

Central Bank's Balance Sheet and Treasury Market Disruptions

Adrien d'Avernas

Stockholm School of Economics

Damon Petersen

MIT

Quentin Vandeweyer

University of Chicago

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Motivation

Drastic evolutions in Treasury and repo markets in the last decade:

- ▷ Frequent market disruptions

data

- repo (qt-ends 2014-2020, Sept. 2019) and Treasury (US: Mar. 2020, UK: Sept. 2022)

- ▷ Non-banks (hedge funds) became more active in Treasury markets

data

- driven by the opening of cash-future basis (Barth and Kahn, 2021)

- ▷ Central banks interventions and act as “lender-of-last-resort”

data

- new facilities to support funding markets and difficulties unwinding balance sheet

This Paper

Goal: Propose a theory that jointly explains those facts with minimal assumptions
→ learn about the mechanisms and policy implications (Lucas' Critique proof)

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Method: Dynamic intermediary AP model matching observations on three shocks:

- ▷ intermediation shock (e.g., quarter-ends, change in regulation, financial crisis)
- ▷ net repo supply shock (e.g., tax deadlines, preference shock, relative risk, CBDC)
- ▷ net treasury supply shock (e.g., issuances, QT, FX reserves rebalancing)

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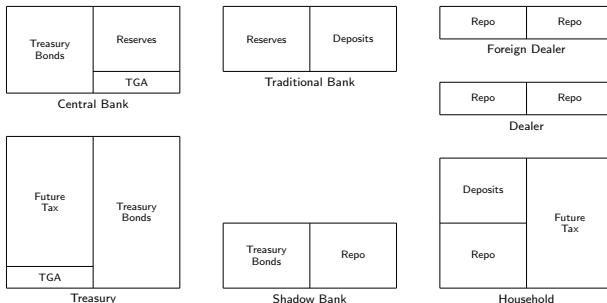
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- ▷ net treasury supply shock (e.g., issuances, QT, FX reserves rebalancing)

Results:

- ▷ Central bank balance sheet is the key state variable (both sides matter)
- ▷ $\exists$ a policy trade-off between shock frequency and intensity
- ▷ shock duration determines if repo or Treasury market gets more affected
- ▷ facility efficiency depends on specific design

Full Framework

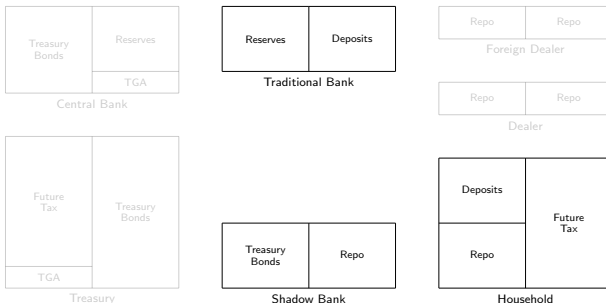


Four frictions:

- ▷ Repo and deposits are imperfect substitutes for households
- ▷ Intraday liquidity requirements (from RLAP)
 - Copeland, Duffie, Yang (2022); d'Avernas, Han, Vandeweyer (2022)
- ▷ Balance sheet cost (from leverage ratio)
 - Du, Tepper, Verdelhan (2018); Anderson, Duffie, Song (2019); Du, Hébert, Li (2022);
- ▷ Treasury transaction cost

Multiple Shocks

Simplified Framework



Four frictions:

- ▷ Repo and deposits are imperfect substitutes for households
- ▷ Intraday liquidity requirements
→ Copeland, Duffie, Yang (2022); d'Avernas, Han, Vandeweyer (2022)
- ▷ ~~Balance sheet cost~~ → traditional banks cannot borrow in repo
- ▷ Treasury transaction cost

~~Multiple shocks~~ → **Single preference shock**

Outline

- 1 Introduction
- 2 Simplified Model**
- 3 Full Model
- 4 Conclusion

Simplified Model Description

full problem

General:

- three agents maximize lifetime utility from consumption
- treasury bonds incur a transaction cost of ν

Households:

- utility derived from holding imperfect substitute repo and deposits:

$$h_t = d_t^{\alpha_t} p_t^{1-\alpha_t}$$

- Preference parameter α_t subject to Poisson shock
→ intensity λ for shock from α^s to $\alpha' \sim \mathcal{U}[\alpha^s, 1]$ and λ' for shock from α' to α^s

Traditional Bankers:

- solve portfolio problem: treasuries b_t , reserves m_t , repo p_t and deposit d_t
- are subject to intraday liquidity stress test (LST): $p_t < \kappa m_t$
- cannot borrow in repo (relaxed below)

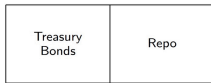
Shadow Bankers:

- solve portfolio problem of holding Treasuries ($\bar{b}_t$) and borrowing in repo ($\bar{p}_t$)
- cannot issue deposits or hold reserves

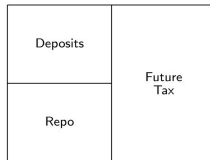
Perfectly Inflexible Benchmark



Traditional Bank

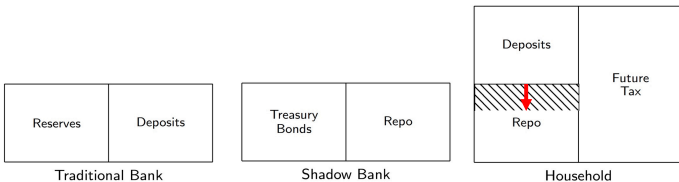


Shadow Bank

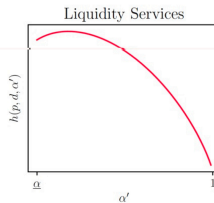
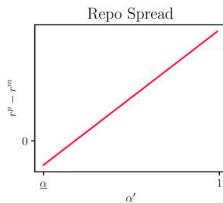
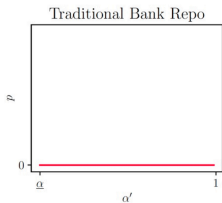


Household

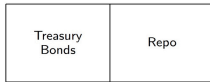
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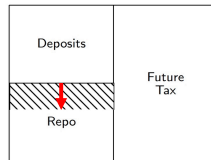
Perfectly Inflexible Benchmark



Traditional Bank

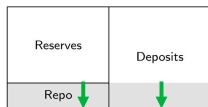


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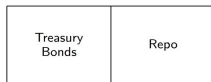


Household

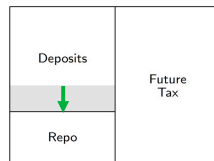
Banks as Lender-of-Next-to-Last-Resort



Traditional Bank

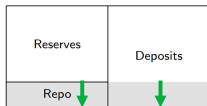
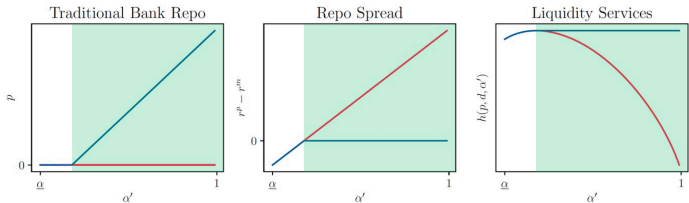


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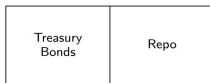


Household

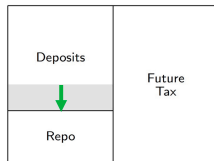
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Traditional Bank

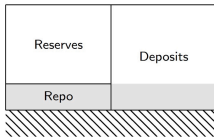


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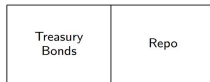


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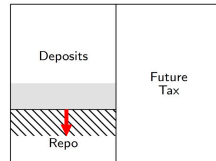
Liquidity Stress Test Regulation



Traditional Bank

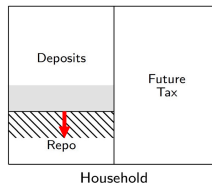
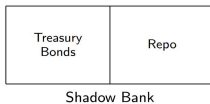
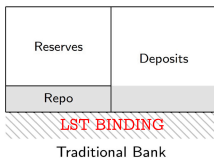
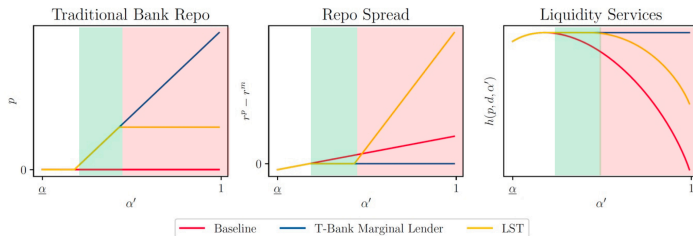


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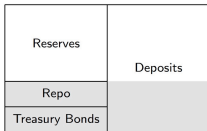


Household

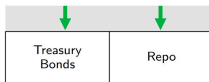
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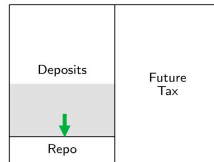
Treasury Sales



Traditional Bank

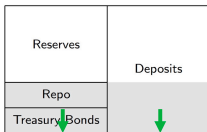
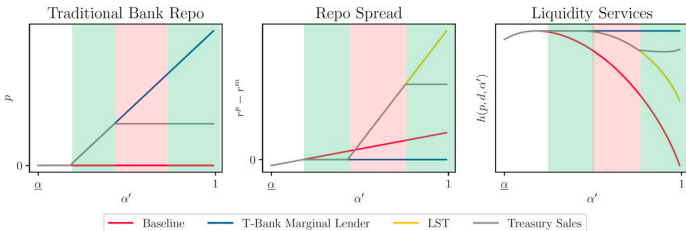


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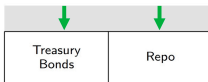


Household

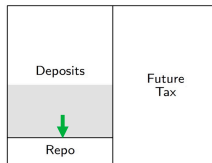
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Traditional Bank

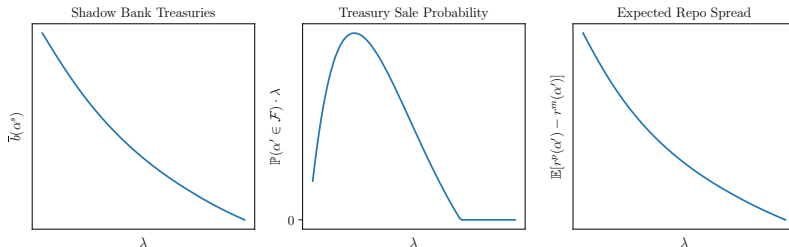


Shadow Bank



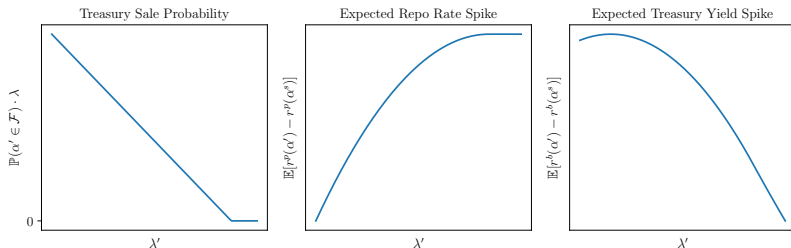
Household

Volatility Paradox



- Lower risk of funding shock (lower Poisson intensity λ):
 - ⇒ More shadow banks Treasury holdings and leverage ex-ante
 - ⇒ Higher chances of fire-sale
 - ⇒ Larger repo and Treasury spikes
 - ⇒ Similar to Brunnermeier and Sannikov (2014)
- ▷ More market intervention can increase fragility

Shock Duration: Repo vs Treasury

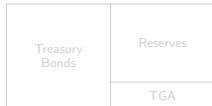


- Higher shock duration (lower Poisson intensity λ'):
 - ⇒ Higher sale region and lower repo rate spike
 - ⇒ Better to sell bonds than sustain losses for a long time
- ▷ September 2019 repo spike versus March 2020 Treasury spike

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Full Framework



Central Bank



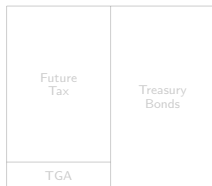
Traditional Bank



Foreign Dealer



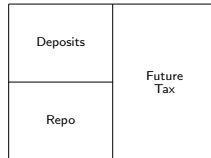
Dealer



Treasury



Shadow Bank



Household

Full Framework

Treasury Bonds	Reserves
	TGA

Central Bank

Reserves	Deposits
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Traditional Bank

Repo	Repo
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Foreign Dealer

Repo	Repo
------	------

Dealer

Future Tax	Treasury Bonds
TGA	

Treasury

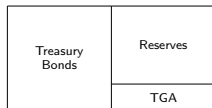
Treasury Bonds	Repo
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Shadow Bank

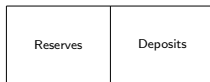
Deposits	Future Tax
Repo	

Household

Full Framework



Central Bank



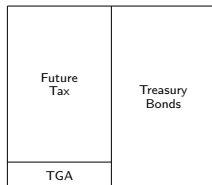
Traditional Bank



Foreign Dealer



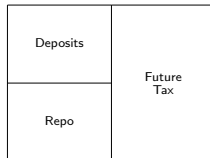
Dealer



Treasury



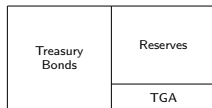
Shadow Bank



Household

- ▷ Traditional banks also borrow in repo but subject to balance sheet cost χ
- ▷ Dealer subsidiaries does matched-book intermediation x_t and f_t
 - between MMFs (triparty repo) and shadow banks (bilateral repo)

Full Framework



Central Bank



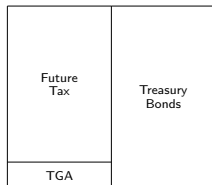
Traditional Bank



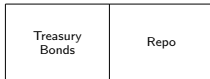
Foreign Dealer



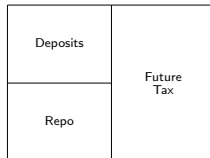
Dealer



Treasury



Shadow Bank



Household

- ▷ Traditional banks also borrow in repo but subject to balance sheet cost χ
- ▷ Dealer subsidiaries does matched-book intermediation x_t and f_t
 - between MMFs (triparty repo) and shadow banks (bilateral repo)
- ▷ Three additional shocks:
 - Foreign dealer capacity
 - Treasury balance sheet
 - Central Bank balance sheet

Central Bank

- ▷ Control effective supply of reserves and Treasuries through its balance sheet

$$\underline{b} + rp_t = m_t + a + rrp_t$$

m_t reserves available to banks, a Treasury account, $\underline{b}$ Treasury bonds

Central Bank

- ▷ Control effective supply of reserves and Treasuries through its balance sheet

$$\underline{b} + rp_t = m_t + a + rrp_t$$

m_t reserves available to banks, a Treasury account, $\underline{b}$ Treasury bonds

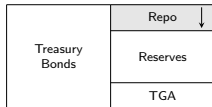
- ▷ Repo (lending) rate r^{rp} with repo facility rp_t
- ▷ Reverse repo (borrowing) rate r^{rrp} with reverse repo facility rrp_t

	Repo Rate	Interm. Spread	RRP vol.	TGA vol.
Quarter End	+	+	+	0
Tax Deadline	+	0	-	+
Treasury Issuance	+	+	0	+

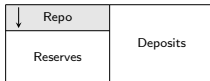
Data Qualitative Summary

- Shock: ↓ foreign dealer balance sheet
- Captures quarter-end effect following window dressing by non-U.S banks
- ▷ Anbil and Senyuz (2020): increase in reverse repo volumes and repo spreads
- ▷ Correa, Du, and Liao (2022): reserve-draining intermediation
- ▷ Diamond, Jiang, Ma (2022): reserves crowd out lending

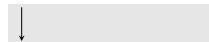
Intermediation Shock



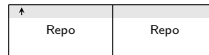
Central Bank



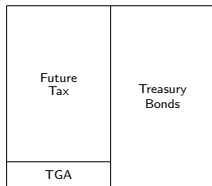
Traditional Bank



Foreign Dealer



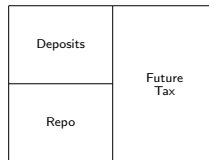
Dealer



Treasury

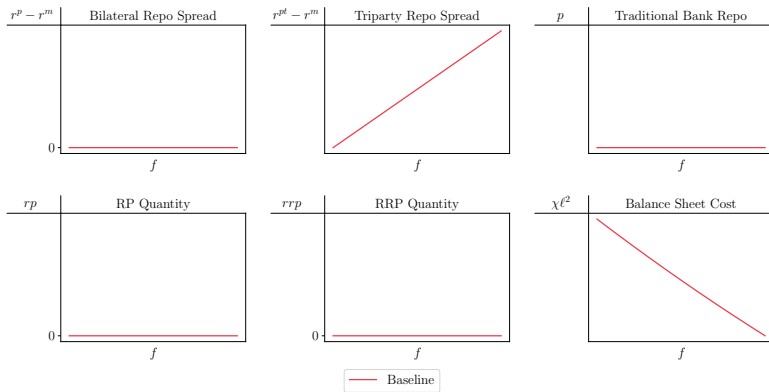


Shadow Bank



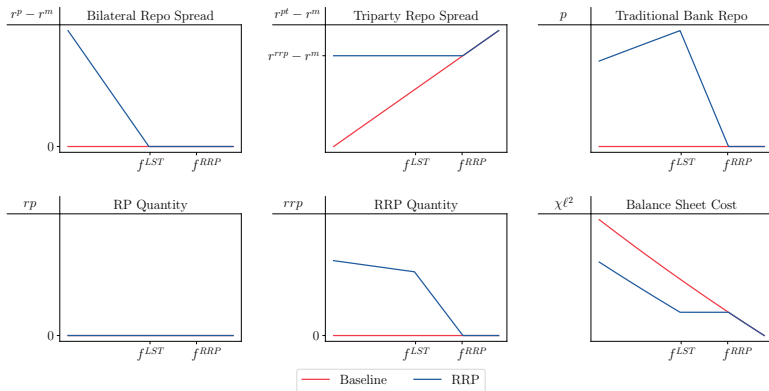
Household

Intermediation Shock



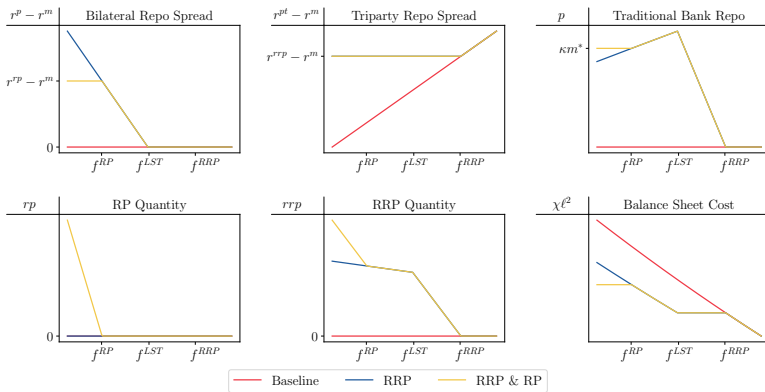
- Reserve-draining intermediation not possible

Intermediation Shock: LST + Reverse Repo Facility



- RRP allows reserve-draining intermediation f^{RRP}
- T-banks need to do matched-book intermediation once LST binds f^{LST}

Intermediation Shock: + Repo Facilities



- Fed becomes repo dealer of last resort with RRP+RP facility
- Need to give access to s-banks o/w r^{RP} not a ceiling

Intermediation Shock: Spike Necessary Conditions

A repo or Treasury spike requires all four elements:

- A balance sheet cost
 - o/w traditional banks, funded with both deposits and repo, hold all Treasuries
- A liquidity stress test regulation (LST)
 - o/w arbitrage between repo and reserves
- A transaction cost
 - o/w shadow banks get rid of Treasuries and funding needs
- A reverse repo facility (RRP)
 - o/w repo spreads adjust through lower Triparty rates

Tax Deadline Shock: Motivation

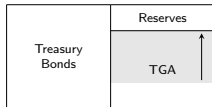
Full Regression

	Repo Rate	Interm. Spread	RRP vol.	TGA vol.
Quarter End	+	+	+	0
Tax Deadline	+	0	-	+
Treasury Issuance	+	+	0	+

Data Qualitative Summary

- Shock: ↑ increase in TGA; ↓ reserves; ↓ repos from households
- Captures:
 - on tax deadlines, corporations move money from MMF to TGA
 - September 2019 repo spike happened on a tax deadline
- Du, Liao, and Correa (2022): TGA increase removes reserves from banks

Tax Deadline Shock



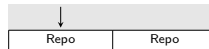
Central Bank



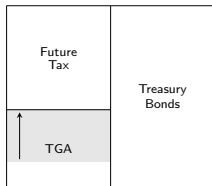
Traditional Bank



Foreign Dealer



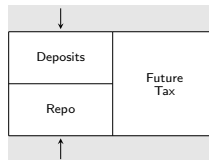
Dealer



Treasury

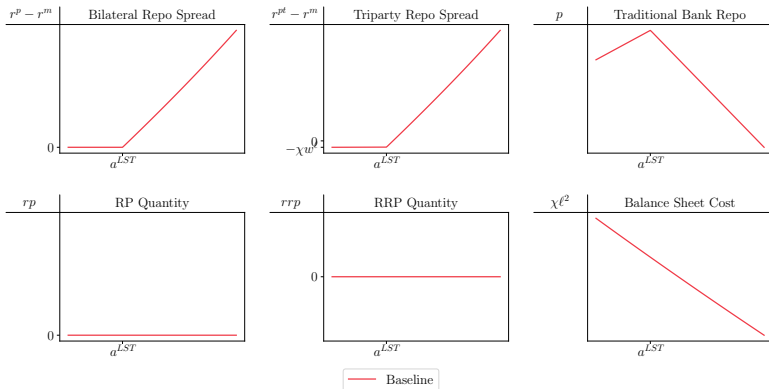


Shadow Bank



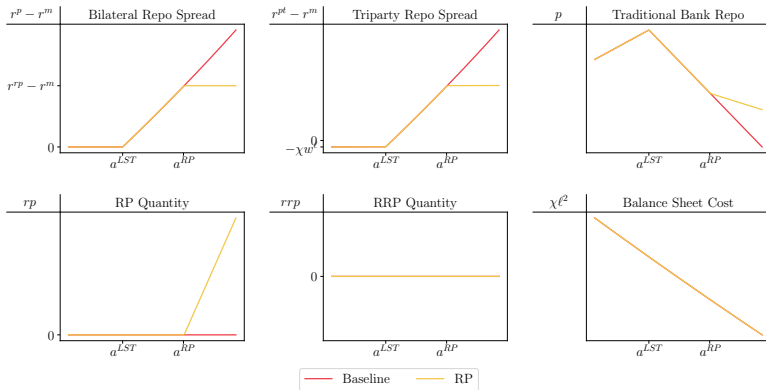
Household

Tax Deadline Shock: Baseline with LST



- Decline in repo funding forces banks to step in
- Decline in reserves creates balance sheet space
- MMFs need to provide more repo funding when LST binding

Tax Deadline Shock: RP Facility



- No RRP necessary
- RP could be open only to t-banks (balance sheet cost would not decrease)

	Repo Rate	Interm. Spread	RRP vol.	TGA vol.
Quarter End	+	+	+	0
Tax Deadline	+	0	-	+
Treasury Issuance	+	+	0	+

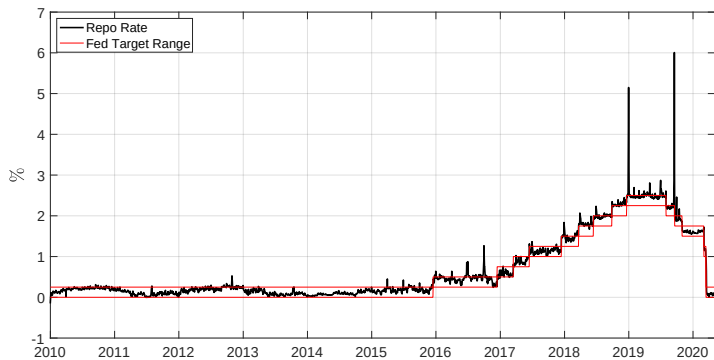
Data Qualitative Summary

- Shock: ↓ reserves; ↑ Treasuries
- Increases the demand for repo from shadow banks
- Decreases reserves available to meet LST requirements

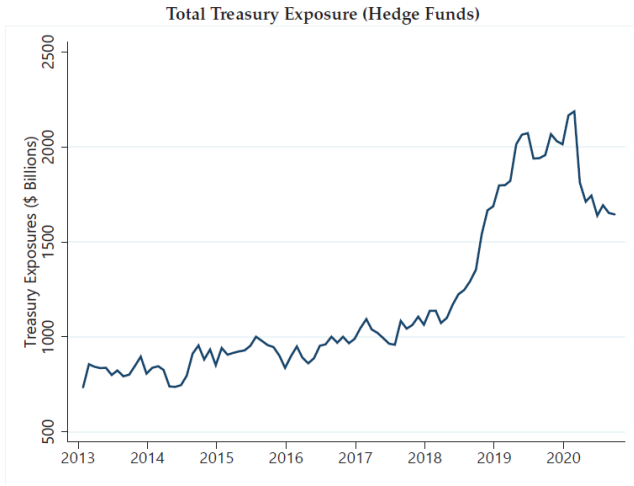
Conclusion

- General equilibrium framework to understand Treasury and repo markets
→ accounting consistency is key (every financial asset is someone else's liability)
- Framework rationalize all recent market disruptions
- Facility access design matters for some shocks but not others
- Volatility paradox: importance of shock persistence and intervention expectations

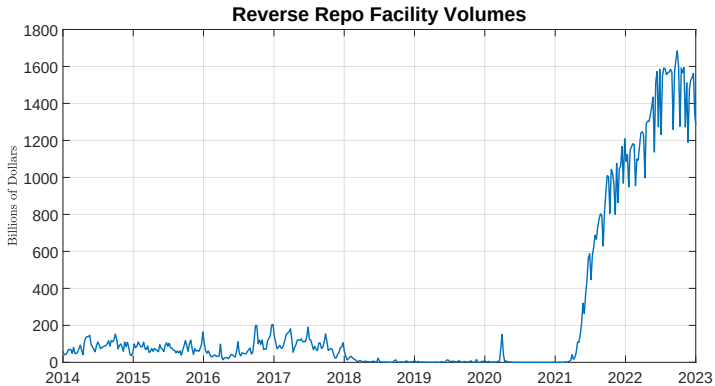
APPENDIX

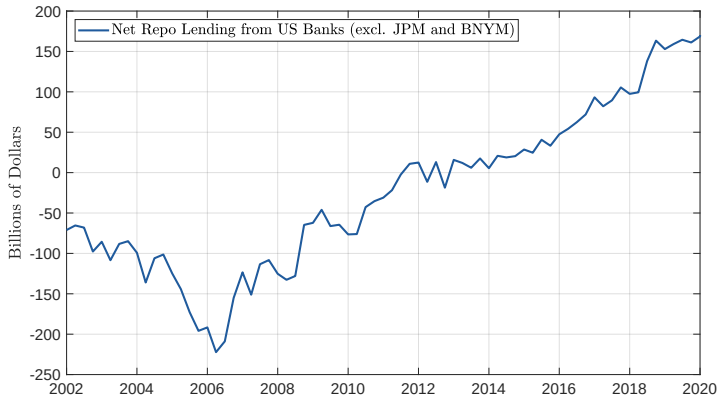






- ▷ Half of all hedge funds positions
- ▷ Positions funded using a quarter of all dealers' repo lending





- Households also value consumption c and liquidity services s

$$\max_{\{c_\tau \geq 0, p_\tau \geq 0, d_\tau \geq 0\}_{\tau=t}^\infty} \mathbb{E}_t \left[\int_t^\infty e^{-\rho(u-t)} \left(\log(c_u) + \beta \log(s_u) \right) du \right]$$

$$s_t = d_t^{\alpha_t} p_t^{1-\alpha_t}$$

$$dn_t = (p_t r_t^{pt} + d_t r_t^d - c_t^h - r_t^\tau n_t) dt$$

$$p_t + d_t = n_t + \tau_t$$

- Net worth n_t , deposits d , repo p , tax liabilities τ_t
- Liquidity preference α_t subject to shocks
- Trade-off between optimal portfolio composition and rates of return

$$\max_{\{c_\tau \geq 0, w_\tau^k \geq 0, w_\tau^b \geq 0, w_\tau^m \geq 0, w_\tau^p, w_\tau^x \geq 0, w_\tau^d \geq 0\}_{\tau=t}^\infty} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$\frac{dn_t}{n_t} = (w_t^k r_t^k + w_t^b r_t^b + w_t^m r_t^m + w_t^p r_t^p + w_t^x (r_t^p - r_t^{pt}) - w_t^d r_t^d - c_t) dt$$

$$- \frac{\chi}{2} \ell_t^2 n_t dt + (e^{-\nu(|dw_t^k| + |dw_t^b|)} - 1) n_t$$

$$w_t^k + w_t^b + w_t^m + w_t^p = 1 + w_t^d$$

$$\ell_t = w_t^d - \min\{0, w_t^p\} + w_t^x$$

$$\max_{\{c_\tau \geq 0, w_\tau^k \geq 0, w_\tau^b \geq 0, w_\tau^m \geq 0, w_\tau^p, w_\tau^x \geq 0, w_\tau^d \geq 0\}_{\tau=t}^\infty} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$\begin{aligned} \frac{dn_t}{n_t} = & (w_t^k r_t^k + w_t^b r_t^b + w_t^m r_t^m + w_t^p r_t^p + w_t^x (r_t^p - r_t^{pt}) - w_t^d r_t^d - c_t) dt \\ & - \frac{\chi}{2} \ell_t^2 n_t dt + (e^{-\nu(|dw_t^k| + |dw_t^b|)} - 1) n_t \end{aligned}$$

$$w_t^k + w_t^b + w_t^m + w_t^p = 1 + w_t^d$$

$$\ell_t = w_t^d - \min\{0, w_t^p\} + w_t^x$$

- n_t is the net worth of the banker
- w_t^k and w_t^b are portfolio weight on capital and Treasury bonds
- Changing portfolio composition is costly due to transaction cost

$$\max_{\{c_\tau \geq 0, w_\tau^k \geq 0, w_\tau^b \geq 0, w_\tau^m \geq 0, w_\tau^p, w_\tau^x \geq 0, w_\tau^d \geq 0\}_{\tau=t}} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$\begin{aligned} \frac{dn_t}{n_t} = & (w_t^k r_t^k + w_t^b r_t^b + w_t^m r_t^m + w_t^p r_t^p + w_t^x (r_t^p - r_t^{pt}) - w_t^d r_t^d - c_t) dt \\ & - \frac{\chi}{2} \ell_t^2 n_t dt + (e^{-\nu(|dw_t^k| + |dw_t^b|)} - 1) n_t \end{aligned}$$

$$w_t^k + w_t^b + w_t^m + w_t^p = 1 + w_t^d$$

$$\ell_t = w_t^d - \min\{0, w_t^p\} + w_t^x$$

- $w_t^d \geq 0$ is the portfolio weight on deposits
- Balance sheet cost: levering up is costly

$$\max_{\{c_\tau \geq 0, w_\tau^k \geq 0, w_\tau^b \geq 0, w_\tau^m \geq 0, w_\tau^p, w_\tau^x \geq 0, w_\tau^d \geq 0\}_{\tau=t}^\infty} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$\begin{aligned} \frac{dn_t}{n_t} = & (w_t^k r_t^k + w_t^b r_t^b + w_t^m r_t^m + w_t^p r_t^p + w_t^x (r_t^p - r_t^{pt}) - w_t^d r_t^d - c_t) dt \\ & - \frac{\chi}{2} \ell_t^2 n_t dt + (e^{-\nu(|dw_t^k| + |dw_t^b|)} - 1) n_t \end{aligned}$$

$$w_t^k + w_t^b + w_t^m + w_t^p = 1 + w_t^d$$

$$\ell_t = w_t^d - \min\{0, w_t^p\} + w_t^x$$

- ℓ_t is leverage
- w_t^p is lending or borrowing in bilateral repo with s-banks
- $w_t^x \geq 0$ is the intermediation of repo from households to s-banks (triparty)

$$\max_{\{c_\tau \geq 0, w_\tau^k \geq 0, w_\tau^b \geq 0, w_\tau^m \geq 0, w_\tau^p, w_\tau^x \geq 0, w_\tau^d \geq 0\}} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$\begin{aligned} \frac{dn_t}{n_t} = & (w_t^k r_t^k + w_t^b r_t^b + w_t^m r_t^m + w_t^p r_t^p + w_t^x (r_t^p - r_t^{pt}) - w_t^d r_t^d - c_t) dt \\ & - \frac{\chi}{2} \ell_t^2 n_t dt + (e^{-\nu(|dw_t^k| + |dw_t^b|)} - 1) n_t \end{aligned}$$

$$w_t^k + w_t^b + w_t^m + w_t^p = 1 + w_t^d$$

$$\ell_t = w_t^d + |[w_t^p]^-| + w_t^x$$

- Liquidity stress test regulation: $w_t^p \leq \kappa w_t^m$
- Repo lending is costly in terms of liquidity

$$\max_{\{c_\tau \geq 0, w_\tau^b \geq 0, w_\tau^p\}_{\tau=t}^\infty} \mathbb{E}_t \left[\int_t^\infty e^{-\rho\tau} \log(c_\tau n_\tau) d\tau \right]$$

$$dn_t = (w_t^b r_t^b - w_t^p r_t^p - c_t) dt + (e^{-\nu(|dw_t^b|)} - 1) n_t$$

$$w_t^b = 1 + w_t^p$$

- No balance sheet cost and liquidity regulation on shadow banks
- Shadow banks use repo for funding (no deposits)

Full Regression

Intermediation

Tax Deadlines

Treasury Issuance

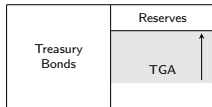
	(1) Δ TGCF-IOR	(2) Δ TGCF-TGCR	(3) Δ RRP	(4) Δ TGA
Quarter End	9.625*** (1.967)	0.0693*** (0.017)	102.4*** (12.117)	29.53*** (4.732)
Quarter End +1	-5.940 (4.111)	-0.0464 (0.028)	-118.7*** (18.006)	-40.93*** (5.245)
Tax Deadline	2.739*** (0.446)	0.00929 (0.006)	-0.304 (3.002)	47.10*** (6.614)
Tax Deadline +1	4.547 (6.230)	-0.00979 (0.012)	11.02*** (2.544)	14.57*** (3.066)
Δ Treasury Issuance	0.0165*** (0.003)	0.0000882*** (0.000)	0.00256 (0.008)	0.0417*** (0.007)
Constant	-0.275 (0.210)	0.000300 (0.001)	-0.511 (0.499)	-4.056*** (0.363)
N	2,010	1,971	1,277	2,010
Adj. R^2				

	Repo Rate	Interm. Spread	RRP vol.	TGA vol.
Quarter End	+	+	+	+
Tax Deadline	+	0	-	+
Treasury Issuance	+	+	0	+

Data Qualitative Summary

- Shock: ↑ increase in TGA; ↓ reserves; ↓ repos from households
- Captures:
 - on tax deadlines, corporations move money from MMF to TGA
 - September 2019 repo spike happened on a tax deadline
- Du, Liao, and Correa (2022): TGA increase removes reserves from banks

Tax Deadline Shock



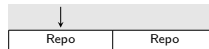
Central Bank



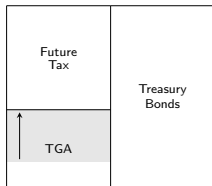
Traditional Bank



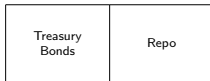
Foreign Dealer



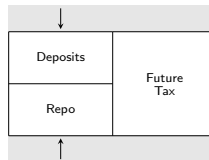
Dealer



Treasury

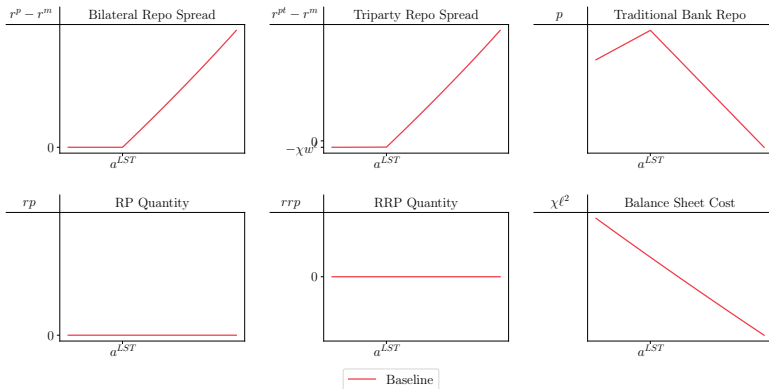


Shadow Bank



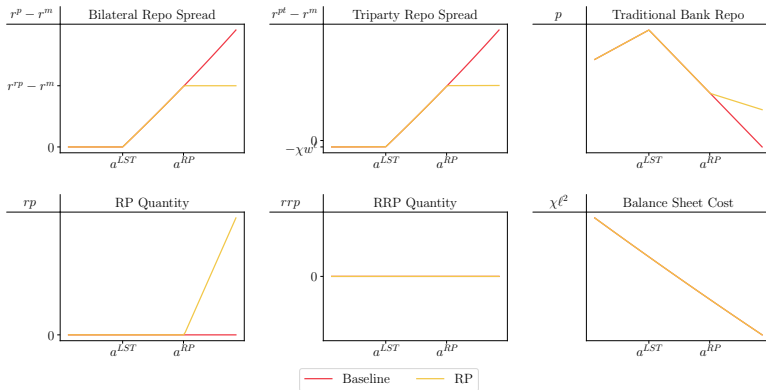
Household

Tax Deadline Shock



- Decline in repo funding forces banks to step in
- Decline in reserves creates balance sheet space
- MMFs need to provide more repo funding when LST binding

Tax Deadline Shock



- No RRP necessary
- RP could be open only to t-banks (balance sheet cost would not decrease)

	Repo Rate	Interm. Spread	RRP vol.	TGA vol.
Quarter End	+	+	+	+
Tax Deadline	+	0	-	+
Treasury Issuance	+	+	0	+

Data Qualitative Summary

- Shock: ↓ reserves; ↑ Treasuries
- Increases the demand for repo from shadow banks
- Decreases reserves available to meet LST requirements

Quantitative Tightening/Easing

Treasury Bonds	Reserves
	TGA

Central Bank

Future Tax	Treasury Bonds
TGA	

Treasury

Repo	Deposits
Reserves	
Securities	
	Net Worth

Traditional Bank

Treasury Bonds	Repo
	Net Worth

Shadow Bank

Repo	Repo
------	------

Foreign Dealer

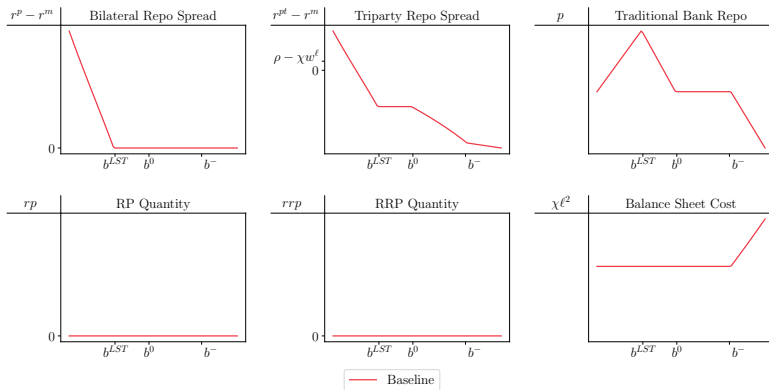
Repo	Repo
------	------

Dealer

Repo	Future Tax
Deposits	
	Net Worth

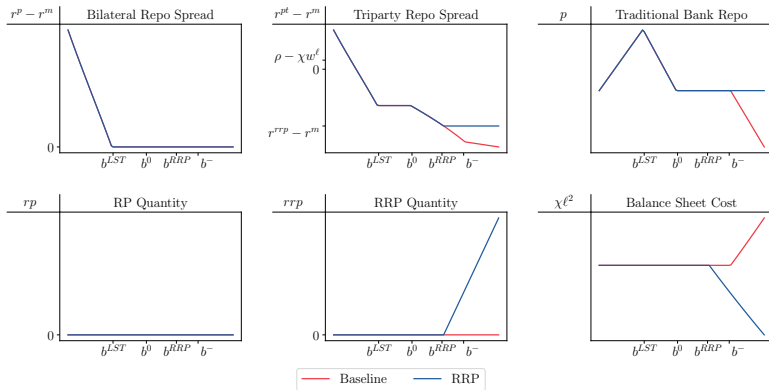
Household

Quantitative Tightening/Easing



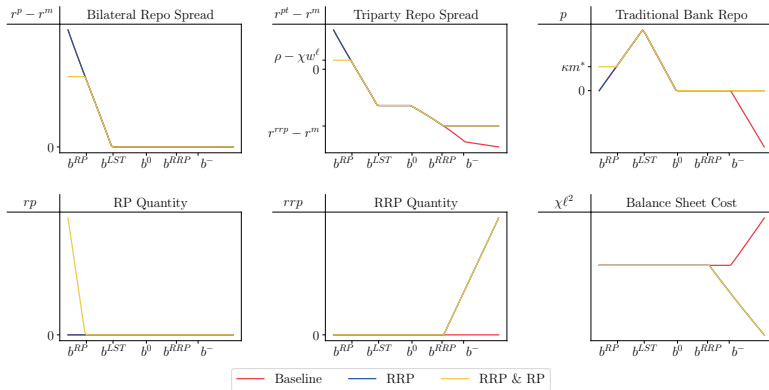
- No disruption when t-banks are marginal repo lenders (b_0 to b^{LST})
- Repo rates increase to attract MMFs when LST binding (below b^{LST})
- Higher reserves/bonds $\rightarrow$ less repo demand from s-banks (above b_0)
- T-banks fund themselves in repo if triparty rate low enough

Quantitative Tightening/Easing: Reverse Repo Facility



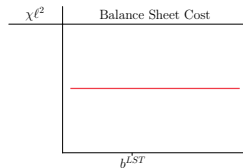
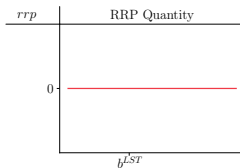
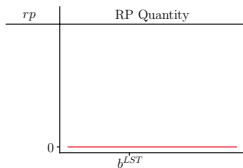
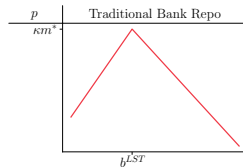
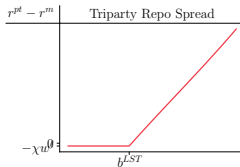
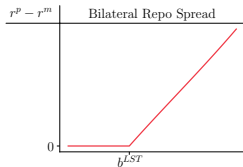
- RRP substitutes reserves for repo and puts a floor on triparty rates
- Less repo intermediated and less reserves → balance sheet cost decrease

Quantitative Tightening/Easing: Reverse Repo + Repo Facilities



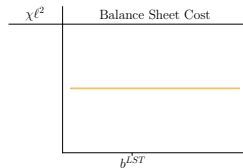
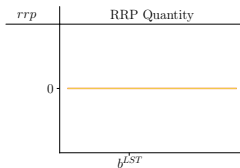
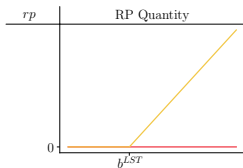
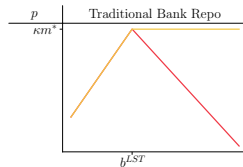
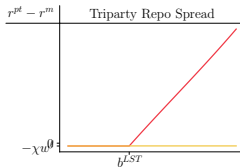
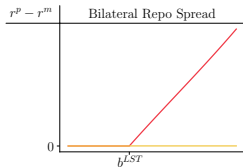
- RP takes care of the spike due to LST
- RRP and RP facilities active at opposite times

Fiscal Shock (Adjusting TGA)



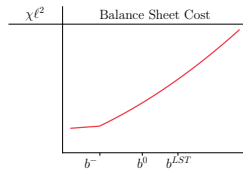
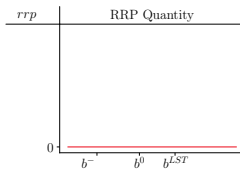
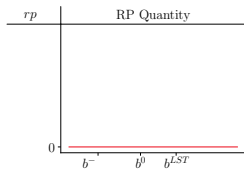
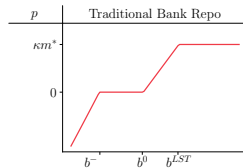
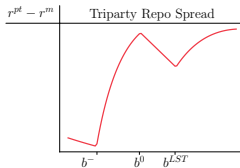
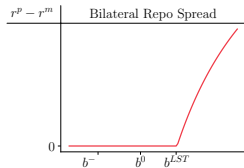
— Baseline

Fiscal Shock (Adjusting TGA)



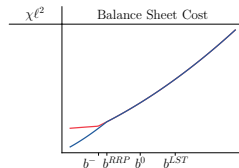
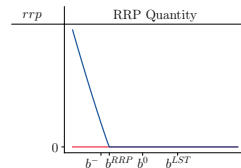
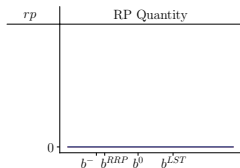
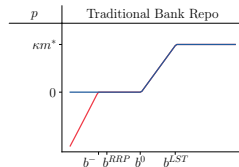
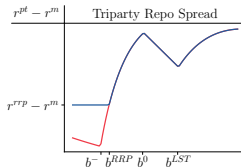
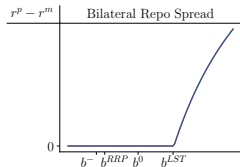
— Baseline — RP

Fiscal Shock (Adjusting Future Tax)



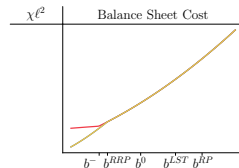
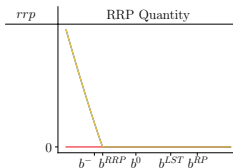
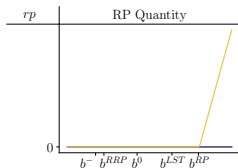
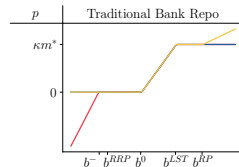
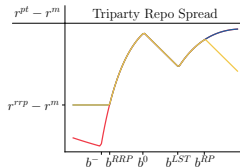
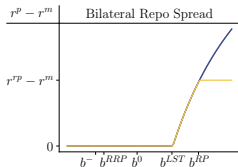
— Baseline

Fiscal Shock (Adjusting Future Tax)



— Baseline — RRP

Fiscal Shock (Adjusting Future Tax)



— Baseline — RRP — RRP & RP