The Reserve Supply Channel of Unconventional Monetary Policy
Diamond, Jiang, Ma (2022)

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Motivation

- Expansion of central bank reserves issued by the Federal Reserve in last years.
- Federal Reserve purchased trillions of dollars in assets in its Quantitative Easing (QE) program.
  - Buys securities from banks and pays with reserves that can only be held in the banking system
- Net injection of trillions of dollars to bank balance sheets
- **This paper studies the impact of this large reserve supply on bank borrowing and lending.**

Motivation

- The impact of increasing the reserve supply on bank lending is ambiguous:
  - ↑ *lending:*
    Reduce costs of selling illiquid assets in a bank run (Diamond and Dybvig, 1983),
    help comply with liquidity regulations.
  - ↓ *lending:*
    cost of meeting capital requirements when equity is scarce (Kashyap and Stein 1993),
    amplify liquidity strains during stress episodes (Acharya and Rajan, 2021),
    bank leverage regulation can make it costly to expand asset holding (Du, Tepper, and Verdelhan, 2018)

Motivation

- Reserves in balance sheets increased from 50 billion (2008) to 2.8 trillion (2015).
- The proportion of illiquid assets on bank balance sheets declined from 83% to 63%.

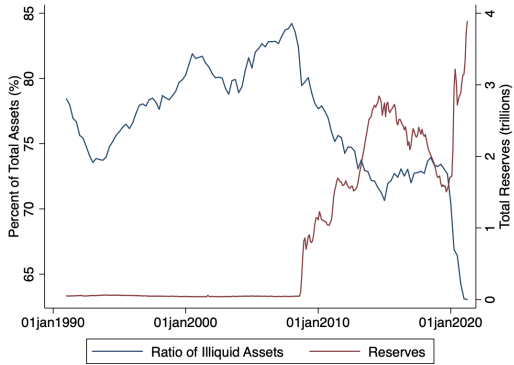


Figure: Supply of Central Banks Reserves and Bank Asset Illiquidity

Goal and Results

- Estimate structural model of the market for bank deposits and loans:
  - Elasticity of deposit and loan demands.
  - How does holding reserves change the cost of deposits and loans
- **Counterfactual Analysis:** Increase supply of bank reserves and compute new interest rates and quantities.

Goal and Results

- Estimate structural model of the market for bank deposits and loans:
  - Elasticity of deposit and loan demands.
  - How does holding reserves change the cost of deposits and loans
- **Counterfactual Analysis:** Increase supply of bank reserves and compute new interest rates and quantities.
- **Main Findings: The Reserve Supply Channel of QE**
  - Demand for bank loans is more interest-rate sensitive than demand for deposits and mortgages.
  - Each dollar of reserves injected from 2008 to 2017 crows out 19 cents of bank lending ($\downarrow$ lending)
  - Deposit and mortgages are less affected
  - **The Reserve Supply Channel of QE**

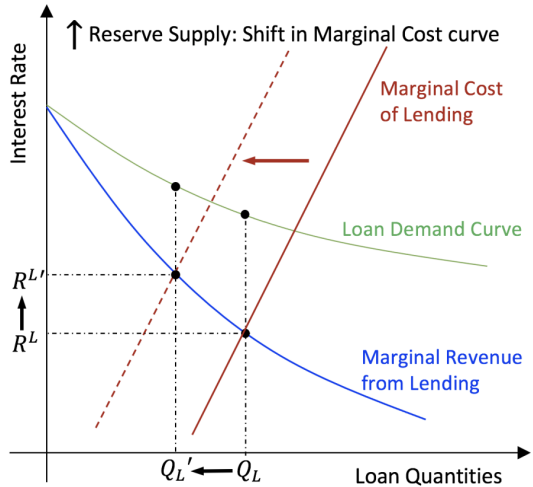
Related Literature

- Estimate new channel of QE transmission through bank balance sheets.
  - Asset pricing (Krishnamurthy and Vissing-Jorgensen, 2011), Bank balance sheets (Rodnyasky and Darmouni, 2017)
- Structural models of deposit competition
  - Egan, Hortaçsu, and Matvos (2017), Wang, Whited, Wu and Xiao (2020).
- Role of imperfect competition in the transmission of conventional monetary policy
  - Deposits (Drechsler, Savov, and Schnabl, 2017), mortgages (Scharhstein and Sunderam, 2016)
- Quantify synergies between illiquid loans, liquid securities, and deposit liabilities on bank balance sheets.
  - Kashyap and Stein (1993), Du, Tepper, and Verdelhan (2018), Diamond and Rajan (2000)

Model of Bank Balance Sheets

Model: Graphical Illustration

- Banks' holding of liquid reserves may impact their marginal cost of lending.



Model

Bank m choose rates and security quantities at time t to maximize the expected present value of its profits at time $t+1$ in all markets n:

$$\begin{aligned}\max_{(R_{D,nmt},R_{M,nmt},R_{L,nmt},Q_{S,mt})} & \sum_n Q_{L,nmt}\left(R_{L,nmt}-R_t^{L,m}\right)+\sum_n Q_{M,nmt}\left(R_{M,nmt}-R_t^{L,m}\right) \\ & +Q_{S,mt}\left(R_{S,t}-R_t^{S,m}\right)-\sum_n Q_{D,nmt}\left(R_{D,nmt}-R_t^{D,m}\right)-C\left(\Theta_{mt}\right)\end{aligned} \tag{1}$$

- $R_{D,nmt}$, $R_{M,nmt}$, $R_{L,nmt}$ are bank deposit, mortgages, and loan rates.
- $R_{S,t}$ is the security rate in the competitive market.
- $R_t^{D,m}$, $R_t^{M,m}$, $R_t^{L,m}$, $R_t^{S,m}$ are the cash flows discount rates of the deposits, mortgages, loans, and securities.
- $Q_{D,nmt}$, $Q_{M,nmt}$,$Q_{L,nmt}$, $Q_{S,mt}$ are the quantities of deposits, mortgages, loans, and securities.
- $C(\Theta_{mt})$ is the balance sheet costs (Θ_{mt} is the vector ($Q_{L,nmt}$, $Q_{M,nmt}$, $Q_{S,mt}$, $Q_{D,nmt}$))

Model

The first order conditions of bank profits with respect to the choice variables, $R_{D,nmt}$, $R_{M,nmt}$, $R_{L,nmt}$, and $Q_{S,mt}$, are

$$
\begin{aligned}
R_t^{D,m} - R_{D,nmt} - \frac{Q_{D,nmt}}{\partial Q_{D,nmt} / \partial R_{D,nmt}} &= \frac{\partial C\left(\Theta_{mt}\right)}{\partial Q_{D,nmt}} \\
R_{j,nmt} - R_t^{j,m} + \frac{Q_{j,nmt}}{\partial Q_{j,nmt} / \partial R_{j,nmt}} &= \frac{\partial C\left(\Theta_{mt}\right)}{\partial Q_{j,nmt}}, \quad j \in \{L, M, S\} \\
\underbrace{R_{S,t} - R_t^{S,m}}_{\text{Reserve spread}} &= \frac{\partial C\left(\Theta_{mt}\right)}{\partial Q_{S,mt}}.
\end{aligned}
$$

Model

The comparative statics with respect to a change in bank m 's liquid security holdings $Q_{S,mt}$ are

$$\frac{\partial\left(R_t^{D,m}-R_{D,nmt}-\frac{Q_{D,nmt}}{\partial Q_{D,nmt}/\partial R_{D,nmt}}\right)}{\partial Q_{D,nmt}}\frac{\partial Q_{D,nmt}}{\partial Q_{S,mt}}=\frac{\partial^2 C\left(\Theta_{mt}\right)}{\partial Q_{D,nmt}\partial\Theta_{mt}}\cdot\frac{\partial\Theta_{mt}}{\partial Q_{S,mt}}$$

$$\frac{\partial\left(R_t^{j,m}-R_{j,nmt}-\frac{Q_{j,nmt}}{\partial Q_{j,nmt}/\partial R_{j,nmt}}\right)}{\partial Q_{j,nmt}}\frac{\partial Q_{j,nmt}}{\partial Q_{S,mt}}=-\frac{\partial^2 C\left(\Theta_{mt}\right)}{\partial Q_{j,nmt}\partial\Theta_{mt}}\cdot\frac{\partial\Theta_{mt}}{\partial Q_{S,mt}},\quad j\in\{L,M\}\}$$

where $\frac{\partial Q_{j,nmt}}{\partial Q_{S,mt}}$ is the response of each bank branch quantity of $j\in\{D,L,M\}$

Demand system

Demand system

- Annual bank-market-level data from 2001 to 2017
- Deposits
  - Deposit quantities: FDIC (branch level, yearly)
  - Deposit rate: RateWatch (10K Money Market rate)
  - County-level market
- Mortgages
  - Mortgage quantities: HMDA (lender, loan size, location of property, loan type)
  - Mortgage rate: RateWatch (15-Year Fixed Rate)
  - County-level market
- Loans:
  - Loan quantities and rates: Dealscan
  - State-level market (defined by location of the borrower)
- Bank-level characteristics from Call Reports
- Property losses from natural disasters from SHELDUS.

Demand system: Descriptives

Table 1: Summary Statistics (Market-Bank-Year Level)

This table reports summary statistics of bank deposits, mortgages, and loans at the market-bank-year level. Rates are reported in basis points and volumes are in millions. The instrument refers to property losses due to natural disasters. The sample period is from 2001 to 2017.

	Num. of Obs.	Mean	25th Pct.	50th Pct.	75th Pct.	Std. Dev.
Log Deposit Market Share	74007	−2.67	−3.45	−2.33	−1.50	1.69
Deposit Volume	74007	188.47	23.05	47.82	103.16	2287.78
Deposit Rate	45894	58.04	10.00	20.00	80.00	77.98
Log Mortgage Market Share	38957	−4.12	−5.32	−3.73	−2.56	2.08
Mortgage Volume	38957	23.67	1.23	3.79	11.62	209.53
Mortgage Rate	11735	457.62	332.50	450.55	570.00	126.41
Log Loan Market Share	25943	−5.06	−6.62	−4.95	−3.45	2.09
Loan Volume	25989	977.24	40.25	132.00	553.78	3218.81
Loan Spread	25943	183.52	101.38	171.43	250.00	120.46

Demand system

- Depositor j investing in bank m in market m has the fowing utility:

$$u_{D,jnmt} = \alpha_D R_{D,nmt} + X_{D,nmt}\beta_D + \delta_{D,nmt} + \varepsilon_{D,jnmt}$$

.
where $R_{D,nmt}$ is the deposit rate, $X_{D,nmt}$ is bank characteristics, $\delta_{D,nmt}$ are unobserved characteristics and $\varepsilon_{D,jnmt}$ is the idiosyncratic shock folows T1EV.

- Estimate logit demand system using 2SLS.
- Similar demands for mortgages and loans.

Demand system

- Market size $\bar{Q}_{D,nt}$:

$$\bar{Q}_{D,nt} = \bar{F}_{D,nt} \frac{\exp\left(\psi_{D,nt}\right)}{1 + \exp\left(\psi_{D,nt}\right)}$$

  where $\psi_{D,nt} = \log\left(\sum_m \exp\left(\alpha_D R_{D,nmt} + X_{D,nmt}\beta_D + \delta_{D,nmt}\right)\right)$ is the desirability of the composite good, and $\bar{F}_{D,nt}$ is the total supply of funds.

- Use a linear approximation $\log \bar{Q}_{D,nt} \approx \log \bar{F}_{D,nt} + \beta_{D,o}\psi_{D,nt}$ to estimate how $Q_{D,nmt}$ responds to changes in $\psi_{D,nt}$.

Demand system: Natural Disaster Instrument

- Reallocation of bank funding after natural disasters, Cortes and Strahan (2017)
- Positive shock to local loan demand followed by reallocation of funds away from other branches creates negative loan supply shocks.
- Natural disasters do not directly affect demand for deposits, loans, and mortgages in unaffected counties (in a way that correlated with banks' branch networks).

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- Natural disasters do not directly affect demand for deposits, loans, and mortgages in unaffected counties (in a way that correlated with banks' branch networks).
- For bank m in market n in year t :

$$z_{nmt} = \frac{1}{N^u_{mt}} \log \left(\sum_{n'} \text{damage}_{n't} \cdot \frac{Q_{D,n'mt}}{\sum_{n_0} Q_{D,n_0mt}} \right)$$

  - N^u_{mt} : number of unaffected branches of bank m
  - damage $e_{n't}$: property loss in market n'
  - $\frac{Q_{D,n'mt}}{\sum_{n_0} Q_{D,n_0mt}}$: fraction of deposits belonging to branches of bank m in affected markets

Demand system

Panel (b): 2SLS Panel Regression

	(1)	(2)	(3)
	Deposit Market Share	Mortgage Market Share	Loan Market Share
Rate (with IV)	46.85***	−574.89***	−487.30***
	(9.07)	(72.33)	(76.96)
Loan Loss Provision	−1.59***	−15.47***	8.41
	(0.24)	(5.21)	(5.23)
Lag Deposit Market Share	0.90***		
	(0.01)		
Lag Insured Deposit Ratio	−0.34***		
	(0.05)		
Log Property Damage	0.12***	0.77***	
	(0.01)	(0.04)	
Observations	217,623	77,329	25,115
Market-Year F.E.	Y	Y	Y

▸ First Stage Estimates

Demand system

- Outside option parameters estimates use market-bank-level average instrument.
- Includes county-level control variables like the average age, average income, college education, log population, etc. quantities.
- The increase in deposit quantity when all banks R_D by 10 basis points:

$$\frac{\partial \log \bar{Q}_{D,nt}}{\partial R_{D,nt}} = \frac{\partial \log \bar{Q}_{D,nt}}{\partial \psi^o_{D,nt}} \frac{\partial \psi^o_{D,nt}}{\partial R_{D,nt}} = 0.28 \times 4.7\% = 1.3\%$$

Panel (b): 2SLS

	(1)	(2)
	Deposit Share	Mortgage Share
ψ^o (with IV)	0.28*	0.07
	(0.14)	(0.04)
Observations	39,053	25,234
R^2	1.00	0.91
Controls	Y	Y
Market-Year F.E.	Y	Y

Cost function

Cost function

For bank m at time t the cost is:

$$C(\Theta_{mt}) = H(Q_{D,mt}, Q_{M,mt}, Q_{L,mt}, Q_{S,mt}) + \sum_n \left(Q_{M,nmt}\varepsilon^Q_{M,nmt} + Q_{L,nmt}\varepsilon^Q_{L,nmt} + Q_{D,nmt}\varepsilon^Q_{D,nmt} \right) + Q_{S,mt}\varepsilon^S_{mt} \tag{2}$$

where $H(\cdot)$ is

$$H(Q_{D,mt}, Q_{M,mt}, Q_{L,mt}, Q_{S,mt}) = \mu_D Q_{D,mt} + \mu_M Q_{M,mt} + \mu_L Q_{L,mt} + \mu_Q Q_{S,mt} + \frac{1}{2}\left(K_1\mathcal{E}^2_{mt} + K_2\mathcal{I}^2_{mt} + K_3 Q^2_{D,mt} + 2K_4\mathcal{I}_{mt}Q_{D,mt} + 2K_5\mathcal{E}_{mt}Q_{D,mt} \right)$$

where $\mathcal{E}_{mt} = Q_{M,mt} + Q_{L,mt} + Q_{S,mt} - Q_{D,mt}$ (bank's equity and non-deposit fund) and $\mathcal{I}_{mt} = Q_{S,mt} + \omega_M Q_{M,mt} + \omega_L Q_{L,mt}$ (liquidity of bank assets).

Cost function

Diferentiating C with respect to $Q_{D,nmt}$:

$$\frac{\partial C}{\partial Q_{D,nmt}} = \mu_D - K_1 \mathcal{E}_{mt} + K_3 Q_{D,mt} + K_4 \mathcal{I}_{mt} + K_5 \left(\mathcal{E}_{mt} - Q_{D,mt}\right) + \varepsilon^D_{nmt} \tag{3}$$

Recall profit maximizer bank's FOC:

$$\frac{1}{N_{mt}} \sum_n \left(\frac{\partial C}{\partial Q_{D,nmt}} - R_t \right) = \mu^*_D - K_1 \mathcal{E}_{mt} + K_3 Q_{D,mt} + K_4 \mathcal{I}_{mt} + K_5 \left(\mathcal{E}_{mt} - Q_{D,mt}\right) + \varepsilon^D_{mt} \tag{4}$$

Analogous expressions for loans, mortgages and reserves.

Cost function

- z^1: Natural disaster shock (bank level)
- z^2: Bank's exposure to regional deposit demand shocks (Bartik instrument). Average deposit market growth in counties where the bank has branches.

- Regress marginal costs of borrowing/lending and all balance sheet quantities on each demand IV:

$$C_{D,mt} = \theta_t^D + \kappa^{i,D} z_{mt}^i + u_{D,mt}^Q$$
$$Q_{D,mt} = \alpha_t^D + \gamma^{i,D} z_{mt}^i + \varepsilon_{D,mt}^Q$$

Cost function: Estimation

Parameter Estimates						
K_1	K_2	K_3	K_4	K_5	ω_M	ω_L
0.283	−0.018	0.043	0.014	0.050	−1.900	1.080

Implied Hessian H				
	$\frac{\partial C}{\partial Q_D}$	$\frac{\partial C}{\partial Q_M}$	$\frac{\partial C}{\partial Q_L}$	$\frac{\partial C}{\partial Q_S}$
Q_D	0.225	−0.260	−0.218	−0.219
Q_M	−0.260	0.220	0.319	0.317
Q_L	−0.218	0.319	0.263	0.264
Q_S	−0.219	0.317	0.264	0.266

▸ Cost instruments estimates

- ↑ \$100 million in reserves for each bank branch
- ↓ 21.9bps in MC of deposits

Counterfactuals

Counterfactuals

- In counterfactual IOER spread increases by an average of 16 bps (11.6 in data).
- Average interest rates on deposits, mortgages, and loans increase by 12.7 bps, 18.8 bps, and 15.6 bps.
- Loans to firms at 19 cents per dollar of reserves
- Deposits and mortgages respond less.

Average Change in Rates (in Basis Points)				Average Change in Quantities (in Trn Dollars)			
Deposits	Mortages	Loans	Securities	Deposits	Mortages	Loans	Securities
12.6728	18.8151	15.6384	15.9824	0.1224	-0.0218	-0.3530	1.8258

Counterfactuals

- Estimated impact of reserve supply in bank loan quantities.

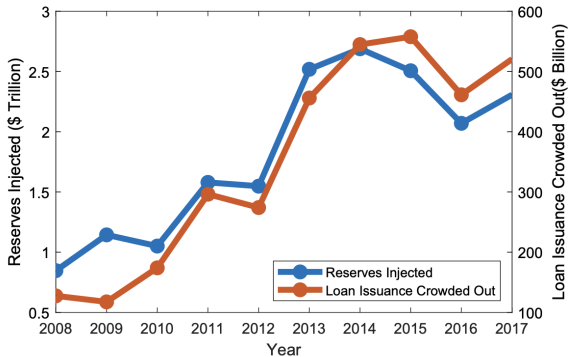

Figure: Reserve Supply and Reduction in Corporate Loan Issuance

Conclusions

Conclusions

- Propose reserve supply channel" to quantify the effect of reserve supply on bank balance sheets.
- Estimate structural model:
  - Demand of deposits, mortgages, and loans
  - Supply with cost interactions between bank balance sheet components
  - Identification: cross-sectional instruments
- $1 of reserves crowd out 19 cents of loans from bank balance sheets.
- **Potential solutions:** Relax bank leverage regulation (SLR), allow non-banks to hold reserves.

Thank you!

Appendix: Demand Estimation First Stage

Back

Panel (a): First Stage Panel Regression

	(1)	(2)	(3)
	Deposit Rate	Mortgage Rate	Loan Rate
IV	1.66***	10.82***	2.15***
	(0.21)	(1.66)	(0.28)
Loan Loss Provision	110.00***	−186.70***	151.49*
	(31.16)	(60.84)	(79.96)
Lag Deposit Market Share	1.58***		
	(0.42)		
Lag Insured Deposit Ratio	45.87***		
	(9.51)		
Log Property Damage	−4.71***	−2.65***	
	(0.96)	(0.49)	
Observations	217,623	77,329	25,115
R^2	0.82	0.91	0.19
Adjusted R^2	0.78	0.85	0.16
Market-Year F.E.	Y	Y	Y

Appendix: Cost Function Instruments Estimates

Back

Panel (a): Results using Natural Disaster Instrument

	Dep Cost	Mtg Cost	Loan Cost	Dep Vol	Mtg Vol	Loan Vol	Sec Vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sheldus Instrument	-1.04^{***}	1.24^{***}	2.14^{***}	11.11^{***}	1.09^{***}	8.84^{***}	3.62^{***}
	(0.10)	(0.19)	(0.70)	(1.77)	(0.33)	(1.40)	(0.81)
Loan Loss Provision	-1.28	-16.55^{***}	4.86^{*}	8.10^{**}	27.00^{***}	536.38^{***}	1.13
	(1.30)	(2.83)	(2.59)	(3.81)	(4.18)	(17.48)	(1.74)
Observations	52,752	12,208	2,953	118,942	119,236	119,236	118,923
R^2	0.59	0.77	0.18	0.002	0.002	0.01	0.001

Panel (b): Results using Bartik Deposit Shock

	Dep Cost	Mtg Cost	Loan Cost	Dep Vol	Mtg Vol	Loan Vol	Sec Vol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bartik Instrument	64.39^{***}	-52.06^{***}	1.44	$1,414.31^{***}$	345.34^{***}	315.13^{***}	439.36^{***}
	(5.30)	(12.14)	(45.04)	(173.95)	(17.37)	(43.36)	(86.24)
Loan Loss Provision	-0.15	-16.68^{***}	3.99	31.07	24.35^{***}	161.54^{***}	-16.77
	(1.27)	(3.00)	(8.69)	(36.38)	(4.17)	(10.41)	(18.04)
Observations	49,265	10,446	2,512	62,352	66,839	66,839	62,346
R^2	0.46	0.77	0.18	0.002	0.01	0.005	0.001