Leverage and Stablecoin Pegs

Gary B. Gorton [1] Elizabeth C. Klee [2]
Chase P. Ross[2] Sharon Y. Ross[2] Alexandros P. Vardoulakis[2]

[1]Yale & NBER
[2]Federal Reserve Board

BDF - PANTHÉON ASSAS - TSE
DIGITAL CURRENCY AND THE FINANCIAL SYSTEM

June 2024, Paris

Cryptocurrency volatility and stablecoins

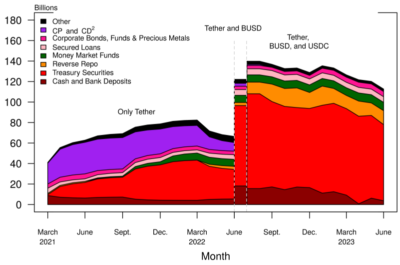
- "*Bitcoin is an innovative payment network and a new kind of money.*"–Bitcoin
  ...but the Bitcoin price is too volatile to be money

- Stablecoins emerged to solve the volatility problem:
  - Promise to maintain a constant price of $1 and to be redeemable at par on demand
  - Collateralized by assets (Tether, USDC, Dai) or uncollateralized/algorithmic (Terra)

Stablecoin Reserve Illiquidity and Run Risk

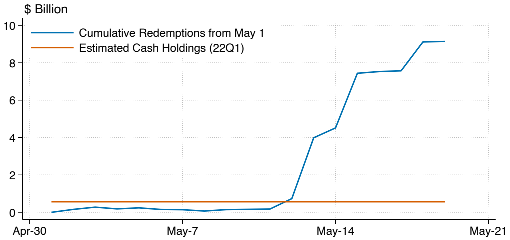
- Stablecoins' reserves can be in illiquid assets exposing them to Diamond-Dybvig runs similar to banks and money market funds

Centralized Stablecoins' Reserves



Source: Azar et al. (EPR, 2024)

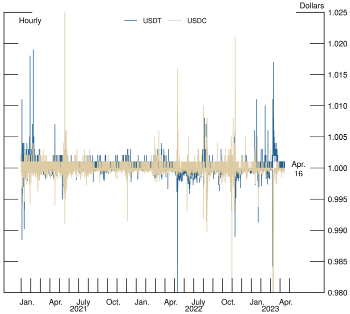
Mini-Run on Tether in May 2022



- Fragile private money is not new: banknotes during the Free Banking Era were not covered fully by specie and runs on those banks were frequent
- Yet, these banknotes were traded at a discount! (Gorton, JME 1999)

Stablecoin traded prices

- Contrary to those banknotes, stablecoins have mostly traded without a discount and have maintained their peg apart from certain episodes



- Yet, stablecoin have mostly paid no interest to compensate for run risk nor have they commanded convenience yields from traditional payments
- Stablecoin demand could accrue from their use as a store of value between crypto trades, or from facilitating cross-border transfers and illicit finance

This paper

Focus on an another use-case, the facilitation of speculation and leverage in crypto trading, and show *theoretically and empirically* that it is important for peg stability

Mechanism in a nutshell

Opposing forces keep a stablecoin pegged to $1

- A stablecoin is subject to run risk depending on its reserves→ price discount
- Speculators want to borrow stablecoins and pay high borrowing rates to take leveraged position on crypto → price premium

Broader implications

- Critical financial stability link for spillovers between crypto speculation and traditional financial markets where stablecoins invest their reserves
- Our framework can study tokenization of traditional liabilities, such as bank deposits or money market fund shares as in JPM Chase Tokenized Collateral Network, that allows them to earn premia from re-use

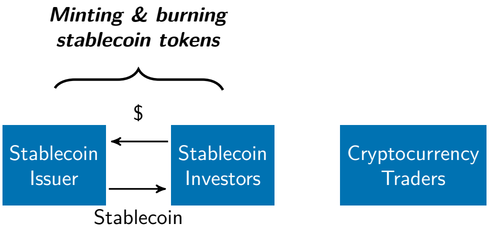
Some literature (more in the paper)

- **Bank runs:** Diamond and Dybvig (JPE, 1983); Goldstein and Pauzner (JF, 2005); Eisenbach (JFE, 2017), Schilling (JF, 2023); Kashyap, Tsomocos, and Vardoulakis (JPE, 2024)
- **Collateralized lending:** Gromb and Vaynos (JF, 2002); Fostel and Geanokoplos (AER, 2008); Brunnermeier and Pedersen (RFS, 2009)
- **Stablecoins:** Gorton, Ross, and Ross (2022); Anadu et al. (2023); Bertsch (2023); Liao et al. (2023); Liu, Makarov, and Schoar (2023); Ma, Seng, and Zhang (2023); Azar et al. (EPR, 2024)
- **Currency Pegs:** Krugman (JMCB, 1979); Obstfeld (AER, 1986); Morris and Shin (AER, 1998); Routledge and Zetlin-Jones (JEDC, 2022)

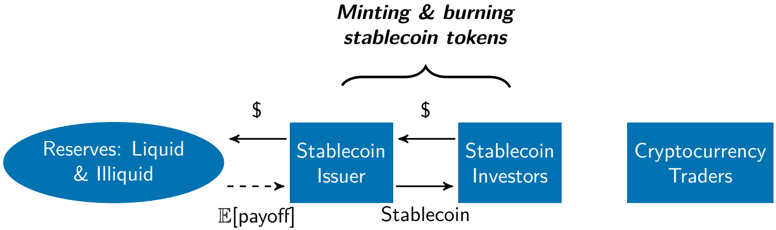
Model Sketch

Combination of leveraged collateralized trading model, akin to Geanakoplos (2010) with bank run global game model, akin to Goldstein and Pauzner (2005)

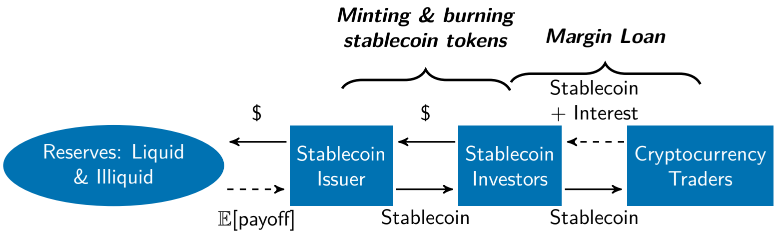
Model Sketch



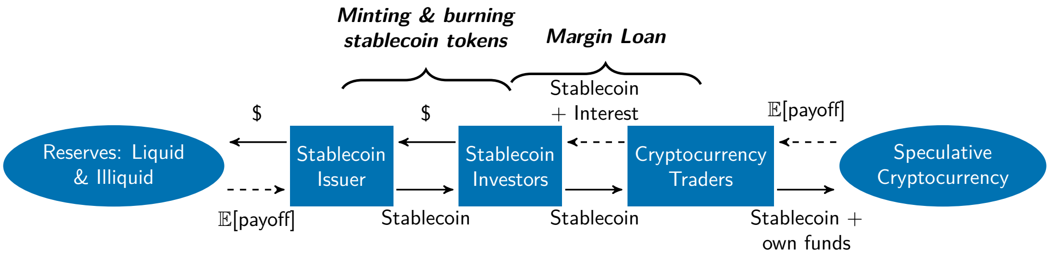
Model Sketch



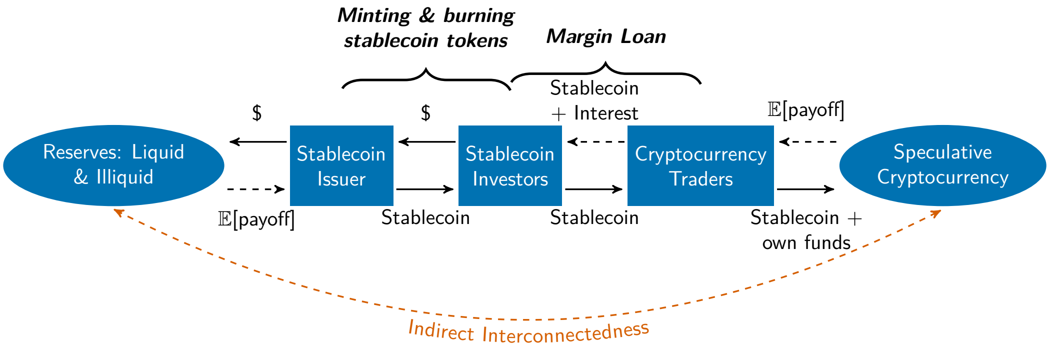
Model Sketch



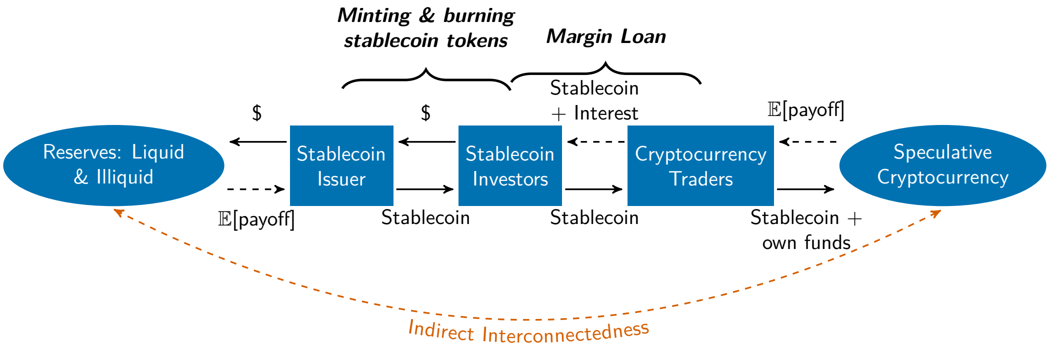
Model Sketch



Model Sketch



Model Sketch



***t* = 0**	***t* = 1**	***t* = 2**
■ Investors put $ in stablecoin and get tokens ■ Issuer invests in liquid & illiquid assets in perfectly elastic supply	■ Private signal about illiquid reserves & redemption decision ■ If enough investors redeem → stablecoin run	■ If no run, investors lend their token to traders who use it to take a levered position in crypto

Lending Rate

- Lending rate makes traders break even between a levered payoff and outside option

$$\underbrace{(y - (1 - m)R)/m}_{\text{Levered payoff}} = \underbrace{\rho(s)}_{\text{Outside option}} \Rightarrow R = \frac{y - m\rho}{1 - m}$$

  - R is lending rate; y is expected return on Bitcoin; m is haircut
  - $d\rho(s)/ds > 0$ where s is stablecoin supply

- **Lending rate is increasing in speculative demand y and decreasing in stablecoin supply s**

Outside Option details

Run Risk and Stablecoin Price

- At $t = 1$ illiquid asset liq. value $\xi < 1 \rightarrow$ run risk
  - Global game techniques pin down a unique probability of a run θ^*
  - **Run risk is decreasing in lending rate R and share of liquid reserves ℓ**

Stablecoin Run Risk

- Stablecoin price at $t = 0$ for lending rate R and run probability θ^*

$$P = \underbrace{\int_{\theta^*}^{1} \theta R(y, s) d\theta}_{\text{no run: receive lending rate}} + \underbrace{\int_{0}^{\theta^*} \left\{\ell + (1 - \ell)\xi\right\} d\theta}_{\text{run: receive liquidated assets}} \quad (= 1)$$

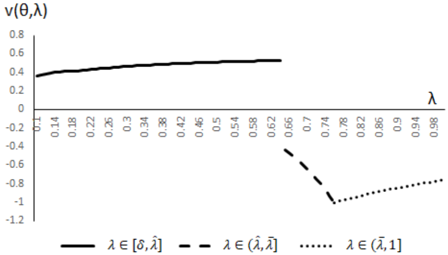
  - **P is increasing in ℓ and R both directly and indirectly via lower θ^***
  - **P is increasing in y and decreasing in s through R**

- Suppose shock $y \downarrow \rightarrow P \downarrow$; before $t = 1$ such that liq. value of illiquid asset is 1
- To stabilize the peg, the issuer can:
  1. **Liquid Asset Portfolio Share Channel**
     increase liquid asset holdings (ℓ), and keep token supply (s) constant, or
  2. **Redemption Channel**
     keep liquid asset holdings (ℓ) constant, and allow lower demand for tokens to manifest in more redemptions and lower token supply (s)
- If issuer can seamlessly adjust ℓ and s (no portfolio re-balancing costs), they can maintain peg for any crypto shock $\rightarrow$ Peg-stability in *normal times*
  - We show in the paper that operates both under observable and unobservable ℓ

Defending the peg

- At $t = 1$ the issuer cannot seamlessly adjust ℓ and s due to shock on illiquid assets
- The *liquidity portfolio channel* is not operational
  - Goes the other way: Issuer will first use liquid asset to meet withdrawals
- *Redemption channel* is useful to defend peg but only for certain redemptions λ

Δ Payoff *not redeeming* vs *redeeming*



- Δ Payoff is positive up to $\hat{\lambda}$ and increasing *due to redemption channel*
- For $\lambda > \hat{\lambda}$, issuer cannot defend the peg due to lack of liquidity portfolio channel
- Positive probability of de-pegging and a run in *stressed times*

Empirical Results

- We focus on our analysis on Tether and centralized exchanges:
  - CEX are the most popular way to trade crypto-assets (Watsky et al. 2024)
  - Tether: biggest SC, not paying interest, and susceptible to runs (Azar et al. 2023)
  - Tether more used for crypto trading and speculation than USDC (Liao et al. 2023)
- We show the following empirical results that complement our theoretical analysis:

1. Speculative demand drives stablecoin lending rates
2. Peg Stability
   2.1 Portfolio share of liquid assets
   2.2 Redemptions and issuance
3. Defending the Peg: May 2022 Turmoil

Summary Statistics

	Days (N)	Mean	Std. Dev.	Min	Max
Stablecoin Prices ($)					
USDT (Tether)	705	1.0010	0.0022	0.9919	1.0114
DAI (Dai)	705	1.0013	0.0024	0.9912	1.0109
Margin Lending Rates (annualized percent)					
USDT	705	7.96	10.00	1.00	66.65
DAI	650	7.26	10.40	0.88	93.41

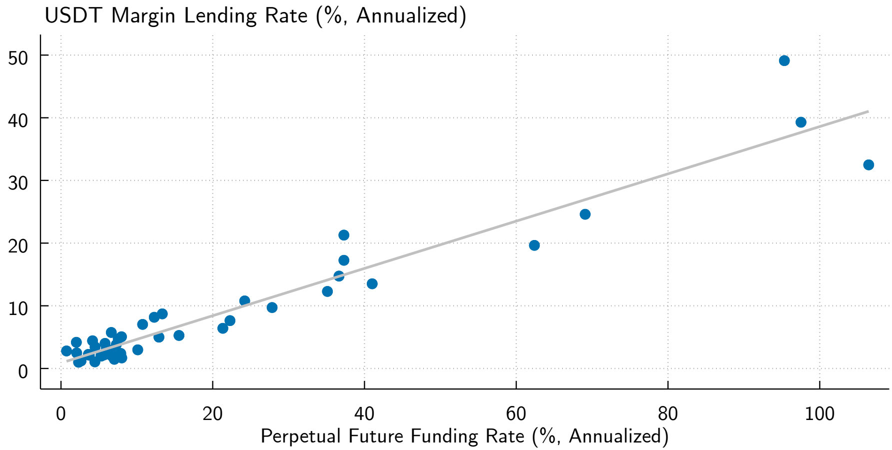
Speculation and Lending Rates

Measuring Leverage Demand
with Perpetual Futures Funding Rates

- Perpetual futures are liquid derivatives that allow leverage up to 125×
  - More than $40 billion daily volume in May 2022
  - Stablecoin-settled
- *Funding payments* keep the spot and future price close
- If the future trades at a premium to the spot, long investors pay a positive funding rate to short investors

Funding Rate Time Series | Other Measures of Speculative Demand

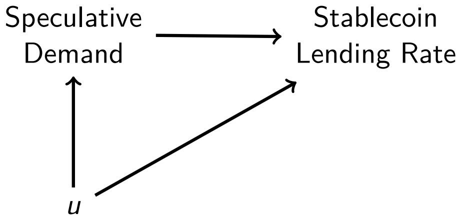
Speculative demand ↑ → stablecoin lending rate ↑



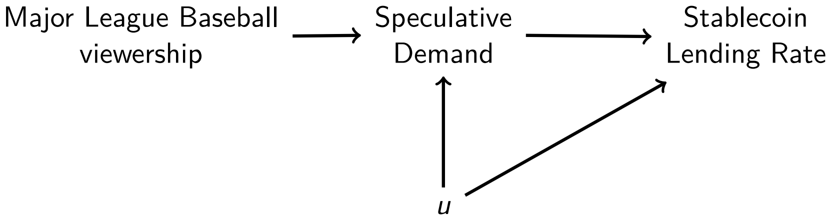
Regression

Instrumental Variables

Instrumental Variables



Instrumental Variables



Instrumental Variables

Major League Baseball viewership → Speculative Demand → Stablecoin Lending Rate

- MLB and FTX sponsorship deal placed the FTX logo on all umpire uniforms
  - Umpires wore the patch for all regular season, postseason, and spring training games

Instrumental Variables

- We collect television viewership data on nationally televised MLB games
  - 7/13/2021 to 11/5/2022 (end of World Series; FTX collapse began Nov. 6)
  - Instrument = daily average of household rating, which measures the percentage of households watching the game
- **Relevance Condition**: advertising is effective
- **Exclusion Restriction**: baseball schedule is set in advance of the season, improbable crypto events affect the timing or viewership of MLB games

Instrumental Variables Regression

Second Stage Regression

$$\text{Futures Funding Rate}_t = \gamma + \delta \text{ Rating}_t + \varepsilon_t$$

$$\text{Tether Lending Rate}_t = \alpha + \beta \text{ Futures } \widehat{\text{Funding}} \text{ Rate}_t + \varepsilon_t$$

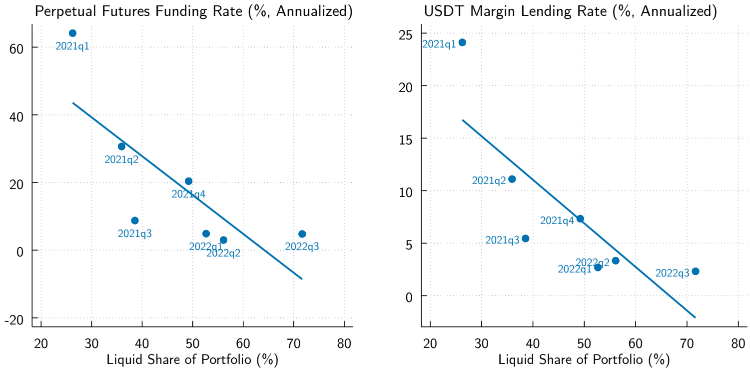
Second Stage	Stablecoin Lending Rate R_t	
	(1)	(2)
Futures $\widehat{\text{Funding}}$ Rate$_t$	**0.279*****	**0.175*****
	(4.310)	(3.069)
Bitcoin Implied Volatility$_t$	0.055	0.035
	(0.721)	(0.540)
Δln(Outstanding Supply$_t$)	-0.006	-0.004
	(-1.167)	(-0.955)
R_{t-1}		0.481***
		(2.969)
N	258	258
Time FE	Yes	Yes

First Stage OLS Placebo

Peg Stability

Liquid Asset Channel: speculative demand ↓ → liquid asset share ↑

Tether Quarterly Disclosures



NOTE: The decrease in ℓ is not driven by the increase in rates by the Federal Reserve

- Spread between 3-month AA CP and 3-month T-bills increased during this period
- Prime MMF—good control group—did not increase their safe asset shares during this period Prime MMF

Redemption Channel Step 1: speculative demand ↓ → redemptions ↑

$$\text{Net Issuance} = \Delta s_{i,t} = \left(\text{Market Cap}_{i,t}/P_{i,t} - \text{Market Cap}_{i,t-1}/P_{i,t-1}\right)$$

	(1)	(2)	(3)
Funding Premium$_{t-1}$	**0.70*****	**0.68*****	**0.63*****
	(4.47)	(4.15)	(3.90)
Bitcoin Implied Volatility$_{t-1}$		-0.86^{**}	-0.82^{*}
		(-2.01)	(-1.81)
$\Delta \ln(s_{i,t-1})$			-0.02
			(-0.47)
$\ln(s_{i,t-1})$			-110.88
			(-1.48)
ln(BTC Vol$_{t-1}$)			-3.58
			(-0.32)
Δ ln(BTC Vol$_{t-1}$)			9.00
			(1.15)
N	704	704	704
R^2	0.34	0.35	0.35
Month FE	Yes	Yes	Yes

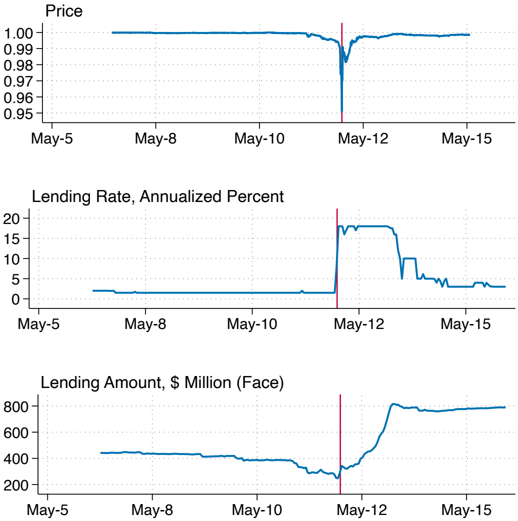
Redemption Channel Step 2: redemptions ↑ → lending rate ↑

$$\Delta R_{i,t} = \gamma \left(\widehat{\text{Net Issuance}_t} \right) + b_t + \text{controls} + \varepsilon_{i,t},$$

	(1)	(2)	(3)
$\widehat{\text{Net Issuance}_t}$	**-3.83****	**-13.14*****	**-11.54*****
	(−2.53)	(−3.03)	(−3.28)
Funding Premium_t		8.96***	8.29***
		(3.09)	(3.16)
Bitcoin Implied Volatility_t		−8.00	−6.84
		(−1.41)	(−1.41)
N	704	704	704
Month FE	Yes	Yes	Yes
Controls	No	No	Yes

Defending the Peg

Defending the Peg: Tether May 2022 Depeg



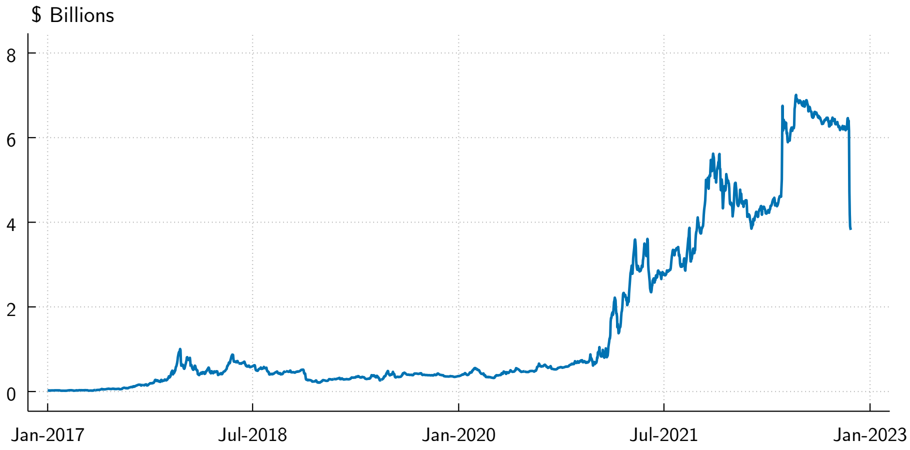
- Terra run had spillovers to Tether given concerns about the quality of reserves
- Though not easy to redeem Tether, redemptions increased and Tether depegged, precipitating a run
- Tether lending rates spiked, which increased demand and helped stabilized the peg
- Lending rates went back down after the full run was averted, *but at a higher level*

Conclusion

- Privately-produced money can maintain a $1 peg even if it is not *no questions asked* (Holmström 2015)
  - We highlight an important use of stablecoins for *speculation* and show how the supply of tokens and the liquidity of issuers' reserves interact with it
  - Our analysis can be generalized for other main or ancillary uses of tokenized money
  - Bigger implications for use of tokenized risky debt (e.g. MMF shares) as private money!
- Stablecoins link crypto speculation to the real economy

Appendix

Lending Volume on FTX



Note: Figure includes face value of lending/borrowing volume across USD, USDT, DAI, USTC, and CUSDT coins.

Outside Option

- Outside option consists of a technology, F, common to all traders, with decreasing marginal returns depending on the aggregate amount of funds invested
- Denote by e the total funds of traders and by $m(1-\lambda)s/(1-m)$ the total funds invested in leveraged cryptocurrency trades, where λ is the number of tokens redeemed at $t=1$ and not available for lending

$$\rho = F'\left(e - \frac{m}{1-m}(1-\lambda)s\right).$$

Back

Stablecoin Run Risk

- Payoffs for traditional financial assets (akin to Goldstein and Pauzner, 2005)
- The illiquid asset yields $X > 1$ at $t = 2$ only with probability θ and zero otherwise, which is uniformly distributed
- The liquidation value of the illiquid asset (ξ) depends on θ
- $\theta \in U[0, 1]$ and its true value is realized at $t = 1$
  - If $\theta \geq \overline{\theta} \rightarrow$ no incentives to run as issuer is liquid and solvent
  - If $\theta < \underline{\theta} \rightarrow$ fundamental run as issuer is insolvent
  - If $\theta \in [\underline{\theta}, \overline{\theta}) \rightarrow$ run due to coordination failure as issuer is illiquid ($\xi < 1$)

Back

Stablecoin Run Risk

- Global game techniques pin down a unique probability of a run that depends on the stablecoin balance sheet (share of safe reserves ℓ) and the lending rate R
- Stablecoin issuer is exposed to run risk because the liquidation value of stablecoin reserves may not cover the potential redemption by all token holders
- Individual token holder receives a private noisy signal x_i about risky asset
  - Token holder uses x_i to form posterior about random liquidation value of risky asset ξ and beliefs about aggregate redemptions λ and θ
  - Token holder decides to redeem if expected payoff $E[v(\xi,\lambda)|x_i] < 0$ where

$$\nu(\theta,\lambda) = \begin{cases} \theta R(\lambda, s) + (1-\theta)\max\left(\frac{\ell-\lambda}{1-\lambda}, 0\right) - 1 & \text{if} \quad \delta \leq \lambda \leq \hat{\lambda} \\ \theta \frac{X(1-\ell)\left(1-\frac{\lambda-\ell}{\xi(1-\ell)}\right)}{1-\lambda} - 1 & \text{if} \quad \hat{\lambda} < \lambda \leq \overline{\lambda} \\ -\frac{\ell+(1-\ell)\xi}{\lambda} & \text{if} \quad \overline{\lambda} < \lambda \leq 1 \end{cases}.$$

  - Token holder redeems if $x_i < x^\star$
- **Run risk is decreasing in lending rate R and share of safe reserves ℓ**

Back

Stablecoin issuer's optimization problem

$$\max_{\ell,s} \int_{\theta^*}^{1} \left\{ \theta \left[X(1-\ell)\left(1 - \frac{\max(\lambda-\ell,0)}{\xi(1-\ell)}\right) + \max(\ell-\lambda,0) - (1-\lambda) \right] s \right\}$$

subject to:

① Peg stability

$$\int_{\theta^*}^{1} \left[\theta R(\delta,s) + (1-\theta)\max\left(\frac{\ell-\delta}{1-\delta},0\right) \right] d\theta + \int_0^{\theta^*} (\ell + (1-\ell)\xi) d\theta = 1$$

② Run threshold determination

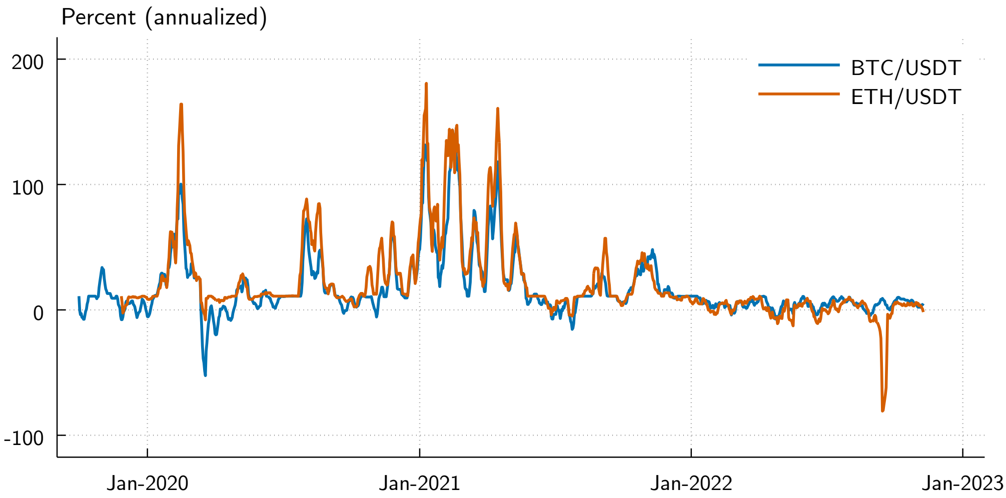
$$\int_{\delta}^{1} \nu(\theta^*,\lambda) d\lambda = 0$$

③ Lending rate determination

$$R(\delta,s) = \frac{y - mF'\left(e - \frac{m}{1-m}(1-\delta)s\right)}{1-m}$$

Perpetual Futures Funding Rate

Annualized Funding Rate



Back

Perpetual Futures Funding Rate

Annualized Funding Rate

	BTC/USDT Binance	ETH/USDT Binance	BTC/BUSD Binance	DOGE/BUSD Binance	BTC/USD FTX	ETH/USD FTX	$\mathbb{E}[R^{BTC}]$ CME	$\mathbb{E}[R^{ETH}]$ CME
BTC/USDT, Binance	1.00							
ETH/USDT, Binance	0.84***	1.00						
BTC/BUSD, Binance	0.80***	0.68***	1.00					
DOGE/BUSD, Binance	0.59***	0.59***	0.61***	1.00				
BTC/USD, FTX	0.79***	0.72***	0.75***	0.50***	1.00			
ETH/USD, FTX	0.73***	0.82***	0.64***	0.47***	0.81***	1.00		
$\mathbb{E}[R^{BTC}]$	0.61***	0.55***	0.53***	0.48***	0.66***	0.62***	1.00	
$\mathbb{E}[R^{ETH}]$	0.61***	0.52***	0.55***	0.54***	0.64***	0.57***	0.83***	1.00

Measuring $\mathbb{E}[R^{BTC}]$ Back

Measuring $\mathbb{E}[R^{BTC}]$

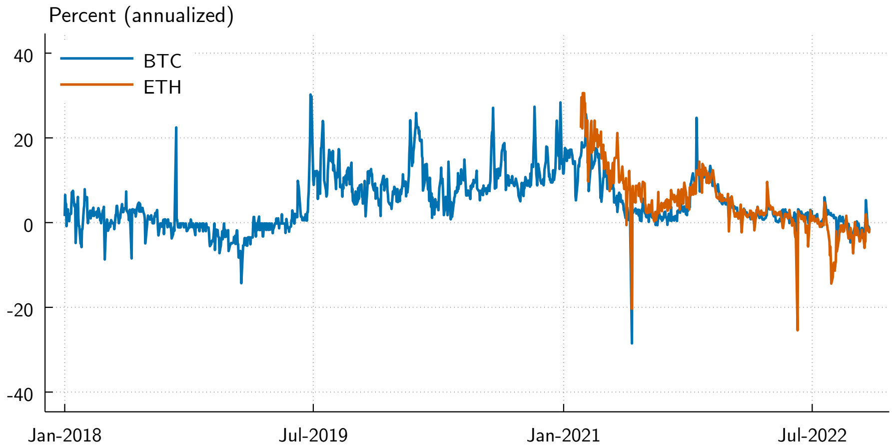
$$\mathbb{E}_{t,t+n\rightarrow t+n+1}[R^{BTC}] \equiv \left(\frac{z_{t,t+n+1}}{z_{t,t+n}}\right)\frac{F_{t,t+n+1}}{F_{t,t+n}}$$

- Let $F_{t,t+n}$ denote the price of a Bitcoin future at time t for delivery at $t+n$
- Let $z_{t,t+n}$ denote the n-period discount factor implied by the risk-free rate
- Infer expected returns using a no-arbitrage argument comparing the present value of $F_{t,t+n}$ and $F_{t,t+n+1}$
- Data
    - Bitcoin and Ether CME futures data from Bloomberg for generic n-month futures
    - Use OIS n-month interest rates, $y_{t,t+n}$, to infer discount rates

$$z_{t,t+n} = \frac{1}{\left(1+\frac{y_{t,t+n}}{12}\right)^{n/12}}$$

    - Focus on 1-month vs. 2-month contract, since they are the most liquid

Measuring $\mathbb{E}[R^{BTC}]$



Back

Speculative demand ↑ → stablecoin lending rate ↑

$$\text{Tether Lending Rate} = \alpha + \beta \text{ Futures Funding Rate}_t + \gamma X_t + \varepsilon_t$$

	(1)	(2)	(3)
Futures Funding Rate$_t$	**0.26*****	**0.19*****	**0.12*****
	(14.41)	(8.10)	(5.17)
Stablecoin Lending Rate$_{t-1}$			0.43***
			(6.01)
BTC Implied Volatility$_t$			0.01
			(0.20)
R_t^{BTC}			0.05
			(0.86)
N	705	705	704
R^2	0.41	0.58	0.63
Month FE	No	Yes	Yes

Back

Speculative demand ↑ → stablecoin lending rate ↑

Daily observations, alternative measure of speculative demand

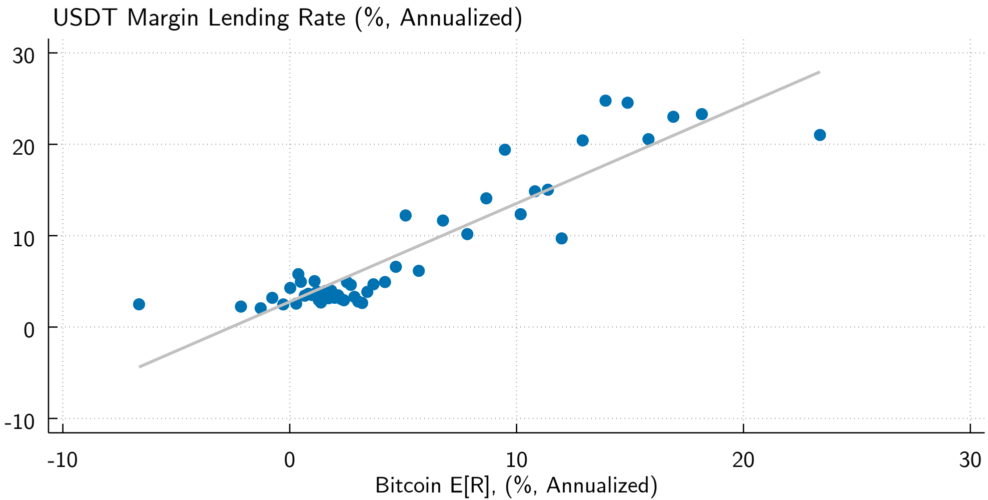
$$\text{Tether Lending Rate} = \alpha + \beta \text{ Futures Funding Rate}_t + \gamma X_t + \varepsilon_t$$

	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbb{E}[R^{BTC}]$	1.38***	0.85***			1.42***	1.23**
	(9.07)	(3.23)			(3.16)	(2.55)
R^{BTC}		0.22				0.04
		(1.52)				(0.19)
$\mathbb{E}[R^{ETH}]$			0.85***	−0.19	−0.03	−0.37*
			(6.10)	(−1.23)	(−0.09)	(−1.99)
R^{ETH}				0.12		0.07
				(1.48)		(0.47)
$\mathbb{E}[R^{S\&P}]$						−3.75
						(−1.02)
N	347	347	298	298	298	298
R^2	0.33	0.43	0.18	0.38	0.29	0.41
Month FE	No	Yes	No	Yes	No	Yes

Back

Speculative demand ↑ → stablecoin lending rate ↑

binscatter of daily observations



Back

Instrumental Variables Regression

First Stage Regression

$$\text{Futures Funding Rate}_t = \gamma + \delta \text{ Rating}_t + \varepsilon_t$$

First Stage	Futures Funding Rate	
	(1)	(2)
Rating_t	2.589***	1.941***
	(3.437)	(2.830)
$\text{Bitcoin Implied Volatility}_t$	0.344*	0.210
	(1.730)	(1.058)
$\Delta ln(\text{outstanding supply}_t)$	0.024*	0.024*
	(1.748)	(1.750)
R_{t-1}		1.145**
		(2.570)
N	258	258
Time FE	Yes	Yes
F-stat	11.82	8.01

Back

Instrumental Variables Regression
OLS

$$\text{Stablecoin Lending Rate}_t = \alpha + \beta \text{ Futures Funding Rate}_t + \varepsilon_t$$

OLS	Stablecoin Lending Rate R_t USDT	
	(1)	(2)
Futures Funding Rate$_t$	0.211***	0.119***
	(14.232)	(5.647)
Bitcoin Implied Volatility$_t$	0.013	0.007
	(0.281)	(0.227)
Δln(outstanding supply$_t$)	0.003	−0.001
	(0.264)	(−0.061)
$R_{i,t-1}$		0.489***
		(6.906)
N	705	704
Time FE	Yes	Yes

Back

Instrumental Variables Regression

Placebo, Second Stage

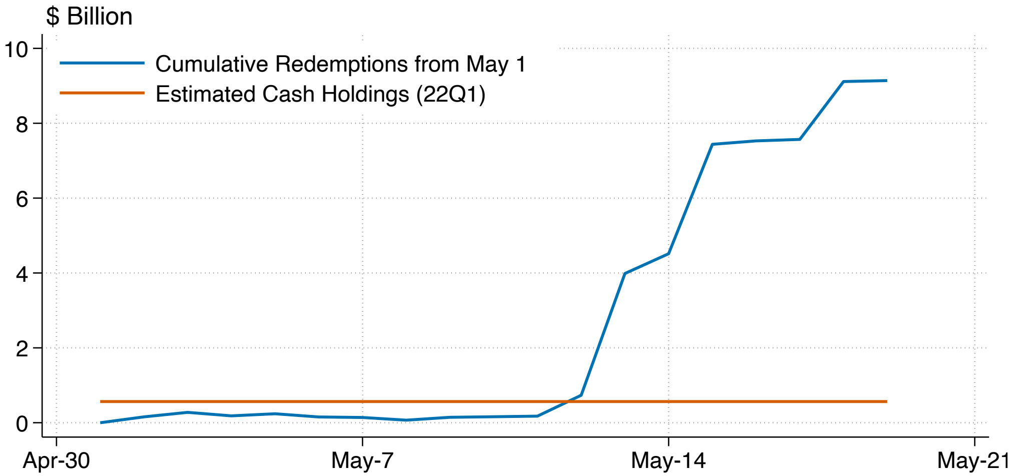
$$\text{Futures Funding Rate}_t = \gamma + \delta \text{ Rating}_{t+7} + \varepsilon_t$$

$$\text{Stablecoin Lending Rate}_t = \alpha + \beta \text{ Futures } \widehat{\text{Funding}} \text{ Rate}_t + \varepsilon_t$$

Placebo	Stablecoin Lending Rate R_t USDT
Futures $\widehat{\text{Funding}}$ Rate_t	0.207
	(1.339)
Bitcoin Implied Volatility_t	−0.039
	(0.725)
$\Delta ln(\text{outstanding supply}_t)$	−0.004
	(1.332)
R_{t-1}	0.519***
	(2.992)
N	258
Time FE	Yes
F-stat	1.25

Back

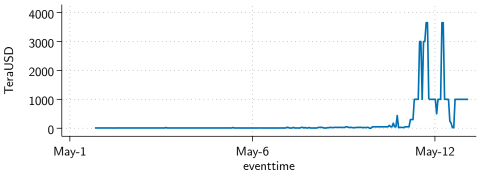
Tether May 2022 Redemptions



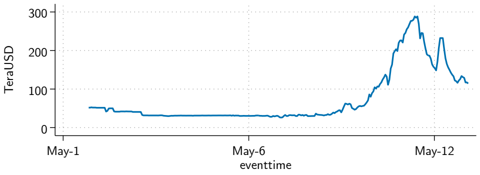
Note: Estimated cash is non-fiduciary cash deposits, estimated using March 2021 ratios.

TerraUSD Failure

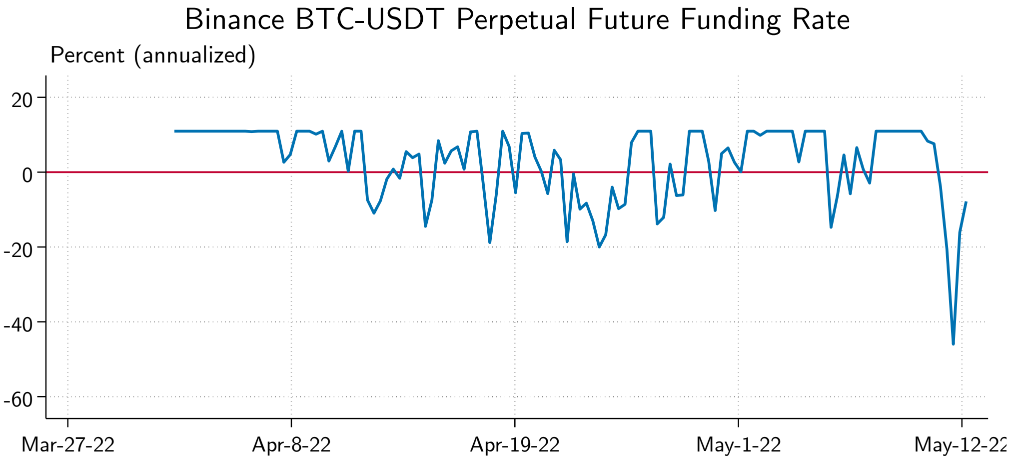
Annualized Margin Lending Rate (%)



Lending Volume, (Face value, millions)

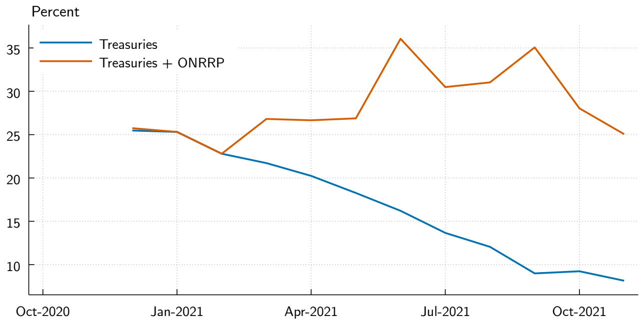


TerraUSD Failure and Leverage Demand



Note: Positive indicates levered long pay shorts.

Prime MMF Treasuries and ONRRP portfolio share



Bank

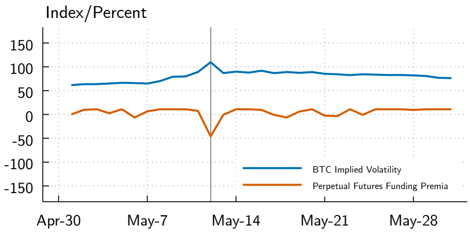
May 2022 Turmoil

May 2022 Turmoil

- In May 2022, the algorithmic stablecoin TerraUSD collapsed
- Crypto sentiment turned extremely bearish
- The turmoil provides a useful natural experiment to study the model's predictions
  1. When demand for the speculative cryptocurrency falls, stablecoin breaks the peg
  2. Stablecoin issuer can keep the peg by increasing liquid assets or redeeming tokens
  3. Lending rate effect is ambiguous: can increase if the token supply is large enough to offset the fall in speculative demand

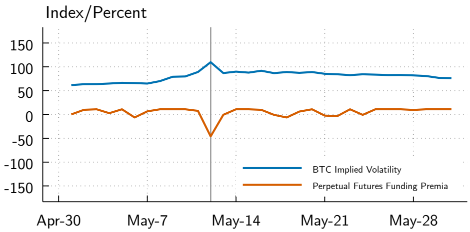
May 2022 Turmoil

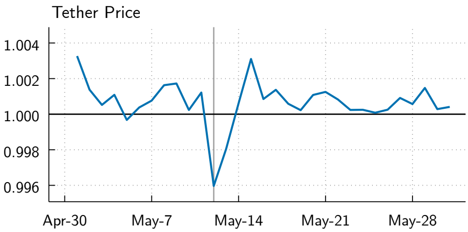
Tether



May 2022 Turmoil

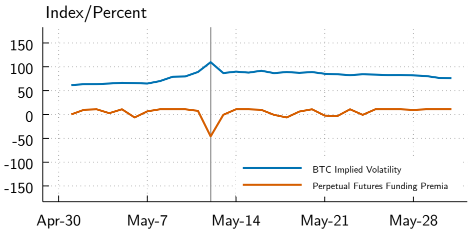
Tether

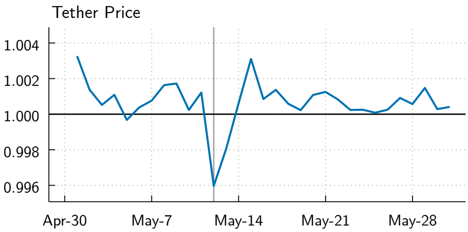


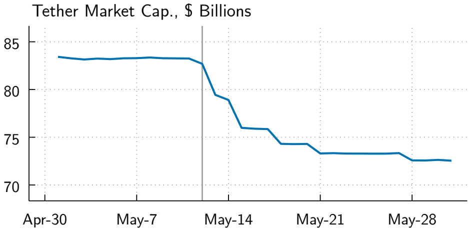


May 2022 Turmoil

Tether







May 2022 Turmoil

Tether