Reserve Demand and Quantitative Tightening

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

Outline

- Conventional and unconventional monetary policy – where does reserve demand fit in
- A graphical framework: Reserve demand and supply
- Deriving reserve demand from banks' optimization
- Estimate reserve demand
- Implications for quantitative tightening

BIG PICTURE

Federal Reserve balance sheet

Table 1. Federal Reserve balance sheet, October 26, 2022

H.4 release, $B

Assets		Liabilities	
Treasuries	5,609	Reserves	3,108
MBS	2,679	Overnight reverse repurchase agreements	2,187
Other	485	Currency	2,285
		Treasury general account	557
		Other	636
	8,773		8,773

The Federal Reserve funds itself with:

1) "Autonomous factors": Currency, TGA, other

These are not chosen by the Fed (i.e., demand for them is accommodated by the Fed)

2) Reserves+ONRRP=Total assets-Autonomous factors

Conventional versus unconventional monetary policy: The role of reserves

Pre-financial crisis: Conventional monetary policy

Tool for controlling short interest rate: Supply of reserves

- Reserves didn't earn interest
  → Very costly for banks to hold them: Foregoing earning interest on alternative short-term investments
- Supply of reserves was small (billions, not trillions)
  → Banks were still on the steep part of their reserve demand curve
  → Fed could change short-term rates (effective federal funds rate) with small changes in reserve supply (via open market operations, buying/selling bonds, paying with/getting reserves)

Financial crisis: Zero/effective lower bound → Unconventional monetary policy

Main tools to control longer interest rates: Forward guidance, quantitative easing (QE)

- Reserve supply expanded massively
- Central banks started paying interest on reserves

Conventional versus unconventional monetary policy: The role of reserves

Post-financial crisis: Policy "normalization"

- Short-rate liftoff from zero-lower bound (more shortly about how to control short rates with ample reserves)
- Quantitative tightening (QT): Runoffs, sales

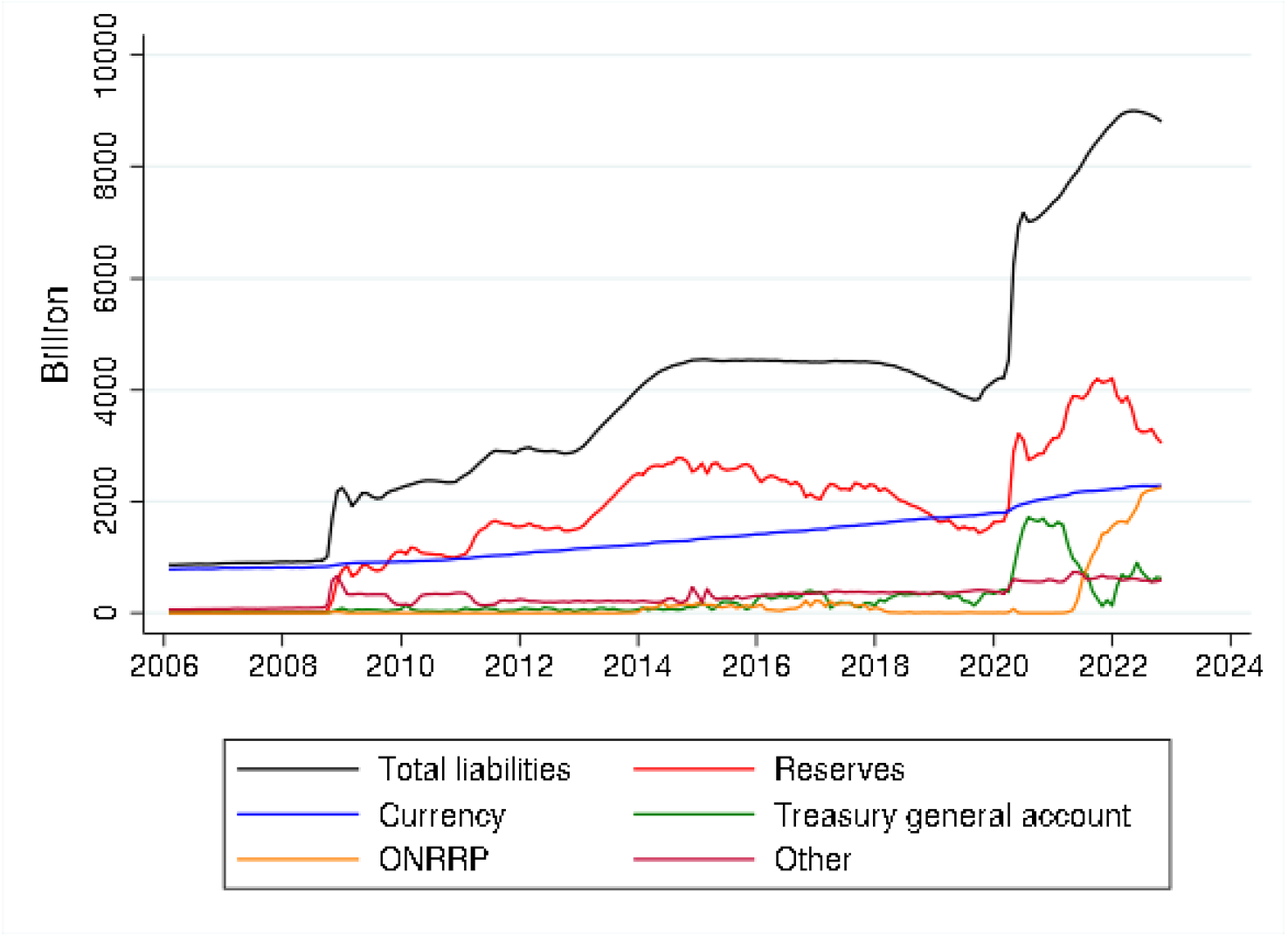
COVID: QE for both financial stability and monetary policy purposes

Post-COVID: Policy "normalization"

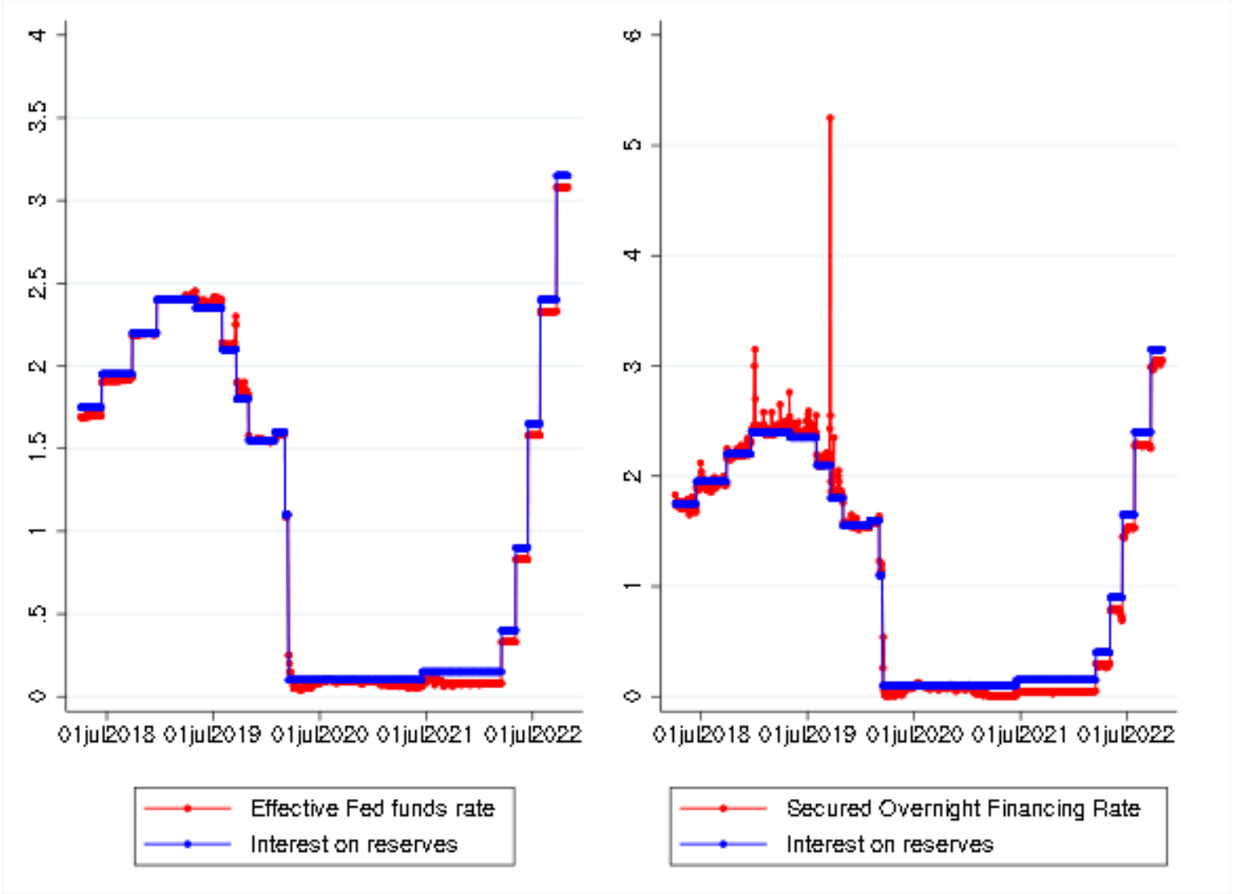
Focus of this paper: Limits to QT

- If reserve supply becomes "too low" relative to reserve demand, there's not enough liquidity in the banking system
  - → Financial instability: Borrowing costs can suddenly spike
  - → Reserve demand affects how much QT is possible

Federal Reserve liabilities, 2006M1-2022M10



Too few reserves → Yield spikes, September 2019 (daily data)



- Sept 17, 2019: Too few reserves in the sense that banks were willing to hold them at a lower rate (IOR) than they could get by lending in the Fed funds market (EFFR)

- 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 Fed reversing quantitative easing

Ample reserves regime

Role of reserve demand for QT has been laid out in public communication:

- *"The Committee currently **anticipates reducing the quantity of reserve balances**, over time, to a level appreciably below that seen in recent years but larger than before the financial crisis; **the level will reflect the banking system's demand for reserve balances** and the Committee's decisions about how to implement monetary policy **most efficiently and effectively** in the future."* [2017 Addendum to Policy Normalization Principles and Plans]

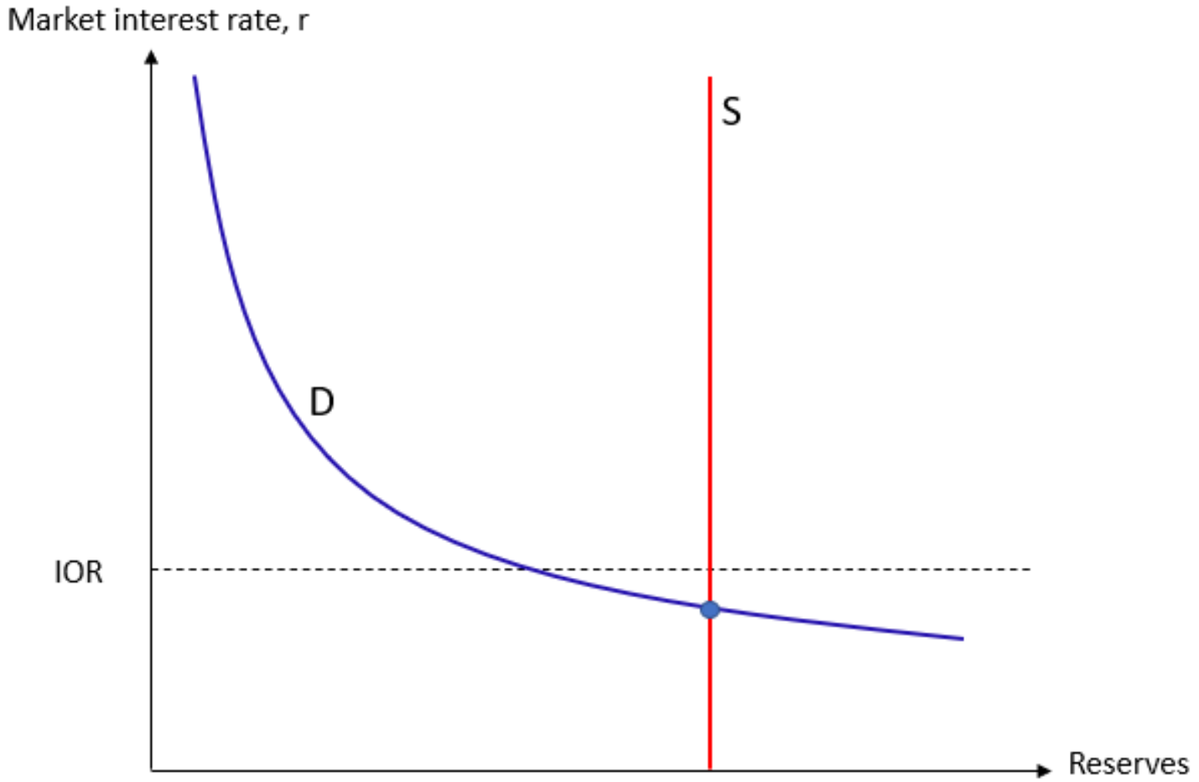
- *"Over time, the Committee intends to maintain securities holdings in amounts needed to implement monetary **policy efficiently and effectively** in its **ample reserves regime**."* [2022 Principles for Reducing the Size of the Federal Reserve's Balance Sheet]

But what is the demand for reserves? How much QT is possible?

A GRAPHICAL FRAMEWORK

Reserve demand under ample reserves: A graphical framework

We can think of reserve demand as money demand for banks



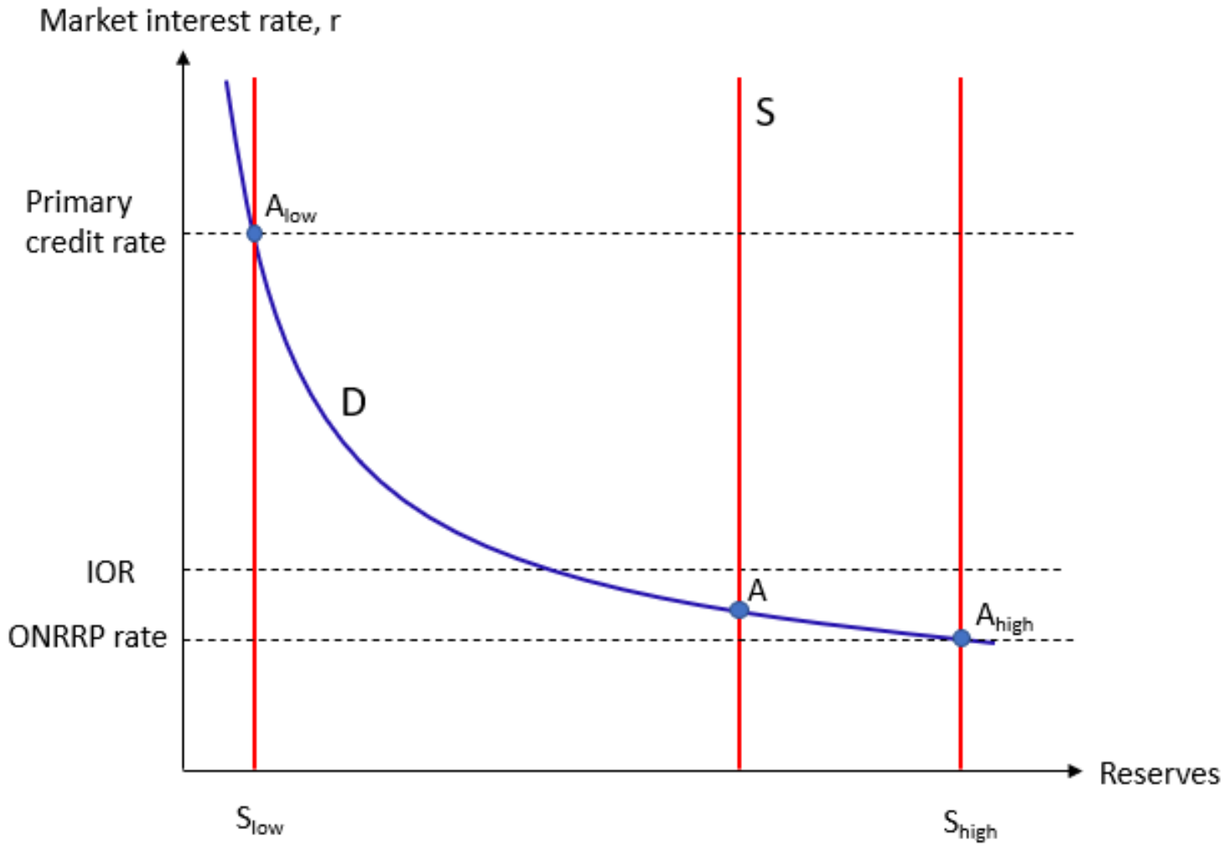
- Demand for currency depends on:
  - Interest rate on money (zero) relative to r
  - GDP → Liquidity benefits of money

- Demand for reserves depends on:
  - Interest on reserves (IOR) relative to r
    Higher IOR shifts demand up
  - Size of the banking sector:
    Deposits → Liquidity benefits of reserves
  - Banks' "balance sheet costs" (capital req's)

  Market equilibrium can involve r<IOR:
  - banks can earn IOR but others cannot (e.g., GSEs, MMFs), and
  - banks have balance sheet costs

Reserve demand under ample reserves: A graphical framework

The Federal Reserve controls equilibrium r via IOR and S as well as rates on discount window and ONRRP facility



Private sector take-up decisions at Fed facilities affect reserve supply which keeps r in the corridor

If r<ONRRP rate:

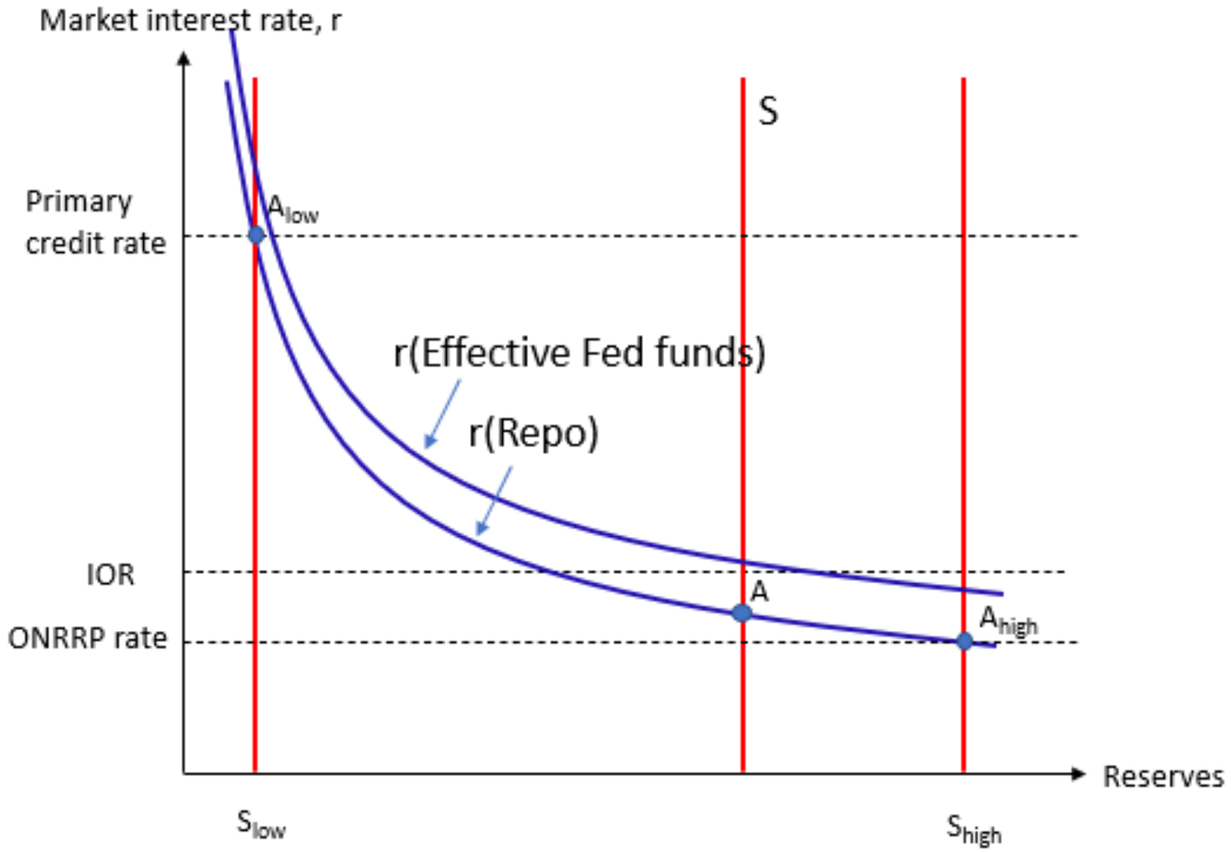
- Investments (by GSEs, MMFs) at ONRRP (for given balance sheet and autonomous factors) decreases reserves, keeping reserves ≤ S_{high}

If r>primary credit rate:

- Bank borrowing at the discount window increases reserves, keeping reserves ≥ S_{low}

Reserve demand under ample reserves: A graphical framework

In practice, there are many market rates

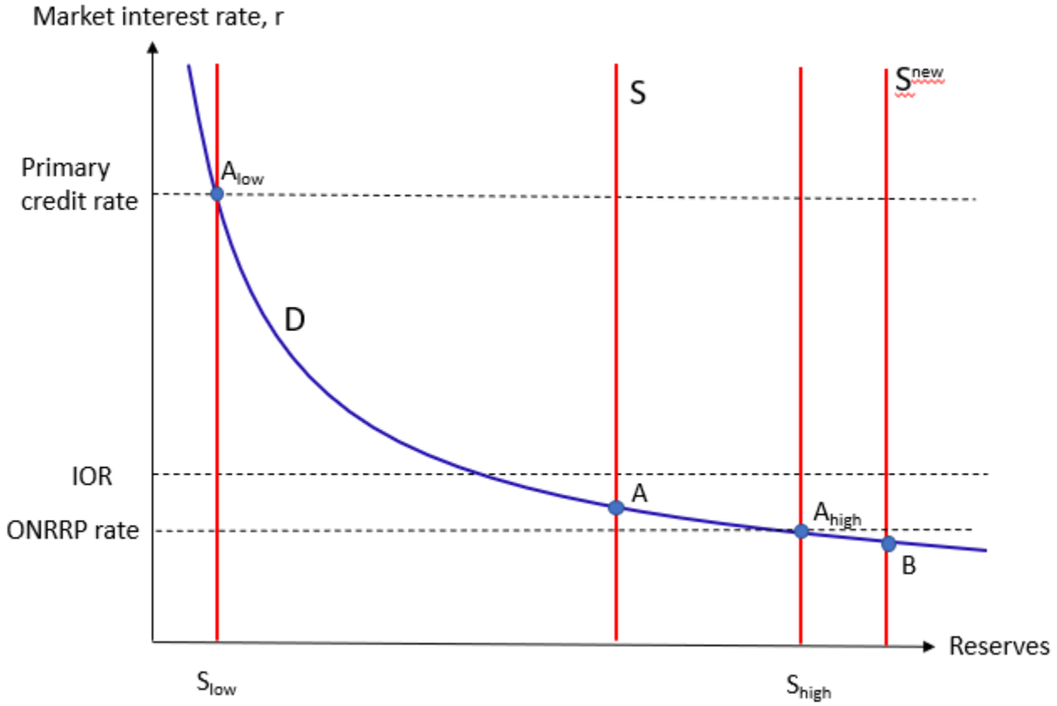


- Each instrument's r(market)-r(IOR) reflects the benefits of reserves and thus slopes down
- Fed particularly interested in effective Fed funds rate (targeted) and repo rates (ONRRP puts floor under repo rate)

When is ONRRP take-up positive? If r<ONRRP rate otherwise

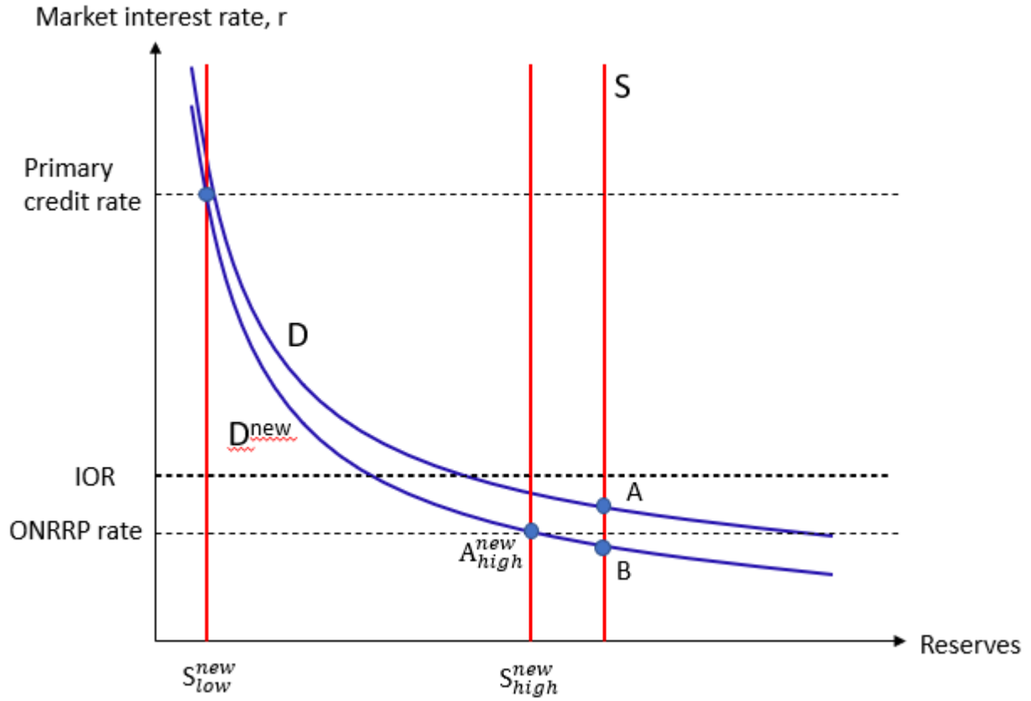
Increase in supply (e.g., due to a reduction in TGA)

- Absent ONRRP facility: Shift from A to B
- With ONRRP facility: Shift to A_{high}
- ONRRP take-up crowds out reserves to S_{high}



Decrease in reserve demand (e.g., due to lower deposits/higher balance sheet costs)

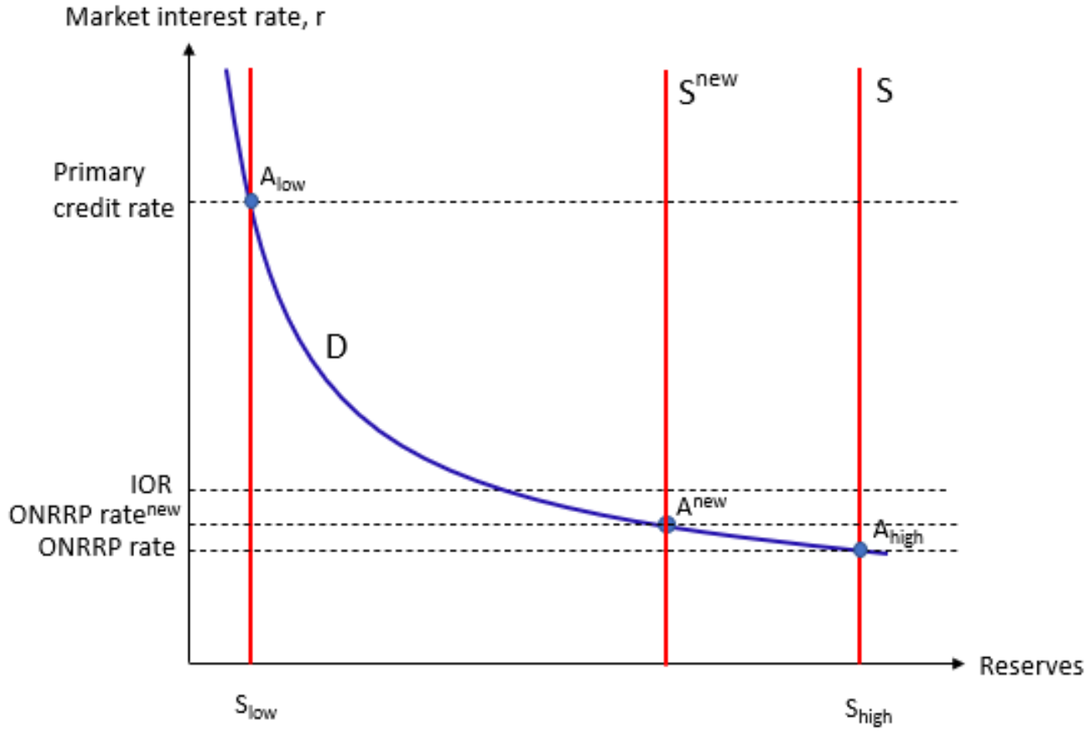
- Absent ONRRP facility: Shift from A to B
- With ONRRP facility: Shift to A_{high}^{new}
- ONRRP take-up crowds out reserves to S_{high}^{new}



When is ONRRP take-up positive? If r<ONRRP rate otherwise

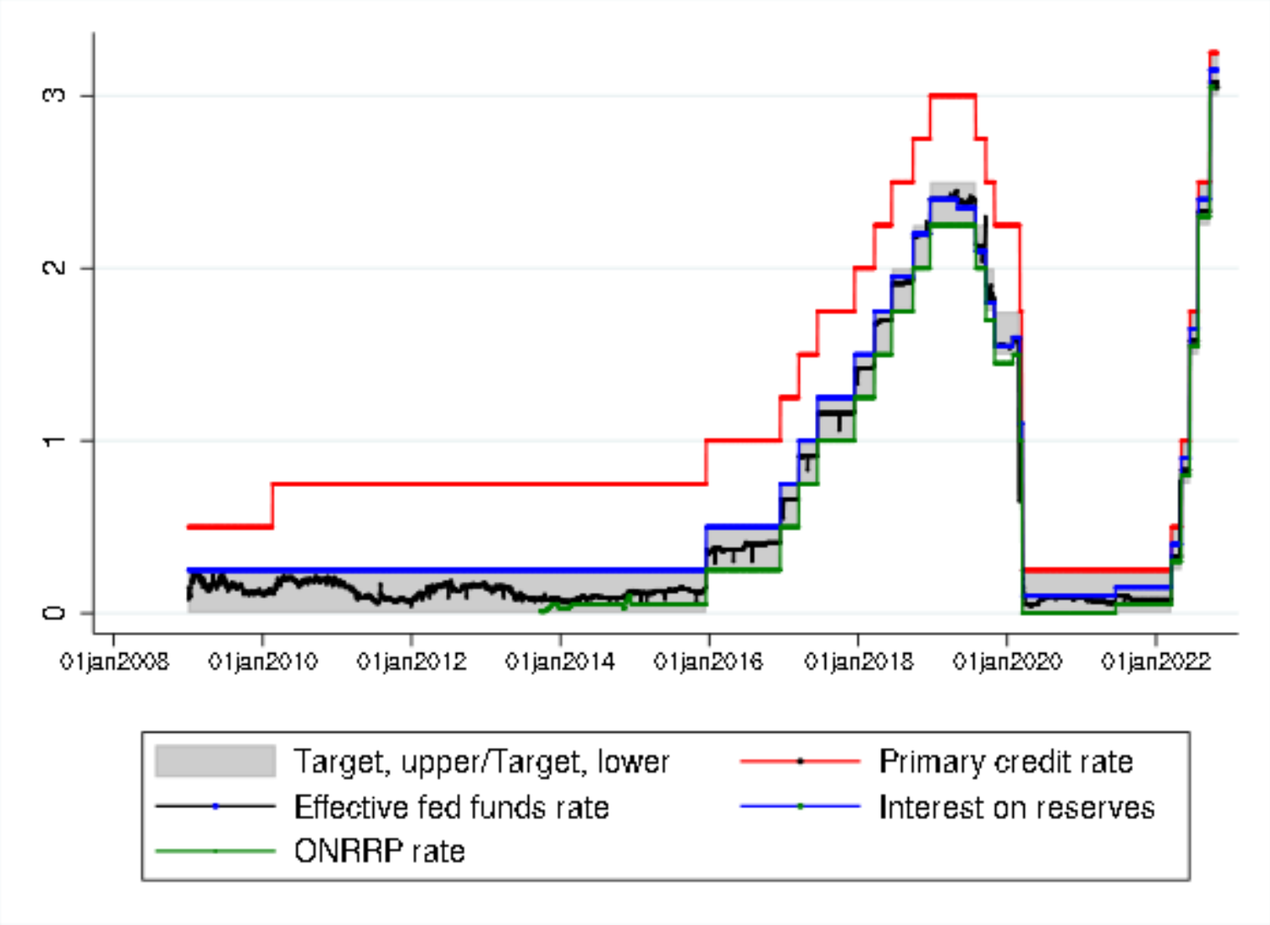
Increase in ONRRP rate for given IOR

- Suppose equilibrium is initially at A_{high}
- ONRRP rate is increased, IOR is unchanged
- ONRRP take-up crowds out reserves from S_{high} to S^{new}
- Equilibrium moves to A^{new}



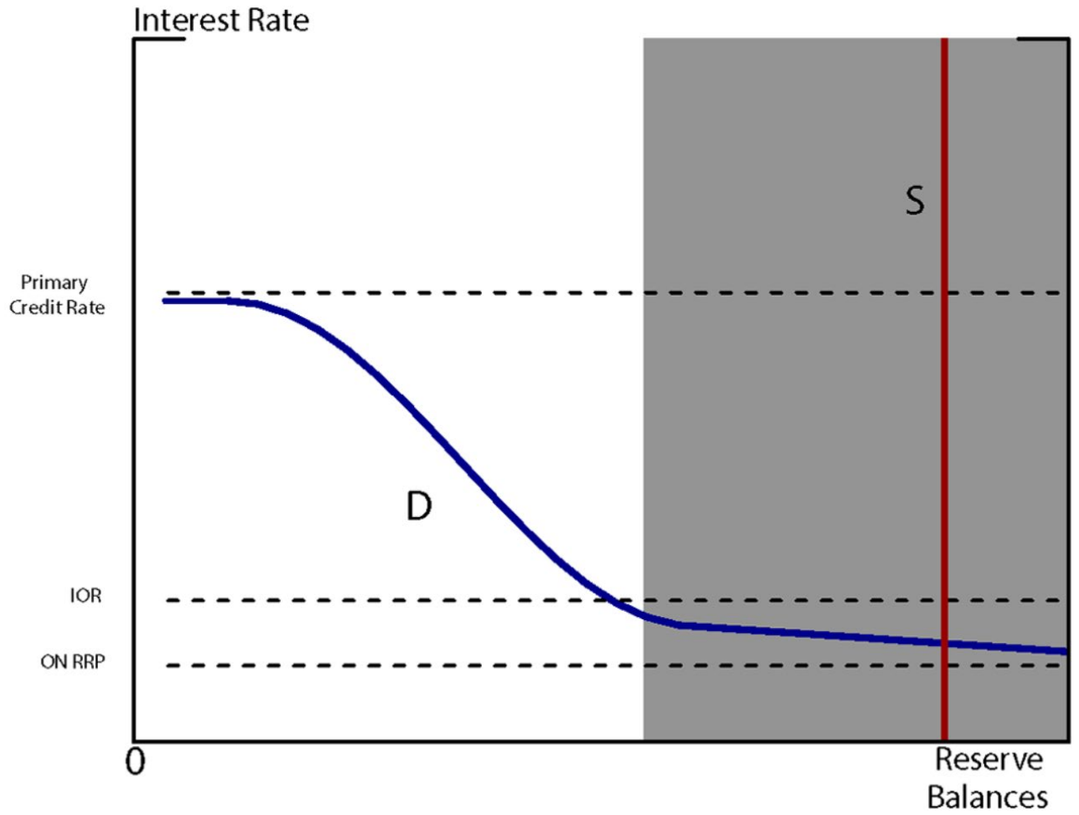
The policy framework has for the most part been successful: Interest rate control

Time series plot of 3 administered rates and effective fed funds rate (daily data, dropping last day of month)



- Effective fed funds rate has cleared in target range, except in September 2019: Successful interest rate control
- But what exactly does the reserve demand function look like?
  - Quantitative estimation
  - Feasible QT

Reserve demand under ample reserves: Federal Reserve's prior framework



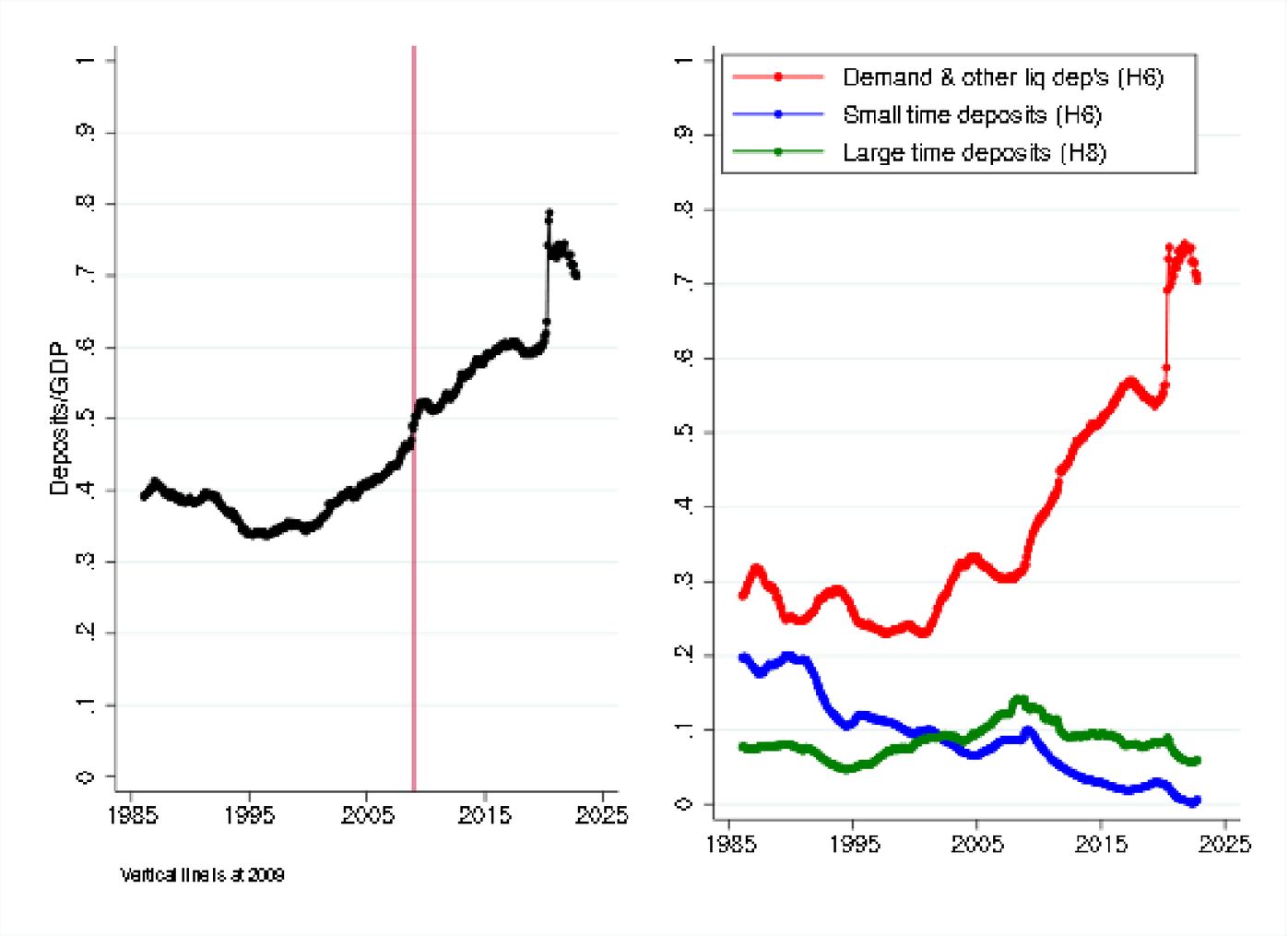
Source: Ihrig, Senyuz and Weinbach (2020)

- Prior framework:
  - Reserve demand is shaped by Fed's three administered rates: Primary credit rate, IOR, ONRRP rate
  - Role of deposits not emphasized

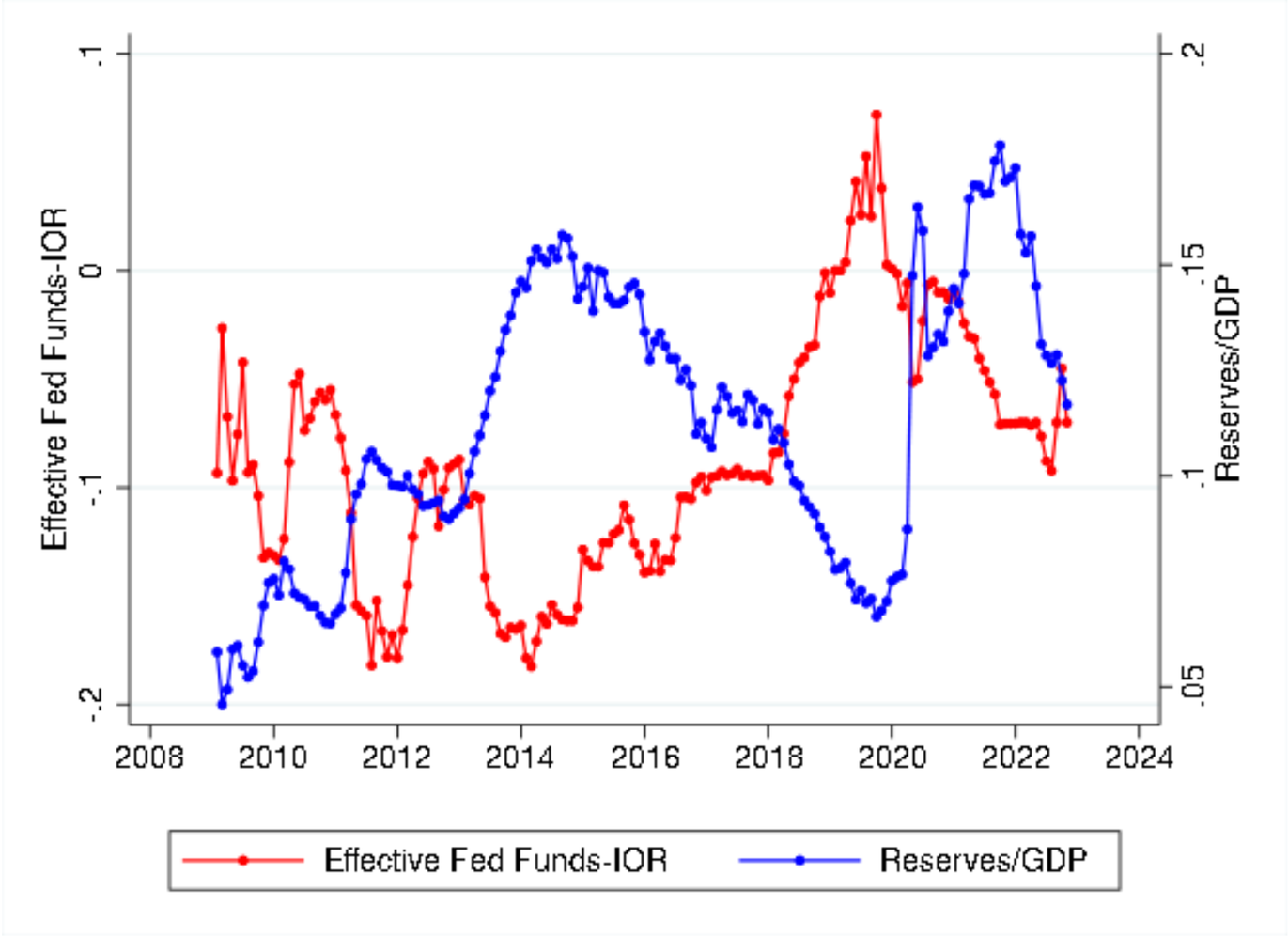
- Our updated version:
  - Reserve demand is shaped by IOR but not directly by the primary credit rate and ONRRP rate – instead supply adjusts
  - Deposits is a reserve demand shifter

Deposit growth

Deposits went up materially over the 2009-2022 period

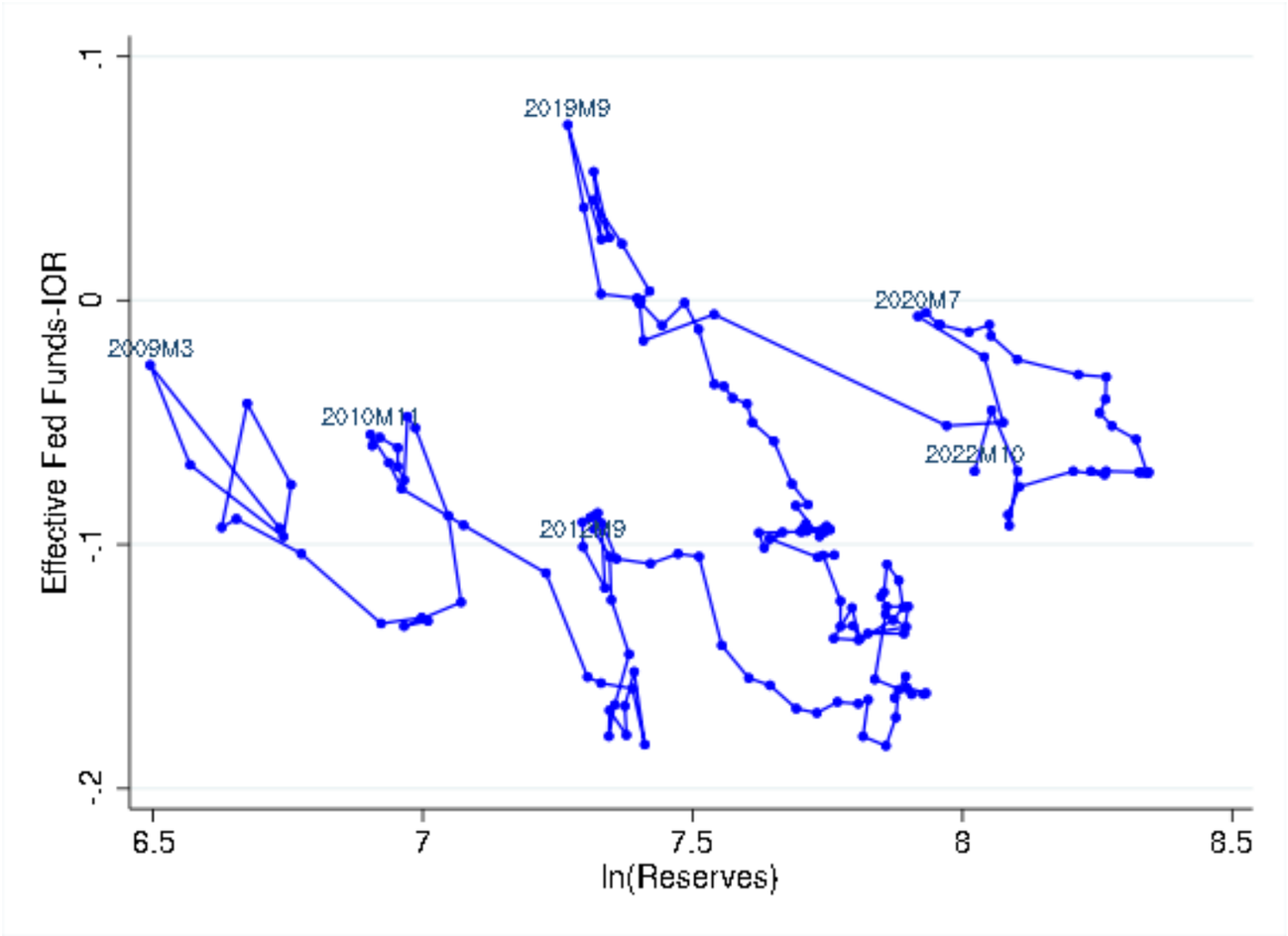


Reserve demand instability without deposit control



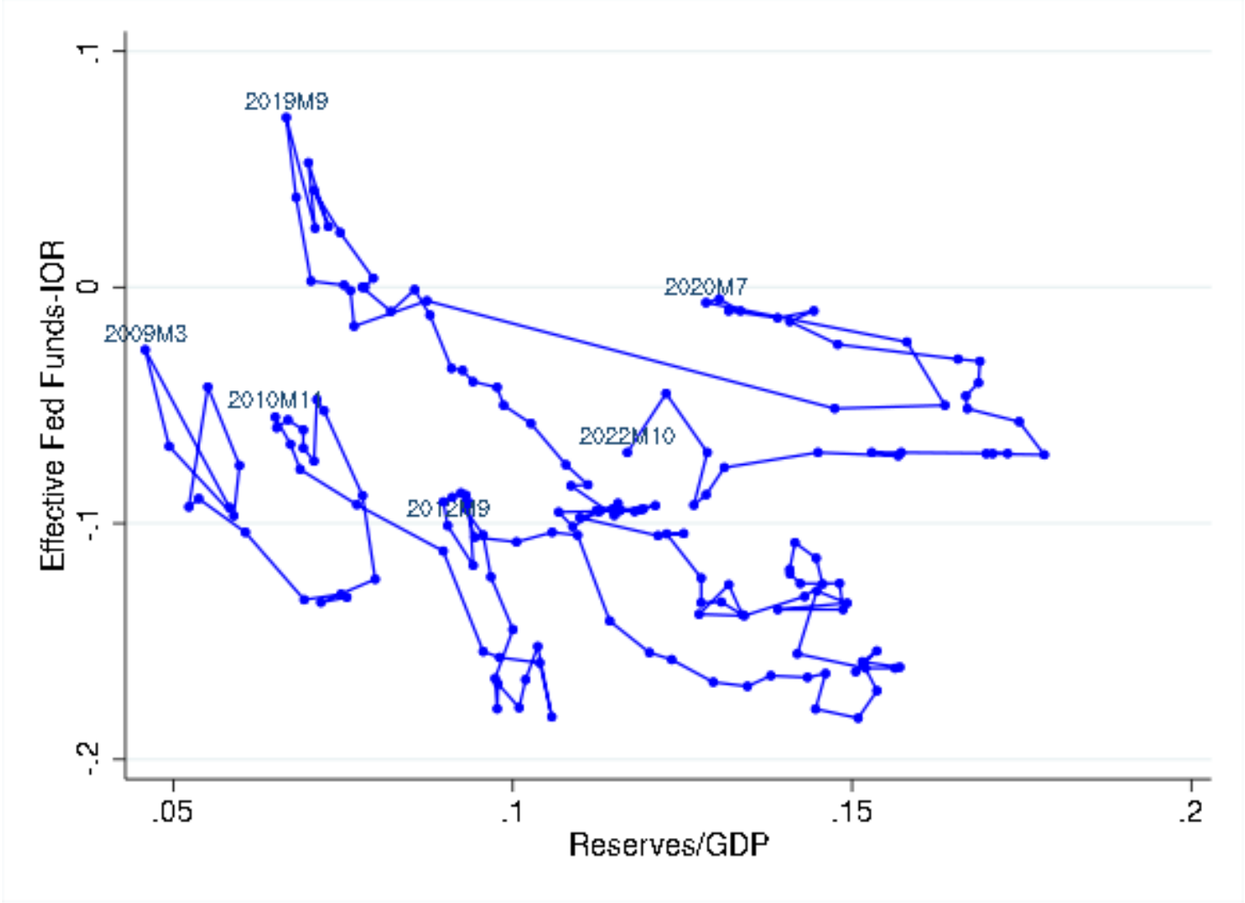
- Monthly data (averages), 2009M1-2022M10
  - QE rounds and COVID-LSAPs visible in reserves/GDP series
- Instability:
  At end of runoff in September 2019
  - Reserves/GDP was around 7%
  - Effective Fed Funds-IOR was much higher than at same Reserves/GDP in 2009-2010

Reserve demand instability without deposit control



Sample: Monthly data, 2009M1-2022M10

Reserve demand instability without deposit control



Sample: Monthly data, 2009M1-2022M10

DERIVING RESERVE DEMAND FROM BANKS' OPTIMIZATION

Deriving reserve demand from banks' optimization

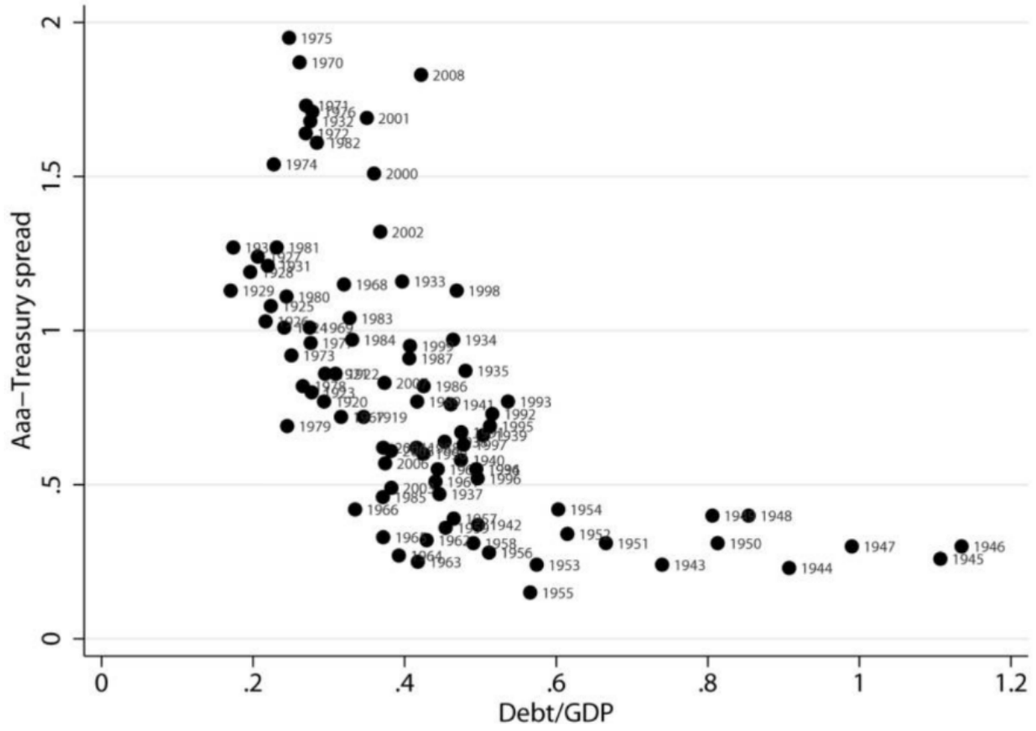
Banks	
Assets	*Liabilities*
Reserves	Deposits
Securities	Federal funds
Loans	Private repo
	Equity

- Banks demand reserves to manage the liquid claims they have issued: Deposits, notably liquid deposits
  - Narrow banking: Reserves=Deposits
  - Fractional reserve banking: Reserves=Fraction*Deposits
  - Ample reserve banking: Reserves=f(Deposits, r(FF)-r(Reserves),…): What we're interested in

    LCR: Reserves=b*HQLA=a*b*Deposits

Deriving reserve demand from banks' optimization

- Transactions cost savings from reserves: Not having to sell bonds/loans when faced with deposit outflows. Can model TC savings as a convenience yield on reserves



- Krishnamurthy and Vissing-Jorgensen (2012): Convenience yield on Treasuries v(Debt/GDP), v'>0, v''<0

- Current setting: Convenience yield on reserves v(Reserves,Deposits)

  $v_R'()>0$: More reserves reduce costs of liquidity management (i.e., higher cost savings)

  $v_D'()<0$: More deposits increase costs of liquidity management

Deriving reserve demand from banks' optimization

- Balance sheet costs for non-equity liabilities: ϕ*(Deposits+Federal funds+Private repo)
- Costs of posting collateral in repo: *w*(Private repo), w'()>0
- Bank profits: $\pi = r(Reserves)*Reserves + r(Securities)*Securities + r(Loans)*Loans$
  $-[r(Deposits)*Deposits + r(FF)*FF + r(Private\ repo)*Private\ repo]$
  $+v(Reserves,Deposits) - \phi*(Deposits+FF+Private\ repo) - w(Private\ repo)$

- FOC for borrowing via federal funds and investing in reserves (dReserves=dFF):

$$r(FF)+\phi = r(Reserves) + v_R'(Reserves,Deposits) \qquad (1)$$

or $r(FF)-r(Reserves) = -\phi + v_R'(Reserves,Deposits)$

or $r(FF) = r(Reserves) - \phi + v_R'(Reserves,Deposits)$ which is the D curve I graphed before

Deriving reserve demand from banks' optimization

- We can define reserve demand relative to each source of for funding reserves:

FOC for borrowing via FF and investing in reserves:

$$r(FF)-r(Reserves) = -\phi+v_R'(Reserves,Deposits) \quad (1)$$

FOC for borrowing via repo and investing in reserves:

$$r(Repo)-r(Reserves) = -\phi+v_R'(Reserves,Deposits)-w'(Repo) \quad (2)$$

FOC for borrowing via deposits and investing in reserves:

$$r(Deposits)-r(Reserves) = -\phi+v_R'(Reserves,Deposits)+v_d'(Reserves,Deposits) \quad (3)$$

Deriving reserve demand from banks' optimization: Assuming functional form

$$r(FF)-r(Reserves)= -\phi + v_R'(Reserves,Deposits) \qquad (1)$$

Result 1. Effects of reserves and deposits on r(FF)-r(Reserves)

Assuming log functional forms: $v_R'(Reserves,Deposits)=d+b*\ln(Reserves)+c*\ln(Deposits)$

and adding an error term *u*, (1) becomes

$$r(FF)-r(Reserves)=a+b*\ln(Reserves)+c*\ln(Deposits)+u \qquad (1^*)$$

with $a=d-\phi$ and where $b<0$ and $c>0$ if $v_R'()$ is decreasing in reserves and increasing in deposits.

- (1*) implies:

$$\text{Reserves} = \alpha\ \text{Deposits}^{\beta} e^{\gamma(r(FF)-r(\text{Reserves}))}\varepsilon$$ Semi-log function for reserve demand

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

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

b<0, c>0 emerges naturally from basic micro foundations for v():

- Net deposit inflows are a fraction $\tilde{F}$ of deposits, distributed uniform(-k,k)
- Withdrawals met using reserves incur no transactions costs
- Withdrawals met using bonds (or loans) incur transactions costs TC(Bonds sold), where TC(x)= $\delta * x^2$

Bonds sold=min($\tilde{F}$D-R,0). Transactions costs: $\widetilde{TC}$= δ*[min($\tilde{F}$D-R,0)]^2

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

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

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

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

ESTIMATING RESERVE DEMAND

Identification

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

Are reserves exogenous?

$$Reserves=Assets-Autonomous\ factors-ONRRP$$

- For reserve supply to not be correlated with the reserve demand shock *u*, it would suffice that:
  (1) Fed assets target other objectives than short market rates: Inflation, employment
  (2) Autonomous factors (currency, TGA etc.) move unrelated to any reserve demand shocks, *conditional on deposits*
  (3) ONRRP take-up is not correlated with reserve demand shocks

- (1) and (2) are plausible, but (3) is not (as graphed before) → Reserves are not exogenous
- But, under (1) and (2), Reserves+ONRRP are exogenous: Use as instrument for reserves

Are deposits exogenous? We'll instrument for deposits as robustness check, but it doesn't change the results

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.
*** indicates statistical significance at the 1% level.

Panel A. Second stage

	Dependent variable: (Effective federal funds rate-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)

	Dependent. variable: 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

Main estimation results: Elasticities/semi-elasticities from 2nd stage

$$Reserves = \alpha\ Deposits^{\beta}\, e^{\gamma(r(FF)-r(Reserves))}\varepsilon$$

$$\ln(Reserves) = ln(\alpha) + \beta * \ln(Deposits) + \gamma * (r(FF) - r(Reserves)) + \ln(\varepsilon)$$

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

- Semi-elasticity of reserve demand with respect to interest rate spread: γ=1/b=-1/0.200=-5

  10 bps reduction in r(FF)-r(Reserves), entices banks to increase reserve holdings by 50% -- very elastic, but not flat

- Elasticity of reserve demand with respect to deposits: $\beta = -\frac{c}{b} = -\frac{0.358}{0.200} = 1.79$

  1% increase in deposits → >1% increase in reserve demand

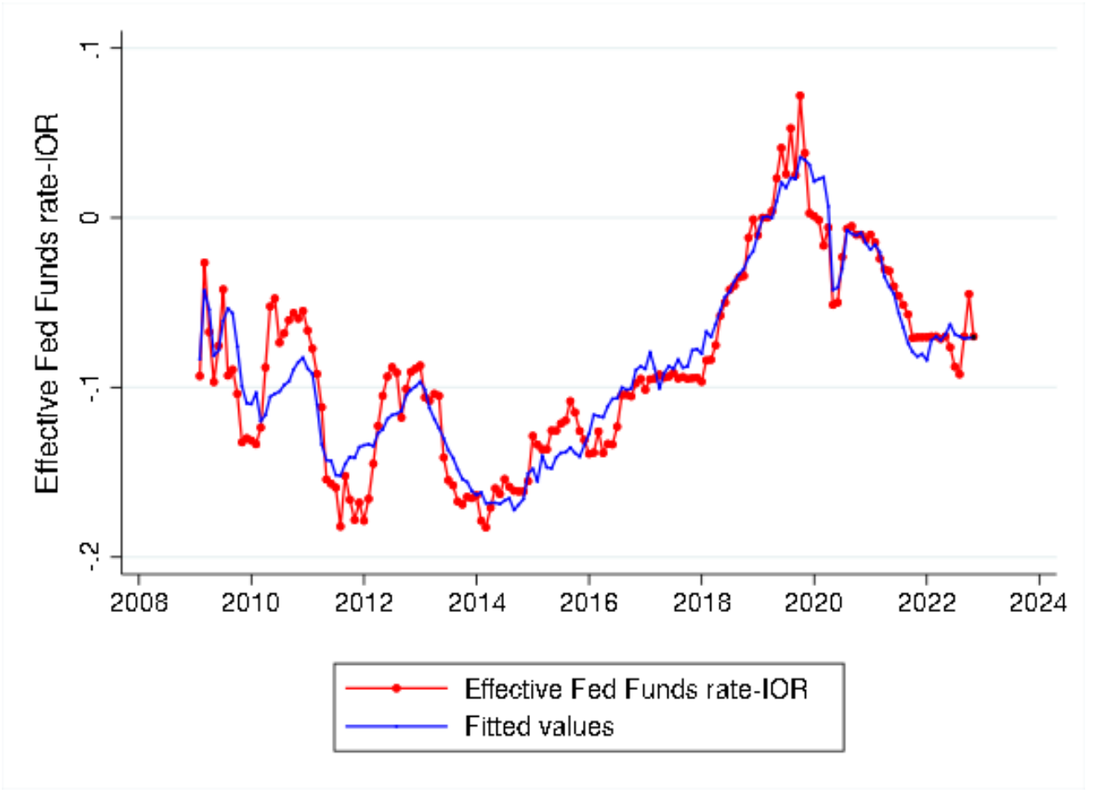
Main estimation results: Fitted values

Reduced form of IV estimation directly links spread to instruments:

r(FF)-r(Reserves)=A+B*ln(Reserves+ONRRP)+C*ln(Deposits)+U

Panel C. Reduced form

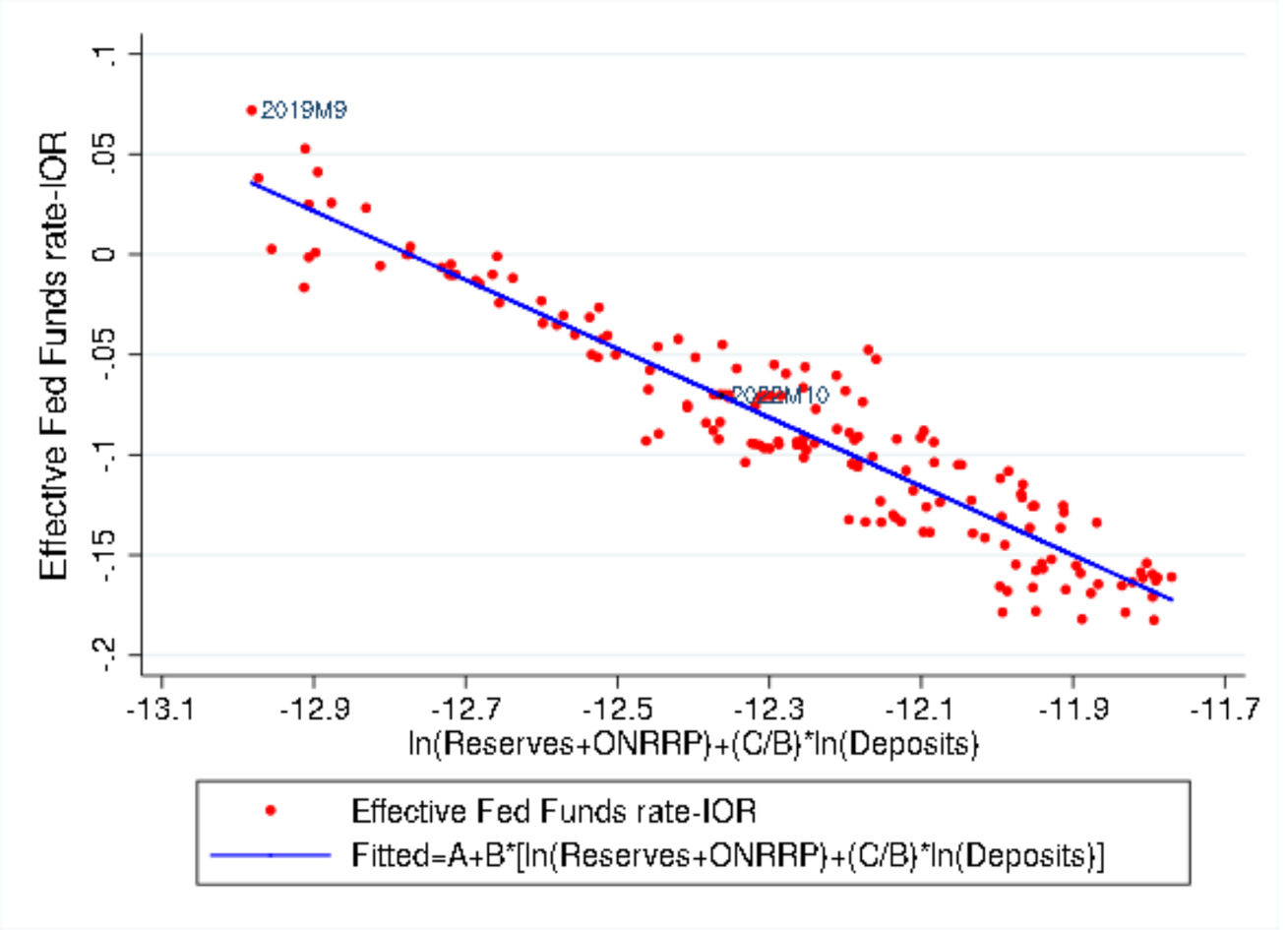
	Dependent. variable: (Effective federal funds rate-IOR)
ln(Reserves+ONRRP)	-0.172***
	(t=-18.78)
ln(Deposits)	0.367***
	(23.81)
Constant	-2.193***
	(-21.12)
N (months)	166
R2	0.895



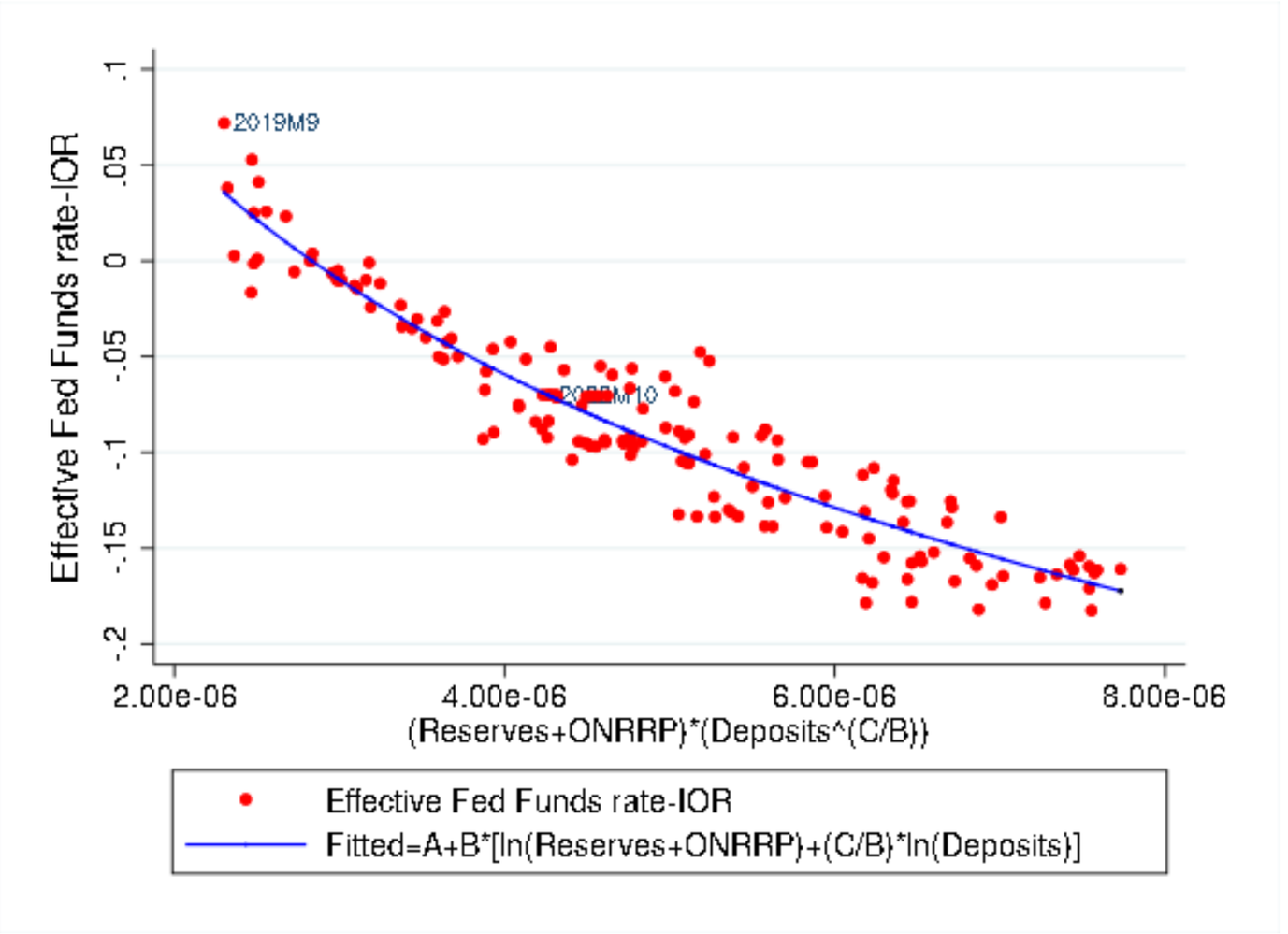
Main estimation results: Fitted values

"Deposit-adjusted supply" has a stable relation to EFFR-IOR spread:

r(FF)-r(Reserves)=A+B*[ln(Reserves+ONRRP)+(C/B)*ln(Deposits)]+U



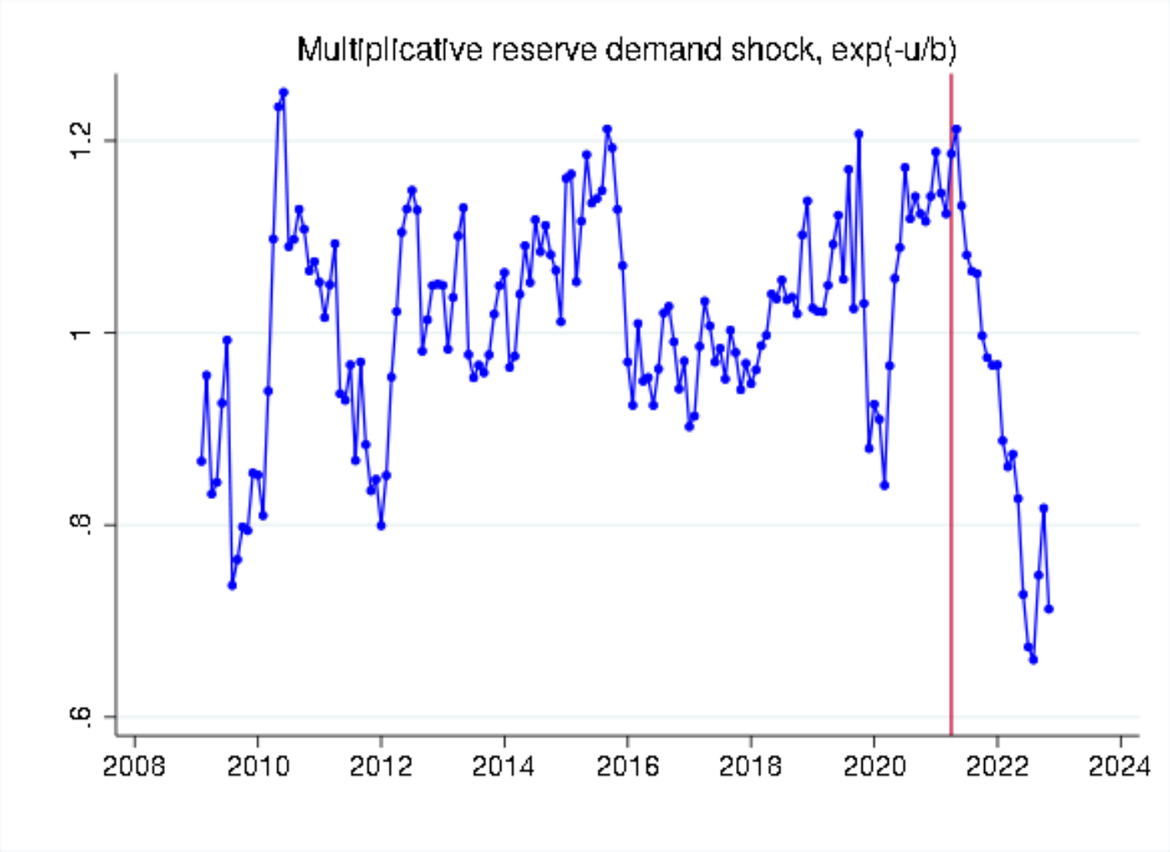
Main estimation results: Fitted values



Estimation results: Did a negative demand shock contribute to ONRRP takeup?

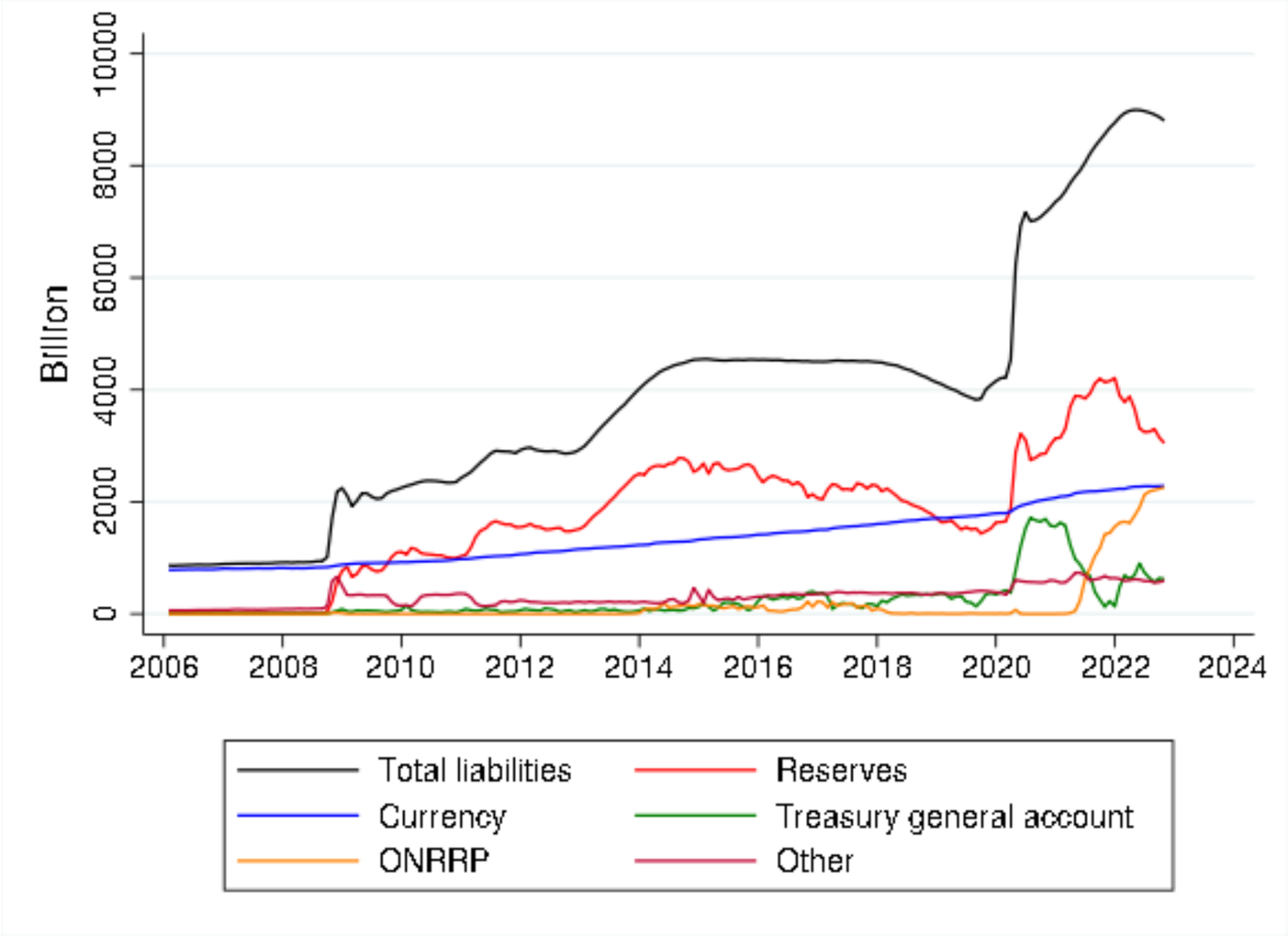
Estimated reserve demand shock: Based on the reserve demand estimation in Table 2, Panel A.

$$Reserves = \alpha\, Deposits^{\beta}\, e^{\gamma(r(FF)-r(Reserves))}\varepsilon, \qquad \varepsilon = e^{-u/b}$$



Vertical line indicates end of March 2021.

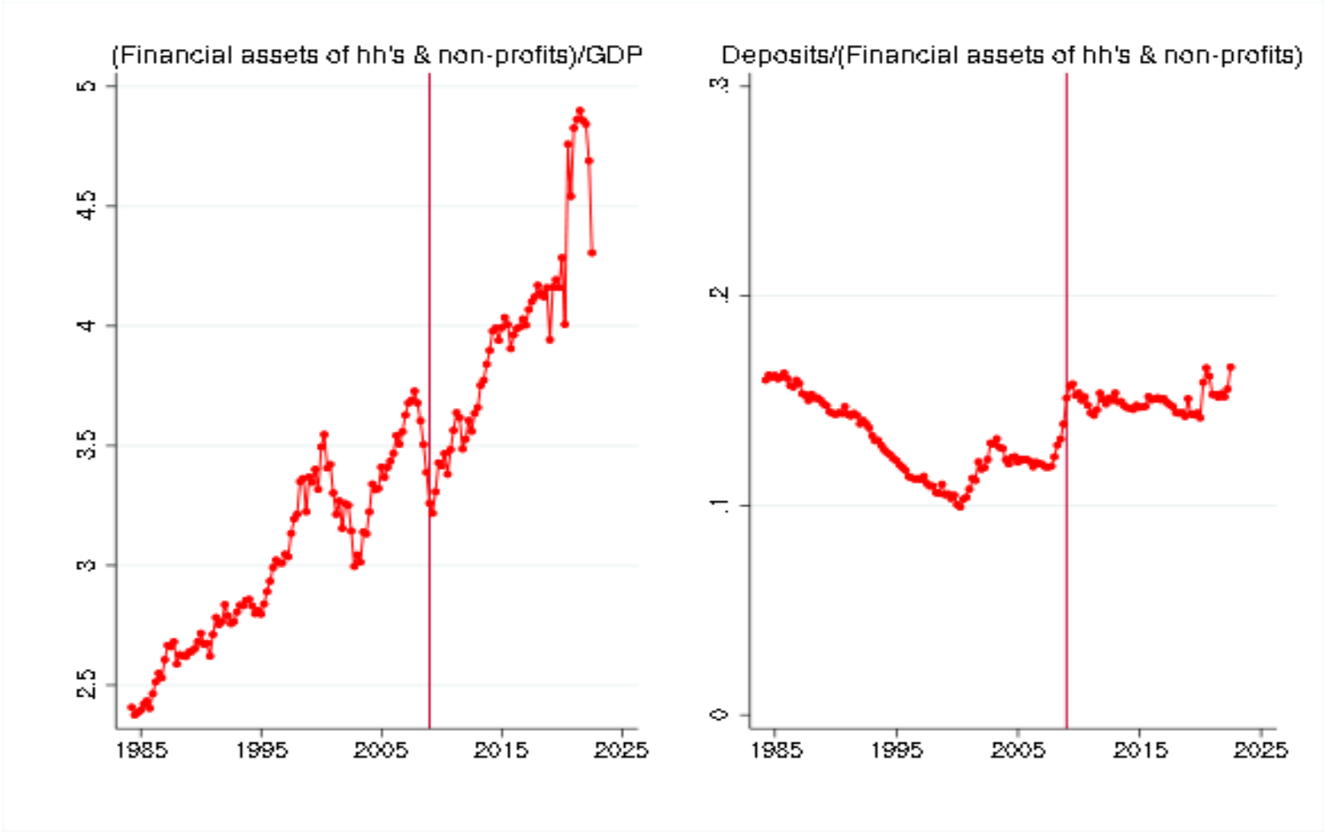
Estimation results: Did a negative demand shock contribute to ONRRP takeup?



Why did deposits grow?

Deposits likely went up mainly due to higher financial assets

- Portfolio choice: Deposits are one of many financial assets
- Over 2009-2022Q2 period: Stable portfolio weight for deposits



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

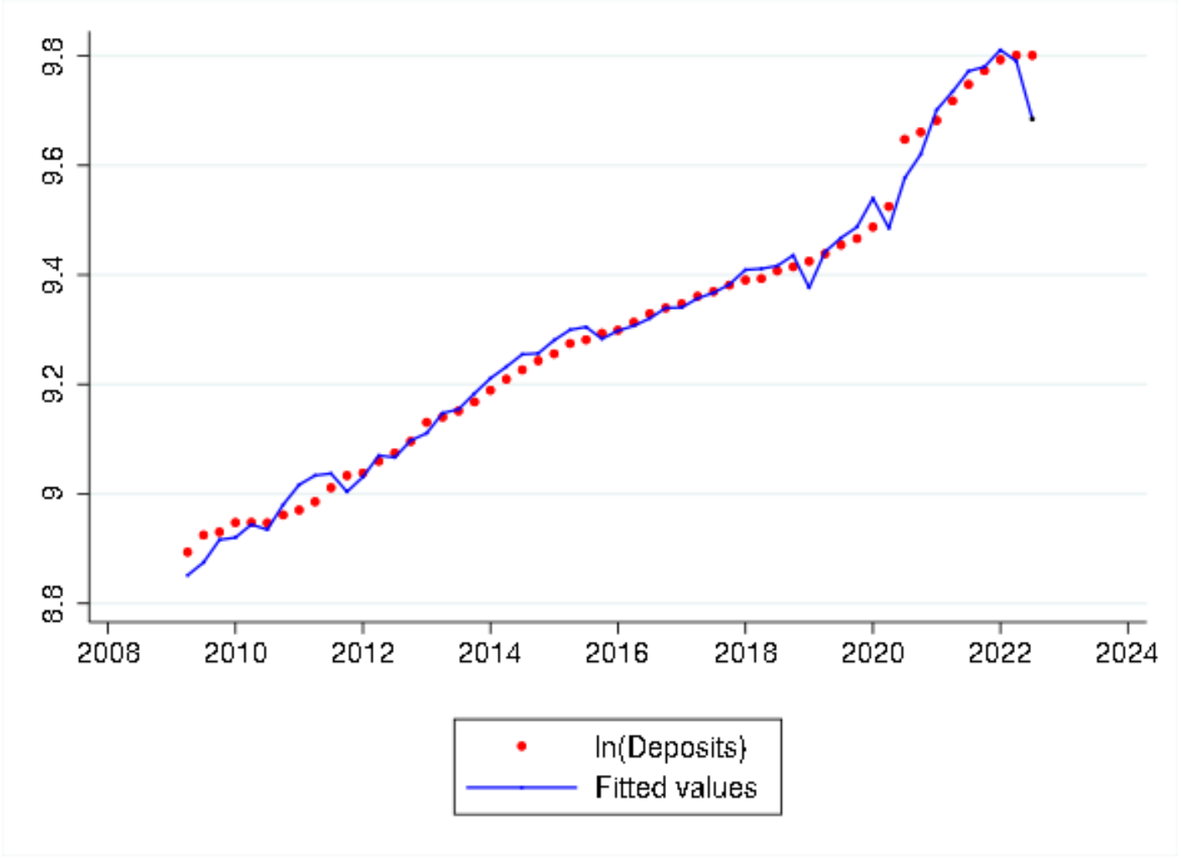
	Dependent variable: (Effective federal funds rate-IOR)
ln(Reserves)	-0.207***
	(t=-11.53)
ln(Deposits)	0.377***
	(12.92)
Constant	-2.025***
	(-11.62)
N (quarters)	54
Sargan test of over-identifying restrictions	p=0.29 (not rejected)

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

	Dependent variable: ln(Reserves)	Dependent variable: 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)

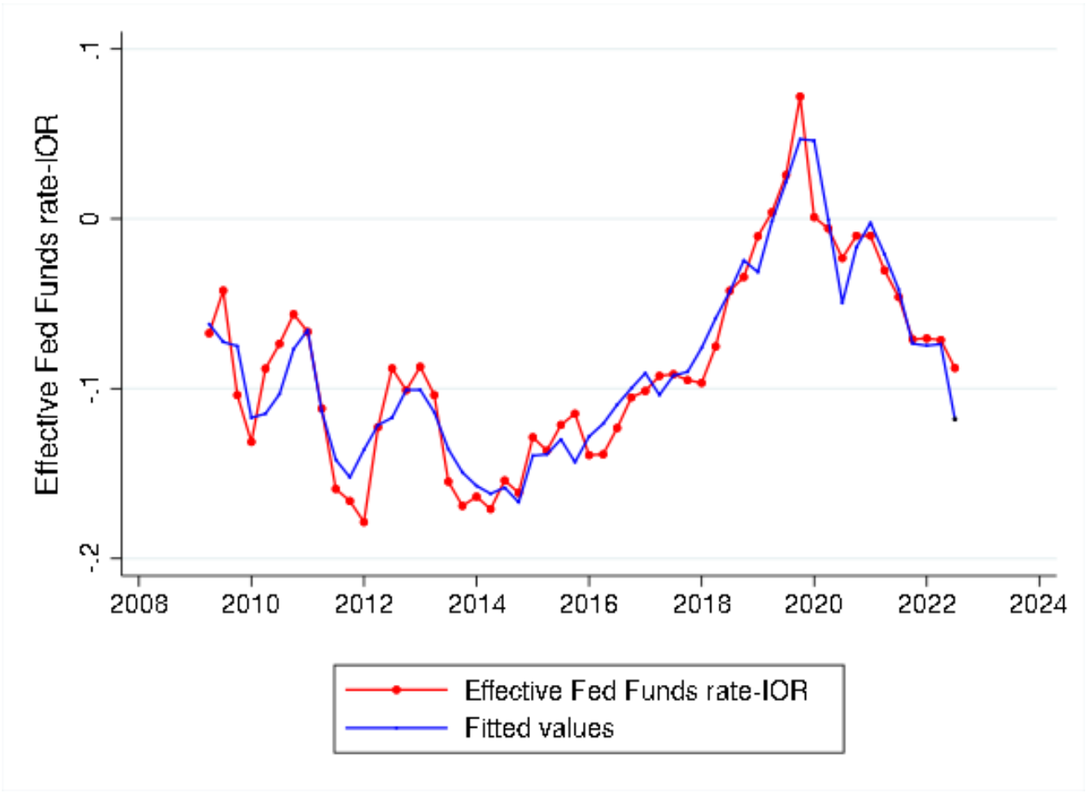
ln(Deposits) and predicted ln(Deposits):



Instrumenting for deposits (and still instrumenting for reserves)

Panel C. Reduced form

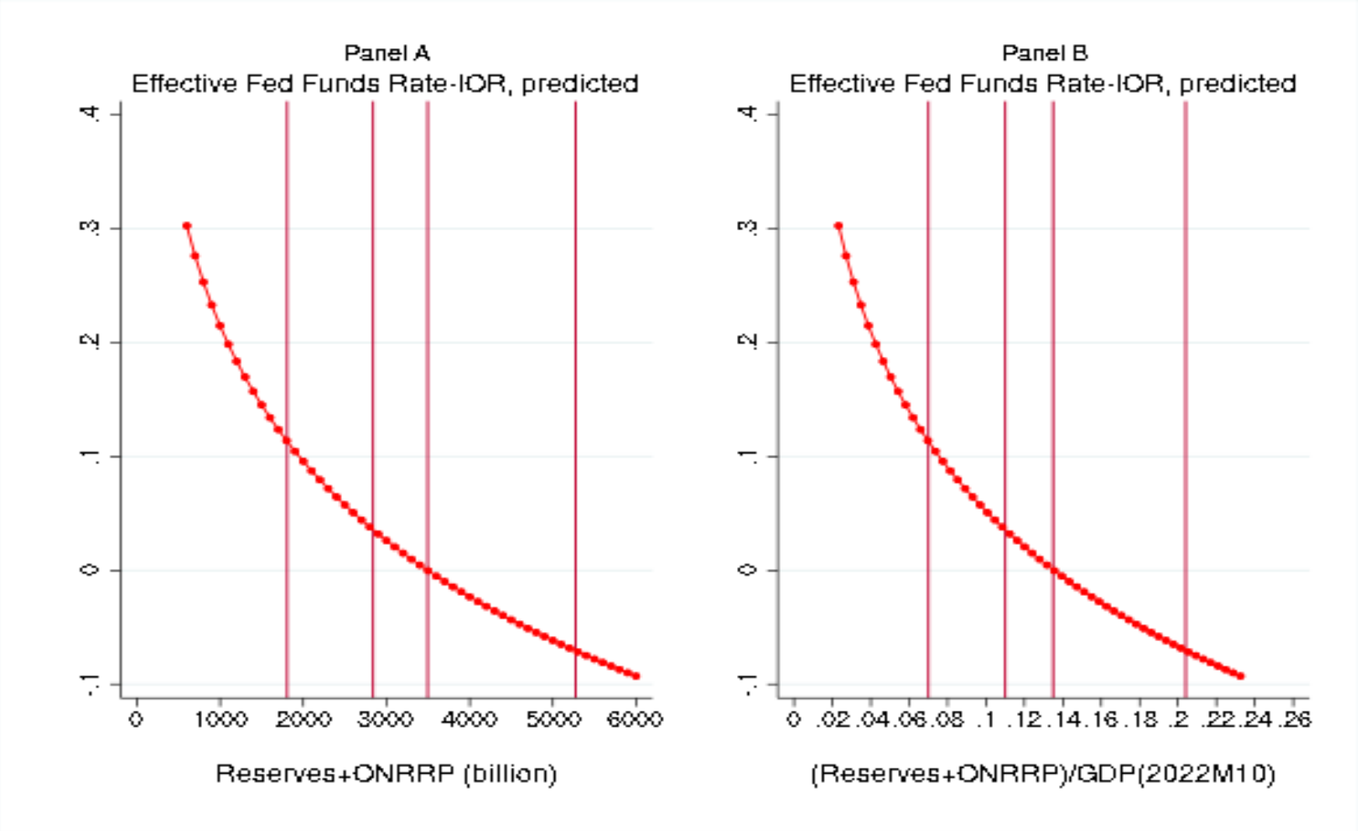
	Dependent. variable: (Effective federal funds rate-IOR)
ln(Reserves+ONRRP)	-0.198***
	(t=-17.57)
ln(Financial assets)	0.430***
	(21.87)
IOR	-0.020***
	(-4.88)
Constant	-3.378***
	(-23.02)
N (quarters)	54
R^2	0.905



IMPLICATIONS FOR QUANTITATIVE TIGHTENING

How much can Reserves+ONRRP be reduced? Approach 1

Predicted r(FF)-r(Reserves)=A+B*ln(Reserves+ONRRP)+C*ln(Deposits) :



Calculate for various Reserves+ONRRP, given current Deposits

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

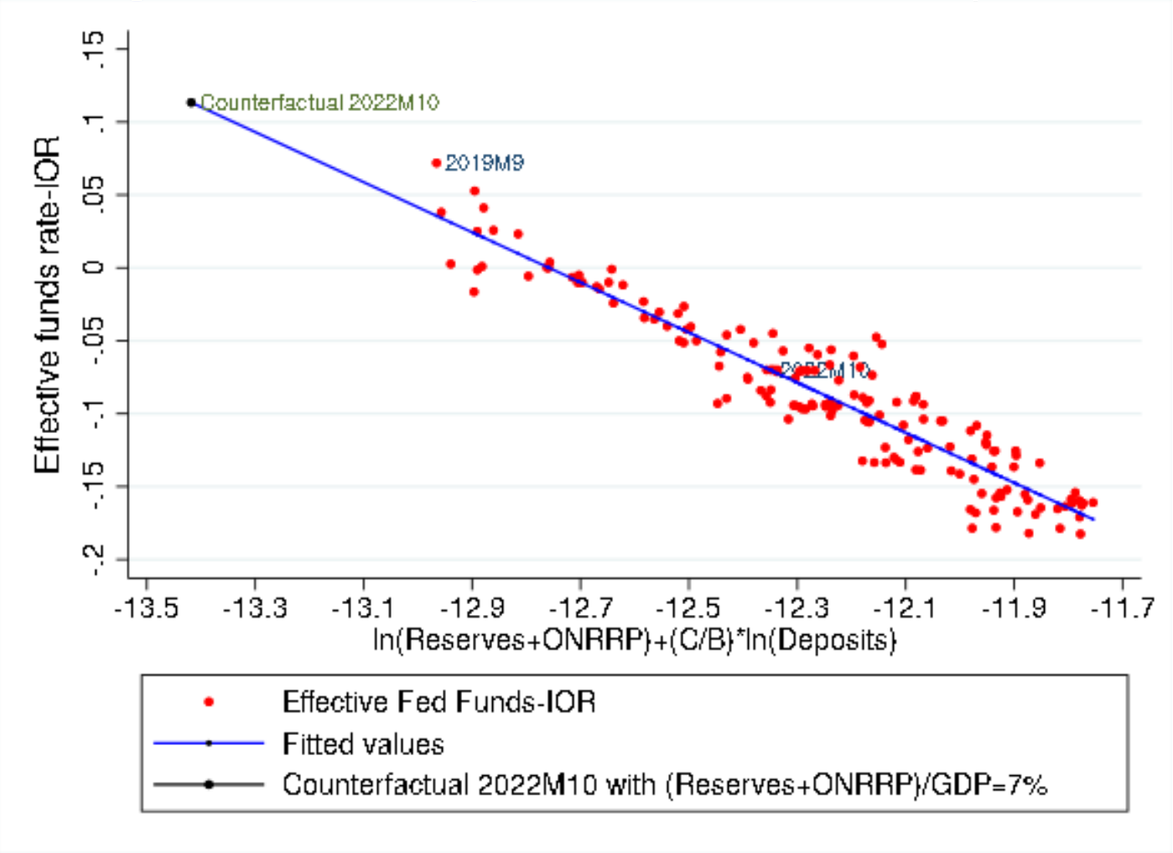
1. *$1.81T, 7% of GDP:*
   Likely too low

2. *$2.84T, 11.0% of GDP:*
   Same predicted value as Sep 2019:
   Probably also too low

3. *$3.50T, 13.5% of GDP:*
   More conservative, leads to predicted r(FF)-r(Reserves)=0, which may be enough to avoid daily spikes

How much can Reserves+ONRRP be reduced? Approach 1

Illustrating the 7% of GDP option: Reserves+ONRRP equal to $1.81T, 7% of GDP: Same % of GDP as last runoff



Would lead to historically low adjusted (Reserves+ONRRP) and a historically high value of r(FF)-r(Reserves) (post-GCF)

Is this a problem for the Fed's ability to reduce its balance sheet size and still hit interest rate target?

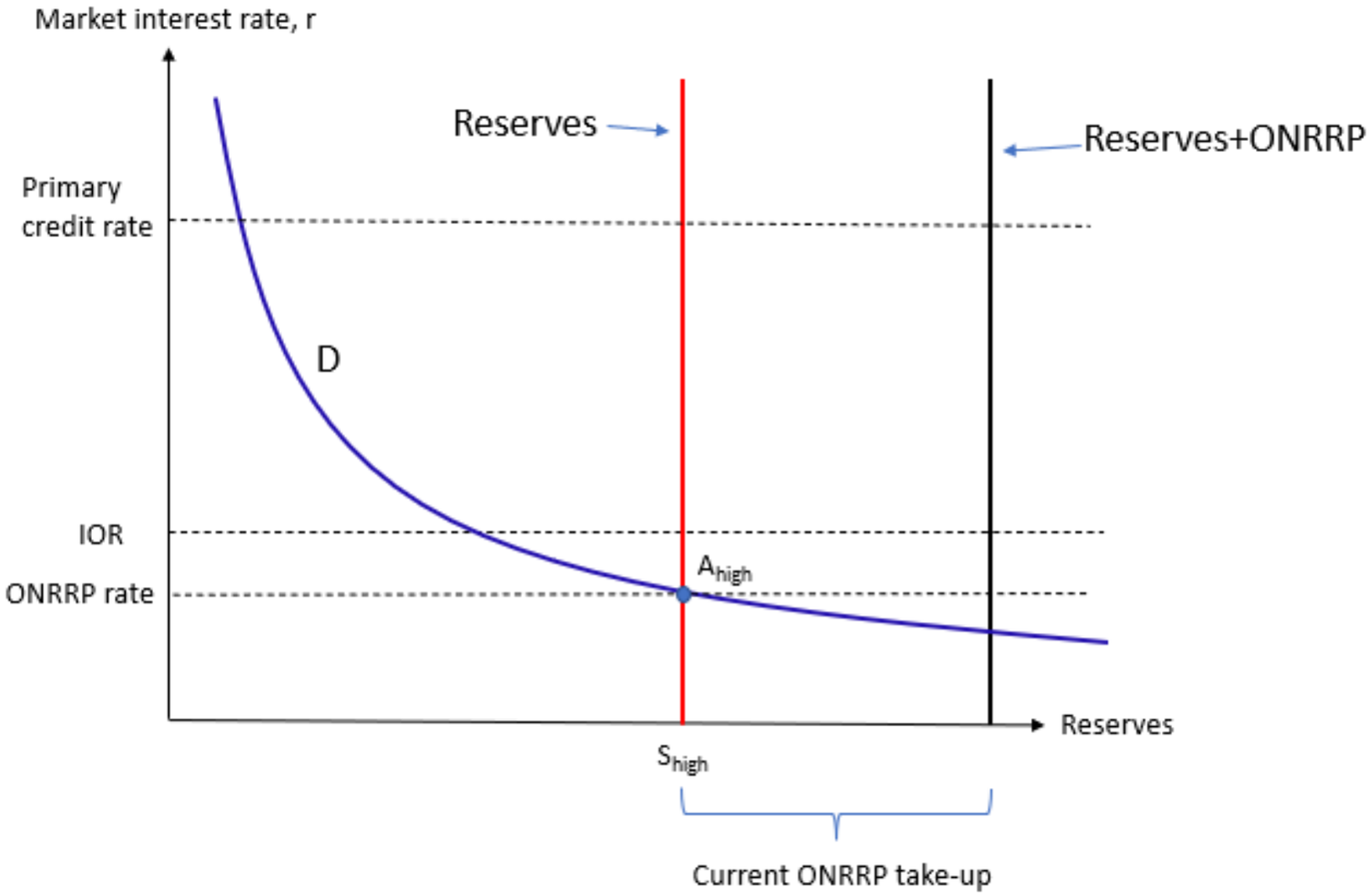
- Can lower IOR and still hit target, on avg.

  For a given Reserves+ONRRP, estimated relation guides setting of IOR

- But, a high r(FF)-r(Reserves) has been associated with daily yield spikes in FF and repo rates (SOFR)

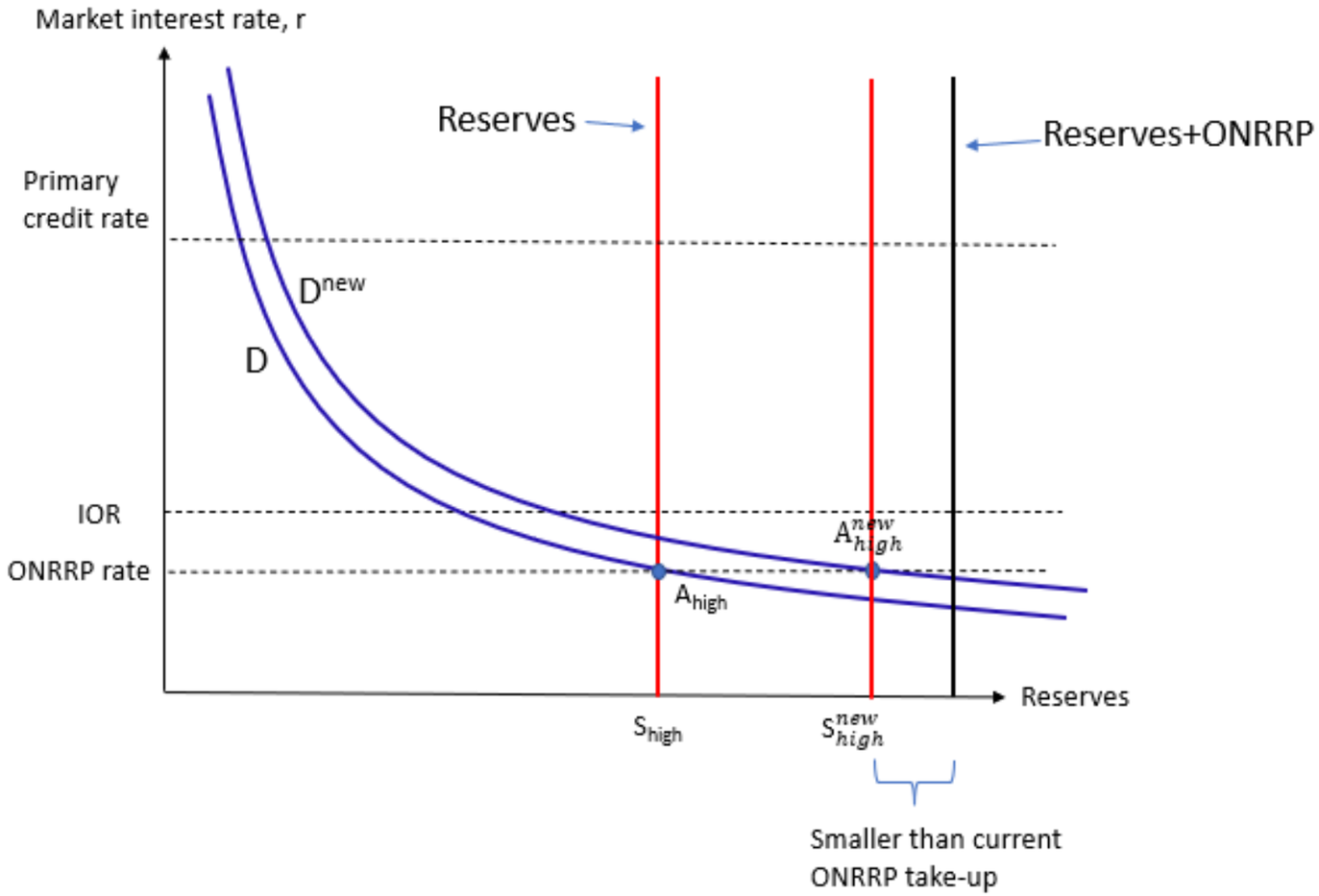
  The Standing Repo Facility helps but are we sure it would fully prevent daily yield spikes?

How much can Reserves+ONRRP be reduced? Approach 2



- Could we lower supply (Reserves+ONRRP) by current ONRRP take-up, $2.2T?
- Yes, if reserve demand curve unaffected: We'll stay at A_{high} and ONRRP take-up will go to zero
- No, if reserve demand curve shifts up
- Who replaces the Fed as bond buyer?
  - Hedge funds with repo funding from MMFs? Then little effect on deposits → D stable
  - Banks, with deposit funding? Then D shifts up → r(repo)>ONRRP with $2.2T runoff

How much can Reserves+ONRRP be reduced? Approach 2



How much can balance sheet be reduced? Accounting for volatility in autonomous factors

Table 1. Federal Reserve balance sheet, October 26, 2022

H.4 release, $B

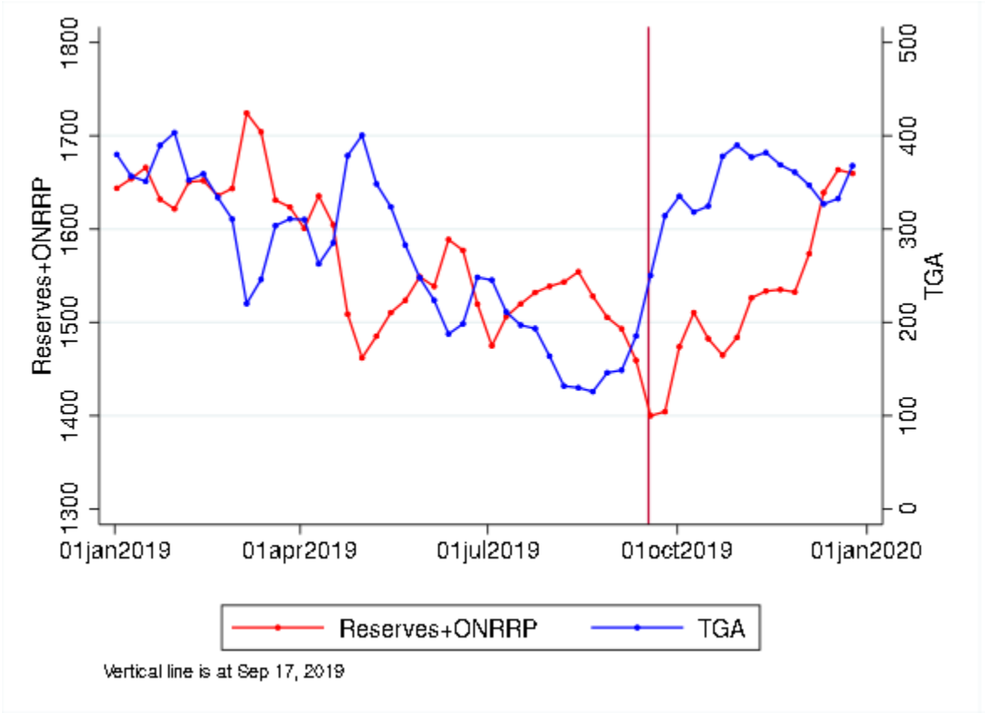
Assets		Liabilities	
Treasuries	5,609	Reserves	3,108
MBS	2,679	Overnight reverse repurchase agreements	2,187
Other	485	Currency	2,285
		Treasury general account	557
		Other	636
	8,773		8,773

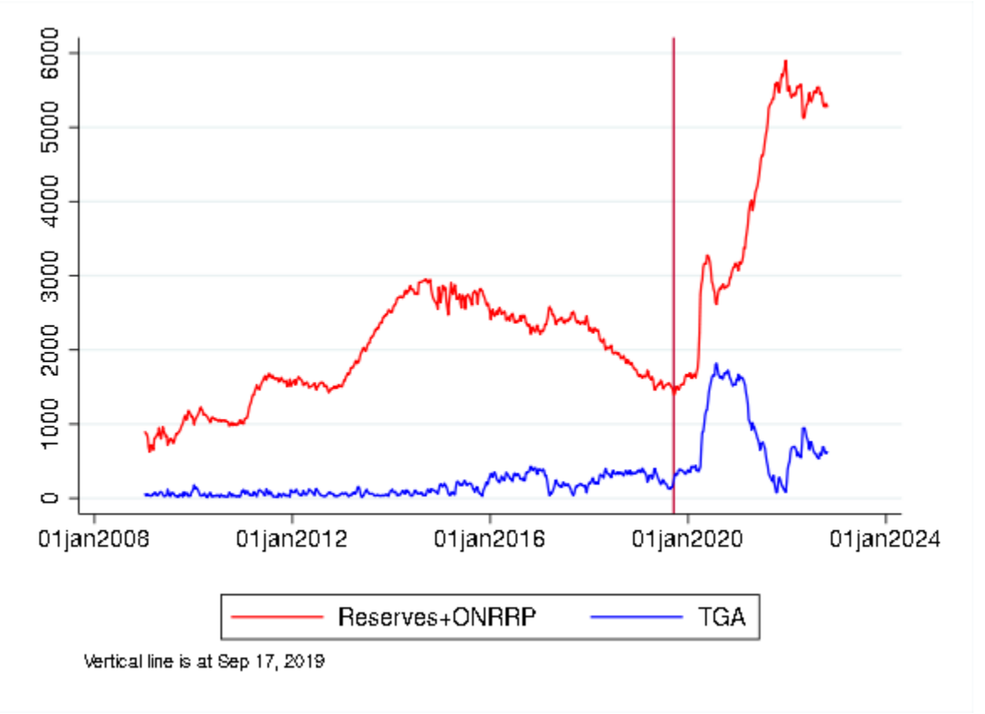
Reserves+ONRRP=Assets-Autonomous factors

- Prudent to run down balance sheet only to the point that fluctuations in autonomous factors will not result in Reserves+ONRRP below the feasible value (e.g., below *$3.495T* in our third option)
- Needed buffer may be several $100B, or hope the Standing Repo Facility can absorb autonomous factor shocks

How much can balance sheet be reduced? Accounting for volatility in autonomous factors

$B





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