Interbank Markets, Foreign Banks, and Monetary Policy Under a Floor System

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Increased reserve holdings of foreign banks and U.S. monetary policy

The Federal Reserve operates monetary policy under a **floor system**.

- The Fed administratively sets the interest on reserve balances (IORB) rate, which in principle would directly determine the fed funds rate.
- Surprisingly, the fed funds rate has been *lower than* the IORB rate.
- **Foreign banks** became active fed funds borrowers and significantly increased their reserve holdings to extract **arbitrage**.

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This paper studies the **behavior of foreign banks** in interbank markets and its implications for monetary policy.

A two-country model of multi-sector banking and interbank markets

U.S. banks vs foreign banks (retail banks)

- Both earn interest on reserve balances.
- U.S. banks face higher "**balance sheet costs**" due to tighter capital requirements.

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Federal Reserve (central bank)

- administratively sets the interest rate on reserves
- adjusts the **size of its balance sheet** by swapping reserves for government bonds

Preview of results: interest rate structure and interbank market activities

	Size of the Fed's Balance Sheet ω		
	$0 < \omega \leq \underline{\omega}$	$\underline{\omega} < \omega \leq \bar{\omega}$	$\bar{\omega} \leq \omega < \infty$
Interest rate structure	$R_b = R_e = R_m$	$R_b = R_e < R_m$	$R_b < R_e < R_m$
Interbank market activities	Inactive	Active (from non-retail to foreign banks)	

Note: R_b - interest rate on government bonds; R_e - interbank loan rate; R_m - interest rate on reserves

Preview of results: effects of a central bank's balance sheet expansion

Balance sheet expansion stimulates **foreign banks' activity** in the interbank market.

- Foreign banks' **holdings of reserves** and their **borrowings** from non-retail banks increase with the central bank balance sheet size.

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1. If the balance sheet size is sufficiently large but not too large, its expansion ...

- involves the Fed's swap of worse collateral (reserves) for better one (gov't bonds).
- **raises balance sheet costs** for all banks, leading to a contraction in the global economy.

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   - involves the Fed's swap of worse collateral (reserves) for better one (gov't bonds).
   - **raises balance sheet costs** for all banks, leading to a contraction in the global economy.
2. If the balance sheet size is very large, its expansion ...
   - **has a redistributive effect** as the market for gov't bonds is segmented from other markets.
   - causes an expansion of retail banks and a contraction of non-retail banks.

Related literature

(1) Empirical findings on **heterogenous bank asset portfolios**:
Kreicher, McCauley, and McGuire (2014), Ennis and Wolman (2015), Banegas and Tase (2022)

→ These papers suggest that the increase in foreign banks' reserve holdings stem from their lower balance sheet costs relative to U.S. banks.

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(2) Implications of **interbank markets** for **monetary policy**: Poole (1968), Ennis and Keister (2008), Afonso and Lagos (2015), Armenter and Lester (2017), Afonso, Armenter, and Lester (2019), Williamson (2019, 2023), Bianchi and Bigio (2022), Afonso, Giannone, La Spada, and Williams (2023), and La Spada, Mertens, and Williams (2023)

→ I focus on the role of foreign banks in the transmission of monetary policy.

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(3) Implications of **foreign banks** in interbank markets for **interest rate policy**: Stern (2022), Oguri and Pizzimenti (2025)

→ I further examine domestic/global implications of the Fed's balance sheet expansion.

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Federal Funds Market

… is a market where reserve balances are borrowed and lent overnight.

- Banks borrow reserves for clearing, settlement, or to meet reserve requirements.
- Banks lend reserves when holding excess reserves.

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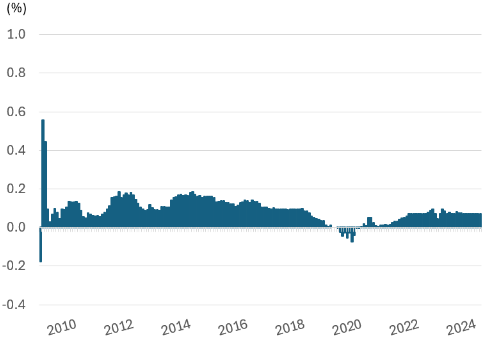
Market participants

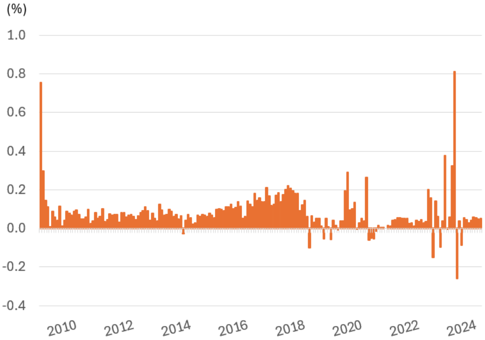
- U.S. banks
- U.S. branches and agencies of **foreign banks**
- Government-sponsored enterprises (GSEs)
  - Fannie Mae, Freddie Mac, and **Federal Home Loan Banks**

Stylized fact 1: one-month Treasury bill rate < fed funds rate < IORB rate

< IORB Rate minus Fed Funds Rate >

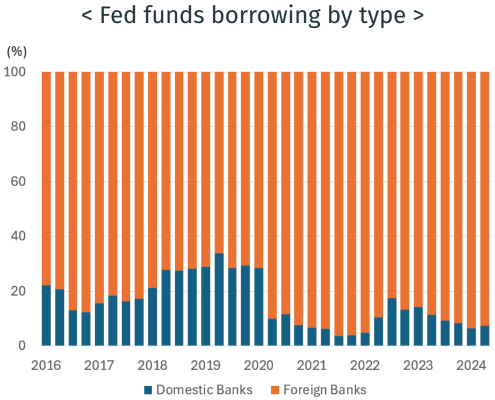


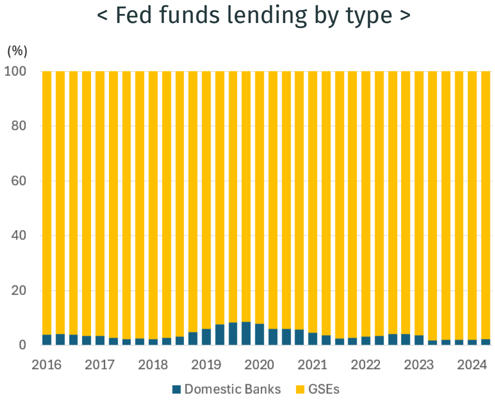
< Fed Funds Rate minus 1-Month T-Bill Rate >



Source: Federal Reserve Economic Data

Stylized fact 2: Foreign banks have been major borrowers since 2008

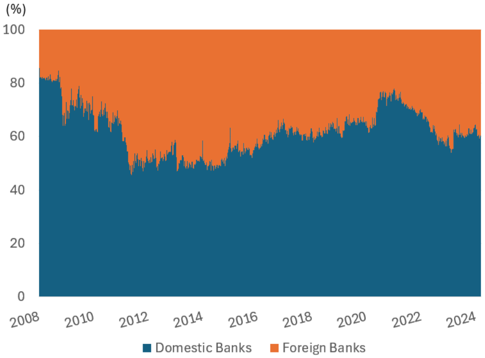




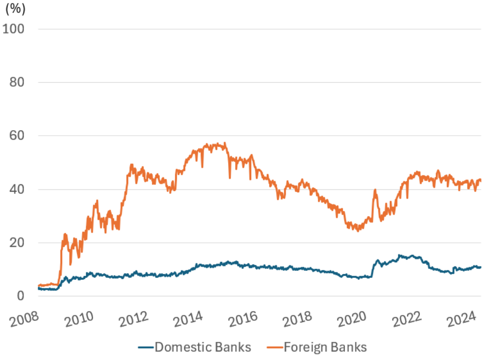
Source: Anderson and Na (2024)

Stylized fact 3: Foreign banks have significantly increased their reserve holdings

< Shares of reserves across banks >



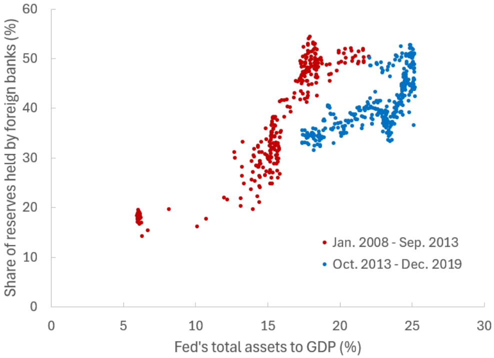
< Reserves to total assets ratio by type >



Source: Federal Reserve Board

Stylized fact 4: Their share of reserves increased with the Fed's balance sheet

< Fed's balance sheet size and foreign bank's share of reserves >



Source: Federal Reserve Board

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Environment

Time is discrete, $t = 0, 1, 2, ...$

Two countries: *Home* and *Foreign*

(Broadly) Three types of agents: buyers, sellers, and banks

- **Limited commitment** and **no memory** (no record-keeping)

Two sequential markets

- *Centralized* market: international Walrasian market
- *Decentralized* market: domestic random matching and bargaining

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Lagos and Wright (2005), Rocheteau and Wright (2005), Williamson (2019, 2023), Kim (2023)

Environment

Three means of payment in the decentralized market

- Currency
- Deposit claims
- Government bonds

Three types of banks

- *Home (retail) banks*: hold reserves and serve a fraction α of Home buyers
- *Foreign (retail) banks*: hold reserves and serve a fraction α^* of Foreign buyers
- *Unconventional banks*: hold *no* reserves and serve all the remaining buyers

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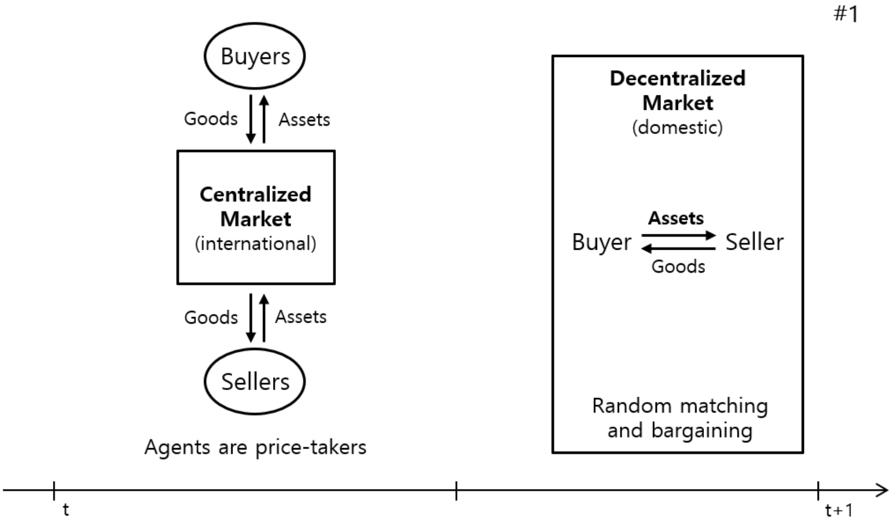
Lagos and Wright (2005), Rocheteau and Wright (2005), Williamson (2019, 2023), Kim (2023)

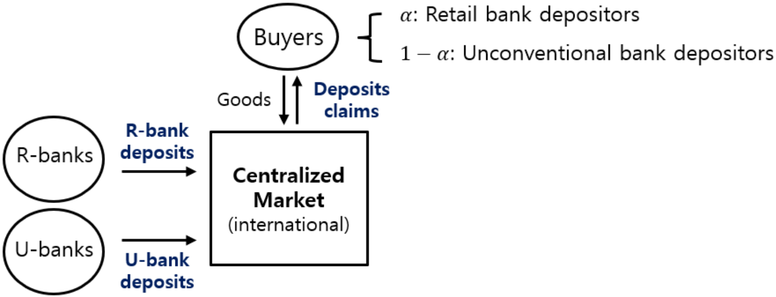
Buyers and sellers

◂ Details



Retail banks and unconventional banks

#2

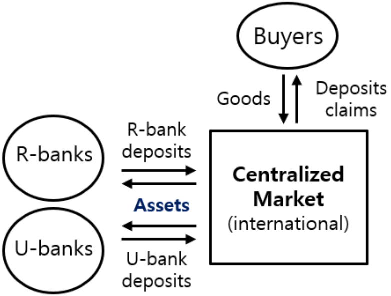


Buyers can withdraw assets from their deposit accounts

Retail banks and unconventional banks

Details

#3



Limited commitment

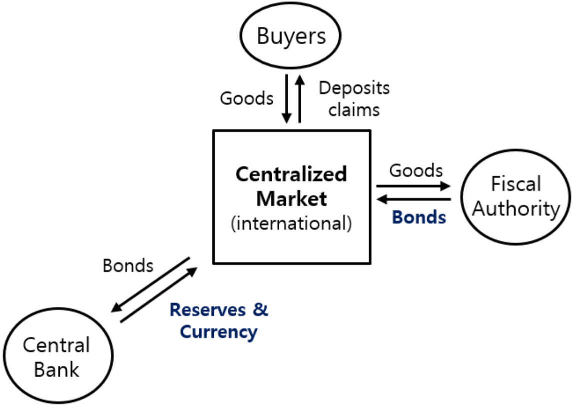
→ Intermediary's liabilities must be backed by its assets

→ Incentive constraint (**collateral constraint**)

Capital requirements imposed to retail banks (**capital constraint**)

Central bank and fiscal authority ◂ Details

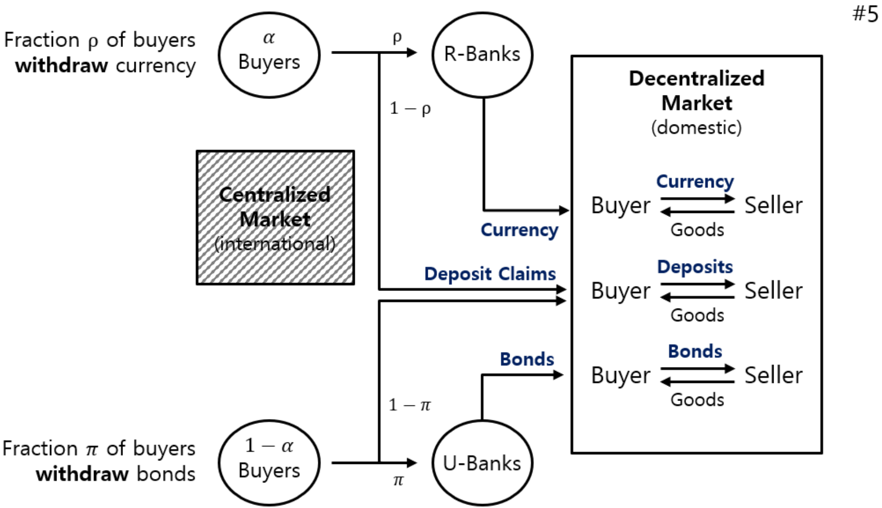
#4



(1) **Nominal interest rate** on reserves

(2) Central bank's **balance sheet size**

After the centralized market closes, ...



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Home (retail) bank's problem in equilibrium

Details

Each bank optimizes by maximizing the representative Home buyer's expected utility:

$$\max_{(k_h,c_h,d_h),(m_h,m_h^*,b_h,b_h^*,e_h)} \mathbb{E}\mathrm{U}_{\text{buyer}}(k_h,c_h,d_h) = -k_h + \rho u(x_c) + (1-\rho)u(x_d)$$

subject to

$$\mathbb{E}[\text{Payoff}_{\text{bank}}|(k_h,c_h,d_h,m_h,m_h^*,b_h,b_h^*,e_h)] = 0, \quad (\text{free entry})$$

$$(1-\delta)\mathbb{E}[\text{Value}_{\text{bank}}^{\text{risk adjusted assets}}|(k_h,\ldots,e_h)] - \mathbb{E}[\text{Value}_{\text{bank}}^{\text{liabilities}}|(k_h,\ldots,e_h)] \geq 0, \quad (\text{capital constraint})$$

- **Deposit contract**: k_h - its price; c_h - Home currency offered to buyer; d_h - deposit claims
- **Asset portfolio**: c_h - currency; (m_h, m_h^*) - reserves; (b_h, b_h^*) - Home & Foreign bonds; e_h - borrowings
- $x_c = x(c_h)$ - consumption in *currency-involved* transaction
- $x_d = x(d_h)$ - consumption in *deposits-involved* transaction

Foreign (retail) bank's problem in equilibrium ◂ Details

Each bank optimizes by maximizing the representative Foreign buyer's expected utility:

$$\max_{(k_f,c_f,d_f),(m_f,m_f^*,b_f,b_f^*,e_f)} \mathbb{E}U_{\text{buyer}}(k_f,c_f,d_f) = -k_f + \rho u(x_c^*) + (1-\rho)u(x_d^*)$$

subject to

$$\mathbb{E}[\text{Payoff}_{\text{bank}}|(k_f,c_f,d_f,m_f,m_f^*,b_f,b_f^*,e_f)] = 0, \quad (\text{free entry})$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{repay}}|(k_f,\ldots,e_f)] - \mathbb{E}[\text{Value}_{\text{bank}}^{\text{default}}|(k_f,\ldots,e_f)] \geq 0, \quad (\text{collateral constraint})$$

- **Deposit contract**: k_f - its price; c_f - Foreign currency offered to buyer; d_f - deposit claims
- **Asset portfolio**: c_f - currency; (m_f,m_f^*) - reserves; (b_f,b_f^*) - Home & Foreign bonds; e_f - borrowings
- $x_c^* = x(c_f)$ - consumption in *currency-involved* transaction
- $x_d^* = x(d_f)$ - consumption in *deposits-involved* transaction

Unconventional bank's problem in equilibrium ◂ Details

Each unconventional bank optimizes by solving the following problem:

$$\max_{(k_u,\hat{b},\hat{b}^*,d_u),(b_u,b_u^*,e_u)} \mathbb{E}\mathrm{U}_{\text{buyer}}(k_u,\hat{b},\hat{b}^*,d_u) = -k_u + \pi\gamma u\left(x_b\right) + \pi(1-\gamma)u(x_b^*) + (1-\pi)u(x_d^u)$$

subject to

$$\mathbb{E}[\text{Payoff}_{\text{bank}}|(k_u,\hat{b},\hat{b}^*,d_u,b_u,b_u^*,e_u)] = 0, \quad \text{(free entry)}$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{repay}}|(k_u,\ldots,e_u)] - \mathbb{E}[\text{Value}_{\text{bank}}^{\text{default}}|(k_u,\ldots,e_u)] \geq 0, \quad \text{(collateral constraint)}$$

- **Deposit contract**: k_u - its price; $(\hat{b},\hat{b}^*)$ - Home & Foreign bonds offered; d_u - deposit claims
- **Asset portfolio**: (b_u,b_u^*) - Home & Foreign bonds; e_u - borrowings (loans if negative)
- $(x_b,x_b^*) = [x(\hat{b}),x(\hat{b}^*)]$ - consumption in *bonds-involved* transaction
- $x_d^u = x(d_u)$ - consumption in *deposits-involved* transaction

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Bank asset portfolios in a stationary equilibrium

◂ Definition of Stationary Equilibrium

Each asset is allocated to institutions that value the asset the most.

(1) When the interest rate on Home (government) bonds is **sufficiently high**,

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Bank asset portfolios in a stationary equilibrium

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- retail banks choose *not to hold* these bonds
- unconventional banks use these bonds as **collateral at the margin**
- unconventional banks start acquiring **interbank loans** as an alternative to bonds

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- unconventional banks start acquiring **interbank loans** as an alternative to bonds

(3) When the interest rate on Home bonds is **very low**,

- these bonds are used *only* as a **means of payment** by unconventional bank depositors

Interest rate structure and interbank market activities

	Interest rate on Home (government) bonds		
	Sufficiently high	Sufficiently low but not too low	Very low
Interbank market activities	**Inactive**	**Active** (From unconventional banks to Foreign banks)	
Interest rate structure	$R_b = R_e = R_m$	$R_b = R_e < R_m$	$R_b < R_e < R_m$
Role of gov't bonds at the margin	**Collateral** by retail banks	**Collateral** by unconv'l banks	**Means of Payment**

Note: R_b - interest rate on Home bonds; R_e - interbank loan rate; R_m - interest rate on reserves

Empirical relevance

(1) Why fed funds rate < IORB rate?

- Scope of arbitrage is limited due to "**balance sheet costs**" faced by banks (Bech and Klee, 2011; Afonso, Entz, and LeSueur, 2013; Ennis, 2018; Williamson, 2019).
  - Increased deposit insurance premiums and binding capital requirements

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  - Increased deposit insurance premiums and binding capital requirements

(2) Why short-term Treasury bill rate < fed funds rate?

- Non-pecuniary demand for safe assets reduces their real interest rates (Caballero, Farhi, and Gourinchas, 2016; Caballero and Farhi, 2018; Del Negro, Giannone, Giannoni, and Tambalotti, 2019; Jorda, Knoll, Kuvshinov, Schularick, and Taylor, 2017).
  - Safe assets are useful due to its high liquidity and collateral value

Empirical relevance

(3) Why only foreign banks borrow in the fed funds market?

- Foreign banks face **lower balance sheet costs** compared to U.S. banks (Kreicher, McCauley, and McGuire, 2014; Afonso, Entz, and LeSueur, 2013; Ennis and Wolman, 2015; Banegas and Tase, 2022).
  - Not insured by the FDIC
  - Different leverage ratio calculations

Balance sheet expansion and the types of equilibrium

Balance sheet expansion involves central bank's swaps of reserves for gov't bonds.

- Balance sheet size ↑ → scarcity of gov't bonds ↑ → interest rate ↓.

	Central bank's balance sheet size		
	Sufficiently small	Sufficiently large but not too large	Very large
Bond interest rate	Sufficiently high	Sufficiently low but not too low	Very low
Equilibrium	Type 1	Type 2	Type 3

- Effects of central bank's policies vary depending on its balance sheet size.

Monetary policy under a floor system

1. Lowering the nominal interest rate on reserves [Effects]
2. Expanding the size of the central bank's balance sheet

Monetary policy under a floor system

1. Lowering the nominal interest rate on reserves ◂ Effects
2. **Expanding the size of the central bank's balance sheet**

Effects of a balance sheet expansion

Balance sheet expansion involves central bank's swaps of reserves for gov't bonds.

- Type-1: **Neutral** because reserves and bonds are **perfect substitutes** at the margin.
-
-

Equilibrium type	Home bank		Foreign bank		Unconv' bank			Interest rates			Spreads	
	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$

Effects of a balance sheet expansion

Balance sheet expansion involves central bank's swaps of reserves for gov't bonds.

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- Type-2: **Balance sheet costs rise** as reserves are **worse collateral** compared to bonds.
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Equilibrium type	Home bank		Foreign bank		Unconv' bank			Interest rates			Spreads	
	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	·	·	·	·	·	·	·	·	·	·	·	·
Type 2	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	·	$\downarrow$	$\downarrow$	$\uparrow$	·

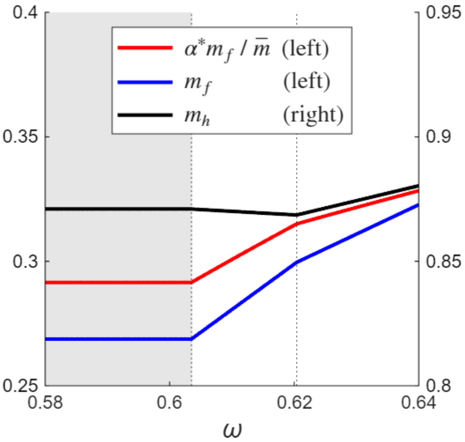
Effects of a balance sheet expansion

Balance sheet expansion involves central bank's swaps of reserves for gov't bonds.

- Type-1: Neutral because reserves and bonds are perfect substitutes at the margin.
- Type-2: Balance sheet costs rise as reserves are worse collateral compared to bonds.
- Type-3: **Not substitutes** → increases **collateral** and decreases **means of payments**.

Equilibrium	Home bank		Foreign bank		Unconv' bank			Interest rates			Spreads	
type	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	·	·	·	·	·	·	·	·	·	·	·	·
Type 2	↓	↓	↓	↓	↓	↓	↓	·	↓	↓	↑	·
Type 3	↑	↑	↑	↑	↓	↑	↑	·	↑	↓	↓	↑

Banks' reserve holdings and Foreign banks' share



Note: m_f - (Home) reserves held by Foreign banks; m_h - reserves held by Home banks; $\alpha^* m_f / \bar{m}$ - Foreign banks' share of reserves; ω - size of the central bank's balance sheet

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Overnight Reverse Repurchase Agreement Facility

The Federal Reserve introduced an **ON-RRP facility** in September 2013.

- Under this operation, the Fed sells a security to a counterparty with an agreement to buy it back the next day.
- ON-RRP operations involve a *reduction* in reserve balances, without affecting the size of the Fed's balance sheet.

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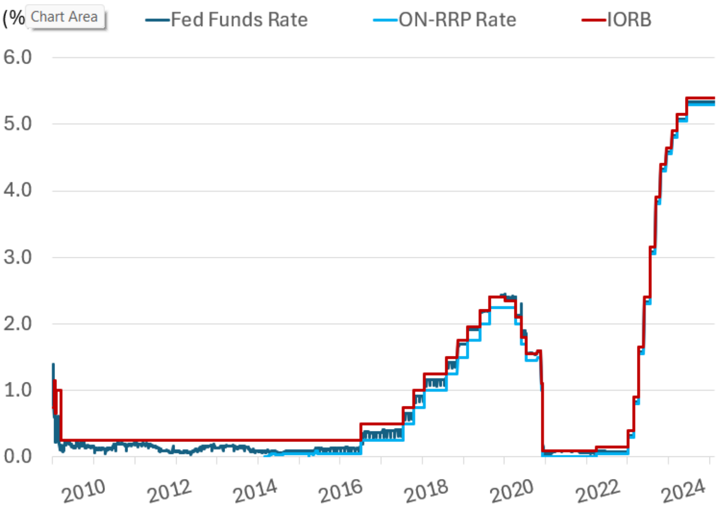
- Under this operation, the Fed sells a security to a counterparty with an agreement to buy it back the next day.
- ON-RRP operations involve a *reduction* in reserve balances, without affecting the size of the Fed's balance sheet.

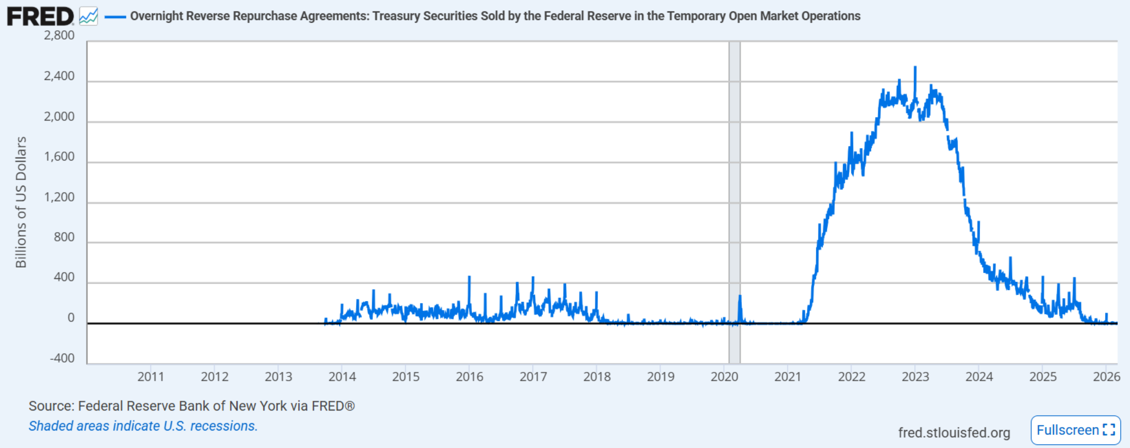
Goal: improve control over the fed funds rate

- Fed funds rate < IORB rate, because not all institutions can earn interest on reserves.
- ON-RRPs allow a broader set of institutions to hold interest-bearing Fed liabilities.
- ON-RRP award rate serves as a lower bound, while the IORB rate as an upper bounds, creating a ***new* corridor system**.

Interest rate structure under a new corridor system

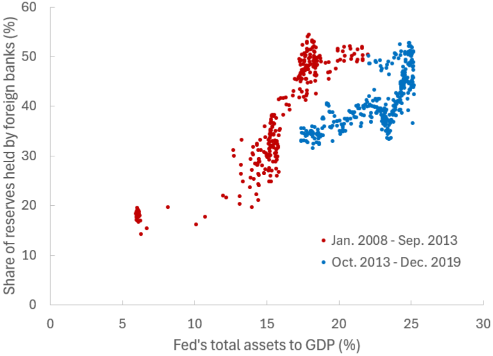


Volume of ON-RRP operations



Structural change in foreign banks' reserve share since October 2013

< Fed's balance sheet size and foreign bank's share of reserves >



Source: Federal Reserve Board

Extended model

Central bank issues ω_o units of **ON-RRPs** in addition to currency and reserves

- Unconventional banks are eligible to hold ON-RRPs.
- Size of the central bank balance sheet: $\omega = \bar{c} + \bar{m} + \omega_o$

Extended model

Central bank issues ω_o units of **ON-RRPs** in addition to currency and reserves

- Unconventional banks are eligible to hold ON-RRPs.
- Size of the central bank balance sheet: $\omega = \bar{c} + \bar{m} + \omega_o$

Central bank determines

- Nominal interest rate on reserves R_m
- Size of the central bank balance sheet ω
- Size of the **ON-RRP facility** ω_o

Effects of expanding the ON-RRP facility

ON-RRP expansion involves central bank's swaps of ON-RRPs for reserves.

- Type-1: **Neutral** because reserves and ON-RRPs are **perfect substitutes** at the margin.
-

Equilibrium type	Home bank		Foreign bank		Unconv' bank			Interest rates			Spreads	
	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	·	·	·	·	·	·	·	·	·	·	·	·

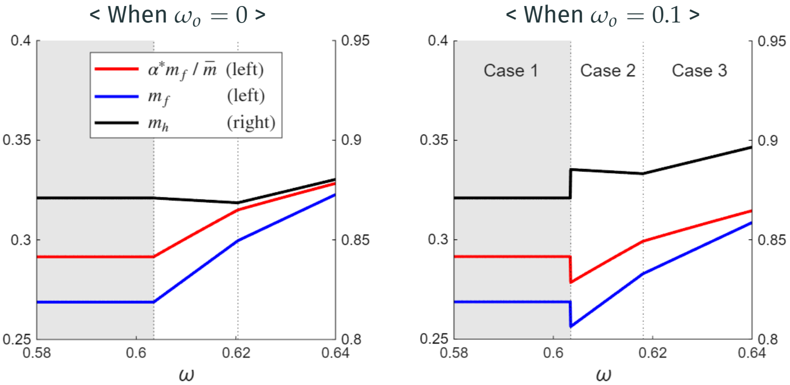
Effects of expanding the ON-RRP facility

ON-RRP expansion involves central bank's swaps of ON-RRPs for reserves.

- Type-1: Neutral because reserves and ON-RRPs are perfect substitutes at the margin.
- Type-2 and Type-3: **Balance sheet costs decline**,
  as ON-RRPs act to relax the scarcity of government bonds, relaxing balance sheet constraints.

Equilibrium type	Home bank		Foreign bank		Unconv' bank			Interest rates			Spreads	
	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$	$\cdot$
Type 2	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\cdot$	$\uparrow$	$\uparrow$	$\downarrow$	$\cdot$
Type 3	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\cdot$	$\uparrow$	$\uparrow$	$\cdot$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$

Banks' reserve holdings and Foreign banks' share



Note: m_f - (Home) reserves held by Foreign banks; m_h - reserves held by Home banks; $\alpha^* m_f / \bar{m}$ - Foreign banks' share of reserves; ω - size of the central bank's balance sheet; ω_o - size of the central bank's ON-RRP facility

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Conclusion

This paper develops a **two-country**, **two-sector banking model** to study:

- behavior of foreign banks in the fed funds market
- implications for interest rates and welfare

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- Foreign banks start borrowing from unconventional banks.

Conclusion

This paper develops a **two-country**, **two-sector banking model** to study:

- behavior of foreign banks in the fed funds market
- implications for interest rates and welfare

When the central bank's balance sheet becomes sufficiently large,

- **Interest rate spread** arises between reserves and interbank loans.
- Foreign banks start borrowing from unconventional banks.

Policy effects vary depending on the size of the central bank's balance sheet.

- Central bank's balance sheet expansion can cause a **contraction** in the financial system, reducing welfare globally.

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Buyers

Supply labor in centralized markets (CM) and consume goods in decentralized markets (DM):

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[-H_t + u(x_t)\right]$$

where $0 < \beta < 1$, H_t is labor supply in the CM, and x_t is consumption in the DM

1. Supply labor to produce goods in the CM
2. Exchange goods for assets in the CM
    - Some buyers (fraction α) deposit with **retail banks**, while others deposit with **unconvent'l banks**
    - After learning the type of transaction, can **withdraw** currency or government bonds
3. *Buy* goods and consume them in the DM

Sellers ◂ back

Consume goods in centralized markets (CM) and supply labor in decentralized markets (DM):

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[X_t^s - h_t^s\right]$$

where X_t^s is consumption in the CM and h_t^s is labor supply in the DM

1. Receive payoffs from asset holdings and exchange assets for goods to consume in the CM
2. *Sell* goods in exchange for assets (currency, gov't bonds, or deposit claims) in the DM

Retail banks

Supply labor and consume goods in the centralized market (CM):

$$E_0 \sum_{t=0}^{\infty} \beta^t [-H_t^b + X_t^b]$$

where H_t^b is labor supply and X_t^b is consumption in the CM

1. In the CM, receive deposits from buyers and acquire asset portfolios
   - Currency, **reserves**, gov't bonds, and interbank loans (or **interbank borrowings**)
2. After the CM closes, give **currency** to those who liquidate their deposits
   - Deposit contracts play an **insurance role** for buyers.
3. In the next CM, receive returns from assets and pay off debts (including deposit liabilities)

Unconventional banks ◂ back

Supply labor and consume goods in the centralized market (CM):

$$E_0 \sum_{t=0}^{\infty} \beta^t [-H_t^g + X_t^g]$$

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1. In the CM, receive deposits from buyers and acquire asset portfolios
   - Currency, gov't bonds, and **interbank loans** (or interbank borrowings)
2. After the CM closes, give **gov't bonds** to those who liquidate their deposits
   - Deposit contracts play an **insurance role** for buyers.
3. In the next CM, receive returns from assets and pay off debts (including deposit liabilities)

Central banks in the two countries

Central bank in the **Home country** (under a **floor system**)

- issues currency $\bar{c}$ and reserves $\bar{m}$
- determines (1) the interest rate on reserves R_m and (2) balance sheet size $\omega = \bar{c} + \bar{m}$

Central bank in the **Foreign country** (under a **floor system**)

- issues currency $\bar{c}^*$ and reserves $\bar{m}^*$
- determines (1) the interest rate on reserves R_m^* and (2) balance sheet size $\omega^* = \bar{c}^* + \bar{m}^*$

<Home Central Bank>

Assets	Liabilities
Home bonds	Home currency
Foreign bonds	Home reserves

<Foreign Central Bank>

Assets	Liabilities
Foreign bonds	Foreign currency
Home bonds	Foreign reserves

Table 1: Balance sheets of central banks

Fiscal authorities in the two countries
back

Fiscal authority in the **Home country**

- issues one-period bonds $\bar{b}$ and gives lump-sum transfer τ to each Home buyer
- sets the total quantity of bonds issued by the fiscal authority $v = \bar{c} + \bar{m} + \bar{b}$

Fiscal authority in the **Foreign country**

- issues one-period bonds $\bar{b}^*$ and gives lump-sum transfer τ^* to each Foreign buyer
- sets the total quantity of bonds issued by the fiscal authority $v^* = \bar{c}^* + \bar{m}^* + \bar{b}^*$

Home (retail) bank's problem in equilibrium ◂ back

$$\begin{aligned}\mathbb{E}[\text{Payoff}_{\text{bank}}] &= k_h + e_h - \rho c_h - m_h - b_h - b_h^* \\ &\quad + \beta\left[-(1-\rho)d_h + \frac{(1+R_m)m_h + (1+R_b)b_h - (1+R_e)e_h}{\mu} + \frac{(1+R_b^*)b_h^*}{\mu^*}\right]\end{aligned}$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{risk adjusted assets}}] = \frac{(1+R_m)m_h + (1+R_b)b_h - I_h(1+R_e)e_h + \rho c_h}{\mu} + \frac{(1-\theta)(1+R_b^*)b_h^*}{\mu^*}$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{liabilities}}] = (1-\rho)d_h + \frac{(1-I_h)(1+R_e)e_h}{\mu} + \frac{\rho c_h}{\mu}$$

- (μ, μ^*) - Home and Foreign inflation rates; $I_h = 0$ if $e_h > 0$; $I_h = 1$ if $e_h < 0$
- θ - fraction of foreign assets excluded from capital ratio calculation
- (R_m, R_e, R_b, R_b^*) - interest rates on reserves, interbank loans, Home bonds, and Foreign bonds

Foreign (retail) bank's problem in equilibrium

back

$$\mathbb{E}[\text{Payoff}_{\text{bank}}] = k_f + e_f - \rho c_f^* - m_f - b_f - b_f^* + \beta\left[-(1-\rho)d_f + \frac{(1+R_m)m_f + (1+R_b)b_f - (1+R_e)e_f}{\mu} + \frac{(1+R_b^*)b_f^*}{\mu^*}\right]$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{repay}}] = -(1-\rho)d_f + \frac{(1+R_m)m_f + (1+R_b)b_f - (1+R_e)e_f}{\mu} + \frac{(1+R_b^*)b_f^*}{\mu^*}$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{default}}] = \theta\left[\frac{(1+R_m)m_f + (1+R_b)b_f - I_f(1+R_e)e_f}{\mu}\right]$$

- (μ, μ^*) - Home and Foreign inflation rates; $I_f = 0$ if $e_f > 0$; $I_f = 1$ if $e_f < 0$
- θ - fraction of foreign assets that cannot be pledged as collateral
- (R_m, R_e, R_b, R_b^*) - interest rates on reserves, interbank loans, Home bonds, and Foreign bonds

Unconventional bank's problem in equilibrium ◂ back

$$\mathbb{E}[\text{Payoff}_{\text{bank}}] = k_u + e_u - b_u - b_u^*$$
$$+ \beta \left[-(1-\pi)d_u + \frac{(1+R_b)(b_u - \pi\hat{b}) - (1+R_e)e_u}{\mu} + \frac{(1+R_b^*)(b_u^* - \pi\hat{b}^*)}{\mu^*} \right]$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{repay}}] = -(1-\pi)d_u - \frac{(1+R_e)e_u}{\mu} + \frac{(1+R_b)(b_u - \pi\hat{b})}{\mu} + \frac{(1+R_b^*)(b_u^* - \pi\hat{b}^*)}{\mu^*}$$

$$\mathbb{E}[\text{Value}_{\text{bank}}^{\text{default}}] = \frac{\theta(1+R_b^*)(b_u^* - \pi\hat{b}^*)}{\mu^*}$$

- (μ, μ^*) - Home and Foreign inflation rates;
- θ - fraction of foreign assets that cannot be pledged as collateral
- (R_m, R_e, R_b, R_b^*) - interest rates on reserves, interbank loans, Home bonds, and Foreign bonds

Definition of stationary equilibrium

back

Definition: Given fiscal policies (v, v^*) and monetary policies $(R_m, \omega, R_m^*, \omega^*)$, a stationary equilibrium consists of

- quantities of DM consumption $(x_c, x_d, x_c^*, x_d^*, x_b, x_b^*, x_d^u)$ and asset holdings $(\{c_i, c_i^*, m_i, m_i^*, b_i, b_i^*, e_i\}_{i=h,f,u})$,
- interest rates on interbank loans and bonds (R_e, R_b, R_b^*), gross inflation rates (μ, μ^*),
- transfers (τ_0, τ), and nominal depreciation rate of Home currency $\frac{\xi_{+1}}{\xi}$,

satisfying consolidated government budget constraints, fiscal policy rules (v, v^*), first-order conditions for intermediaries' problems, and asset market clearing conditions

Equilibrium conditions

- Consolidated Home government budget constraints:

$$\bar{c} + \bar{m} + \bar{b} = \tau_0 \qquad \text{for } t = 0$$
$$\bar{c} + \bar{m} + \bar{b} = \frac{\bar{c} + (1+R_m)\bar{m} + (1+R_b)\bar{b}}{\mu} + \tau \qquad \text{for } t = 1, 2, \ldots$$

- Consolidated Foreign government budget constraints:

$$\bar{c}^* + \bar{m}^* + \bar{b}^* = \tau_0^* \qquad \text{for } t = 0$$
$$\bar{c}^* + \bar{m}^* + \bar{b}^* = \frac{\bar{c}^* + (1+R_m^*)\bar{m}^* + (1+R_b^*)\bar{b}^*}{\mu^*} + \tau^* \qquad \text{for } t = 1, 2, \ldots$$

- Fiscal policy rules:

$$v = \bar{c} + \bar{m} + \bar{b}$$
$$v^* = \bar{c}^* + \bar{m}^* + \bar{b}^*$$

Equilibrium conditions, continued

- Market clearing conditions :

$$
\begin{aligned}
&\alpha\rho c_h = \bar{c},\\
&\alpha b_h + \alpha^* b_f + (2-\alpha-\alpha^*) b_u = \bar{b},\\
&\alpha m_h + \alpha^* m_f = \bar{m},\\
&\alpha^* \rho c_f^* = \bar{c}^*,\\
&\alpha b_h^* + \alpha^* b_f^* + (2-\alpha-\alpha^*) b_u^* = \bar{b}^*,\\
&\alpha m_h^* + \alpha^* m_f^* = \bar{m}^*,\\
&\alpha e_h + \alpha^* e_f + (2-\alpha-\alpha^*) e_u = 0,
\end{aligned}
$$

First-order conditions for a Home bank's problem

$$
\begin{aligned}
&(c_h) \quad \mu = \beta[u'(x_c) - \delta u'(x_d) + \delta] \\
&(m_h) \quad 1 + R_m \leq \frac{\mu}{\beta[(1-\delta)u'(x_d) + \delta]} \\
&(b_h) \quad 1 + R_b \leq \frac{\mu}{\beta[(1-\delta)u'(x_d) + \delta]} \\
&(b_h^*) \quad 1 + R_b^* \leq \frac{\mu^*}{\beta\{(1-\delta)[(1-\theta)u'(x_d) + \theta] + \delta\}} \\
&(e_h) \quad \frac{\mu}{\beta u'(x_d)} \leq 1 + R_e \leq \frac{\mu}{\beta[(1-\delta)u'(x_d) + \delta]}
\end{aligned}
$$

where $x_c = \frac{\beta c_h}{\mu}$ and $x_d = \beta d_h$ are the solutions to the bargaining problems

First-order conditions for a Foreign bank's problem

$$
\begin{aligned}
(c_f^*) &\quad \mu^* = \beta u'(x_c^*) \\
(m_f) &\quad 1 + R_m \leq \frac{\mu}{\beta[(1-\theta)u'(x_d^*) + \theta]} \\
(b_f) &\quad 1 + R_b \leq \frac{\mu}{\beta[(1-\theta)u'(x_d^*) + \theta]} \\
(b_f^*) &\quad 1 + R_b^* \leq \frac{\mu^*}{\beta u'(x_d^*)} \\
(e_f) &\quad \frac{\mu}{\beta u'(x_d^*)} \leq 1 + R_e \leq \frac{\mu}{\beta[(1-\theta)u'(x_d^*) + \theta]}
\end{aligned}
$$

where $x_c^* = \frac{\beta c_f^*}{\mu^*}$ and $x_d^* = \beta d_f$ are the solutions to the bargaining problems

First-order conditions for an unconventional bank's problem

$$(b_u) \quad 1 + R_b = \frac{\mu}{\beta\gamma u'(x_b)}$$

$$\gamma u'(x_b) \geq u'(x_d^u), \quad if\ \pi x_b = \frac{\beta b_u}{\mu}; \qquad \gamma u'(x_b) = u'(x_d^u), \quad if\ \pi x_b < \frac{\beta b_u}{\mu}$$

$$(b_u^*) \quad 1 + R_b^* = \frac{\mu^*}{\beta(1-\gamma)u'(x_b^*)}$$

$$(1-\gamma)u'(x_b^*) \geq (1-\theta)u'(x_d^u) + \theta, \qquad if\ \pi x_b^* = \frac{\beta b_u^*}{\mu^*}$$

$$(1-\gamma)u'(x_b^*) = (1-\theta)u'(x_d^u) + \theta, \qquad if\ \pi x_b^* < \frac{\beta b_u^*}{\mu^*}$$

$$(e_u) \quad \frac{\mu}{\beta u'(x_d^u)} = 1 + R_e$$

where $x_b = \frac{\beta\hat{b}(1+R_b)}{\mu}$, $x_b^* = \frac{\beta\hat{b}^*(1+R_b^*)}{\mu^*}$, and $x_d^u = \beta d_d$ are the solutions to the bargaining problems

Capital constraint and collateral constraints

- Home bank's capital constraint:

$$
\begin{aligned}
&-(1-\rho)d_h - \frac{\delta\rho c_h}{\mu} + \frac{(1-\theta)(1-\delta)(1+R_b^*)b_h^*}{\mu^*} \\
&\qquad + \frac{(1-\delta)[(1+R_m)m_h + (1+R_b)b_h] - (1-\delta I_h)(1+R_e)e_h}{\mu} = 0
\end{aligned}
$$

- Foreign bank's collateral constraint:

$$
\begin{aligned}
&-(1-\rho)d_f - \frac{(1-I_h)(1+R_e)e_h}{\mu} + \frac{(1+R_b^*)b_h^*}{\mu^*} \\
&\qquad + \frac{(1-\theta)[(1+R_m)m_f + (1+R_b)b_f] - (1-\theta I_f)(1+R_e)e_f}{\mu} = 0
\end{aligned}
$$

- Unconventional bank's collateral constraint:

$$
-(1-\pi)d_u - \frac{(1+R_e)e_u}{\mu} + \frac{(1+R_b)(b_u - \pi\hat{b})}{\mu} + \frac{(1-\theta)(1+R_b^*)(b_u^* - \pi\hat{b}^*)}{\mu^*} = 0
$$

Nominal exchange rate

back

- The law of one price holds in the centralized market.
- Depreciation rate of the Home currency:

$$\frac{\xi_{+1}}{\xi} = \frac{\mu}{\mu^*}$$

or

$$\frac{\xi_{+1}}{\xi} = \frac{1+R_b}{1+R_b^*} \cdot \frac{\gamma u'(x_b)}{(1-\gamma)u'(x_b^*)}$$

Effects of lowering the interest rate on reserves back

Lowering the interest rate causes a **substitution** of currency for reserves.

Reduced amount of reserves tightens balance sheet constraints globally.

- Foreign and unconventional bank depositors' consumption **decreases** in all transactions.
- Home bank depositors' consumption **increases** in currency-involved transactions and **decreases** in deposits-involved transactions.

Interest rate spread between R_m and R_e rises in type 2 and 3 equilibrium.

Equilibrium type	Home bank		Foreign bank		Mutual fund			Interest rates			Spreads	
	x_c	x_d	x_c^*	x_d^*	x_b	x_b^*	x_d^u	R_m	R_e	R_b	$R_m - R_e$	$R_e - R_b$
Type 1	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\cdot$	$\cdot$
Type 2	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\cdot$
Type 3	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\cdot$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	?