and N. Kiyotaki (2015): "Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy," *American Economic Review*, 105, 2011–2043.

A1: Swap lines

Swap Line Announcements: Raw List of Events

Date	Time (EST)	Description	Affected currencies
12-Dec-2007	10:00:00	First swap lines established	EUR, CHF
11-Mar-2008	8:30:00	Expansion of existing swap line capacity	EUR, CHF
02-May-2008	9:15:00	Technical adjustments to operations	EUR, CHF
30-Jul-2008	8:45:00	Further capacity expansion	EUR, CHF
18-Sep-2008	3:00:00	Major $180B expansion + 3 new CBs	EUR, CHF, JPY, GBP, CAD
24-Sep-2008	1:00:00	Addition of 4 Nordic/Oceanic CBs	AUD, SEK, DKK, NOK
26-Sep-2008	11:00:00	Quarter-end funding operations	EUR, CHF
29-Sep-2008	10:00:00	Total capacity increased to $620B	EUR, CHF, JPY, GBP, CAD, AUD, SEK, DKK, NOK
13-Oct-2008	2:00:00	Unlimited access for major CBs	EUR, CHF, JPY, GBP
28-Oct-2008	17:00:00	New Zealand added to network	NZD
29-Oct-2008	15:30:00	Emerging markets addition	BRL, MXN, KRW, SGD
03-Feb-2009	10:00:00	Expiration announcement (Feb 2010)	AUD, BRL, CAD, DKK, GBP, EUR, KRW, MXN, NZD, NOK, SGD, SEK, CHF
25-Jun-2009	12:00:00	Extension through Oct 2009	AUD, BRL, CAD, DKK, GBP, EUR, KRW, MXN, NZD, NOK, SGD, SEK, CHF
09-May-2010	9:15:00	Reactivation for Euro crisis	CAD, GBP, EUR, CHF
21-Dec-2010	9:00:00	Extension through Aug 2011	CAD, GBP, EUR, CHF, JPY
29-Jun-2011	9:00:00	Further extension	CAD, GBP, EUR, CHF
31-Oct-2013	2:00:00	Conversion to standing arrangements	CAD, GBP, EUR, CHF, JPY
15-Mar-2020	17:00:00	COVID-19: Enhanced terms (OIS+25bp)	CAD, GBP, EUR, CHF, JPY
19-Mar-2020	9:00:00	COVID-19: Temporary lines reactivated	AUD, BRL, DKK, KRW, MXN, NOK, NZD, SGD, SEK
20-Mar-2020	10:00:00	Daily 7-day operations announced	CAD, GBP, EUR, CHF, JPY
29-Jul-2020	14:00:00	Extension to March 2021	AUD, BRL, DKK, KRW, MXN, NOK, NZD, SGD, SEK
16-Dec-2020	14:00:00	Extension to Sept 2021	AUD, BRL, DKK, KRW, MXN, NOK, NZD, SGD, SEK
16-Jun-2021	14:00:00	Final extension to Dec 2021	AUD, BRL, DKK, KRW, MXN, NOK, NZD, SGD, SEK

Polluted events

- 13-Oct-2008 02:00 → Massive European/UK bank rescue packages were announced Oct 13 (e.g., UK £37bn recap; Germany's €500bn plan; EU-wide guarantees), dominating markets the same day.
  - Polluted countries: EUR, GBP
- 09-May-2010 09:15 → ECB announced the Securities Markets Programme (SMP) and additional euro-area crisis measures on the same day.
  - Polluted countries: EUR
- 16-Jun-2021 14:00 → Brazil's COPOM raised Selic 75bp on Jun 16
  - Polluted countries: BRL
- 19-Mar-2020 09:00 → ECB's PEPP (€750bn) had been unveiled late Mar 18; BoE emergency rate cut + QE, RBA easing package, DN rate hike, SNB intervention signal, BoC repo expansion all landed Mar 19.
  - Polluted countries: AUD, DKK, GBP, EUR, CHF, CAD, NOK, MXN, NZD, SGD, SEK
- 20-Mar-2020 10:00 → Fed broadened MMLF to municipal MMFs (same day); Norges Bank cut to 0.25%; Banxico unscheduled 50bp cut + FX measures; BoC announced further liquidity programs; BoE QE purchases started; DN's rate hike became effective.
  - Polluted countries: CAD, GBP, EUR, CHF, JPY, NOK, MXN, DKK

Back

FIMA vs Swap Lines

- **Swap lines**
  - Fed swaps USD for foreign currency at market rate + spread.
  - Counterparty: small set of trusted central banks (ECB, BoJ, BoE, etc.).
  - Fed books foreign currency on its balance sheet, but cannot redeploy it.
  - Not collateral in the strict sense; credit risk managed via counterparty selection.
  - Purpose: allow partner central banks to on-lend USD to domestic banks.
- **FIMA repo facility**
  - Fed provides USD against repoed U.S. Treasuries.
  - Counterparty: all foreign central banks with Fed custody accounts.
  - Collateral is genuine and liquid (Fed could sell Treasuries if needed).
  - True repo, structurally same as domestic Fed repo ops.
  - Purpose: give official institutions a liquidity backstop without fire-selling Treasuries.
- **Summary:**
  - Swap lines = club good (trust-based, uncollateralized in practice)
  - FIMA = safety valve (collateralized, broad access).

From Ad Hoc to Standing Architecture: Fed USD Liquidity Abroad

Timeline (selected milestones)

- **2008–2010** ; Global crisis: Fed deploys and repeatedly expands USD *swap lines*; reactivations during euro-area stress (2010).
- **2013** ; *Standing* swap lines established among Fed, ECB, BoJ, BoE, BoC, SNB (permanent network).
- **Mar 2020** ; COVID shock: temporary FIMA repo facility created (broad official-sector access against U.S. Treasuries); swap lines reactivated/expanded.
- **Jul 2021** ; FIMA repo converted to a *standing* facility (alongside the domestic SRF).

Mechanism: two complementary standing tools

- **Standing swap lines** (club-based, trust-driven): USD provided to select central banks via FX swaps; those CBs on-lend to local institutions.
- **FIMA standing repo** (broad, collateralized): USD provided against U.S. Treasuries held in Fed custody by foreign official institutions.

Takeaway: The Fed's international USD provision is now an *embedded, standing policy tool*—a two-tier backstop (swap lines + FIMA) that can be activated quickly in stress.

A2: Model Details

Bankers

Back

$$V_{i,t} = \max_{S_{i,t}, D^*_{i,t}} \quad E_t\Big[(1-\sigma)\Lambda_{t,t+1}N_{i,t+1}) + \sigma\Lambda_{t,t+1}V_{i,t+1}\Big]$$

$$\psi_t \equiv \frac{V_t}{N_t} = E_t\Big[\Lambda_{t,t+1}(1-\sigma+\sigma\psi_{t+1})\frac{N_{t+1}}{N_t}\Big]$$

$$\begin{aligned} \psi_t = \max_{\phi_t, x_t} \quad & \left[\mu_t\phi_t + \mu_t^*\phi_t x_t + \nu_t\right] \\ \text{s.t.} \quad & \psi_t \geq \Theta(x_t, \gamma_t)\phi_t \end{aligned}$$

Banks' FOCs

- Banks choose scale (ϕ_t) and funding mix (x_t)

$$\phi_t = \frac{\nu_t}{\Theta(x_t, \gamma_t) - (\mu_t + \mu_t^* x_t)} \qquad \mu_t^* = \left[\frac{\Theta(x_t, \gamma_t)}{\Theta_x(x_t, \gamma_t)} - x_t\right]^{-1} \mu_t$$

where

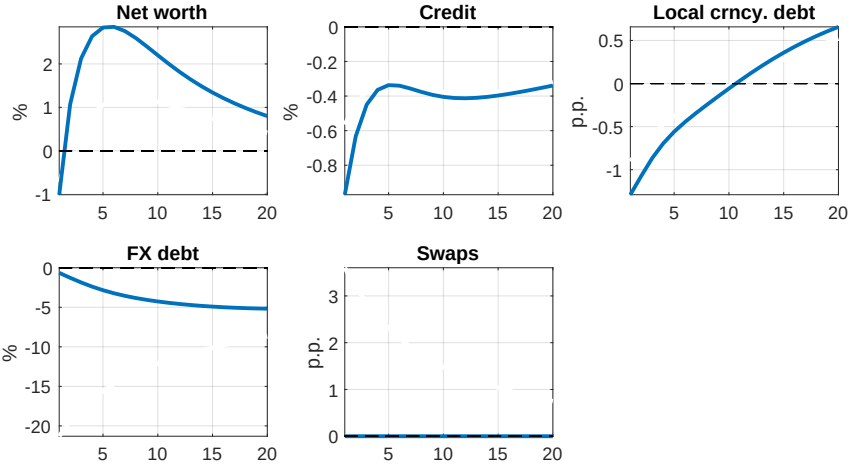
* Leverage: $\phi_t = q_t S_t / N_t$
* Domestic excess return: $\mu_t = E_t\left[\Omega_{t+1}(R_{K,t+1} - R_{t+1})\right]$
* Foreign excess return: $\mu_t^* = E_t\left[\Omega_{t+1}(R_{t+1} - \frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t} R_{t+1}^*)\right]$
* UIP deviations: $\mu_t^{FX} = E_t\left[\Omega_{t+1}(R_{K,t+1} - \frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t} R_{t+1}^*)\right]$
* Marginal value of internal funds: $\Omega_{t+1} = \Lambda_{t,t+1}(1 - \sigma + \sigma\psi_{t+1})$
* Marginal saving from extra unit of net worth: $\nu_t = \left[\Omega_{t+1} R_{t+1}\right]$

Calibration

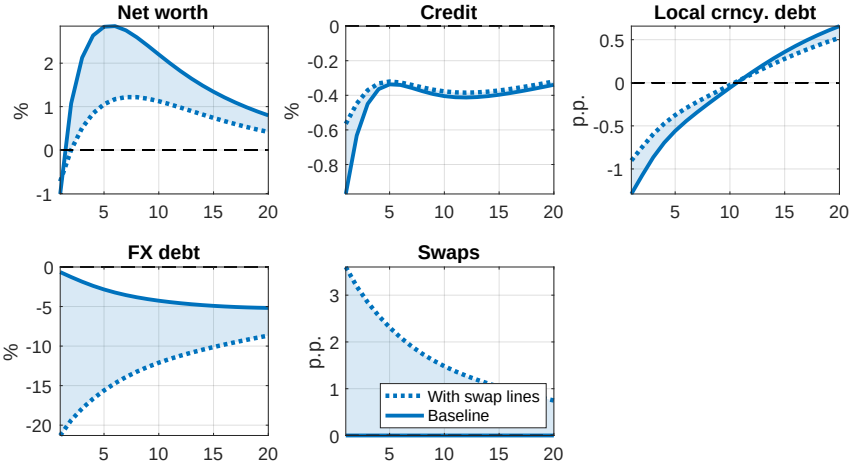
Parameter	Symbol	Value
Home discount factor	β	0.9925
Foreign discount factor	β^*	0.9950
Relative home size	ξ/ξ^*	0.33
Capital share	α	0.33
Depreciation rate	δ	0.025
IES	σ	1
Price mark-up	θ_p	0.2
Inverse Frisch elasticity	χ	3.79
Prob. keeping prices fixed	ξ_p	0.84
Price indexation parameter	ι_p	0.24
Investment adjustment cost	ψ_I	0.5
Trade price elasticity	$(1+\rho)/\rho$	1.5
Home trade openness	ω	0.2
Foreign trade openness	ω^*	0.2/0.33
Bank survival rate	σ_b	0.93
Divertable fraction upon default	θ	0.27
Bank endowment	ξ_b	0.07
Home bias in bank funding	γ^{ss}	3
Policy rate persistence	γ^r	0.82
Foreign Taylor rule inflation coeff.	ϕ_π	1.5
Home Taylor rule FX coeff.	γ_e	0.05,0.4,0.99

Dollar shortage shock

Credit market



The effect of swap lines



Banks: Optimization problem

- Bank maximize:

$$\mathbb{V}_{it}^{b} = \max_{S_{it}, D_{it}^{*}} (1-\sigma)\mathbb{E}_t(\Lambda_{t,t+1}N_{i,t+1}) + \sigma\mathbb{E}_t(\Lambda_{t,t+1}V_{i,t+1})$$

subject to an incentive compatibility constraint

$$V_{it} \geq \theta\left(1+\gamma x_{it}^{2}\right) q_t S_{it}$$

and the law of motion for net worth

$$N_{i,t+1} = (R_{K,t+1} - R_{t+1})q_t S_{i,t} + \left(R_{t+1} - R_{t+1}^{*}\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right)\mathcal{Q}_t D_{it}^{*} + R_{t+1}N_{it}$$

Households & Employment agencies

- Continuum of households indexed by $i \in [0, 1]$
- Each household is a monopolistic supplier of specialized labor L_{it} (Erceg, Henderson and Levin (2000))
- Competitive "employment agencies" combine L_{it} into a homogeneous labor input

$$L_t = \left(\int_0^1 L_{it}^{\frac{1}{1+\theta_w}} di \right)^{1+\theta_w}$$

- Retail firms producing intermediate goods pay

$$W_t = \left(\int_0^1 W_{it}^{-\frac{1}{\theta_w}} dj \right)^{-\theta_w}$$

Households & Employment agencies

- Households maximize:

$$\mathbb{V}^h = \max_{\substack{\{C_{Dt+j},\, M_{Ct+j},\, C_{t+j} \\ D_{t+j},\, W_{it+j},\, L_{it+j}\}_{j=0}^{\infty}}} \mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j \left(\frac{\sigma}{1-\sigma} \left(C_{t+j} - \frac{\chi_0}{1+\chi} L_{t+j}^{1+\chi} \right)^{\frac{\sigma-1}{\sigma}} \right) \right]$$

subject to

$$P_t C_t + P_t D_t \leq W_t L_t + P_t R_t D_{t-1} + R_t^n B_{t-1} + \mathcal{W}_{it} + \Pi_t$$

where C_t is a CES aggregate of domestic (C_D) and imported (M_C) composite goods:

$$C_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} C_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} M_{Ct}^{\frac{1}{1+\rho}} \right]^{1+\rho}$$

and P_t is given by

$$P_t = \left[(1-\omega) P_{Dt}^{-\frac{1}{\rho}} + \omega P_{Mt}^{-\frac{1}{\rho}} \right]^{-\rho}$$

Firms & Price setting

- Retail firms produce intermediates with the following technology $Y_{it} = K_{it}^{\alpha} L_{it}^{1-\alpha}$
- Prices are set on a staggered basis as in Calvo (1983)
  - Probability of not being able to reset prices in t is $\xi \in [0, 1]$
- A retail firm that can reset its price at time t solves

$$\mathbb{V}^f = \max_{P_{Di,t}} \mathbb{E}_t \left[\sum_{j=0}^{\infty} \xi_p^j \Lambda_{t,t+j} \left(P_{Di,t} Y_{i,t+j} - W_{t+j} L_{i,t+j} - Z_{t+j} K_{i,t+j} \right) \right]$$

- Final output is a CES composite of retail firms' output:

$$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{1}{1+\theta_p}} di \right)^{(1+\theta_p)}$$

Capital goods producers

- Capital producers produce new capital goods subject to cost of adjusting investment
- The representative capital producer solves

$$\mathbb{V}^i = \max_{\{I_{t+j}\}_{j=0}^{\infty}} \mathbb{E}_t \left[\sum_{j=0}^{\infty} \Lambda_{t,t+j} \left(q_{t+j} I_{t+j} - \frac{p_{D,t+j}}{P_{t+j}} \phi_{It} \right) \right]$$

where I_t is a CES aggregate of domestic (C_D) and imported (M_C) composite goods:

$$I_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} I_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} M_{It}^{\frac{1}{1+\rho}} \right]^{1+\rho}$$

- Investment adjustment cost:

$$\phi_{I,t} = \frac{\psi_I}{2} (I_t / I_{t-1} - 1)^2 I_t$$

Foreign economy

- US households analogous to Home, but they invest in EM bank deposits (no US banks)
- US economy mirrors EM except for:
  - Size
  - Financial frictions

Market clearing and BoP

- Market-clearing home good:

$$Y_t = C_{Dt} + I_{Dt} + \frac{\xi^*}{\xi}(M^*_{Ct} + M^*_{It}) + \phi_{It}$$

- Market-clearing claims on physical capital (held by banks):

$$S_t = (1-\delta)K_t + I_t$$

- Balance of payments:

$$C_t + I_t + p_{d,t}\phi_{It} - p_{d,t}Y_t = \mathcal{Q}_t(D^*_t - R^*_t D^*_{t-1})$$

Monetary policy

- Monetary policy follows inertial Taylor rule:

$$R^n_{t+1} = \left(R^n_t\right)^{\gamma_r}\left(\beta^{-1}\pi_t^{\frac{1-\gamma_e}{\gamma_e}}\left(e_t/e_{t-1}\right)^{\frac{\gamma_e}{1-\gamma_e}}\right)^{(1-\gamma_r)} u^r_t$$

with

$$\pi_t = P_{D,t}/P_{D,t-1} = \pi_{c,t}p_{Dt}/p_{Dt-1}$$

$$\mathcal{E}_t = \mathcal{Q}_t P_t/P^*_t$$

A3: Bank Runs

Depositors price in the *risk* of runs

- Deposits pay a non-contingent gross rate $\bar{R}_{t+1}$. But if there is a run, depositors face equal haircuts

$$R^d_{t+1} = \begin{cases} \bar{R}_{t+1} & \text{if no bank run} \\ h_{t+1}\bar{R}_{t+1} & \text{if bank run} \end{cases}$$

- So, with the probability of a bank run p_t, deposit rate is:

$$1 = \left[(1-p_t)\,\mathbb{E}_t(\Lambda_{t,t+1}) + p_t\,\mathbb{E}_t(\tilde{\Lambda}_{t,t+1}h_{t+1})\right]\bar{R}_{t+1}$$

- The risk of financial panics is reflected in higher funding costs for banks
  - $p_t \uparrow$ or $h_{t+1} \downarrow \quad \Rightarrow \quad \bar{R}_{t+1} \uparrow$
- Identical for foreign depositors and $\bar{R}^*$ (work in progress)