Reserve Demand, Interest Rate Control, and Quantitative Tightening

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Thank you to many Monetary Affairs Division colleagues who helped us think through these issues

The role of reserves in US monetary policy

Pre-financial crisis: Conventional monetary policy

- Reserves didn't earn interest: Reserve demand was modest
- Reserve supply was small even relative to demand: Equilibrium was on the steep part of reserve demand curve
- Fed could change short-term rates (effective federal funds rate) with small changes in reserve supply via open market operations

Financial crisis: Zero/effective lower bound → Unconv. monetary policy: Forward guidance, QE

- Reserve supply expanded massively
- The Fed started paying interest on reserves

Conventional versus unconventional monetary policy: The role of reserves

Our focus:

1. What is the role of reserve demand for interest rate control in the ample reserves setting?
2. How can we use reserve demand to guide QT?
    - Reserve demand determines how QT affects interest rate volatility
    - Different angle in Vissing-Jorgensen (June 2023, ECB Sintra paper)
      Reserve demand affects the "convenience-maximizing" supply of reserves

Steps:

1. Framework:
    - Deriving reserve demand from banks' optimization and reserve supply from CB actions
    - Equilibrium
2. Estimate reserve demand:
    - Implications for interest rate control: iso-fed funds curves
    - Implications for quantitative tightening

Federal Reserve balance sheet

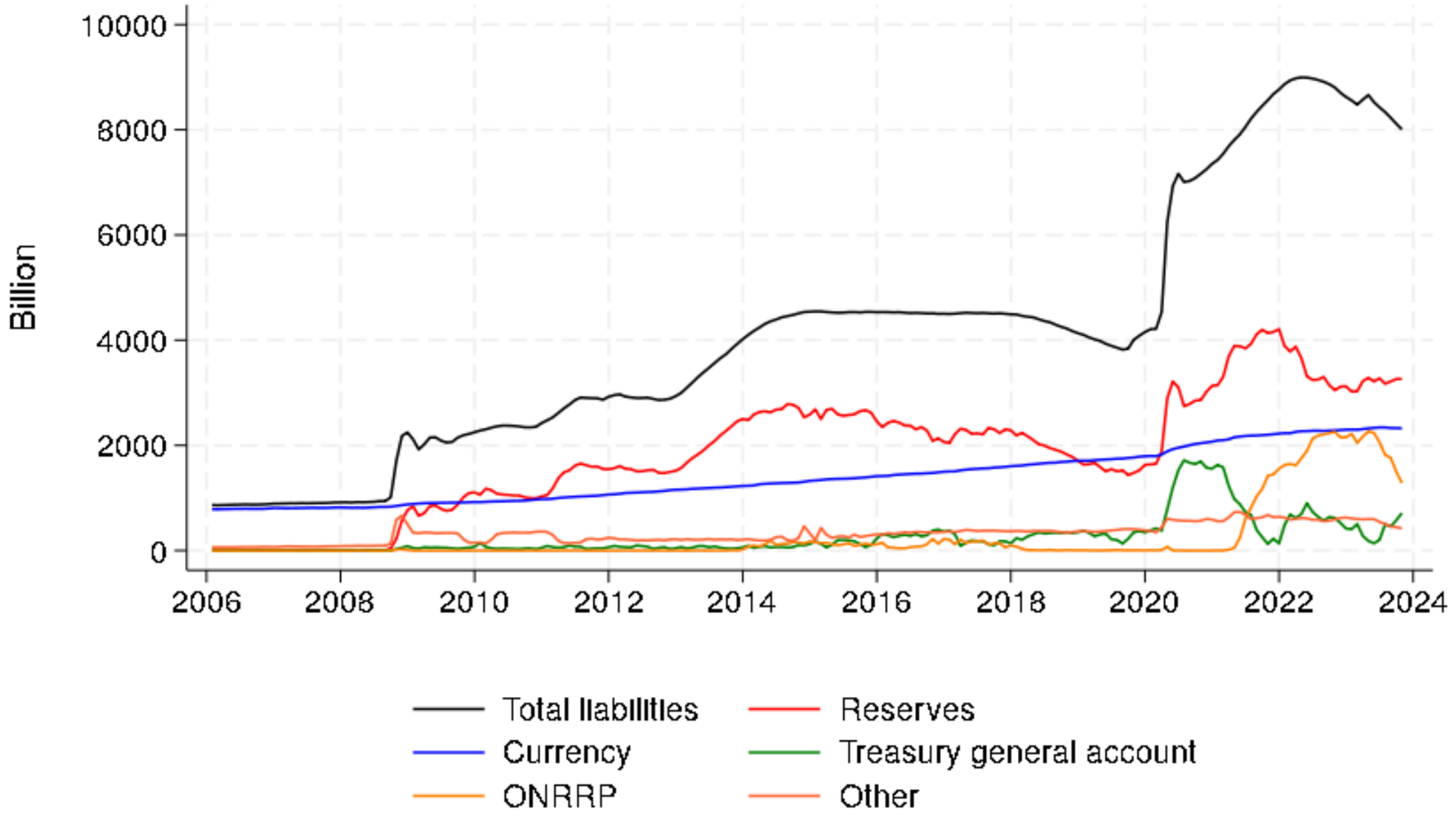
Federal Reserve balance sheet, November 1, 2023
H.4.1 release, $B

Assets		Liabilities	
Treasuries	4,873	Currency	2,325
MBS	2,463	Treasury general account	753
Loans	163	Reserves	3,315
Other	418	Overnight reverse repurchase agreements	1,079
		Other	445
	7,917		7,917

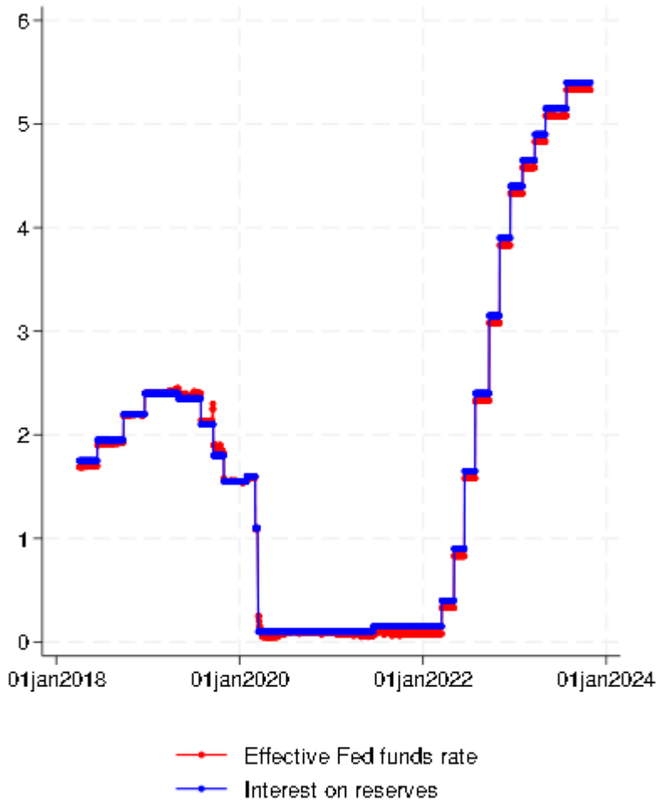
The Federal Reserve funds itself with:

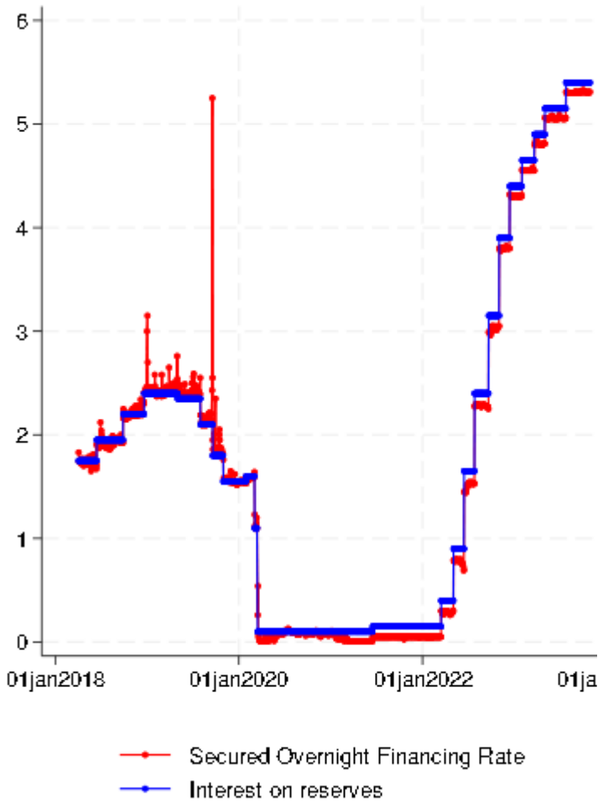
- Autonomous factors (Currency, TGA): Not chosen by Fed (demand accommodated)
- Reserves, ONRRP

Federal Reserve liabilities, 2006M1-2023M10



Low reserve supply → Yield spikes, September 2019 (daily data)





- Sept 17, 2019: Reserve scarcity in the sense that banks were willing to hold them at a much lower rate (IOR) than they could get by lending in the Fed funds market (EFFR) or repo market (SOFR)

- Market worries that current QT will end abruptly with another yield spike e.g., WSJ 9/3/2022

The Other Doomsday Scenario Looming Over Markets

A U.K. fund manager says the big worry isn't inflation, it's the reversing quantitative easing

RESERVE DEMAND

Deriving reserve demand from banks' optimization

Bank Assets	*Bank Liabilities*
Reserves	Deposits
Securities	Federal funds
Loans	Repo
	Equity

Banks demand reserves to manage liabilities: Deposits, notably liquid deposits

- Narrow banking: Reserves=Deposits
- Fractional reserve banking: Reserves=Fraction*Deposits
- Ample reserve banking: Reserves=f(Deposits, r(FF)-r(Reserves),…): Our focus

Deriving reserve demand from banks' optimization

1. Interest on reserves: IOR
2. Reserves have liquidity benefits: Don't have to sell illiquid assets/cut lending/delay payments if deposits drop
   Reserves also useful for supervision & reg. purposes

$v(Reserves, Deposits)$	Convenience value: Expected savings on transactions costs/other costs
$v'_R(Reserves, Deposits)$	Convenience yield: Marginal value of more reserves Decreasing in reserves, increasing in deposits

3. Bank balance sheet cost φ per dollar of assets (capital requirements)

4. Cost of posting collateral in repo borrowing: *w*(Private repo), w'()>0 (foregone securities lending revenues)

Deriving reserve demand from banks' optimization

Bank profits: π = *IOR*Reserves+r(Securities)*Securities+r(Loans)*Loans*
*-[r(Deposits)*Deposits+r(FF)*FF+r(Repo)*Repo]*
+v(Reserves,Deposits) -φ(Reserves+Securities+Loans)-w(Repo)*

We can define reserve demand relative to any source of funding for holding reserves:

- FOC for borrowing via FF and investing in reserves:

$$\underbrace{r(\mathrm{FF})}_{\substack{\text{Highest interest rate}\\ \text{bank is willing to pay}\\ \text{to borrow to invest in reserves}}} = \underbrace{\mathrm{IOR} + v_R'(Reserves, Deposits) - \varphi}_{\text{Net benefit of reserves}} \qquad (1)$$

- FOC for borrowing via repo and investing in reserves:

$$r(\mathrm{Repo}) = \mathrm{IOR} + v_R'(Reserves, Deposits) - \varphi - w'(\mathrm{Repo}) \qquad (2)$$

- FOC for borrowing via deposits and investing in reserves:

$$r(\mathrm{Deposits}) = \mathrm{IOR} + v_R'(Reserves, Deposits) - \varphi + v_D'(Reserves, Deposits) \qquad (3)$$

Reserve demand under ample reserves: Micro-founding v(Reserves,Deposits)

$v(Reserves, Deposits)$ emerges naturally from basic micro foundations:

- Net deposit outflows are a fraction $\tilde{F}$ of deposits (D), distributed uniform(-k,k)
- Withdrawals met using reserves (R) incur no transactions costs
- Withdrawals x met using bonds (or loans) incur transactions costs TC(x) = δ*x^2
- Bonds sold=min($\tilde{F}$D-R,0). Transactions costs: $\widetilde{TC}$= δ*[min($\tilde{F}$D-R,0)]^2

$$E\left(\widetilde{TC}\right) = \int_{-k}^{k} \delta[\min(F\mathrm{D} - \mathrm{R}, 0)]^2 \, f(F)dF = \int_{\frac{R}{D}}^{k} \delta(F\mathrm{D} - \mathrm{R})^2 \frac{1}{2k} dF = \frac{\delta}{2k}\frac{1}{3D}(k\mathrm{D} - \mathrm{R})^3$$

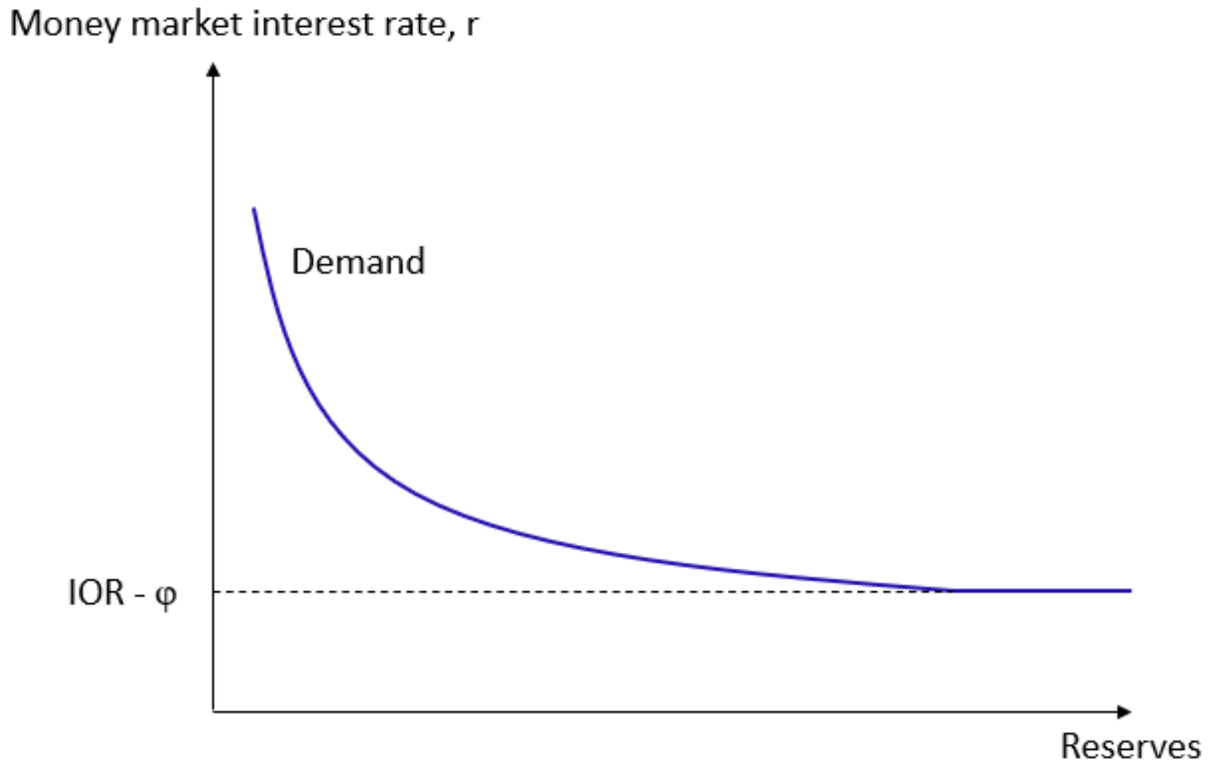
$$v(Reserves, Deposits) = E\left(\widetilde{TC}(Reserves = 0, Deposits\right) - E\left(\widetilde{TC}(Reserves, Deposits\right)$$

$$v'_R(Reserves, Deposits) = -\frac{\partial E(\widetilde{TC})}{\partial R} > 0$$

$v'_R(Reserves, Deposits)$ is decreasing in reserves and increasing in deposits for R<kD.

Reserve demand under ample reserves: A graphical framework

$$r(\mathrm{FF}) = \mathrm{IOR} + v_R'(ExcessReserves, Deposits) - \varphi$$



- Demand for reserves depends on:
  - Interest on reserves (IOR)
  - Liquidity benefits of reserves
  - Banks' balance sheet costs
- Demand for reserves:
  - Slope comes from $v_R'(.)$
  - Shifts up with IOR, down with φ
  - Asymptotes to IOR-φ if $v_R'(.) \rightarrow 0$

RESERVE SUPPLY

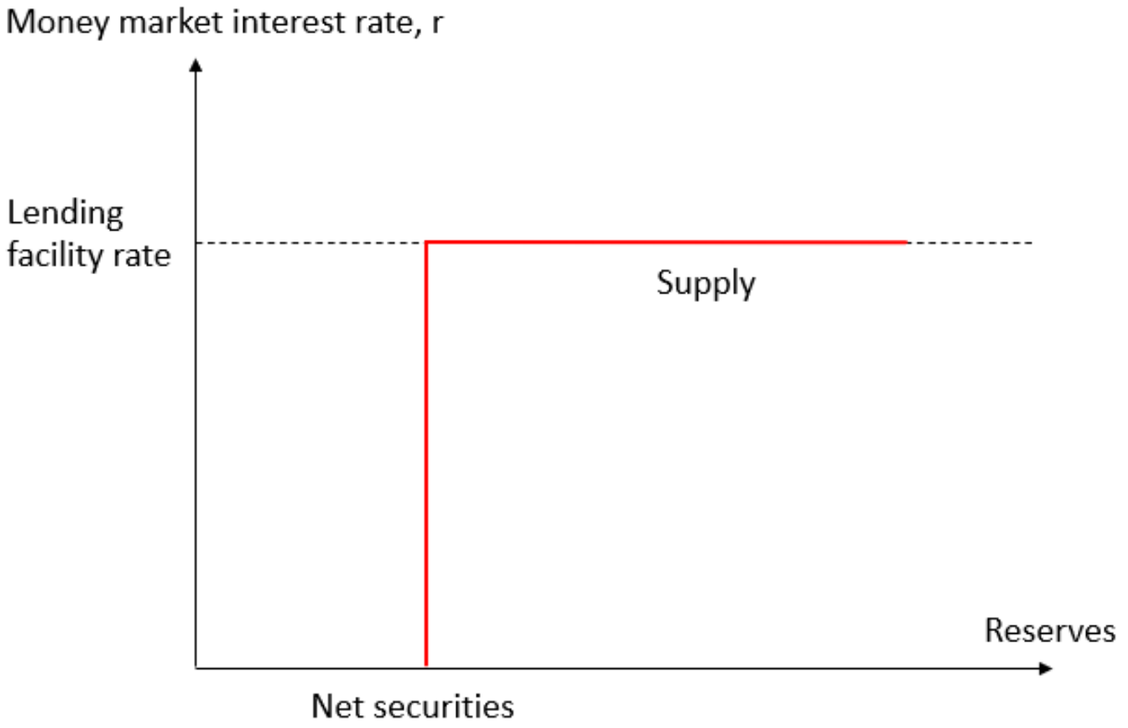
Reserve supply

Fed Assets	*Fed Liabilities*
Securities	Currency, govt. deposits: Autonomous factors
Loans to banks	Reserves
	ONRRP (non-bank facility)

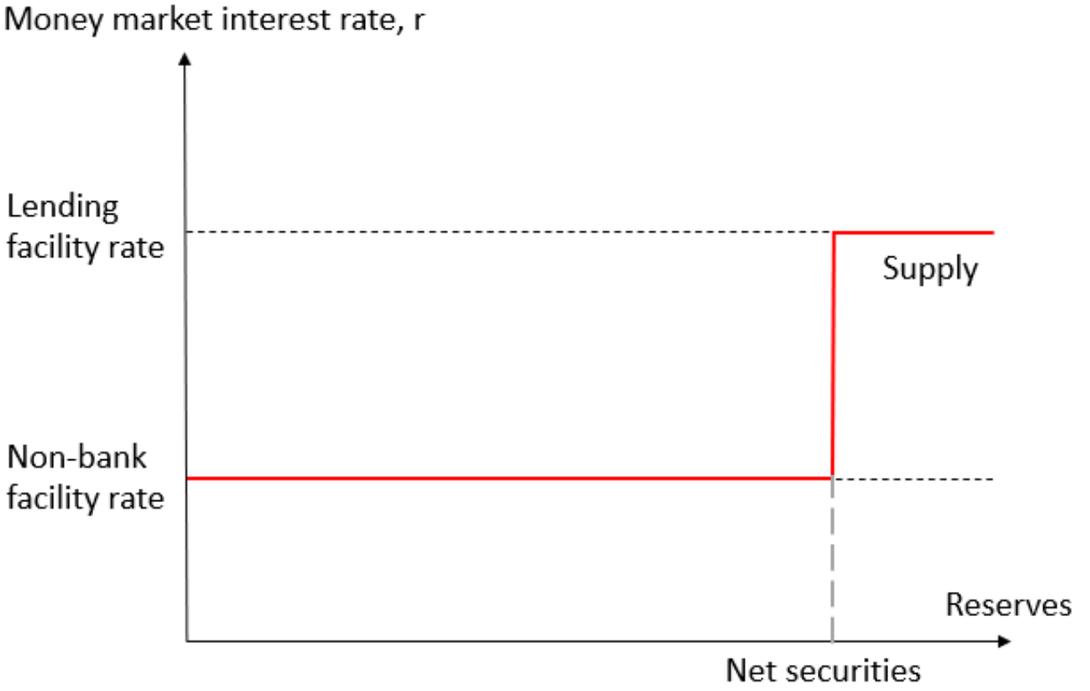
$$\text{Reserves} = \underbrace{[\text{Securities} - \text{Autonomous factors}]}_{Net\ securities} + \underbrace{\text{Loans to banks}}_{\substack{Reserves\ borrowed \\ from\ the\ central\ bank \\ by\ banks}} - \underbrace{\text{ONRRP}}_{\substack{Reserves\ lent \\ to\ the\ central\ bank \\ by\ non-banks}}$$

Reserve supply

Case A. With lending facility for banks but no investment facility for non-banks

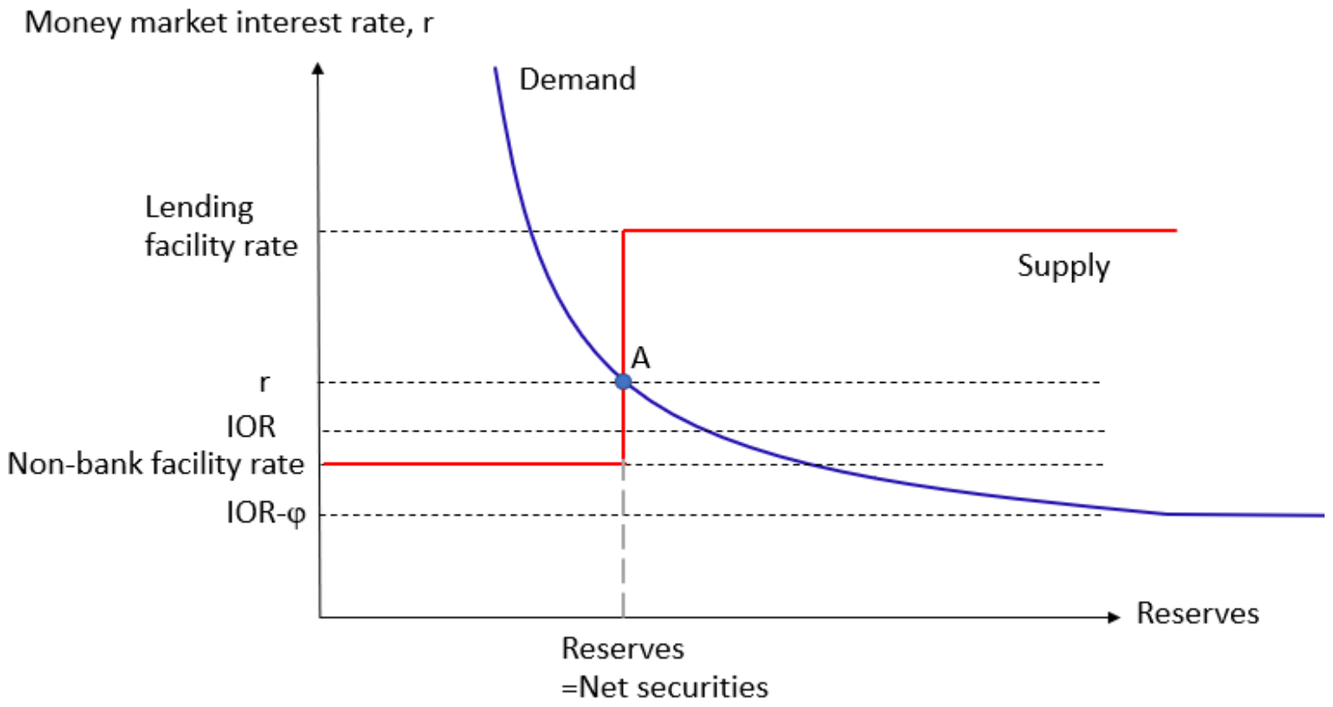


Case B. With investment facility for non-banks



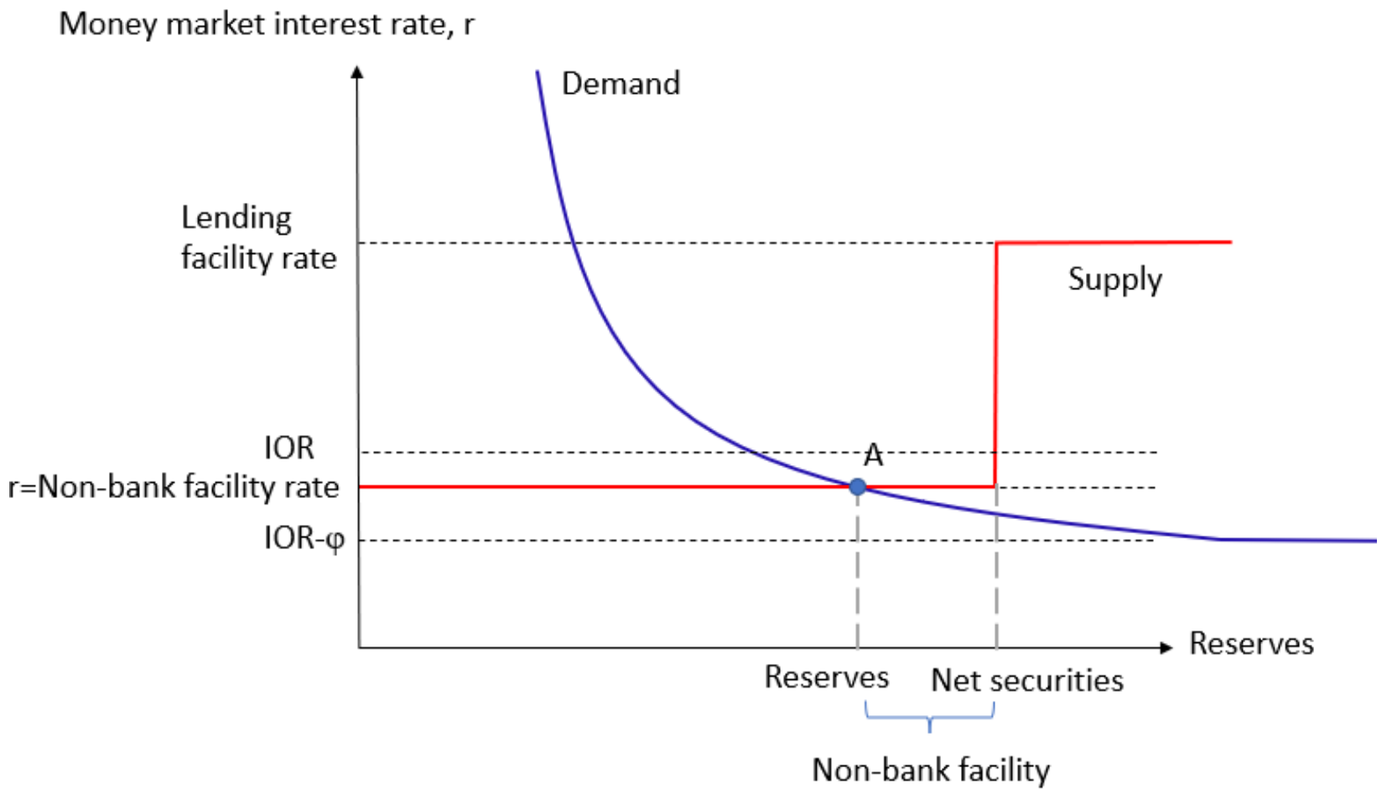
EQUILIBRIUM

Equilibrium 1: Demand crosses supply on the vertical part → Neither facility is used



$$\text{Reserves} = \underbrace{[\text{Securities} - \text{Autonomous factors}]}_{Net\ securities}$$

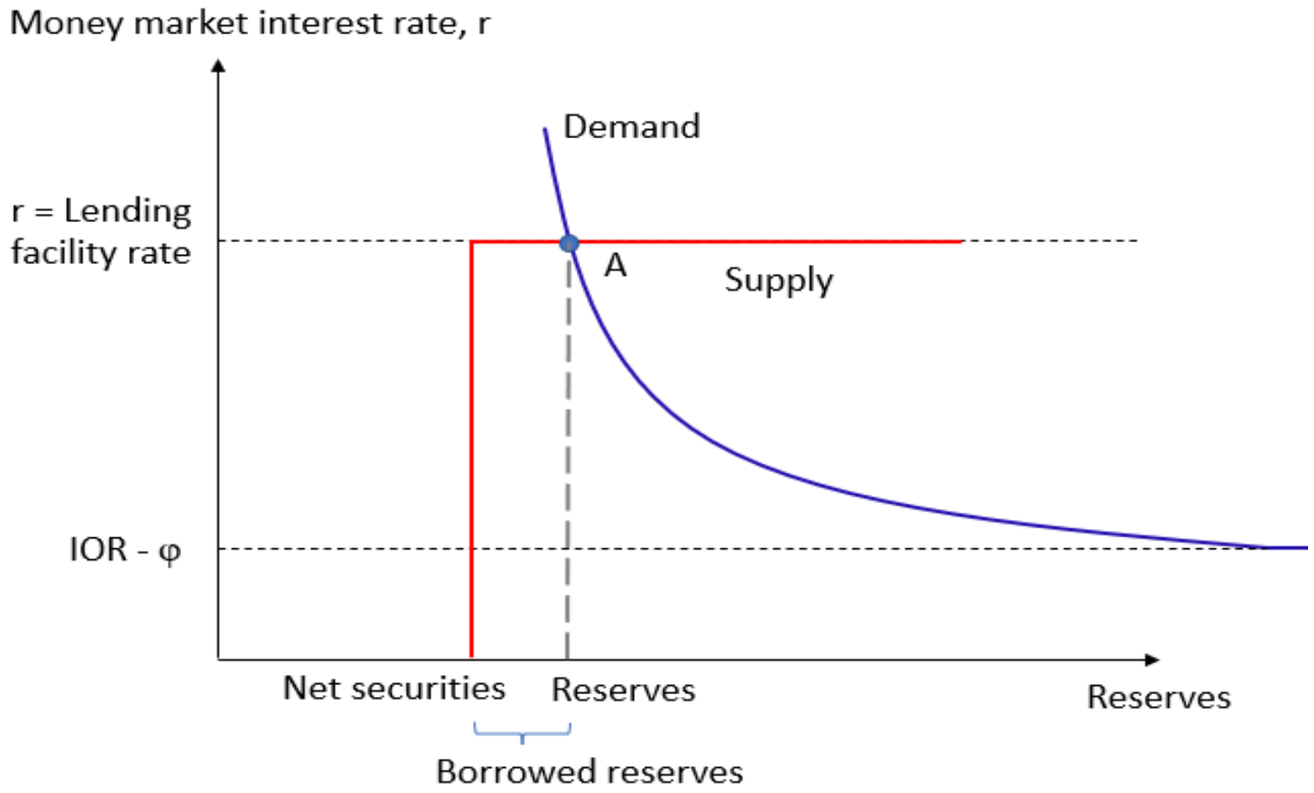
Equilibrium 2: Demand crosses supply on the bottom flat part → ONRRP facility is used



- Reserve demand evaluated at ONRRP rate < Net securities
- Low demand /high net securities supply /high non-bank facility rate

$$\text{Reserves} = \underbrace{[\text{Securities} - \text{Autonomous factors}]}_{\textit{Net securities}} - \underbrace{\text{ONRRP}}_{\textit{Reserves lent to the central bank by non-banks}}$$

Equilibrium 3: Demand crosses supply on the top flat part → Lending facility is used



- Reserve demand evaluated at lending facility rate > Net securities
- High demand /low net securities supply /low lending facility rate

$$\text{Reserves} = \underbrace{[\text{Securities} - \text{Autonomous factors}]}_{\textit{Net securities}} + \underbrace{\text{Loans to banks}}_{\substack{\textit{Reserves borrowed} \\ \textit{from the central bank} \\ \textit{by banks}}}$$

Equilibrium: Takeaways about interest rate control

Central bank controls short market interest rates via:

- Choice of net securities
- Administered rates
  - IOR
  - Rate on the lending facility (discount window)
  - Rate on the investment facility for non-banks (ONRRP facility)
- Private-sector use of the facilities changes the equilibrium supply of reserves which keeps the market-clearing interest rate between rates in discount window and ONRRP facility

RESERVE DEMAND ESTIMATION (2009M1-2022M10)

Estimating reserve demand: Functional form

- Log functional form:

$$v_R'(\text{Reserves}, \text{Deposits}) = \text{d} + \text{b} * \ln(\text{Reserves}) + \text{c} * \ln(\text{Deposits})$$

where we expect b<0 and c>0 (should be *excess* reserves – will be updated in next draft)

- Allowing for reserve demand shock, u:

$$r(\text{FF}) - \text{IOR} = v_R'(\text{Reserves}, \text{Deposits}) - \varphi + u$$
$$= \text{a} + \text{b} * \ln(\text{Reserves}) + \text{c} * \ln(\text{Deposits}) + \text{u}$$

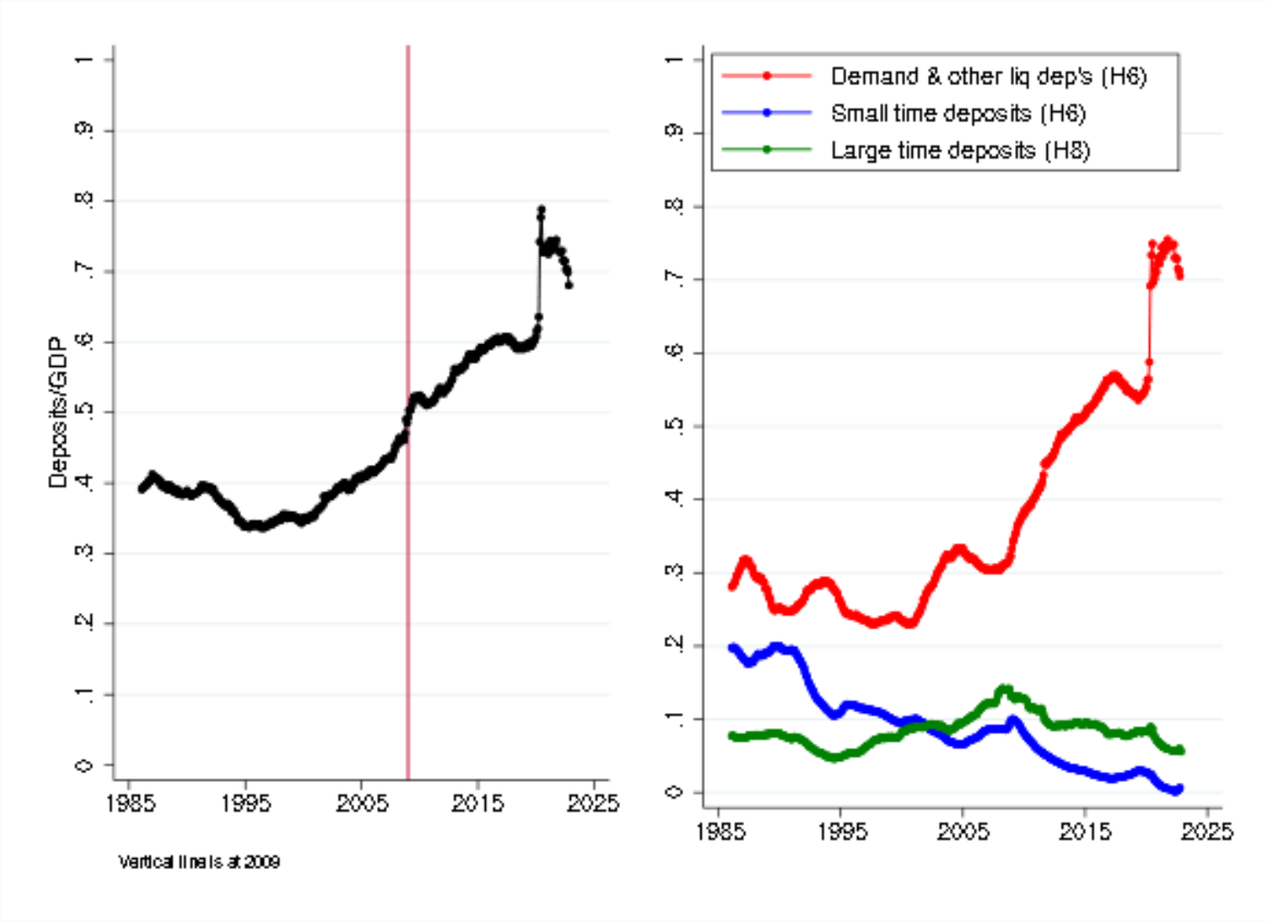
where $a = d - \varphi$

→ $\text{Reserves} = \alpha\, \text{Deposits}^{\beta} e^{\gamma(\text{r(FF)}-\text{IOR})} \varepsilon$ Semi-log

$\alpha = e^{-a/b}$, $\beta = -c/b$, $\gamma = 1/b$, and $\varepsilon = e^{-u/b}$

Estimating reserve demand: Deposit growth

Deposits grew a lot over the 2009-2022 period, even relative to GDP (data to 2022M10)

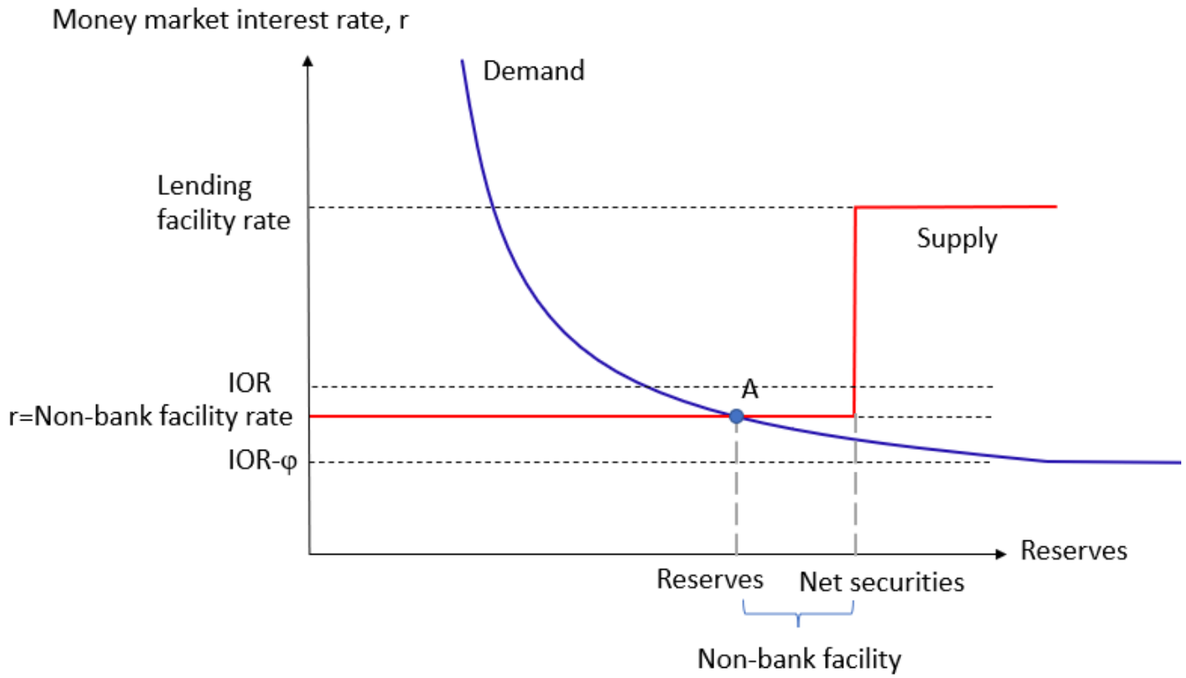


Estimating reserve demand: Identification

$$r(FF) - IOR = a + b * \ln(Reserves) + c * \ln(Deposits) + u$$

- Reserves are endogenous when ONRRP>0
  - Instrument with Reserves+ONRRP
  - Reserves+ONRRP=Net Securities (when loans to banks are small)
  - Net securities likely uncorrelated with u during post-GFC period

- Instrumenting for deposits has little effect
  - Will show robustness to instrumenting
  - Controlling for deposits crucial to get stable reserve demand function
  - Similar results with liquid deposits



Estimating reserve demand: Main estimation results

Table 2. Reserve demand estimation, instrumenting for reserves

Monthly data, 2009M1-2022M10. IV estimation. t-statistics are robust to autocorrelation up to order 12.

Panel A. Second stage

	Dept. var.: EFFR-IOR
ln(Reserves)	-0.200***
	(t=-10.44)
ln(Deposits)	0.358***
	(11.86)
Constant	-1.900***
	(-10.64)
N (months)	166

Panel B. First stage for ln(Reserves)

	Dept. var.: ln(Reserves)
ln(Reserves+ONRRP)	0.860***
	(t=14.07)
ln(Deposits)	-0.049
	(-0.47)
Constant	1.467
	(1.64)
N (months)	166
R^2	0.960

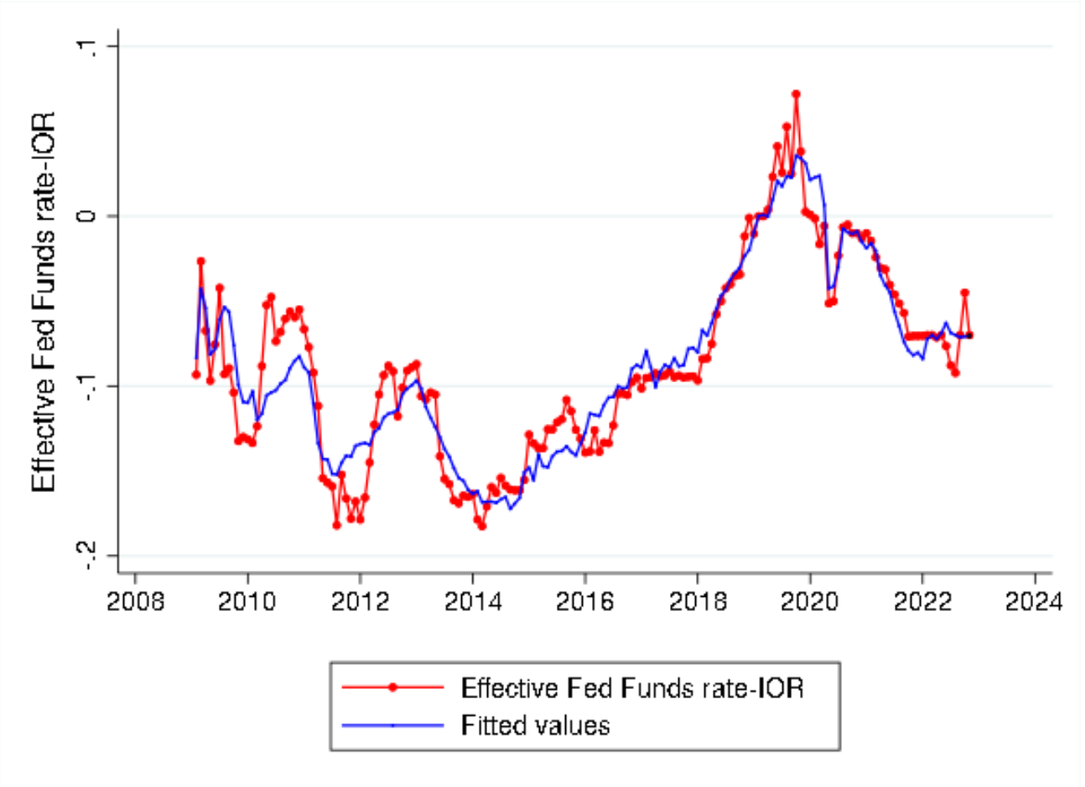
- EFFR-IOR ↓ by 10 bps → Reserve demand ↑ by 50% -- very elastic, but not flat
- 1% increase in deposits → >1% increase in reserve demand (less so if using liquid deposits)

Estimating reserve demand: Fitted values

Reduced form of IV: $\mathrm{r(FF)} - \mathrm{IOR} = A + \mathrm{B} * ln(Reserves + ONRRP) + C * ln(Deposits) + U$

Panel C. Reduced form

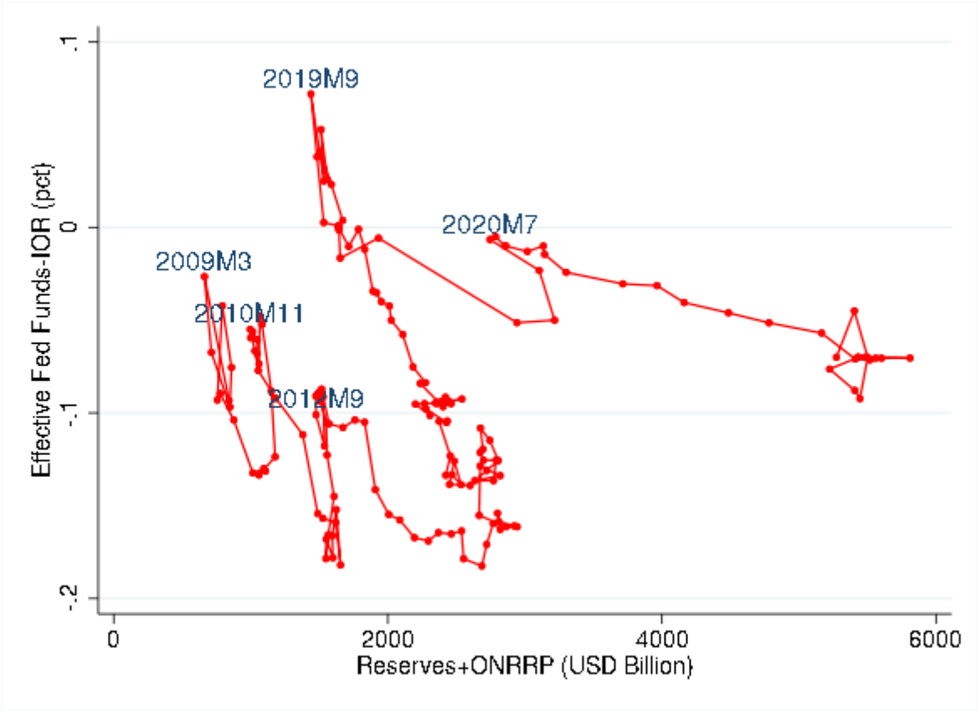
	Dependent variable: (EFFR-IOR)
ln(Reserves+ONRRP)	-0.172***
	(t=-18.78)
ln(Deposits)	0.367***
	(23.81)
Constant	-2.193***
	(-21.12)
N (months)	166
R2	0.895

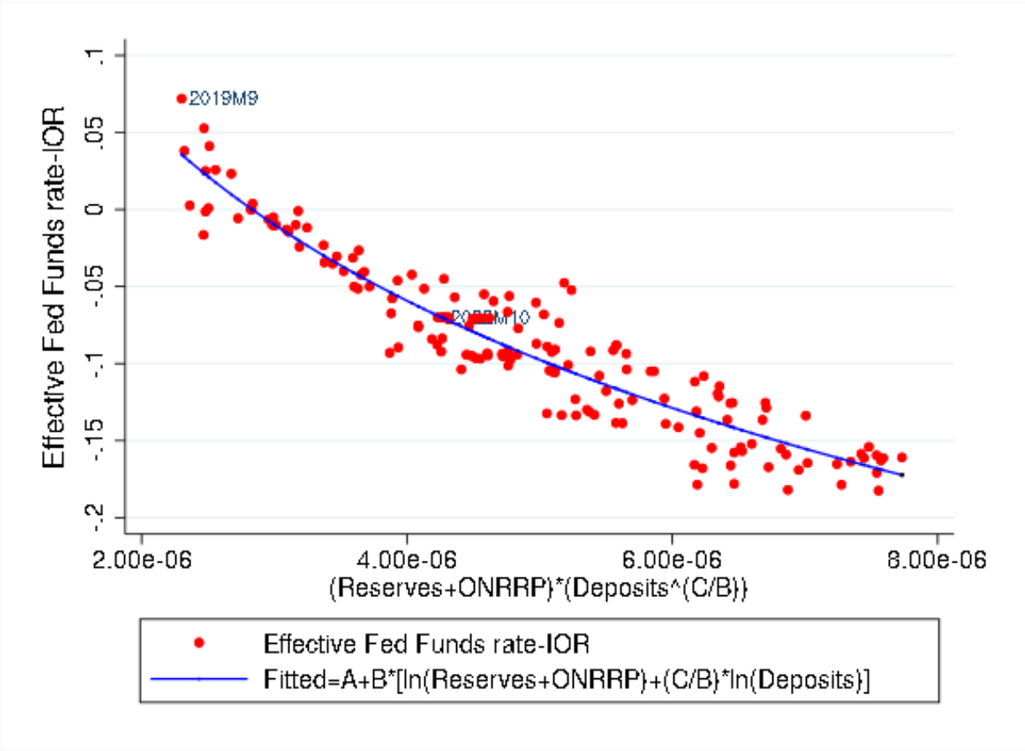


Estimation results: Fitted values

Reduced form of IV: $\mathrm{r(FF)} - \mathrm{IOR} = A + \mathrm{B} * ln(Reserves + ONRRP) + C * ln(Deposits) + U$

$$= A + \mathrm{B} * ln\underbrace{\left[(Reserves + ONRRP) * (Deposits)^{\frac{C}{\mathrm{B}}}\right]}_{Deposit-adjusted\ Reserves+ONRRP\ supply} + U$$

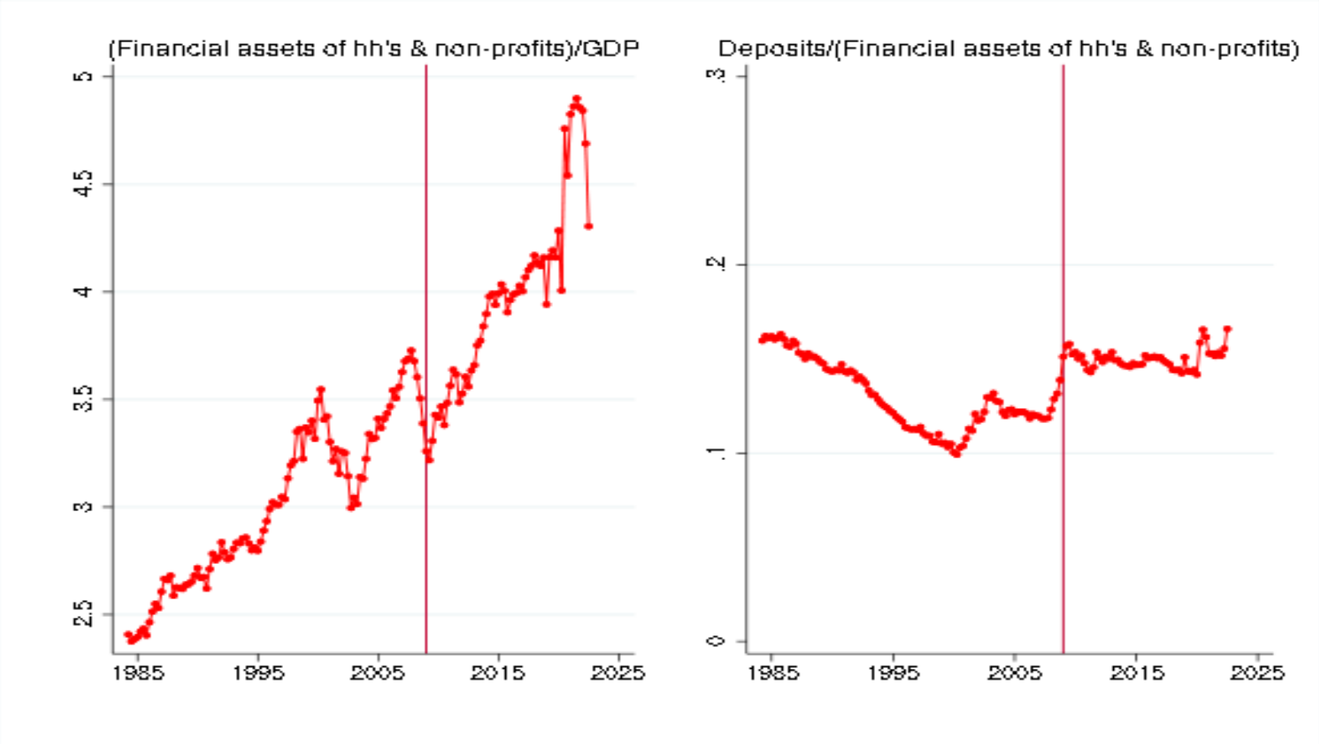




Why did deposits grow? Increased deposit demand

Deposits likely went up mainly due to higher financial assets

- Deposits are one of many financial assets
- Over 2009Q1-2022Q2 period: Fairly stable portfolio weight for deposits



- Instrument deposits with financial assets and the level of IOR (deposits spread, r(Deposits)-IOR, falls with IOR)

Instrumenting for deposits (and still instrumenting for reserves)

Table 3. Reserve demand estimation, instrumenting for both reserves and deposits

Quarterly data (last month of the quarter), 2009Q1-2022Q2. t-statistics are robust to autocorrelation up to order 4. *** indicates statistical significance at the 1% level.

Panel A. Second stage

	Dependent variable: (EFFR-IOR)
ln(Reserves)	-0.207***
	(t=-11.53)
ln(Deposits)	0.377***
	(12.92)
Constant	-2.025***
	(-11.62)
N (quarters)	54
Sargan test of over-identifying restrictions	p=0.29 (not rejected)

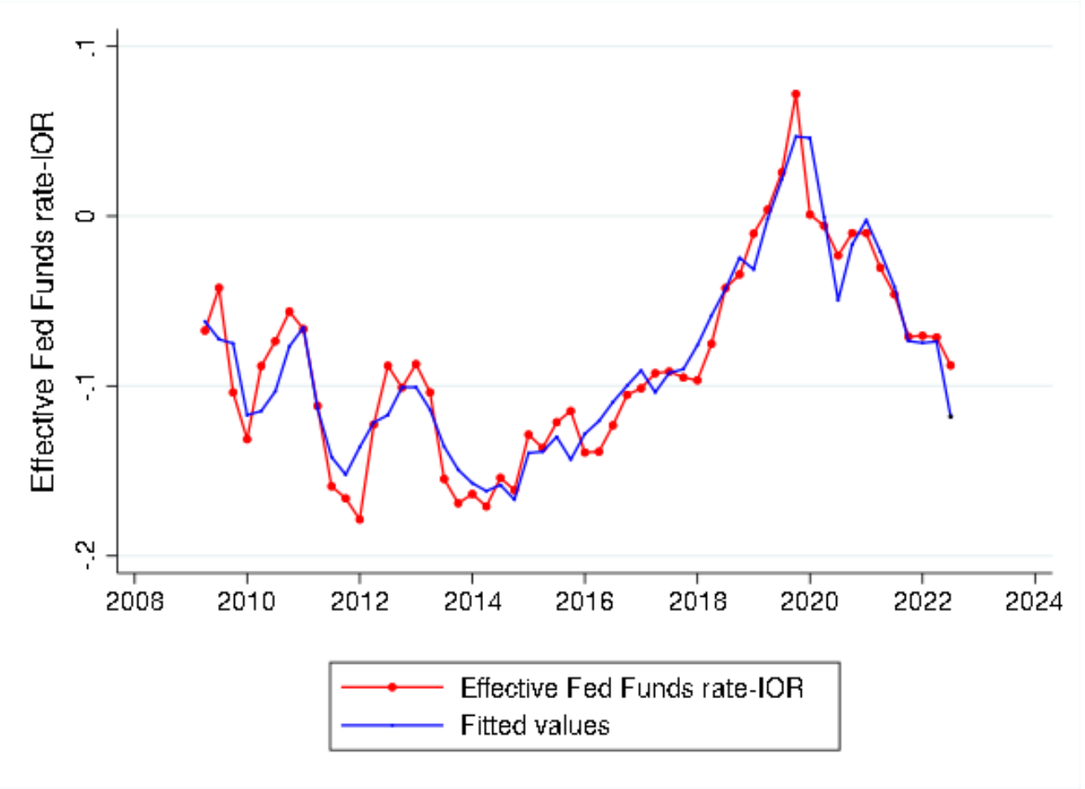
Panel B. First stages for ln(Res.), ln(Deposits)

	Dep.var: ln(Reserves)	Dep.var: ln(Deposits)
ln(Reserves+ONRRP)	0.845***	-0.029
	(t=8.53)	(t=-0.85)
ln(Financial assets)	0.035	1.091***
	(0.24)	(20.65)
IOR	-0.010	-0.035***
	(-0.31)	(-2.62)
Constant	0.746	-2.671***
	(0.66)	(-7.43)
N (quarters)	54	54
R^2	0.971	0.987

Instrumenting for deposits (and still instrumenting for reserves)

Panel C. Reduced form

	Dependent. variable: (EFFR-IOR)
ln(Reserves+ONRRP)	-0.198***
	(t=-17.57)
ln(Financial assets)	0.430***
	(21.87)
IOR	-0.020***
	(-4.88)
Constant	-3.378***
	(-23.02)
N (quarters)	54
R^2	0.905



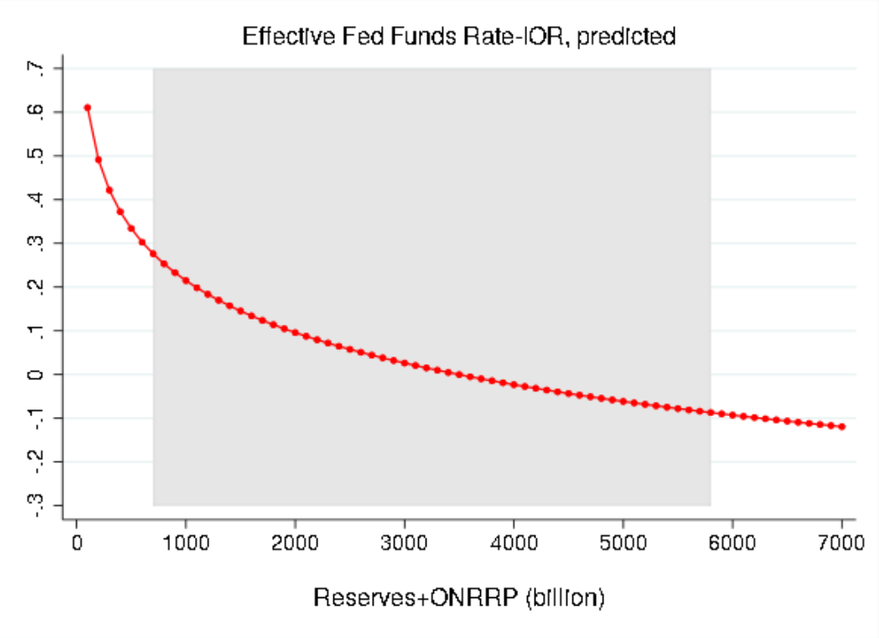
IMPLICATIONS OF ESTIMATED RESERVE DEMAND FOR POLICY

Iso-fed funds curves: $(IOR, Reserves + ONRRP)$ combinations that achieve same target

How to set the IOR to hit the target, given balance sheet size

Given deposits of $17.753T as of 2022M10:

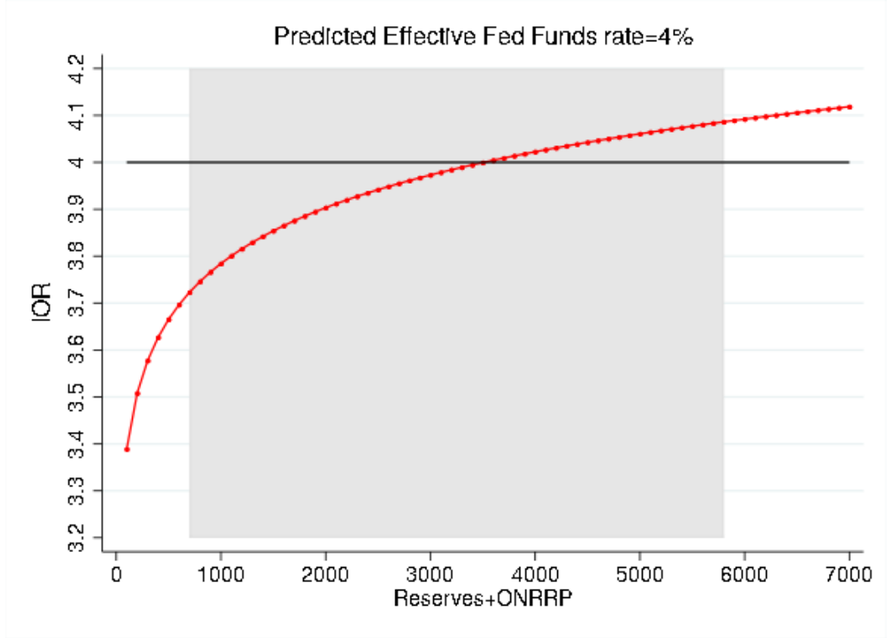
$$r(\mathrm{FF}) - \mathrm{IOR} = \hat{\mathrm{A}} + \hat{\mathrm{B}} * ln(Res. + ONRRP) + \hat{\mathrm{C}} * ln(Deposits)$$



Gray shading: Observed x-range in sample (from $662B to $5,811B)

Iso-fed funds curve (ex. for a 4% target):

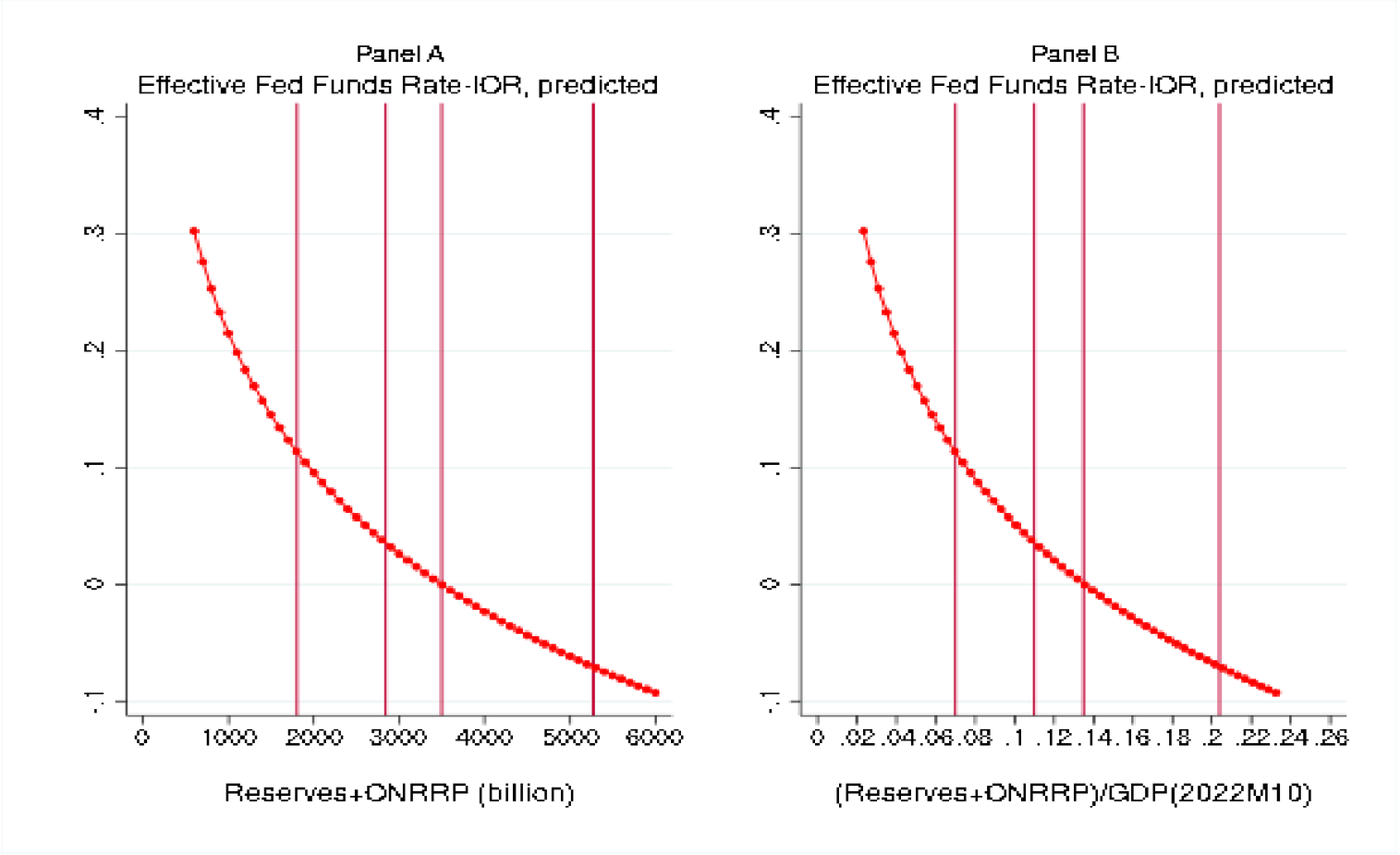
$$IOR = 4\% - [\hat{\mathrm{A}} + \hat{\mathrm{B}} * ln(Res, + ONRRP) + \hat{\mathrm{C}} * ln(Deposits)]$$



- Bianchi and Bigio (ECMA, 2022): Theory, introduced idea of iso-fed funds curves

How much can Reserves+ONRRP be reduced before rates get volatile?

$$r(\mathrm{FF}) - \mathrm{IOR} = \hat{\mathrm{A}} + \hat{\mathrm{B}} * ln(Reserves + ONRRP) + \hat{\mathrm{C}} * ln(Deposits)$$ for deposits=$17.753T as of 2022M10



Reserves+ONRRP are at $5.27T (20.4% of GDP) as of 2022M10 ($4.39T as of Nov 2023)

1. *$1.81T, 7% of GDP:* Tighter than Sep 2019
2. *$2.84T, 11.0% of GDP:* Pred. spread as Sep 2019
3. *$3.50T, 13.5% of GDP:* Pred. spread=0, may be enough to avoid daily spikes

Estimates will evolve with deposits

How much can balance sheet be reduced before rates get volatile?

1. Standing Repo Facility: May help reduce the risk of yield spike for a given reserves+ONRRP
   - Introduced in July 2021
   - Allows dealers and depository institutions to borrow funds from Fed via repo borrowing

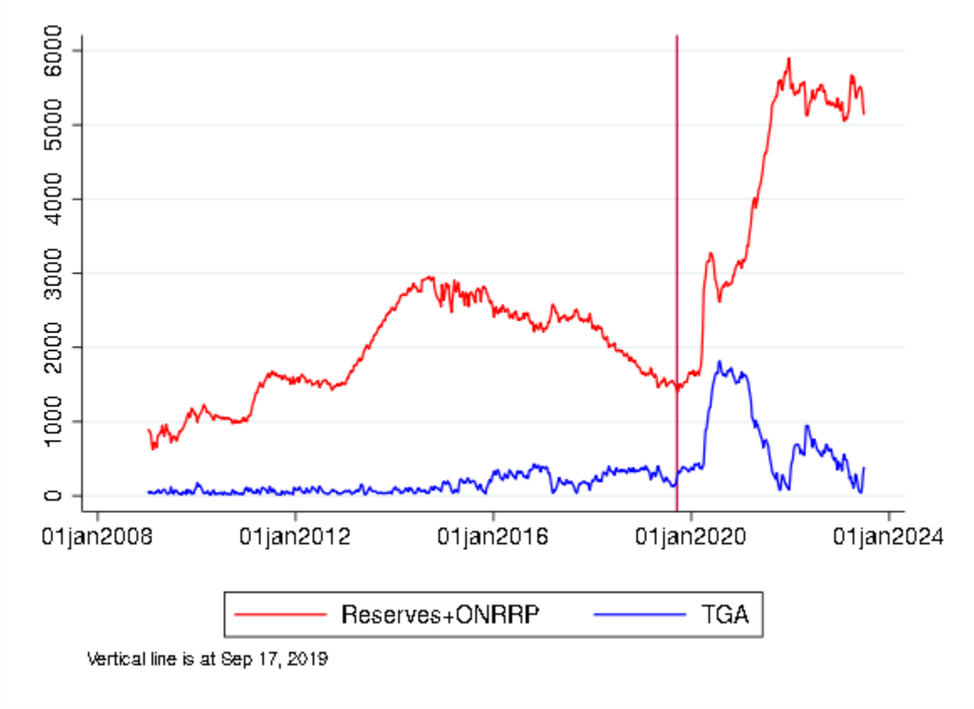
2. Autonomous Factors Volatility

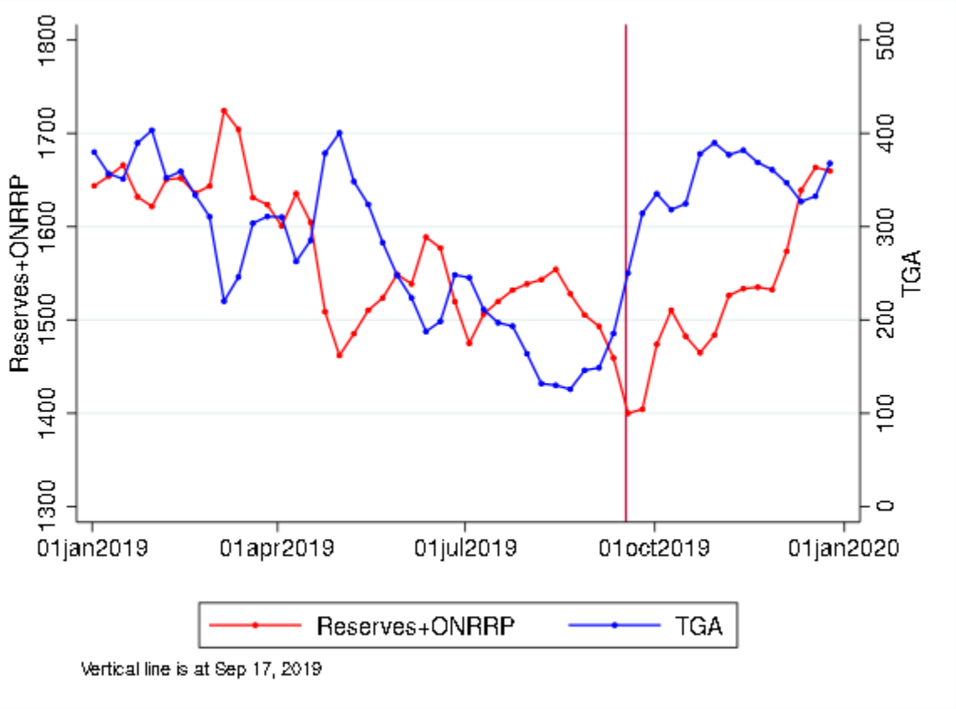
Fed Assets	*Fed Liabilities*
Securities	Currency, government deposits: Autonomous factors
Loans to banks	Reserves
	ONRRP (non-bank facility)

- Reserves+ONRRP=Fed Assets-Autonomous factors
- Autonomous factors are volatile
  - To keep Reserves+ONRRP at “target” value: Change assets with autonomous factors
  - Or, allow for buffer, so fluctuation in AFs don’t push Reserves+ONRRP below “target”

How much can balance sheet be reduced before rates get volatile?

$B





- Sept 2019 was mainly due to low reserve supply given size of banking sector, but: Increase in TGA was final straw that set off yield spike in September 2019 (Treasury issuance, tax payment)