The Reserve Supply Channel of Unconventional Monetary Policy

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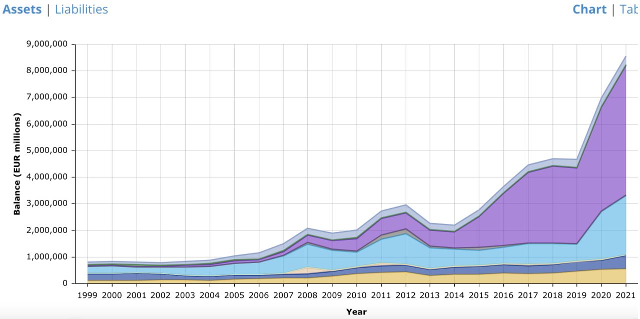
Motivation

- Continued expansion of central bank balance sheets since 2008
- Reserves outstanding in the U.S.: \$50 billion in 2006, \$2.8 trillion in 2015, and \$4.1 trillion in 2021
- The ECB's balance sheet has also grown substantially:



Motivation

- Main contributor is QE/APP: purchase of securities by issuing central bank reserves
  - Securities purchased are predominantly held by non-banks
  - Reserves are safe, liquid assets that can only be held by banks
- Bank balance sheet space is costly from post-crisis regulation
  - E.g. leverage ratio requirements
- **What is the impact of this large reserve supply on borrowing and lending by banks? Are there any side-effects of having a large reserve supply in the banking system?**
  - Important for thinking about optimal central bank balance sheet size

Reserves and Bank Lending: Previous Theory

The impact of reserve supply on bank lending is ambiguous in theory

1. Reserves could crowd-in bank lending:
    - Reserves are a scarce liquid asset whose supply constrains bank lending (e.g. Kashyap and Stein 93)
2. Reserves could also crowd-out bank lending
    - Scarce supply of bank equity (e.g. He and Krishnamurthy 13) and bank leverage regulation (e.g. Du, Tepper and Verdelhahn 18) makes it costly for banks to expand.

Reserves and Bank Lending in the Time Series

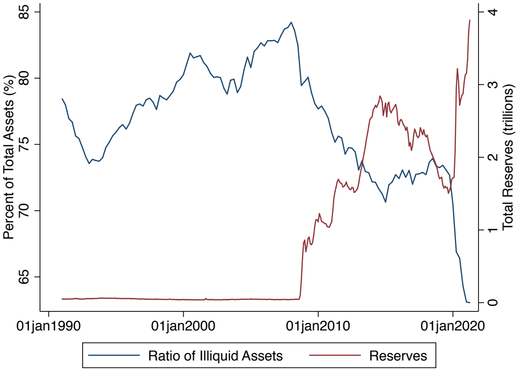


Figure: Reserve Supply and Bank Asset Illiquidity

- Time-series trends could be due to increase in reserve supply or the recession that triggered it in the first place

Our Approach

- Time-series trends suggestive but could be caused by the recession that led to QE
- We estimate a structural model of the market for bank deposits and loans, which answers two key questions.
  1. How elastic is the demand for deposits/loans?
  2. How does holding reserves change the cost of supplying deposits/loans?
- Counterfactual analysis: increase supply of bank reserves and compute new deposit/loan interest rates and quantities.

Main Findings

The "Reserve Supply Channel" of Unconventional Monetary Policy:

1. Adding the actual amounnt of reserves injected from 2008 to 2017, each dollar of reserves crowds out 19 cents of corporate bank lending.
2. Deposit and mortgage quantities are less affected
    - Demand for large corporate loans is much more rate-elastic than deposit and mortgage demand

Mechanism: only banks can hold reserves and balance sheet space is costly

Relation to Literature

1. Estimate a new channel of QE transmission through bank balance sheets
   - Asset prices: e.g. Krishnamurthy and Vissing-Jorgensen 11
   - Bank balance sheet: e.g. Rodnyansky and Darmouni 17, Chakraborty et al. 20, Kandrac and Schlusche 2021
   - Financial stability implications: Acharya and Rajan 22
2. Quantify synergies between illiquid loans, liquid securities and deposit liabilities on bank balance sheets
   - Synergies: e.g. Kashyap and Stein 93, Diamond and Rajan 00, Kashyap et al. 02
   - Balance sheet constraints: e.g. He and Krishnamurthy 13, Du et al. 18
3. Develop a structural banking model identified using cross-sectional instruments
   - BLP: Egan, Hortacsu, and Matvos 17, Buchak 18, Wang et al. 20, Xiao 20, Buchak et al. 20
   - Revealed preferences: Akkus et al 16, Schwert 18, Craig and Ma 18

Roadmap

1. **Model**
2. Demand System
3. Cost Function
4. Counterfactual
5. Conclusion

Model in One Slide

- Each bank m faces a residual demand curve $Q_L(R_{L,m}, R_{L,-m})$ for the quantity it can lend at rate $R_{L,m}$. Similar for deposits and mortgages.
- Bank pays a "liquidity cost" $C(Q_L, Q_D, Q_M, Q_S)$, maximizes profits

$$(R_{L,m} - R_{0,L})Q_L + (R_{M,m} - R_{M,0})Q_M + (R_S - R_0)Q_S \\ -(R_{D,m} - R_{D,0})Q_D - C(Q_L, Q_D, Q_M, Q_S).$$

- Optimal loan rate R_L given by

$$\overbrace{\frac{d}{dR_L}((R_{L,m} - R_{L,0}) \cdot Q_L(R_{L,m}, R_{L,-m}))}^{\text{Marginal Revenue}} = \overbrace{C_L(Q_L, Q_D, Q_M, Q_S)Q_L'(R_{L,m}; R_{L,-m})}^{\text{Marginal Cost}}.$$

- Similar equations for deposits and mortgages. For liquid securities, market is competitive:

$$(R_S - R_0) = C_S(Q_L, Q_D, Q_M, Q_S).$$

Graphical Illustration

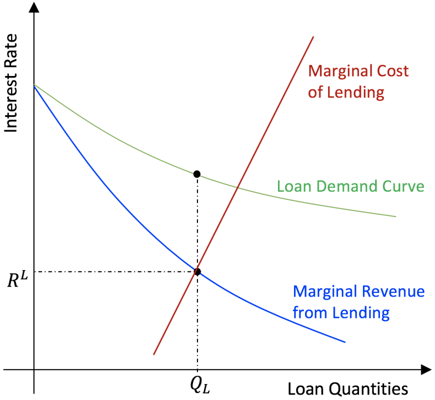


Figure: Demand, MR, and MC in an Imperfectly Competitive Loan Market

Graphical Illustration

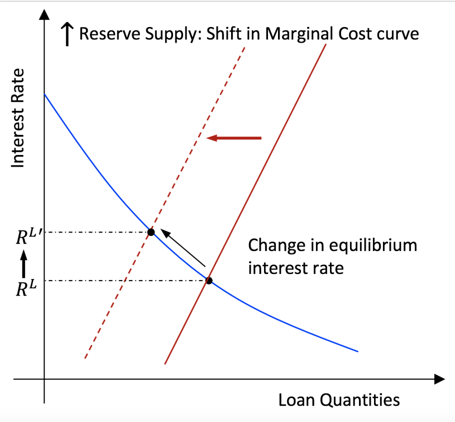


Figure: Effect of Reserve Supply Increase

Graphical Illustration

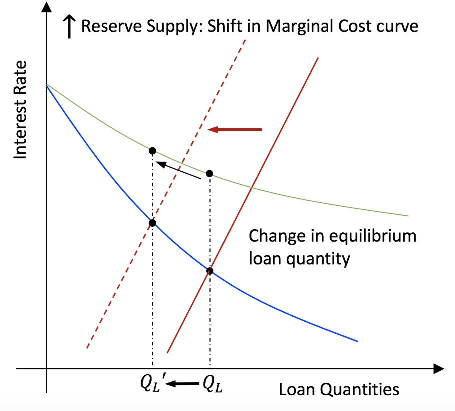


Figure: Effect of Reserve Supply Increase

Our Approach: Objects to Estimate

1. The residual demand curve $Q_L(R_{L,m}, R_{L,-m})$ for bank loans, deposits, mortgages
    - IO-style demand estimation (Berry, Levinsohn, Pakes (1995))
    - Need: supply shock IV
2. Banks' marginal cost of lending in terms of balance sheet composition
    - Multiple balance sheet components simultaneously respond
    - Need: multiple IVs

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Demand System Estimation: Data

- Annual bank-market-level data from 2001 to 2017
  1. Deposits
     - County-level market
     - Deposit volume: FDIC
     - Deposit rate: RateWatch (10K Money Market rate)
  2. Mortgages
     - County-level market
     - Mortgage volume: HMDA
     - Mortgage rate: RateWatch (15 Year Fixed Rate)
  3. Loans
     - State-level market (defined by location of borrower)
     - Loan volume and rates: Dealscan
- Bank-level characteristics from Call Reports

Demand System Estimation: Instrument

- Need: shock to loan/deposit supply to trace out demand curves
- Supply shock: Reallocation of bank funding after natural disasters following Cortes and Strahan 17
  - Natural disasters provide a positive shock to local loan demand
  - Banks reallocate funds away from other bank branches to meet demand
  - $\rightarrow$ negative loan supply shocks at other branches of bank
- Assumption for validity: Natural disasters do not directly affect demand for deposits, loans, and mortgages in unaffected counties (in a way that correlated with banks' branch network)

Demand System Estimation: Instrument

- For bank m in market n in year t:

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

  - N^u_{mt}: number of unaffected branches of bank m
  - $damage_{n't}$: 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 Estimation

- We use a logit demand system, where deposit quantities $Q_{D,nmt}$ satisfy the following linear relationship

$$\log Q_{D,nmt} - \log Q_{D,nm't} = \alpha_D(R_{D,nmt} - R_{D,nmt}) + \beta_D(X_{D,nmt} - X_{D,nm't}) + (\delta_{D,nmt} - \delta_{D,nm't}).$$

- Estimate α_D by 2 stage least squares:

$$\begin{aligned} R_{D,nmt} &= \gamma_{D,nt} + \gamma_D z_{D,nmt} + X_{D,mt}\gamma_D + e_{D,nmt}, \\ \log Q_{D,nmt} &= \zeta_{D,nt} + \alpha_D R_{D,nmt} + X_{D,nmt}\beta_D + \delta_{D,nmt}. \end{aligned}$$

- Similarly for mortgages and loans

Demand System Estimation: 2SLS Results

	(1)	(2)	(3)
	Deposit Market Share	Mortgage Market Share	Loan Market Shar
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

10 bps increase in deposit rate ⇒ deposit volume increase by 4.685%

Demand System Estimation: Outside Options and Mark-up

- α_D describes how the **difference** between two bank's log quantities depends on the **difference** between their interest rates.
- What happens when the overall **level** of deposit rates in a county increases?
- We aggregate our instrument to a county-level shock to see how aggregate quantities respond to an aggregate shock to interest rates δ^o.
- Interpretation: If all banks change their deposit rate by 10bps
  - Change in deposits: 1.3%:
  - Change in mortgages: 4.0%.
  - Change in loans: 16.1%

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Cost Function

- Recall the key first-order condition for bank i's lending rate:

$$\overbrace{\frac{d}{dR_{L,m}}((R_{L,m} - R_{L,0}) \cdot \frac{Q_L(R_{L,m}, R_{L,-m}))}{Q'_L(R_{L,m}; R_{L,-m})}}^{\text{Marginal Revenue}} = \overbrace{C_L(Q_L, Q_D, Q_M, Q_S)}^{\text{Marginal Cost}}.$$

- We estimated the demand system on the left hand side = realized data of banks' marginal cost of providing deposits/mortgages/loans
- Next step: See how marginal costs respond when bank adjusts balance sheet (Q_L, Q_D, Q_M, Q_S) in response to a demand shock.

Cost Function

- For bank m at time t, we let the cost function be

$$\begin{aligned} C(\Theta_{mt}) &= \mu_D Q_{D,mt} + \mu_M Q_{M,mt} + \mu_L Q_{L,mt} + \mu_Q Q_{S,mt} \\ &+ \frac{1}{2}(K_1 \mathcal{E}_{mt}^2 + K_2 \mathcal{I}_{mt}^2 + K_3 Q_{D,mt}^2 + 2K_4 \mathcal{I}_{mt} Q_{D,mt} + 2K_5 \mathcal{E}_{mt} Q_{D,mt}) \\ &+ \sum_n (Q_{M,nmt} \varepsilon_{M,nmt}^Q + Q_{L,nmt} \varepsilon_{L,nmt}^Q + Q_{D,nmt} \varepsilon_{D,nmt}^Q) + Q_{S,mt} \varepsilon_{mt}^S. \end{aligned}$$

  where bank equity is $\mathcal{E}_{mt} = Q_{M,mt} + Q_{L,mt} + Q_{S,mt} - Q_{D,mt}$ and bank asset liquidity is $\mathcal{I}_{mt} = Q_{S,mt} + \omega_M Q_{M,mt} + \omega_L Q_{L,mt}$.

- In a standard supply-and-demand model, we observe how much a demand shock moves both prices and quantities to trace out the slope of the supply curve.

- In our context, if we have e.g. a deposit demand shock, both deposit and loan quantities can respond and they both affect C.

Cost Function Estimation

- Multiple endogenous variables → need multiple instruments
  1. z^1: Natural disaster shock (reused at bank level → demand shock)
  2. z^2: Bank's exposure to regional deposit demand shocks (Bartik instrument).
     - Average deposit market growth in counties where the bank has branches

Cost Function Estimation

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  1. z^1: Natural disaster shock (reused at bank level → demand shock)
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- Regress marginal costs of borrowing/lending and all balance sheet quantities on each demand IV, e.g., deposits

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

- Regression coefficients jointly determine cost function parameters

Cost Function Estimation: Marginal Cost IV Regression

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

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)
-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)
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)
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)

Cost Function Estimation: Results

Cost function hessian → how balance sheet quantities impact marginal costs of borrowing and lending.

	$\frac{\partial C}{\partial D}$	$\frac{\partial C}{\partial M}$	$\frac{\partial C}{\partial L}$	$\frac{\partial C}{\partial S}$
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

- ↑ $100 million in reserves for each bank branch
  - 21.9 bps ↓ in MC of deposits
  - 31.7 bps ↑ in MC of mortgages
  - 26.4 bps ↑ in MC of loans
  - 26.6 bps ↑ in MC of securities

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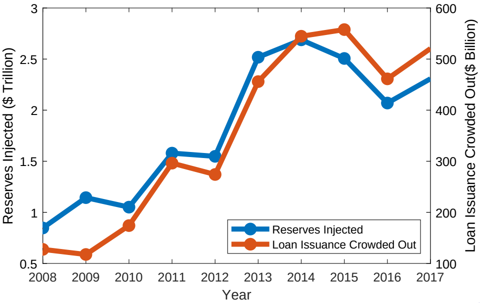
Counterfactual Analysis: QE

- We use our model to simulate the impact of a higher reserve supply
- We conduct a counterfactual with the actual amount of reserves added from 2008 to 2017
- Banks trade new reserves in a competitive market with each other, and choose new optimal deposit/mortgage/loan interest rates.
- Both interest rates and quantities respond in deposit/mortgage/loan markets in new equilibrium.

Counterfactual Analysis: Results

- IOER spread: increases by an average of 16 bps
  - Observed IOER-FFR spread in the data: 11.6 bps
- Average interest rates on deposits, mortgages, and loans increase by 12.7 bps, 18.8 bps, and 15.6 bps
- Most significant response in bank loans to firms at 19 cents per dollar of reserves; deposits and mortgages respond less



Conclusion

- This paper: new "reserve supply channel" to quantify the effect of reserve supply on bank balance sheets
- Structural model:
  - Demand: Imperfect competition in deposits, mortgages, and loans
  - Supply: cost synergies between bank balance sheet components
  - Identification: cross-sectional instruments
- Counterfactual: $1 of reserves **crowd out** 19 cents of loans from bank balance sheets
- Potential solutions for crowding out: relax bank leverage regulation (SLR), allow non-banks to hold reserves.