

## **Anatomy of a Run: The Terra Luna Crash**

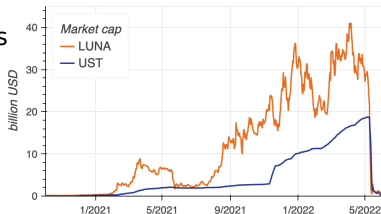
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| MIT Sloan   | LSE          | MIT Sloan, NBER   |

7th Annual Macroprudential Conference

August 30-31, 2023

# Motivation: Terra

- One of the most hyped crypto projects
  - Market cap: \$50B
  - Daily volume: \$1B
  - Algorithmic stablecoin: UST
- First large run in crypto
- Started a chain reaction that led to the collapse of many prominent players: Celsius, Three Arrows Capital, and beyond



# Motivation: Implications

- Not just about Terra
  - Lessons apply to the entire crypto space
  - Highlights limitations of private money creation
- Unique environment to advance our knowledge of runs
  - All transactions are online and instantaneous
  - No regulatory safety nets
  - Public blockchain provides detailed information about the network and participants' actions

## Main Results

- Terra's economics was dominated by two main factors
  - Subsidized UST deposit and borrowing rates
  - Speculation about the price of LUNA
- Subsidized UST rate led to an excessive issuance of UST, which made the network prone to runs
- Blockchain allowed investors to monitor each other's exits and amplified the speed of the run
- Wealthier and more sophisticated investors processed information more efficiently and experienced significantly smaller losses

## Literature

- **Design and operation of stablecoins:** d'Avernas et al. (2022), Li and Mayer (2022), Lyons and Viswanath-Natraj (2023), Uhlig (2022), Eichengreen (2019), Arner et al. (2020), Makarov and Schoar (2022), Gorton and Zhang (2021), Gorton et al. (2022)
- **Runs on financial institutions:** Bryant (1980), Diamond and Dybvig (1983), Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), Morris and Shin (1998), Goldstein and Pauzner (2005), Goldstein (2013), Abreu and Brunnermeier (2003), Iyer and Puri (2012), Iyer et al. (2016), Schmidt et al. (2016)
- **International finance:** Krugman (1979), Flood and Garber (1984), Eichengreen et al. (1994), Obstfeld (1996), Chamley (2003), Cukierman et al. (2004)

# Terra

# Terra Network

- Smart-contract blockchain developed by TerraForm Labs (TFL)
- LUNA is the native token
- ICO (2019): 1B LUNA (812M – TFL, 188M – investors)
- Sources of LUNA value
  - Transaction demand
  - Claim on Terra's fees
  - Speculative demand



# UST

- UST: algorithmic stablecoin pegged against dollar, backed by LUNA
- Uses the native swap smart contract (a piece of code) to facilitate arbitrage if UST deviates from the peg
  - Allows swapping UST for \$1 worth of LUNA and vice versa
  - Swapping UST for \$1 worth of LUNA entails:
    - Obtaining the current LUNA price  $P$
    - Reducing UST supply by 1 unit (burning)
    - Increasing LUNA supply by  $1/P$  units (minting)
  - $UST > \$1 \Rightarrow$  buy LUNA, swap LUNA for UST, and sell UST
  - $UST < \$1 \Rightarrow$  buy UST, swap UST for LUNA, and sell LUNA

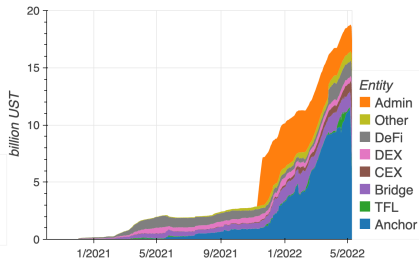
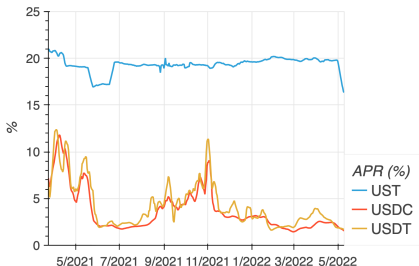


## Viability of the Pegging Mechanism

- UST ~ convertible debt with a face value of \$1 backed by LUNA
- For LUNA to back UST
  - the Terra network must have enough real value
  - converting UST to LUNA should have a limited impact on the LUNA price (or there can be a run on LUNA)
- Swapping UST for LUNA dilutes existing holders of LUNA
- If investors price LUNA without considering UST's dilutive effect or if speculative demand is a large component of LUNA's value, states where UST and LUNA have similar market caps become fragile and prone to runs

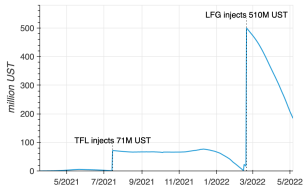
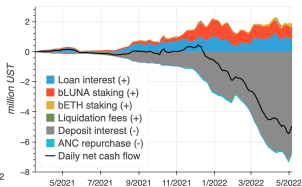
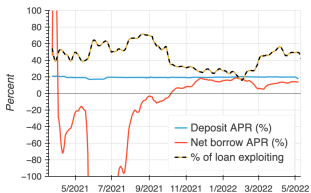
# Results

# UST Fundamentals



- To promote UST, UST rate was set  $\gg$  other stablecoin rates
- Anchor, Terra's main deposit and borrowing platform, was main destination for newly issued UST

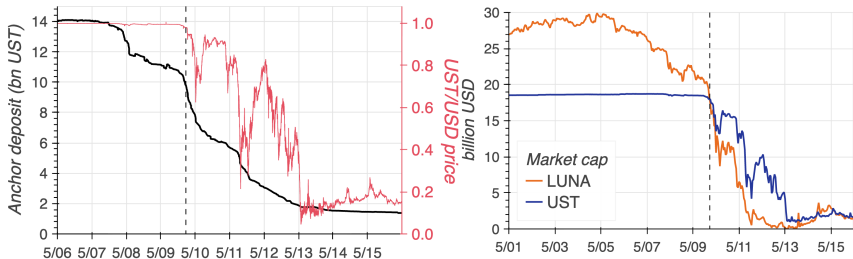
# Anchor



- Borrowing rate:  $2\% + 42\% \times$  outstanding loans/outstanding deposits
- Net borrowing rate: borrowing rate - staking yield + subsidy rate
- Outcome: Net borrowing rate < deposit rate
  - Subsidized APR was unsustainable in the long-run
  - Starting from May 1, Anchor's APR was tied to amount of reserves

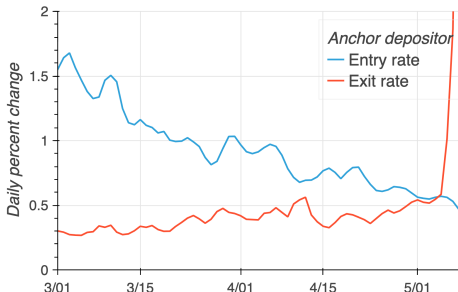
# The Run

# The Run Dynamics



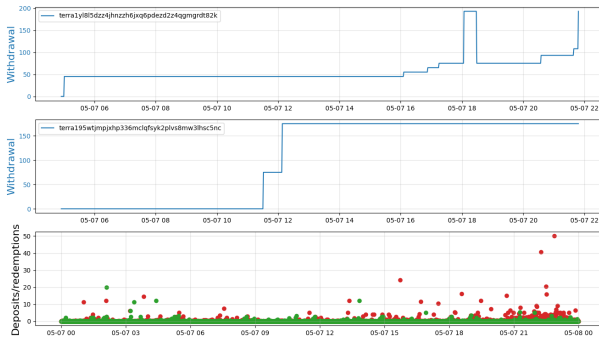
- The run was closely linked to behavior of Anchor depositors
- May 7: First sign of run and increasing withdrawals
- May 7–11: TFL tries to defend the peg
- Run accelerates when LUNA and UST market caps become equal

# The Timing of the Run



- Prior to the run, there is an increase in exit rates and decrease in entry rates to Anchor

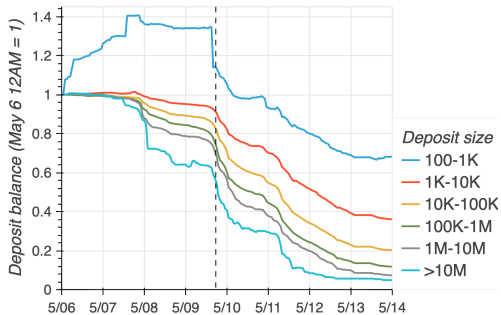
# The Beginning of the Run



- The run started with two large wallets withdrawing their balances from Anchor followed by other several large wallets



## How Investors Run? (Size)



- Wealthier investors run earlier, more decisively
- Smaller investors run late, more likely to buy into initial price drop

## How Investors Run? (Sophistication)

|                     | Full sample      |                  | Percent loss     |                 |                 |                 |                 |                 |
|---------------------|------------------|------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                     |                  |                  | Balance subgroup |                 |                 |                 |                 |                 |
|                     | (1)              | (2)              | <1K<br>(3)       | 10K<br>(4)      | 100K<br>(5)     | 1M<br>(6)       | 10M<br>(7)      | >10M<br>(8)     |
| log balance         | -6.00<br>(0.05)  |                  |                  |                 |                 |                 |                 |                 |
| Size[1K-10K]        |                  | -15.24<br>(0.24) |                  |                 |                 |                 |                 |                 |
| Size[10K-100K]      |                  | -27.98<br>(0.27) |                  |                 |                 |                 |                 |                 |
| Size[100K-1M]       |                  | -37.00<br>(0.43) |                  |                 |                 |                 |                 |                 |
| Size[1M-10M]        |                  | -41.97<br>(1.11) |                  |                 |                 |                 |                 |                 |
| Size[>10M]          |                  | -47.08<br>(3.67) |                  |                 |                 |                 |                 |                 |
| log(volume/balance) | 1.10<br>(0.09)   | 1.30<br>(0.09)   | 3.57<br>(0.16)   | 0.85<br>(0.16)  | -1.97<br>(0.21) | -3.92<br>(0.39) | -0.25<br>(1.08) | -1.27<br>(3.73) |
| log age             | 5.74<br>(0.16)   | 5.63<br>(0.16)   | 6.26<br>(0.31)   | 5.95<br>(0.26)  | 5.18<br>(0.30)  | 5.67<br>(0.53)  | 6.29<br>(1.36)  | 0.41<br>(3.58)  |
| No. of CEXs used    | -4.39<br>(0.10)  | -4.68<br>(0.10)  | -4.80<br>(0.24)  | -5.48<br>(0.17) | -3.75<br>(0.17) | -2.44<br>(0.28) | -2.81<br>(0.76) | 1.93<br>(2.49)  |
| Used bridges?       | -3.02<br>(0.22)  | -3.72<br>(0.22)  | -3.33<br>(0.49)  | -4.48<br>(0.36) | -2.29<br>(0.40) | -2.49<br>(0.70) | -4.71<br>(2.01) | -8.01<br>(6.04) |
| Constant            | 105.30<br>(0.44) | 72.04<br>(0.28)  | 67.86<br>(0.49)  | 58.12<br>(0.41) | 47.06<br>(0.48) | 37.47<br>(0.89) | 28.74<br>(2.43) | 29.75<br>(7.28) |
| $R^2$               | 0.12             | 0.12             | 0.03             | 0.02            | 0.02            | 0.03            | 0.02            | 0.02            |
| $N$                 | 159669           | 159669           | 43885            | 63360           | 40688           | 10397           | 1230            | 109             |

- Sophisticated investors even conditional on wealth had smaller losses

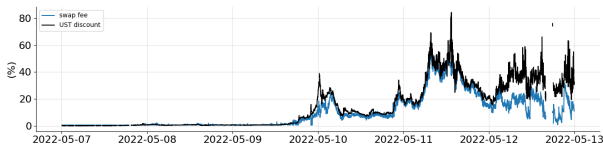
## How Investors Run? (Sophistication)

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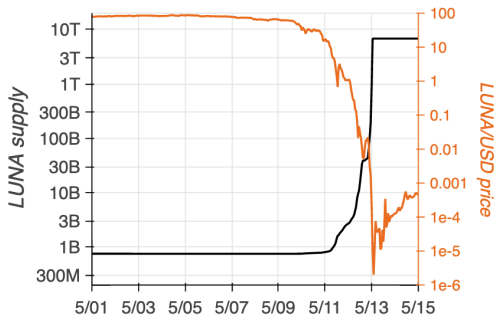
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## LUNA vs. UST Run

- UST < \$1  $\Rightarrow$  investors can either
  1. sell UST at market price
  2. swap UST for Luna for its nominal value and sell Luna at market price
- In the absence of frictions, option (2) delivers strictly higher profits
- In practice, to prevent oracle price manipulation the native swap contract had built-in fees that increased with the volume
- Investors kept swapping UST for LUNA until the point where the swap fees got equal to the UST discount



# Death Spiral



- Large swap volume led to a sharp increase in the supply of LUNA and decline in the LUNA price

# Conclusions

- Ascend of Terra was largely fueled by unsustainable deposit rates
  - Led to sharp expansion of UST supply; made the network prone to runs
  - The network's complexity made it difficult even for insiders to understand the buildup of risk
- The run was precipitated by growing concerns about the network's sustainability
  - Blockchain allowed investors to monitor each other's exits; amplified the speed of the run
  - Wealthier, more sophisticated investors processed information more efficiently and had much smaller losses
- Open-access does not create an equal footing for all investors