

Anatomy of a Run: The Terra Luna Crash

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Abstract

We examine the dramatic collapse of the Terra blockchain in May 2022. Using granular blockchain data, we analyze the mechanisms underlying the run and draw parallels to the traditional financial system. We show that the early success of Terra’s algorithmic stablecoin, UST, was fueled by highly subsidized deposit rates, which attracted many investors but created a fragile system prone to runs. The blockchain allowed investors to observe Terra’s worsening fundamentals and monitor each other’s exits. The presence of large investors, whose actions were observable and could impact prices, alleviated the need for coordination typical in canonical models of runs. Larger and sophisticated investors reacted faster to adverse signals and served as catalysts for the run. These findings challenge the idea that blockchain transparency levels the playing field and highlight how greater observability and concentration can amplify financial fragility. Our results contribute to the understanding of the limits of private money and the dynamics of runs in fully digital financial systems.

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Financial history has repeatedly demonstrated the fragility of the private creation of safe assets. From bank runs in the Free Banking era of 19th-century United States to runs on money market funds during the 2008 Financial Crisis, privately issued money-like instruments have been prone to runs when investor confidence falters, see for example [Gorton and Zhang \(2021\)](#). More recently, cryptocurrency platforms have begun issuing a new generation of private money in the form of stablecoins—cryptocurrencies pegged to a reference fiat currency—which raises familiar questions in a new technological environment: What determines their stability? Which design choices mitigate or exacerbate fragility? How do runs begin and unfold in this context? This paper uses the 2022 collapse of Terra as a natural laboratory to study these fundamental questions. We show that the economics of the Terra network shared several important parallels with traditional financial systems and collateralized stablecoins. Therefore, our results have implications not only for cryptocurrency runs but also for our understanding of runs more broadly. Blockchain data offers detailed information on both network structure and participant behavior allowing us to examine the dynamics of the run at the individual investor level.

A defining feature of the Terra ecosystem was its algorithmic stablecoin, UST. UST aimed to function as a money-like asset and to facilitate transactions on the Terra blockchain. Rather than rely on external collateral or government backing, UST maintained its peg through an algorithmic arbitrage mechanism backed solely by Terra’s native cryptocurrency, LUNA. Therefore, the system’s solvency depended entirely on the market capitalization of LUNA. This self-referential design proved vulnerable to runs.

We document three main results. First, we provide a comprehensive analysis of the economic forces driving the Terra network prior to the run. Abstracting from operational details, Terra can be conceptualized as a bank. In this analogy, LUNA represents an equity claim on the bank’s franchise, while UST is akin to private money issued by the bank. We show that Terra’s initial success was fueled by highly subsidized deposit and lending rates on UST, which attracted users to the platform and led to large issuance of UST and a run-up in the price of LUNA. But this dynamic ultimately proved unsustainable because the platform failed to meaningfully attract users without significant subsidies to UST.

Second, we provide micro-evidence on the connection between informational transparency and coordination. We show that blockchain transparency enabled investors to track deteriorating fundamentals and to monitor each other’s actions in real time. The presence of large investors, whose actions were observable and could affect prices, reduced the need for coordination typical for canonical models of runs. Once a few large

UST holders began unwinding their positions, their sales triggered a cascade where other traders quickly followed suit.

Finally, by leveraging wallet-level data, we examine how different investors behaved and reacted to information during the run. The run on Terra displayed clear cross-sectional differences: larger and more sophisticated investors ran faster and reacted more quickly to adverse signals, acting as catalysts for the run and underscoring their superior ability to process and act on information. As a result, smaller investors suffered larger losses. Our results demonstrate that transparency alone is insufficient to level the playing field in financial markets, and in fact, it may exacerbate heterogeneous outcomes across investors.

To understand the context of the collapse, we first describe the design of the Terra network and its underlying economics. Terra was developed by TerraForm Labs (TFL), founded in 2018 by Do Kwon and Daniel Shin. Like other smart contract platforms such as Ethereum, Terra aimed to host a range of applications and services on the blockchain to attract users and generate fees for cryptocurrency holders. Starting in March 2020, Terra introduced a suite of algorithmic stablecoins pegged to different fiat currencies, the most prominent being UST pegged to the US dollar.

Unlike collateralized stablecoins such as Tether and USDC, which are backed by off-chain assets, UST was backed by Terra’s native cryptocurrency, LUNA, via a pegging mechanism designed to incentivize traders to engage in arbitrage whenever the stablecoin deviated from the peg. Specifically, one UST could always be exchanged for \$1 worth of LUNA, and vice versa. If UST traded below \$1, arbitrageurs could buy it at a discount and redeem it for \$1 worth of LUNA, shrinking UST’s supply. Conversely, if UST traded above \$1, they could issue new UST in exchange for LUNA, expanding UST supply until peg was restored. While this mechanism offered a means to profit from UST deviations from peg, it also exacerbated the risk of a self-fulfilling run.

With no external collateral, UST’s stability depended entirely on the value of LUNA, which derived value from three main sources. First, LUNA holders could stake their tokens with validators and earn a share of transaction fees and block rewards. In the banking analogy, these rewards were similar to dividends from a bank’s fee income. Second, LUNA served as a medium for accessing Terra-based applications, generating transaction demand. Third, LUNA attracted speculative demand from investors betting on Terra’s adoption and LUNA’s appreciation. Because conversion of UST to LUNA increased LUNA supply, it diluted existing LUNA holders. Unless fully anticipated and priced in by investors ex ante, this dilution had a negative effect on LUNA’s price, potentially reducing demand for LUNA and lowering the network value.

Thus, while operational details may appear different across collateralized stablecoins, traditional banks, and Terra, all share the same core vulnerability first highlighted in the seminal work by [Diamond and Dybvig \(1983\)](#), i.e., the feedback effect from redemptions to the declining value of backing assets, making the decision to run a strategic complement across investors.

The feedback effect is likely to be weaker for collateralized stablecoins and traditional banks, where absent asset impairment, the primary risk stems from fire sales triggered by redemption requests.¹ Historically, stablecoin demand for safe assets has been small relative to the U.S. Treasury bill market, making the latter reliable collateral. However, as stablecoins grow and absorb a larger share of this market, the risk of fire-sale spillovers to U.S. Treasuries increases.

As with collateralized stablecoins, the feedback effect in Terra depended on the relative size of outstanding UST supply and the value of its backing asset, LUNA. The larger the UST supply relative to network value, the more exposed the network became to run risk. Despite this built-in fragility, Terra’s insiders famously dismissed warnings about these vulnerabilities and worked aggressively to increase UST demand and supply.

The centerpiece of this strategy was Anchor, a borrowing and savings protocol where LUNA holders could stake their tokens and borrow UST. Unlike other DeFi protocols, where lending yields derive from interest paid on borrowings, on Anchor, both borrowing and lending rates were heavily subsidized. In particular, UST holders could deposit their UST in Anchor and earn a fixed 19.5% yield, far above rates available for other major stablecoins. Additionally, the net borrowing rate was consistently below the lending rate, prompting many users to borrow from Anchor only to redeposit for a profit.

The high deposit rate on Anchor attracted substantial capital inflows and led to a large increase in UST supply, and a sharp appreciation in the price of LUNA.

The highly subsidized deposit rate on Anchor led some observers to compare the economics of Terra-LUNA to a Ponzi scheme. Unlike classic Ponzi schemes, however, the Anchor subsidies did not come from newly joining investors, but were distributed from community funds which were publicly disclosed and verifiable on the blockchain. However, the large-scale UST issuance was facilitated by a high valuation of LUNA, raising an important question: what sustained this high valuation despite rapidly growing UST supply?

A rational explanation might be that investors believed strong network effects in

¹Both stablecoins and banks typically earn a spread on their assets, which is an increasing function of the short-term risk-free rate, creating positive franchise value that should be taken into account when valuing assets; see [Drechsler et al. \(2023\)](#).

the adoption of stablecoins might justify the initial subsidies. Whereas franchise value for collateralized stablecoins accrues to the issuing firm as interest income on collateral, in Terra’s case the expected franchise value was capitalized into LUNA’s price and thus distributed across all token holders. Initially, the Terra community appeared willing to fund these subsidies. However, our analysis shows that users did not meaningfully adopt other services within the Terra ecosystem. Instead, participation remained concentrated on exploiting the subsidized UST deposit rate on Anchor and speculative trading of LUNA.

An alternative explanation for the simultaneous expansion of UST supply and the appreciation of LUNA is that many investors might have failed to understand the dilutive nature of UST and the potential impact of UST conversion on LUNA price given the network’s complexity – while those who understood strategically exploited the subsidies while they lasted. Since issuance of UST required first purchasing LUNA and then converting it to UST, the concurrent growth of UST supply and LUNA appreciation could have been the direct result of investor flows - with new UST investors effectively transferring value to incumbent LUNA holders.

Ultimately, the subsidies to Anchor created a self-reinforcing dynamic in which maintaining a high deposit rate became essential for absorbing the ever-increasing UST supply. As the Anchor balance grew, it became increasingly apparent that subsidies at this level could not be sustained indefinitely. This rendered the network increasingly fragile, setting the stage for the run that culminated in the collapse of Terra. By April 2022, daily subsidy expenditures had reached \$6 million, prompting the Terra community to approve a proposal to gradually reduce the 19.5% Anchor interest rate to a more market-driven level beginning May 1, 2022. A run on UST began just one week later.

Standard models of fragility (e.g., [Morris and Shin \(1998\)](#), [Goldstein and Pauzner \(2005\)](#), or [Abreu and Brunnermeier \(2003\)](#)) emphasize the coordination problem among dispersed, atomistic depositors. We show that Anchor holdings were highly concentrated: the top 10 addresses controlled 15%–20% of UST, and the top 100 controlled 30%–40%. The presence of these large investors - whose actions were observable on the blockchain and could affect prices - reduced the need for coordination. We show that the start of the run on Terra was not a random panic but a response to the unwinding of positions by a few large players.

The first signs of the run appeared on May 7, 2022, when two large addresses withdrew 375 million UST from Anchor. Following these withdrawals, other investors began unwinding their positions and selling UST across exchanges, causing UST to lose its peg. Despite TFL’s attempts to stabilize the peg through UST purchases, withdrawals

continued. The pace intensified during the late hours of May 9, 2022, coinciding with the moment when market capitalization of LUNA equaled the outstanding supply of UST.

Consistent with the limited-rationality story discussed above, many investors appear to have held a simplistic valuation model: they failed to recognize that UST was a claim on the value of LUNA. Instead, the moment the market capitalizations of LUNA and UST equalized appear to have served as a signal to many investors that insufficient value existed to support the outstanding UST supply. As a result, UST depegged sharply, plummeting to \$0.75. By May 13, fewer than 2 billion UST remained in Anchor, and UST had fallen below \$0.20.

Rather than stabilize UST, the peg mechanism accelerated the run: as UST lost its peg and more UST was swapped for LUNA, LUNA supply exploded, drastically devaluing LUNA. The resulting price collapse created a death spiral in which dilution and declining prices fed on each other.

The blockchain data allow us to analyze how different investors behaved and responded to information during the run. We classify the size of addresses by their maximum Terra balance and proxy for investor sophistication using metrics such as cross-exchange activity and use of cross-chain bridges. We show that large and sophisticated investors were the first to run. We estimate a Cox proportional hazard model with time-varying coefficients by investor size and document that large investors not only ran faster but reacted especially quickly to adverse signals such as the early UST withdrawals on May 7 and the LUNA-UST market capitalization crossing. Smaller, less sophisticated wallets followed and consequently sustained larger losses.

Our findings highlight the limits of blockchain transparency and challenge the prevailing notion in the cryptocurrency space that open access levels the playing field for all investors. Although the prices of UST and LUNA, as well as trades on Terra, were publicly observable on the blockchain, large and sophisticated investors maintained an advantage in monitoring the blockchain’s health, which allowed them to run before other investors and serve as catalysts for the run. Thus, far from leveling the playing field, open access appears to have magnified investor heterogeneity.

In the last step, we also analyze an earlier de-pegging incident in May 2021, showing that it foreshadowed the risks and economic mechanisms important during the May 2022 collapse. As in May 2022, UST’s deviation from peg coincided with LUNA market capitalization declining to a level close to the aggregate market value of UST, alongside withdrawals from Anchor. Additionally, withdrawals were concentrated among larger investors, while smaller investors continued to deposit in Anchor.

One might ask why the run was avoided in May 2021 but not in May 2022. A critical

factor appears to have been the smaller outstanding UST supply in May 2021, which allowed TFL to act as a lender of last resort. We show that nearly all UST-LUNA swaps were initiated by TFL, which presumably held the newly minted LUNA rather than sell it. Furthermore, as the SEC lawsuit against TFL alleges, the peg was restored due to stabilization purchases of UST by a third party, reportedly identified as Jump Trading. Market participants, however, were unaware that TFL and Jump Trading were conducting stabilization operations. As a result, when participants saw the peg restored, they apparently interpreted it as a sign of the system’s stability. In contrast, in May 2022, traders knew that TFL was using funds held in LFG addresses to support the peg. They also knew that UST supply and the amount of UST locked in Anchor were significantly larger than the resources available to support the peg. Thus, traders may have doubted that stabilization would succeed.

Our paper contributes to several different strands of the literature. First, a growing body of work examines the design and operation of stablecoins. For overviews of different design features and stabilization mechanisms, see for example, [Eichengreen \(2019\)](#); [Arner et al. \(2020\)](#); [Makarov and Schoar \(2022\)](#); [Gorton and Zhang \(2021\)](#). [Gorton et al. \(2022\)](#) provide a comparative analysis of stablecoins and private money creation during the wildcat banking period of 19th century United States. [d’Avernas et al. \(2022\)](#) and [Li and Mayer \(2022\)](#) develop equilibrium models of the underlying pegging mechanisms for stablecoin protocols and underscore that mechanisms lacking external collateral are vulnerable to run risks if significant negative demand shocks arise, even if they remain stable for small shocks. [Ma et al. \(2025\)](#) highlight the inherent trade-off between greater price stability in secondary markets and increased run risk when designing an efficient arbitrage mechanism for stablecoins. [Lyons and Viswanath-Natraj \(2023\)](#) analyze the stability mechanisms of Tether and Dai.

The pegging mechanism behind UST and LUNA is also related to the literature that studies contingent convertibles, see [Glasserman and Nouri \(2016\)](#), [Pennacchi and Tchistyi \(2019\)](#), and [Hillion and Vermaelen \(2004\)](#).

Second, our results are related to a vast literature on runs on financial institutions, see [Brunnermeier and Oehmke \(2013\)](#) for an excellent recent survey of this literature. One part of this literature, starting with [Bryant \(1980\)](#) and [Diamond and Dybvig \(1983\)](#), posits that bank runs can arise as sunspot phenomena because of the liquidity mismatch and coordination problems among depositors. Another part emphasizes the role of information asymmetry about bank fundamentals, see for example, [Chari and Jagannathan \(1988\)](#) and [Jacklin and Bhattacharya \(1988\)](#). Following [Morris and Shin \(1998\)](#), a growing body of literature explores the interaction between fundamentals and strategic behavior by market participants as, for example, in [Goldstein and Pauzner](#)

(2005), Goldstein (2013), and Abreu and Brunnermeier (2003).

A few recent empirical papers have analyzed the behavior of depositors during bank runs using individual account information. Iyer and Puri (2012) and Iyer et al. (2016) highlight the importance of depositor composition for the speed of the run. In particular, customers with smaller account balances and those with stronger bank relationships run more slowly. Examining runs on money market funds following the Lehman Brothers collapse, Schmidt et al. (2016) find that institutional investors redeem more strongly than the retail ones, and fund outflows decrease in the expense ratio, used as a proxy for investor sophistication. We contribute to this literature by being able to document in detail the precise run dynamics and the coordinating role of a small set of large investors in the run. We are also able to directly classify depositors not just by size but also by their observed sophistication.

Third, our results also relate to the idea that greater observability can reduce bank stability. Dang et al. (2017) show that opacity allows banks to keep information symmetric across traders and thus increases the liquidity of privately issued money. In the context of Terra, we show that blockchain transparency seems to have reduced opacity disproportionately for larger and more sophisticated investors, who reacted quickly once a few large addresses started divesting from Anchor. While smaller and less sophisticated investors initially reacted slowly, once the market capitalizations of UST and LUNA converged, even these investors began to run rapidly. Similar concerns have recently become more pronounced for traditional financial institutions. During the Silicon Valley Bank crisis, social media appear to have accelerated depositor withdrawals, see, for example Cookson et al. (2026).

The rest of the paper is organized as follows. Section 1 describes the data used in this study. Section 2 provides description of the Terra network and an analysis of the economics of Terra leading up to the run. Section 3 documents the run on UST and the collapse of LUNA. In Section 4, we compare the interventions of TFL in the May 2022 crash to the earlier de-pegging event in May 2021. Section 5 concludes.

1. Data

Our primary data source is the Terra blockchain. We are unaware of any data source that provides fully Terra data. In our research, we worked closely with two leading blockchain data analytics companies, Nansen and Flipside.² We learned from them how to process Terra blockchain transactions and used their data to validate our data parsing methodology.

²See <https://flipsidecrypto.xyz/> and <https://www.nansen.ai/>.

We use several data sources in our analysis. First, we use Terra token transfers from October 2021 to August 2022 derived from transaction logs. When a transaction is settled, the blockchain records logs containing the transfer, minting (creation), and burning (destruction) of tokens. The tokens include LUNA, Terra stablecoins, and CW20 standard tokens.³ To collect the logs, we run a Terra Classic node using data from ChainLayer Quicksync, which stores copies of blockchains to speed up synchronization.⁴ We use Terra Classic’s API to query the data in each block. We first use the LCD (Light Client Daemon) API to query transactions, fees, and the log of transactions. Next, we parse the logs into structured data, recording the time of transfer, source account, destination account, token, and transfer amount. For transactions that require a delay or condition to settle, we use the RPC (Remote Procedure Call) API to query settlement events in each block.

Second, we use genesis files from Terra’s online code repository.⁵ Genesis files are snapshots of the blockchain state at each upgrade, (i.e., each fork). When the Terra developers release a major software upgrade, validators take a snapshot of the state of the blockchain and resume from there. A snapshot thus fully characterizes the blockchain state before an upgrade. We collect five snapshots that date back to April 23, 2019 (Columbus-1), June 6, 2019 (Columbus-2), December 13, 2019 (Columbus-3), October 3, 2020 (Columbus-4), and September 30, 2021 (Columbus-5). We reconstruct the daily balances of UST, LUNA, and CW20 tokens since Columbus-5 by finding the cumulative sum of token transfers and adding the initial balance.

Third, we use Flipside preprocessed data for specific transactions. These data include (1) Terraswap, Astroport, and Terra native swaps; (2) LUNA delegation and undelegation; (3) airdrops of ANC, MIR, and MINE; and (4) governance proposals and voting records on both Terra and Anchor.

To link pseudonymous addresses with real-world entities, we use Flipside and Nansen address labels as well as labels obtained from online forums, social media, and open-source code repositories. We also manually label some addresses by examining their transaction logs and graphs. For example, centralized exchanges typically require users to specify their account number in deposit transactions, which makes it possible to identify them in the data. We also identify unnamed smart contracts from transaction logs and collect their addresses from smart contract instantiation or execution transactions.

We also use the Ethereum blockchain data. We parse transactions that correspond

³CW20 is the standard for fungible tokens on Terra such as aUST, bLUNA, and ANC. The data do not cover transfers of NFTs that follow the CW721 standard. Both CW20 and CW721 standards closely resemble the ERC20 and ERC721 standards on Ethereum. See <https://github.com/CosmWasm/cw-plus/blob/main/packages/cw20/README.md> for more detail.

⁴See <https://www.chainlayer.io/quicksync/>

⁵See <https://github.com/terra-money/classic-mainnet>.

to trades on the Curve pool between UST and other stablecoins and trace UST and LUNA bridge transfers between Terra and Ethereum blockchains.

Finally, we obtain exchange trading data from Kaiko, a leading provider of trading data on centralized exchanges. Kaiko provides minute-level order book depths, tick-level trading records, and minute-level funding rates of perpetual futures. The data cover 19 exchanges and 131 trading pairs for UST, LUNA, ANC, and MIR tokens.

Together, our data cover 7.5 million blocks containing 228 million transactions from October 3, 2020, to May 15, 2022. These data cover 3.7 million addresses, including 25 centralized exchanges (CEXs), 864 trading pairs on 4 decentralized exchanges (DEXs), 10 interchain bridges, 58 DeFi protocols, 319 blockchain validators, 69 other entities including hedge funds and venture capital firms, 4,498 CW20 tokens, and 58,941 unnamed smart contracts.

2. Terra Network Prior to the Run

In this section, we analyze the economic structure of the Terra network prior to its collapse. We begin with a description of the Terra blockchain and its main components and then show that the key attraction of the Terra ecosystem was its lending protocol, Anchor, which offered heavily subsidized deposit and borrowing rates (Section 2.1). These rates were a primary driver of UST demand and contributed to a sharp expansion in UST supply. As Anchor deposits grew, required subsidies escalated and eventually became unsustainable.

Terra’s architecture shared many features with other smart contract platforms. Although smaller than Ethereum, Terra enabled developers to build a similar array of applications, ranging from borrowing and lending protocols to savings and trading applications. The original network was named Terra but is currently referred to as Terra Classic. For ease of reference, we continue to use the name Terra.

The Terra network was developed by TerraForm Labs (TFL), a company started by Do Kwon and Daniel Shin in 2018. In January 2019, TFL raised \$62 million in an initial coin offering (ICO) by selling Terra’s native cryptocurrency, LUNA, at a price of \$0.8 per LUNA. The initial supply of LUNA was set to 1B, with seed and other investors receiving 188M LUNA and the remainder going to TFL. TFL used this initial allocation to provide block rewards to validators and to fund additional projects.

LUNA’s value could be linked to three main factors. First, users used LUNA to access Terra applications generating transaction demand. Second, users could delegate their LUNA tokens to chosen validators and receive rewards proportional to their stake. While the rewards initially were partially funded from TFL’s reserves, they were ex-

pected to be sustained by Terra’s transaction fees in steady-state. Staking LUNA also allowed holders to propose and vote on governance proposals. Finally, since LUNA represented a claim on the Terra’s revenues, it attracted speculative demand from investors betting on Terra’s adoption and LUNA’s appreciation.

Starting in March 2020 Terra introduced a suite of algorithmic stablecoins pegged against different fiat currencies, the most prominent being UST which was pegged against the US Dollar.⁶ Unlike collateralized stablecoins such as Tether and Circle, which are backed by non-crypto assets, UST was backed by LUNA via a pegging mechanism that is meant to incentivize traders to engage in arbitrage whenever the stablecoin deviates from the peg.

At the core of the pegging mechanism was a *native swap* smart contract that allowed users to exchange one unit of UST for \$1 worth of LUNA, and vice versa. When UST was traded above \$1, users could buy \$1 worth of LUNA, swap LUNA for UST, which amounted to burning (destroying) LUNA and minting (creating) new UST, and sell UST at a premium above \$1, pocketing the difference as profit. In contrast, when UST was traded below \$1, users could buy UST, burn UST to mint new LUNA, and then sell LUNA with a profit.

The LUNA price necessary for the native swap was supplied by an oracle from off-chain centralized exchanges every 30 seconds.⁷ To prevent oracle price manipulation, fees associated with the native swap were designed to increase with volume. Without swap fees, a user could execute the following strategy: sell LUNA on off-chain exchanges to temporarily depress the LUNA price, use the native swap contract to swap a large quantity of UST for LUNA at the lower price, buy LUNA on off-chain exchanges to bid up the price, and finally use the native swap contract to swap back a large quantity of LUNA for more UST.

Swap fees were set so that on-chain liquidity provided by the native swap contract remained below the liquidity of off-chain exchanges used by the oracle. These fees decreased over time as off-chain exchange liquidity increased. Initially, the Terra protocol allowed swapping \$400 thousand per day with a 2% spread, with the spread increasing if the volume exceeded the daily limit. The daily limit was raised to \$20 million in Feb 2021 (Terra proposal 36). Following the May 2021 de-pegging event, Terra proposal 90 was passed to increase the daily limit to \$135 million and decrease the spread to 0.5%, and Terra proposal 185 further increased the daily limit to \$293 million in February 2022.

⁶Others included TerraCNY (Chinese yuan), TerraEUR (euro), TerraBGP (British pound), TerraJPY (Japanese yen), or TerraKWR (South Korean won).

⁷Blockchain oracles are services that provide smart contracts with external information. They serve as bridges between blockchains and outside data.

UST was marketed as a crypto-native stablecoin and aimed to become a cross-chain medium of exchange. Since Terra entered the market late, competing with first movers such as Tether and USDC, UST had to compensate for its convenience yield by offering additional benefits. These benefits came in the form of heavily subsidized deposit and borrowing rates on Terra’s borrowing and lending protocol, Anchor, described in next section.

2.1. Anchor

In this section, we outline the main features of the Anchor protocol. For a detailed description of its mechanics, please refer to the Appendix. Anchor served as the primary borrowing and lending platform on the Terra network. Its design was similar to other decentralized lending platforms like Aave or Compound on Ethereum, which function like narrow banks with fully collateralized borrowing. However, unlike Aave or Compound, where deposit rates are financed by borrowing rates, both deposit and borrowing on Anchor were heavily subsidized.

2.1.1. Anchor Rates

The Anchor deposit rate depended on two parameters: *target deposit rate* and *threshold deposit rate*. The target deposit rate, known as the Anchor rate, was the rate, which the protocol attempted to achieve from the interest gained from the borrowers. The threshold deposit rate served as a floor to the deposit rate triggering a subsidy from the *yield reserve pool*—a Terra community fund—if deposit rate fell below this threshold. When Anchor was originally launched, the target deposit rate and the threshold deposit rate were set at 20% and 18%, respectively, and later changed to 20.5% and 19.5%.

The borrowing rate was an increasing function of the utilization ratio and given by the formula:

$$2\% + 42\% \times \frac{\text{loans outstanding}}{\text{deposits outstanding}}$$

The borrowers were required to post LUNA as collateral, therefore forgoing the LUNA staking yield. To compensate them for this opportunity cost, Anchor distributed its native token, ANC, as a subsidy. Initially, the protocol distributed 87,000 ANC per day pro rata to loan balances; this subsidy later increased to 260,000 ANC per day. As a result, the net borrowing rate, which incorporates the opportunity cost of collateral and the ANC subsidy, often turned negative, sometimes falling below -100% .

Figure 1 plots Anchor’s deposit rate alongside the net borrowing rate. Notably, the net borrowing rate remained consistently below the deposit rate, creating an arbitrage

opportunity that prompted users to borrow from Anchor to redeposit the proceeds. We term these *recursive loans*.

[Fig. 1 About Here]

The figure also displays the proportion of recursive loans as a share of total borrowing. As expected, this share varied inversely with the deposit-borrowing rate spread, ranging from 20% to as high as 60%.

Anchor’s deposit rate far exceeded market rates on competing platforms. Deposit rates on major stablecoin lending protocols ranged from 2% to 3% during January–May 2022 — in stark contrast to Anchor’s 20%.

2.1.2. Anchor Balance and Cash Flows

The high Anchor rates attracted a lot of public attention and became a primary driver of UST demand. In response to this demand, TFL significantly expanded UST supply. Figure 2 shows the aggregate supply of UST broken down by entities that swapped LUNA for UST. It reveals that the majority of newly created UST ended up in the Anchor protocol.

[Fig. 2 About Here]

The first large increase in the supply of UST occurred in February–March 2021 following the launch of the Mirror protocol. The protocol enabled users to create synthetic assets that tracked the price of real-world assets, such as stocks and used UST as collateral. After March 2021, the supply of UST stayed around 2–2.5 billion until the Columbus-5 upgrade.

Columbus-5 introduced a significant change to the network economics. Prior to Columbus-5, only 5 percent of LUNA swapped for UST was burned; the rest accrued to the community pool. Under Columbus-5, all swapped LUNA was burned. Terra Proposals 133 and 134, introduced by Do Kwon and passed on November 10, 2021, directed that 88.675 million pre-Columbus-5 LUNA in the community pool be swapped for UST. This produced a sharp increase in UST supply from \$2.5 billion to \$6.5 billion, with the proceeds deposited in community administrative accounts.

The supply of UST continued to increase and reached 18.5 billion by the time of the May 2022 collapse. Right before the crash, Anchor held approximately 12 billion UST and the community accounts held another 3 billion UST.

As Anchor deposits grew, so did the subsidies. The left panel of Figure 3 displays Anchor’s cash inflows and outflows. Inflows include interest on outstanding loans (blue

series), staking rewards from collateral staked as LUNA (red series) or ETH (yellow series), and fees charged on liquidated loans (green series). Outflows include interest paid to depositors (gray series) and buybacks of ANC tokens on the Astroport exchange (teal series).

The solid black series shows net cash flows. Beginning in December 2021, outflows substantially outpaced inflows. The yield reserve absorbed these imbalances, accumulating surpluses when net flows were positive and covering shortfalls when negative. The right panel of Figure 3 shows the yield reserve balance. Because of persistent negative net flows, TFL had to replenish the yield reserve several times. TFL first injected 71 million UST in July 2021, and LFG injected an additional 510 million UST in February 2022.

[Fig. 3 About Here]

Dwindling reserves prompted widespread concern that the 20% Anchor rate was unsustainable, generating a series of proposals beginning in March 2022 to lower the deposit rate. Anchor Proposal 20 passed on March 23 and took effect on May 1, 2022, tying the deposit rate to changes in the yield reserve over trailing one-month windows. The rate rose when reserves grew and fell when reserves declined. The maximum monthly adjustment was capped at 1.5 percentage points.⁸

2.2. Network Structure and Transaction Volume

The previous section documents that Anchor rates were heavily subsidized. To assess the impact of these subsidies, we analyze transaction volumes on the Terra network using on-chain data. Our sample spans September 30, 2021 (the Columbus-5 upgrade) through May 6, 2022 (immediately before the collapse).

We treat each address as a separate entity unless available information indicates several addresses belong to the same entity. This approach likely biases our volume estimates upward, as some entities control multiple addresses. However, the bias is less severe than on Bitcoin, where Makarov and Schoar (2025) show a single entity can control ten or more million addresses. As an *account*-based network like Ethereum, Terra had far fewer addresses than Bitcoin. A typical entity on Terra typically controlled only one or a few addresses.

Some smart contracts, such as Nexus, adjust positions by rebalancing the whole position. For example, in the following sample transaction, the Nexus contract adjusts

⁸See Anchor Protocol, Twitter, March 24, 2022, https://x.com/anchor_protocol/status/1507052921745256449.

the amount borrowed from Anchor from 16,226,512 UST to 16,227,559 UST by first repaying the outstanding balance and then borrowing the new amount.⁹ The net effect is an increase in the borrowed position by 1,047 UST. Simply summing the two transfers would grossly overstate actual network volume. Therefore, in our volume calculation, we net token transfers between any two addresses occurring at the same time.

Table 1 reports total transaction volume for major tokens. Aggregate UST and LUNA volume during the sample period totaled \$360 billion and \$217 billion, respectively. The next four largest tokens by volume are aUST, bLUNA, ANC, and bETH, with \$114, \$50, \$13, and \$9 billion, respectively. As we explain in the Appendix, volume in these tokens is closely linked to Anchor activity. Other tokens constitute only a small fraction of UST and LUNA volume. We therefore focus on UST and LUNA in what follows.

Figure 4 shows the decomposition of transaction volume for UST (left panel) and LUNA (right panel) across address categories on the Terra blockchain. We classify addresses into broad groups associated with main network participants. *Admin* addresses denote network administration accounts, including the community pool, Terra’s native swap, transaction fee addresses, and LFG wallets. *TFL* addresses are those used to mint new UST and to defend the peg. *Anchor* denotes addresses via which Anchor protocol transactions are conducted, including its yield reserve, money market operations, staking accounts, and related functions. *Other* captures regular Terra users, including retail traders, hedge funds, and all unlabeled addresses. *CEX*, *DEX*, and *Bridges* denote the wallets of centralized exchanges, decentralized exchanges, and cross-chain bridge entities, respectively. *DeFi* captures smart contracts that are not exchanges or bridges—for example, NFT marketplaces or crowdfunding platforms. For detailed category definitions, see Appendix Table A.1.

[Fig. 4 About Here]

The size of each node reflects the total volume of that category. Similarly, edge width between nodes is proportional to volume between categories. The number next to each edge shows the corresponding volume. For clarity, we display only categories with at least \$10 billion in the UST network and \$5 billion in the LUNA network, and edges with at least \$1 billion.

The left panel shows that Anchor was by far the dominant protocol in the UST network, accounting for 46% of total network volume. The next two largest categories, CEX and DEX, together account for 26% of volume. The largest flow between nodes runs between Anchor and Other, highlighting Anchor’s centrality.

⁹See <https://finder.terra.money/classic/tx/e874a1d3824854bbdb4f8743f18484fdc07361bc62538b10369c8dc9fe7a3faf>.

The right panel maps transactions on the LUNA network. CEX, DEX, and addresses affiliated with TFL and Admin accounts account for 84% of aggregate volume. This indicates that the majority of LUNA transactions involve trading on exchanges, consistent with the view that demand for LUNA was substantially driven by speculative motives.

2.3. The Economics of Terra

With its value tied to the US dollar, UST functioned as a type of private money. Setting aside operational details, Terra resembled a bank, with LUNA representing an equity claim and UST serving as private money—each convertible into the other.

The network’s solvency therefore depended on the market capitalization of LUNA, which—as documented above—was powered by speculative demand from investors betting on future network adoption. The convertibility option made UST effectively a claim on LUNA’s value and increased the fragility of the network. Because conversion of UST to LUNA increased the supply of LUNA, it diluted existing holders’ stakes. Unless fully anticipated and priced in by investors *ex ante*, this dilution depressed LUNA’s price, and therefore could reduce demand for LUNA and lower the network value. Furthermore, since other blockchains offered similar services, users who lost confidence in Terra could readily migrate to alternative blockchains, driving LUNA demand to zero.

Thus, while operational details differ across collateralized stablecoins, traditional banks, and Terra, all three share the same core vulnerability identified by [Diamond and Dybvig \(1983\)](#): a feedback loop in which redemptions depress the value of backing assets, making the decision to run a strategic complement.

The larger the UST supply relative to network value, the more exposed Terra became to run risk. This created a self-reinforcing dynamic in which maintaining a high deposit rate on Anchor became essential for absorbing the ever-increasing UST supply.

Despite this inherent fragility, Terra’s insiders publicly dismissed multiple warnings about this vulnerability, but in January 2022, Do Kwon announced the establishment of the Luna Foundation Guard (LFG) to build reserves to defend the peg during market stress. The LFG was governed by a council that included several co-founders of TFL and lead investors. LFG initially raised \$1 billion through the sale of LUNA tokens, with Jump Trading and Three Arrows Capital as principle investors. The reserve pool expanded via additional sales of LUNA and transfers from TFL. An audit by JS Held, conducted after the collapse, documents that as of May 6, 2022, LFG held approximately 80,300 BTC, 26 million USDT, and 24 million USDC, with minor positions in

other tokens.¹⁰ The total value of reserves was approximately 15% of the outstanding supply of UST at the onset of the run and proved to be insufficient to halt it.

The heavily subsidized deposit rate on Anchor led some observers to compare Terra to a Ponzi scheme. However, as documented in Section 2.1.2, Anchor subsidies were paid from community funds that were publicly disclosed and verifiable on the blockchain.

Figure 5 plots the market capitalization of UST and LUNA. The large issuance of UST was contemporaneous with a large appreciation in LUNA. One interpretation therefore is that investors believed UST would generate substantial value for the Terra network. Whereas franchise value for collateralized stablecoins accrues to the issuing firm as interest income on collateral, in Terra’s case expected franchise value was capitalized into LUNA’s price and thus distributed across all token holders.

Strong network effects in the stablecoin market could, in principle, justify the initial subsidies. Our analysis in Sections 2.1 and 2.2, however, shows that the high deposit rate was a suboptimal subsidy design. Users did not meaningfully adopt other services within or outside the Terra ecosystem. Instead, participation remained concentrated in the subsidized deposit rate on Anchor and in speculative LUNA trading.

An alternative explanation for the simultaneous expansion of UST supply and the appreciation of LUNA is that many investors failed to understand the dilutive nature of UST and the potential impact of UST conversion on LUNA price given the network’s complexity – while those who understood strategically exploited the subsidies while they lasted. Since issuance of UST required first purchasing LUNA and then converting it to UST, the concurrent growth of UST supply and LUNA appreciation could have been the direct result of investor flows - with new UST investors effectively transferring value to incumbent LUNA holders.

3. LUNA and UST Run

We now analyze the dynamics of the run. The Terra collapse shares many parallels with traditional bank runs, but a distinguishing feature was that the signal and action spaces were significantly larger than in canonical models of self-fulfilling runs, such as Morris and Shin (1998) and Goldstein and Pauzner (2005). First, investors could receive not only private and public signals about fundamentals but also observe each other’s actions on the Terra blockchain and react to them. Additionally, investors could observe LUNA and UST prices. Second, because of the pegging mechanism, investors could run through two channels: sell UST holdings at market price or convert UST to

¹⁰See <https://lfg.sg/audit/LFG-Audit-2022-11-14.pdf> for the audit report.

LUNA at nominal value and then sell LUNA at market prices.

Another important difference from standard models was the heterogeneity in investor size. Standard models assume that each investor is infinitesimal and that their actions have no impact on equilibrium outcomes. This necessitates coordination and introduces synchronization risk.

In contrast, the left panel of Figure 6 shows that Anchor holdings were highly concentrated. From January 2022, the top 10 addresses controlled between 15% and 20% of deposits; the top 100 controlled 30% to 40%; and the top 1,000 controlled approximately 60%. The presence of large investors, whose actions were observable and could impact prices, reduced the need for coordination. Their actions could serve as focal points and therefore be conducive to runs.

We describe the price dynamics during the run in Section 3.1. We show that early withdrawals and price deviations were initiated by large players and triggered panic among other market participants. The UST peg remained tenuously intact until the evening of May 9, supported by aggressive interventions by TFL and LFG. However, once the market capitalization of LUNA dropped below the outstanding UST supply, investor confidence evaporated, as traders perceived that LUNA no longer had sufficient value to backstop UST.

The UST-LUNA peg mechanism allowed investors to swap 1 UST for 1 USD worth of LUNA when UST traded below \$1, creating an arbitrage opportunity. We show in Section 3.2 that instead of stabilizing UST price, this mechanism accelerated the run: as more UST was swapped into LUNA, the LUNA supply exploded, which in turn drastically devalued LUNA. The resulting price collapse created a death spiral, where dilution and declining prices fed into each other.

Finally, in Section 3.3, we study how different investors behaved and reacted to information during the run. We show that the run on Terra displayed a clear cross-sectional pattern: larger and sophisticated investors were much faster to run and react to adverse signals like the initial UST de-pegging or the LUNA-UST market cap crossing, reflecting superior ability to process and act on information.

3.1. The Timing of the Run

The first signs of the run appeared on May 7, 2022, as reported in several industry reports and on social media.¹¹ On that day, two addresses—hereafter Wallet A and

¹¹See, e.g., the report by Nansen at <https://www.nansen.ai/research/on-chain-forensics-demystifying-terrausd-de-peg>.

Wallet B—withdrew \$400 million UST from Anchor.¹² The withdrawals were made in batches and sent to Curve and Binance, the most liquid UST DEX and CEX, respectively. The top two panels of Figure 7 show the timing of these withdrawals. Wallet A withdrew first, removing \$45 million UST around 5:00 UTC and sending the funds to Binance. Following this withdrawal, Wallet B withdrew \$175 million UST around noon and sent the funds to Ethereum via the Wormhole bridge without immediately selling them. Wallet A then withdrew another \$35 million around 5:00 PM, followed by another \$20 million around 8:30 PM and 9:30 PM, sending all funds to Binance. Finally, at 21:48 UTC, Wallet A withdrew the remaining \$85 million and sent them to Curve. The bottom panel of Figure 7 shows the timing of all other Anchor deposits and withdrawals on May 7. Deposits are green and withdrawals are red. We can see that starting from noon, other large wallets began exiting Anchor.

[Fig. 7 About Here]

Concurrent with rising Anchor withdrawals, the UST price on both Curve and Binance began falling. The top panel of Figure 8 shows swap transaction prices for UST against three major stablecoins—USDT, USDC, and DAI—on May 7, 2022. Swaps from UST into the other three stablecoins are shown in red, and swaps into UST are shown in green. The y-axis is logarithmic. The bottom panel shows net signed volume and the deviation of the UST price from \$1 in basis points.

Figure 8 highlights that during May 7, swapping out of UST intensified, leading to a gradual increase in the UST discount. Selling activity increased sharply after 21:44 UTC, marked by the dashed gray line, corresponding to the moment when TFL removed \$150 million UST from the UST-3Crv pool to migrate to a new UST-4Crv pool. This was a preplanned transition: the new pool was scheduled to go live on Ethereum the following week. Terra and FRAX, another algorithmic stablecoin growing at the time, aimed to establish a dedicated Curve pool to deepen liquidity and generate higher yields for their stablecoins.

Note that the withdrawal of \$150 million UST from UST-3Crv by itself was not an adverse event for investors concerned about convertibility of UST into other stablecoins: the quantity of other stablecoins available remained unchanged. In fact, removing UST increased the UST price relative to other stablecoins by reducing the supply of UST relative to other stablecoins, reflected in the small decrease in the UST discount immediately following the event.

The withdrawal of \$150 million UST by TFL was followed by Wallet A withdrawing \$85 million UST from Anchor and selling the entire amount on Curve in a single

¹²Wallets A and B have been attributed to Jane Street and Celsius; see <https://twitter.com/FrankResearcher/status/1630545591397670916>.

transaction. The immediate effect was a widening of the UST discount to 80 basis points. This was followed by a flood of other large sales, including a trade by Wallet B, which sold \$150 million UST it had bridged to Ethereum earlier that day. Notably, Wallet B prepared for a possible sale earlier that day but only began selling UST once other large traders started exiting and the price dropped. As a result, the UST discount on Curve reached 250 basis points. In response, TFL bots began trading on Curve in an attempt to restore the peg. These interventions partially succeeded, reducing the UST discount to 50 basis points for the rest of May 7.

[Fig. 8 About Here]

The UST discount on Curve was mirrored on Binance. The top panel of Figure 9 shows UST/USDT trades. Sell-initiated trades are marked in red and buy-initiated in green. The y-axis is logarithmic. The bottom panel shows net signed volume and the deviation of the UST price from \$1 in basis points.

Comparing trades on Curve and Binance reveals many more but smaller trades on Binance. Because large orders had smaller price impact on Curve than on Binance, Curve attracted larger traders. The smaller Binance trade sizes may also reflect a higher concentration of retail investors, who trade in smaller quantities. Although the UST discounts on both exchanges were highly correlated, signed volume moved in opposite directions. Cumulative net selling on Curve totaled around \$200 million UST. By contrast, Binance recorded net buying of \$200 million UST. Thus, UST price and signed volume moved in opposite directions on Binance on May 7, contrary to standard price-volume relationships.¹³ This negative relationship could arise if sellers on Binance placed large limit orders at the prevailing price, which were filled by buy market orders. These orders may have originated either from noise traders who tried to buy the dip, or from TFL and other parties trying to defend the peg.

[Fig. 9 About Here]

Finally, Figure 10 plots aggregate hourly Anchor deposits and the UST price during the week after May 7. Investors continued to withdraw funds from Anchor, but the UST price remained close to \$1 until the evening of May 9. During this period, TFL and LFG defended the peg through a series of UST and LUNA purchases to support the price. The LFG audit report documents that TFL and LFG spent about \$2.5 billion (80,071 BTC, 26.3 million USDT, and 23.6 million USDC) during this period.¹⁴

¹³See, e.g., [Evans and Lyons \(2002\)](#), [Chordia et al. \(2002\)](#), [Hasbrouck \(1995\)](#), [Hendershott and Menkveld \(2014\)](#); for cryptocurrency markets, see [Makarov and Schoar \(2020\)](#).

¹⁴See JS Held, “Analysis: Terraform Labs’ and Luna Foundation Guard’s Defense of the UST Price Peg,” November 2022.

[Fig. 10 About Here]

Late on May 9, withdrawals from Anchor accelerated, and the UST price collapsed to \$0.75. This decline coincided with the market capitalization of LUNA equaling outstanding UST supply. Following a general decline in cryptocurrency prices, the gap between the market capitalization of LUNA and UST had been shrinking since mid-April. On May 7, the gap was approximately \$4 billion. It closed completely on the evening of May 9.

If investors were fully rational and considered the dilutive effect of redemptions on LUNA, the crossing point would not necessarily have been salient. However, investors appeared to use a simpler heuristic. The moment market capitalizations crossed served as a signal that insufficient value remained in LUNA to support all UST outstanding, triggering a rush to exit.

3.2. Swapping of UST and LUNA

The UST peg design added an additional dimension to investors' strategy space. Whenever the price of UST fell below \$1, investors who no longer wished to hold it could follow two main strategies. They could either (1) sell UST at market price or (2) swap UST for LUNA at its nominal value and then sell LUNA at market price. Absent frictions, the second option delivered strictly higher profits, increasing with the UST discount.

In practice, investors faced several frictions. First, as discussed in Section 2, the native swap contract had built-in fees designed to increase with volume to prevent oracle price manipulation. Second, trades in both the LUNA and UST markets were subject to price impact—a co-movement of prices in the direction of trades. Finally, there could be settlement delays between when investors sent their funds to an exchange and when their funds were cleared for trading. These delays were especially important if investors anticipated that other investors would sell their LUNA holdings, resulting in a predictable future price decline.

Figure 11 documents the trading activity in the native swap market from May 7, 2022 to May 13, 2022, when the convertibility between UST and LUNA got suspended. The top panel plots the UST discount and the swap fees over time. The middle panel shows the difference between the UST discount and the swap fees that measures the attractiveness of swapping UST for LUNA over selling UST at the market price. The difference can also be thought of as an arbitrage spread from buying UST at the market price, swapping it for LUNA, and selling LUNA at the market price. Finally, the bottom panel shows the dollar amount of UST that were swapped in a given minute.

[Fig. 11 About Here]

Figure 11 shows that the UST discount, swap fees, and swap volume moved together. As the UST discount widened, it became increasingly profitable to swap UST for LUNA and engage in UST-LUNA arbitrage. During May 7–13, users swapped 7.42 billion UST worth \$4.65 billion.

Table IA.1 in the online Appendix shows the top 20 addresses that swapped the largest amounts of UST during the run. The largest swaps came from two smart contracts arbitraging the relative price of UST and LUNA between Astroport, Terra’s primary DEX, and the native swap contract. Alameda Research, a cryptocurrency trading firm co-founded by Sam Bankman-Fried and closely linked to the FTX exchange, swapped the third largest amount. The Alameda Research case is notable because most top addresses did not have Anchor exposure and used swaps for UST-LUNA arbitrage. We estimate that of the \$12 billion in Anchor balances, at most \$700 million UST was routed to the native swap; the majority of funds went to CEXs and DEXs. Of the top 20 addresses in Table IA.1, only Alameda Research and terra1...4c2t held balances on Anchor (\$311 million and \$73 million UST, respectively). The swap fees and uncertainty about execution prices on CEXs appear to have deterred most participants from using the native swap contract as an exit route. Alameda Research, with favorable access to FTX, had an advantage over other players and appears to have exploited it.

Figure 12 shows that as users swapped UST for LUNA, the price of LUNA declined precipitously, resulting in ever-increasing amounts of LUNA being swapped for UST. From May 11 to May 13, LUNA supply increased from under one billion to 5.89 trillion, while the LUNA price dropped from \$50 to approximately \$0.000001, leading to a dramatic “death spiral.”

[Fig. 12 About Here]

The enormous increase in LUNA supply also had important implications for Terra’s governance. Since Terra used a one LUNA, one vote system, owners of newly minted LUNA obtained de facto control over the Terra network by diluting the positions of existing holders of LUNA. To defend its dominant position, TFL swapped a large amount of UST for LUNA and eventually disabled on-chain swaps.¹⁵

¹⁵One might draw a parallel between the run on Terra and the recent Silicon Valley Bank (SVB) collapse, which affected the collateral backing Circle’s USDC. Two differences are notable. First, Circle’s remaining collateral was held in off-chain liquid securities. Second, Circle paused redemptions quickly. As a result, investors could not redeem, but could only sell USDC at a discount reflecting the expected impairment. In contrast, Terra stopped UST–LUNA convertibility only after the run was underway, and its collateral value was tied to the network, making it vulnerable to the feedback loop from redemptions. Therefore, it was difficult to assign a fair impairment value.

3.3. How Did Investors Run?

We first analyze withdrawals from Anchor, since the run originated there. Permissionless blockchains theoretically provide all investors equal access to on-chain information. To test this, we evaluate how different types of investors were able to exit during the run. An important advantage of blockchain transparency is that we can observe transactions of individual investors over time. This allows us to infer investor characteristics such as wealth and sophistication. We build a proxy for wealth using address maximum balance (in mark-to-market USD) on the Terra network prior to the run. To measure sophistication, we assume that usage of complex protocols (such as bridges) or complex strategies (such as trading across multiple exchanges) are signs of investor sophistication. We drop addresses held by known intermediaries or large institutions and remove addresses with less than \$100 UST on Anchor.

Figure 13 shows a stark gradation by size, with largest addresses running first and smaller groups lagging. The largest group, addresses with more than \$10 million UST, began withdrawing on May 7, 2022, and withdrew earlier and more decisively on average, so that by the end of May 12 they had withdrawn almost 100% of their balances. In contrast, addresses with \$1,000 to \$10,000 UST began withdrawing almost two days later and by the end of May 12 still had about 50% of their balances on Anchor. The smallest group, addresses with under \$1,000 UST, reacted last, and still had about 70% remaining by the end of May 12.

[Fig. 13 About Here]

To gain further insight into investors' behavior during the run, we estimate a Cox proportional hazard model with time-varying coefficients. This model specifies the hazard rate of investor i withdrawal as

$$\lambda_i(t) = \lambda_0(t) \exp\{\beta(t)\text{Size}_i\}, \quad (1)$$

where $\lambda_0(t)$ is the baseline hazard rate and Size_i is the logarithm (base 10) of the address's maximum balance on the Terra network prior to the run. The baseline hazard rate is the hazard function for an investor with $\text{Size}_i = 0$. We define a withdrawal event as occurring when an address withdraws at least 75% of its pre-run balance.¹⁶

[Fig. 14 About Here]

We estimate the model using the R package *timereg*.¹⁷ The left panel of Figure 14 shows the estimates of $\lambda_0(t)$ and $\beta(t)$. The right panel plots $\lambda_0(t)$ and the UST

¹⁶Results are similar using 50% and 95% thresholds.

¹⁷Available at <https://CRAN.R-project.org/package=timereg>.

discount. The coefficient $\beta(t)$ on Size is positive and varies considerably over time, with four distinct peaks.

The first peak occurs at the beginning of the run and coincides with the moment UST broke its peg. The second peak occurs in the late hours of May 9, when the market capitalization of LUNA equaled outstanding UST supply. The third and fourth peaks appear on May 11 and May 12, when TFL failed to provide sufficient support for the peg and the UST discount reached 70%.

Compared to $\beta(t)$, the baseline hazard rate also exhibits peaks on May 9, May 11, and May 12. However, unlike $\beta(t)$, which has its largest peak at the beginning of the run, the baseline hazard rate shows only a muted response to the first signs of the run. The estimates of $\beta(t)$ imply that a wealthy investor with wealth of \$1 million ran 30 times faster than an investor with wealth of \$100 at the beginning of the run.

Comparing the behavior of $\lambda_0(t)$, $\beta(t)$, and the UST discount, peaks in $\beta(t)$ precede peaks in $\lambda_0(t)$, which in turn, precede peaks in the UST discount. This implies that wealthy investors not only ran faster but also reacted more quickly and strongly to adverse information.

Next, we show that investors who ran more decisively also experienced lower losses. To calculate the total loss for each address, we first compute the USD value of each address’s token portfolio on May 6 at market prices. The portfolio covers UST, LUNA, aUST, bLUNA, bETH, and ANC holdings. We then calculate the USD value of inflows and outflows of these six tokens during the run, marking every token transfer to market. Since some addresses hold tokens outside the Terra blockchain, such as on Ethereum via bridges or on centralized exchanges, we regard any inflows before the first outflow as part of the initial balance, which we term the balance adjustment. Finally, we calculate the ending balance at the end of May 13. We compute loss as:

$$\text{loss} = \left(1 - \frac{\text{post-run USD balance} + \text{USD outflow} - \text{USD inflow} + \text{adjustment}}{\text{pre-run USD balance} + \text{adjustment}} \right) \times 100\% \quad (2)$$

Since we lack reliable price data for some minor tokens, to reduce the impact of outliers, we winsorize losses at the 0.5th and 99.5th percentiles.

We first tabulate average loss by pre-run address size in Table 2. Losses decrease monotonically in size, with addresses above \$10 million experiencing a 26% loss and addresses above \$1 million experiencing a 32% loss. In contrast, addresses below \$10,000 and below \$1,000 lost an average of 60% and 76%, respectively.

Since size might be correlated with other characteristics, especially financial sophistication, we also analyze the percentage loss of an address as a function of size,

financial sophistication, and the age of the address. Age is measured as months since the address was established. Since participants can create new addresses at will, our measure of age likely represents a lower bound on true participant tenure.

Our measures of sophistication are derived from prior transactions observed on-chain. We construct (1) the number of different CEXs the address used; (2) an indicator for whether the address used a bridge (e.g., Wormhole, Shuttle) to move assets across blockchains; and (3) trading intensity, defined as token inflows (USD) divided by token balance (USD) before the run.

Table 3 Column (1) shows results from a multivariate regression of percentage loss over the period from May 6 to May 13 on log size, log age on Terra, and our sophistication measures. Column (2) repeats the same regression using dummies for size bins instead of the continuous log size variable. As in the descriptive statistics, there is a strongly negative and significant relationship between balance at the start of the run and loss incurred. Column (2) shows that largest addresses with balances above \$10M experienced 45 percentage points lower losses compared to smallest addresses with balances below \$1K.

Column (2) also shows that trading intensity, the number of CEXs used, and bridge usage all exhibit a substantial and significant negative relationship with loss during the run. In contrast, log age has a positive and significant coefficient: older addresses experienced greater losses. While address age is only a noisy proxy for participant experience, it suggests that older addresses may have been more inclined to trust in the stability of the system. Perhaps their owners were more committed to the ecosystem, or perhaps they had experienced a previous de-pegging event in May 2021 and learned to trust in stability of the system. The positive coefficient on age also suggests that experience alone does not explain why some depositors fared better during the run. Our sophistication measures appear to be distinct from experience with the Terra ecosystem.

In Columns (3) to (8), we analyze whether the importance of sophistication varies across the size distribution. We repeat the same specification breaking out addresses by pre-run balance. We use the following size bins: below \$1,000, \$1,000–\$10,000, \$10,000–\$100,000, \$100,000–\$1 million, \$1–\$10 million, and above \$10 million. Across the size distribution, addresses that score higher on sophistication—measured by bridge use, number of centralized exchanges, and trading intensity—experienced smaller losses. The importance of sophistication appears greater for smaller and mid-sized addresses, while for addresses above \$10M, none of the sophistication measures are significant. Similarly, the positive relationship between losses and age is significant and comparable in magnitude across addresses with different balances. Thus, regardless of balance size,

older addresses were more likely to experience losses since they tended to run later. Again, the exception is addresses above \$10 million, where there is no correlation between age and loss magnitude. These patterns suggest that for addresses above \$10 million, our measures of sophistication do not capture differences in trading strategies, likely because they were all relatively sophisticated and aware of developments on Terra. Additionally, the group contains only 109 addresses; thus, idiosyncratic differences may play a larger role than in other subgroups.

In summary, our findings have important implications for understanding the risks and benefits of open blockchain architecture in creating a level playing field. Although information about prices and trades of large wallets on the Terra blockchain was observable to all depositors, outcomes were highly uneven. The larger losses experienced by smaller and less sophisticated depositors are not explained by depositors having preferential access to insiders—an issue documented for traditional banks. For example, [Iyer et al. \(2016\)](#) show that bank staff or depositors connected to bank insiders experienced smaller losses in a run. Instead, our results suggest that many participants lacked the ability or found it too costly to process information in real time. Thus, open access and blockchain transparency do not compensate for differences in financial literacy and wealth and may even exacerbate them.

4. De-pegging Event in May 2021

May 2022 was not the first time UST de-pegged from the US dollar. Terra experienced a prior de-pegging event between May 19 and May 25, 2021.¹⁸ Comparing this episode to the May 2022 collapse foreshadows some of the risks and mechanisms that proved important later. It also allows us to analyze why the interventions TFL undertook to stabilize UST worked during the 2021 de-pegging but not in May 2022.

The de-pegging began on May 19, 2021, when China announced a crackdown on cryptocurrencies and the price of LUNA fell from \$16 to \$4. Many other cryptocurrencies also declined at this time. As in the May 2022 collapse, the sharp drop in LUNA's price resulted in its market capitalization declining to a level close to the aggregate value of outstanding UST, as illustrated in Figure 5.

Figures [IA.2–IA.5](#) in the online Appendix document many parallels between May 2021 and May 2022 de-pegging events. First, selling intensified initially among larger addresses. Between May 19 and May 24, 2021, investors sold a net 25 million UST, producing a 10% discount on UST. However, four addresses purchased a combined 135

¹⁸A second, smaller de-pegging occurred on January 27, 2022, but it was short-lived and relatively minor.

million UST during this period. Had these addresses not aggressively supported UST, the discount would have been significantly greater.¹⁹

Second, the decline in UST’s price coincided with withdrawals from Anchor. As in the May 2022 collapse, withdrawals were concentrated among wealthier investors, while smaller investors continued depositing in Anchor.

Finally, because of swap fees, the swap spread closely tracked the UST discount, restricting the ability of arbitrageurs to profit from the UST deviation from the peg.

Several commentators blamed the de-pegging on the on-chain redemption cap.²⁰ As discussed in Section 3.2, while the swap mechanism can support UST’s price, it can also contribute to a death spiral if investors who swap UST for LUNA sell their LUNA holdings. It is important therefore to understand as to why the run was avoided in May 2021, but not in May 2022.

A critical factor appears to be that outstanding supply of UST was much smaller in May 2021, enabling TFL to function as lender of last resort. Table IA.2 in the online Appendix displays the top 20 addresses that swapped the largest amounts of UST during the de-pegging period. In contrast to May 2022, nearly all swaps were initiated by TFL, which presumably held onto the newly swapped LUNA instead of selling it.

The SEC’s lawsuit against TFL provides further insight. The SEC alleges that the peg was restored through purchases of UST by a third party, identified as Jump Trading. Between May 23 and May 27, Jump Trading made net purchases of over 62 million UST across at least two cryptocurrency trading platforms. In return, Jump Trading allegedly received UST allocations from TFL at a discounted price of \$0.40 to compensate for the stabilization trades.

If the SEC’s allegations are correct, the fact that market participants in May 2021 were unaware TFL and Jump Trading were stabilizing UST could have been another factor in why the run was avoided. When participants observed the peg restoring, they interpreted it as a sign of the system’s stability. In contrast, in May 2022, traders knew that TFL was using funds from LFG addresses to support the peg. They also knew that UST supply and the amount of UST locked in Anchor was significantly larger than the resources available to defend the peg. Thus, traders may have doubted that stabilization would succeed.

¹⁹These four addresses are 0x5dd09afc9ca51b46d6cda2189478b505ace7f37b, 0xe3bdda6413313ed58585e47441815e9662bdd818, 0x2747363d886c7fdcc5187217f1ca493922aa4940, and 0xaf7bbcfb1c1f987e0ae409c684289b332a425254. They purchased \$66 million, \$33 million, \$19 million, and \$17 million, respectively.

²⁰See, e.g., <https://medium.com/coinmonks/should-depositors-in-anchor-protocol-pay-attention-to-ust-de-peg-risk-8b59849d75bf>.

5. Conclusion

This paper provides a detailed analysis of the run on Terra and identifies the economic mechanisms and risks that led to the collapse. We show that rapid UST issuance, combined with heavily subsidized deposit rates on Anchor, created an unsustainable and fragile system. The price of LUNA initially rose sharply with the inflow of depositors to Anchor, but participants may not have fully understood the underlying economics and failed to price in the potential dilution from the outstanding supply of UST. Our analysis suggests that the run on Terra followed increasing concerns about the viability of the system. It began on May 7th with a few large investors withdrawing UST deposits from Anchor and selling them on exchanges. These withdrawals were observable to all investors and acted as a catalyst for the run.

Blockchain transparency is often touted as a key advantage of the blockchain technology. However, our results highlight its limitation. While the data itself is theoretically available to everyone, the ability to effectively interpret and act on this information varies significantly among investors. We show that larger and more sophisticated investors, who might have greater resources and experience, processed information more efficiently. They ran faster and experienced smaller losses than smaller and less sophisticated investors. Our analysis suggests that transparency alone is insufficient to level the playing field across investors in financial markets, as the real challenge lies in the ability to utilize information effectively.

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Figures

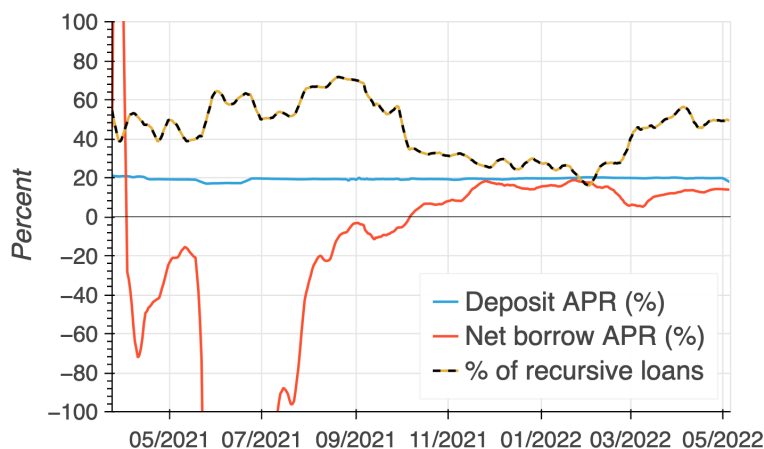


Figure 1: Anchor net rates and recursive loans. This figure shows the daily APR of lending (blue line) and borrowing (red line) on Anchor after considering the opportunity cost of the collateral and the ANC subsidy. We assume borrowers use the minimum permitted amount of collateral by the LTV limit and sell ANC subsidies after receiving them. The dashed line shows the proportion of loans from Anchor that are posted back to Anchor as deposits. The series are smoothed with 7-day rolling averages.

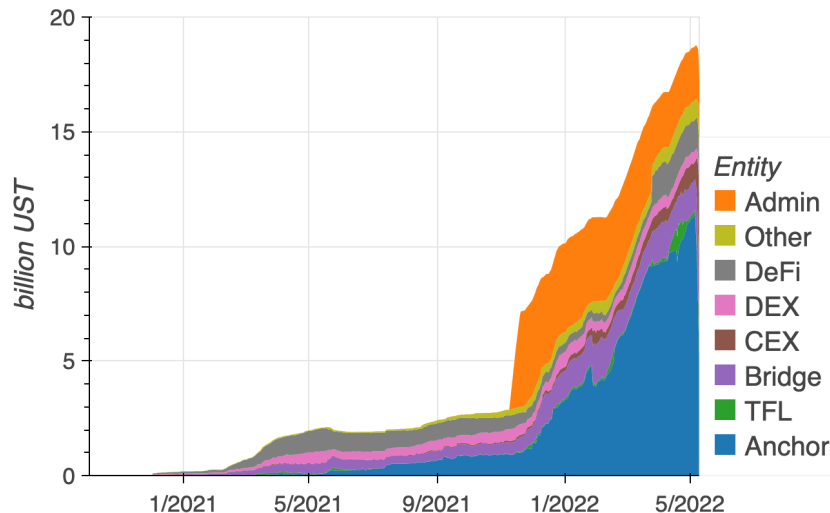


Figure 2: UST supply by entity. This Figure breaks out the aggregate supply of UST by the types of entities that held them. Definitions of the entity groups are in Table A.1 in the Appendix.

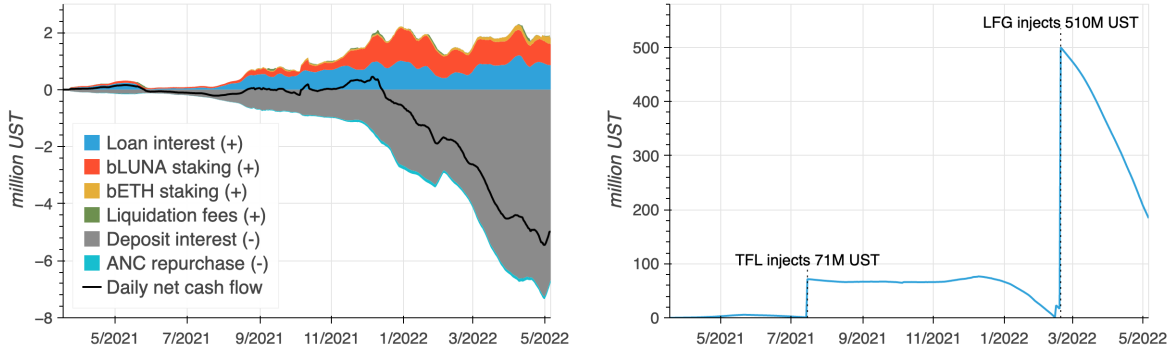


Figure 3: Cash flow decomposition on Anchor. The left panel shows the daily inflows (positive) and outflows (negative) on Anchor in billion UST broken out by their sources. Inflows include the interest on outstanding loans (blue), the staking rewards produced by the staked LUNA as collateral (red) or ETH as collateral (yellow), and proportional fees charged on the liquidated loans (green). Outflows include the interest paid to depositors (gray), and the buyback of ANC tokens from the Astroport DEX (teal). The black line plots the daily net cashflow. The right panel shows the balance of the Anchor's yield reserve address, as well as two waves of UST injections by TFL and LFG into the address.

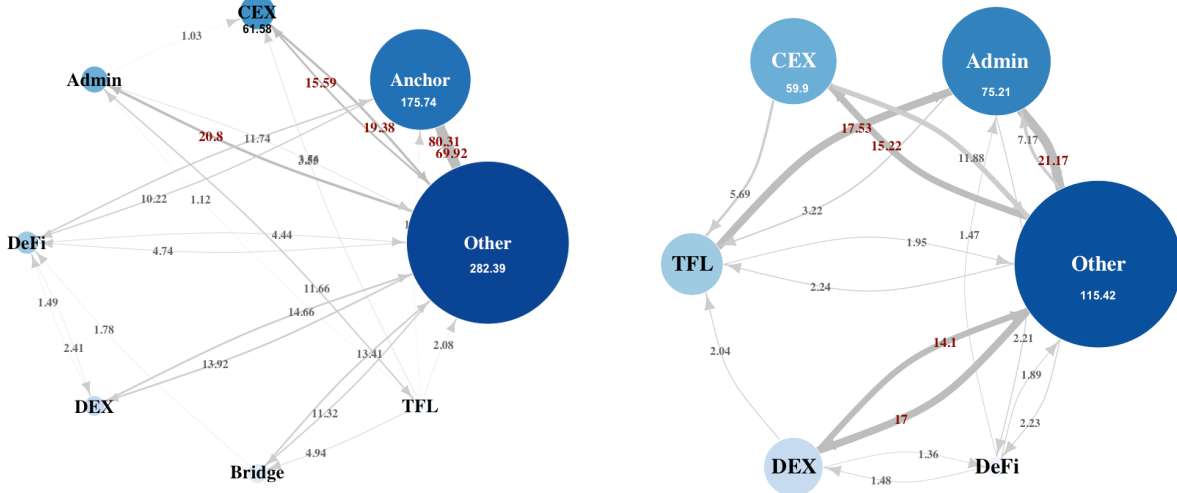


Figure 4: Network volume of UST (left) and LUNA (right). This figure shows the largest nodes in the Terra Luna network by transaction volume and the flow of volume between nodes. The size of the node reflects the total volume that flows through the category. The (grey) edge size between nodes is proportional to the volume between the two nodes. The numbers next to an edge show the corresponding volume. Definitions of the entity groups are in the text. We only show categories with at least \$10 billion of total volume in the UST network and \$5 billion in the LUNA network, and edges with at least \$1 billion of volume.

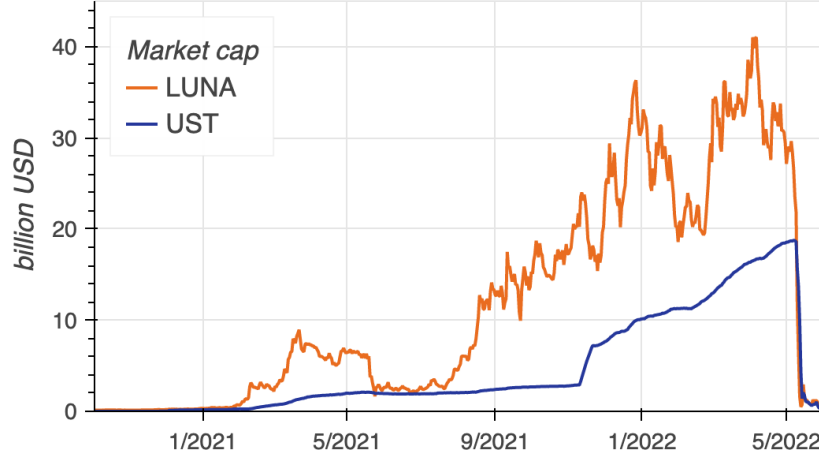


Figure 5: LUNA and UST Market Capitalization. This figure shows the circulating market capitalization of UST (blue line) and LUNA (orange line) in billions of US dollars from October 2020 to May 2022.

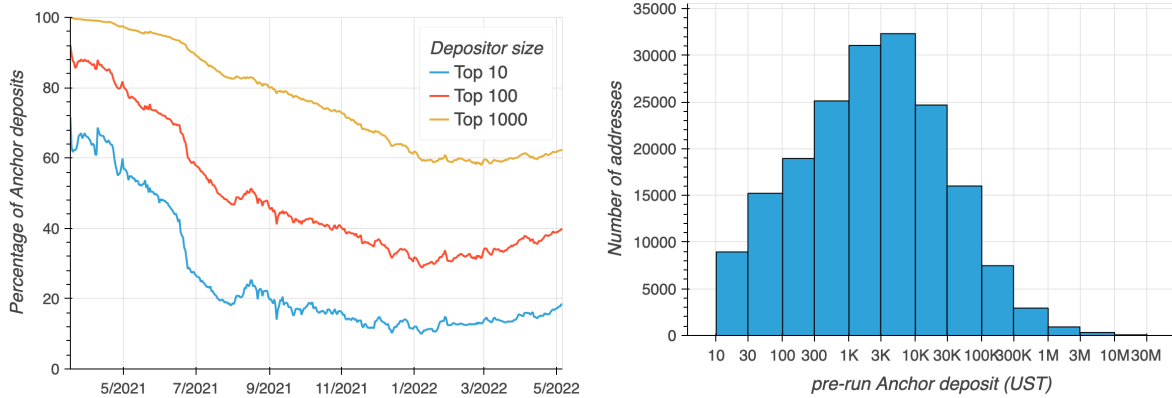


Figure 6: Concentration of Anchor deposits. The left panel plots the percentage of deposits held by the top 10, 100 and 1000 users on Anchor on a given day between May 2021 and May 2022. The right panel plots the histogram of the number of wallets by size of deposits on Anchor before the run on May 6, 2022. We exclude addresses that are exchanges, smart contracts, or other intermediaries.

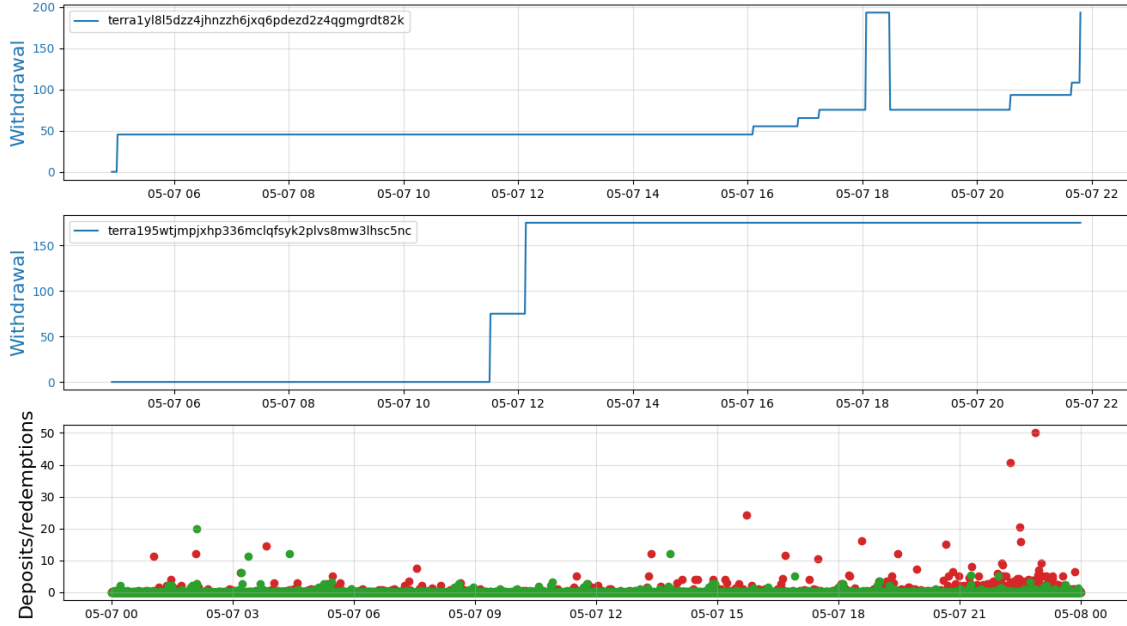


Figure 7: Anchor flows on May 7, 2022. The top two panels show the exact timing of the withdrawals by Wallet A and Wallet B from Anchor which constitute the beginning of the run. The bottom panel shows the timing of all other Anchor deposits (green) and withdrawals (red) on May 7. The y-axis denotes the size of each trade in millions of US dollars.

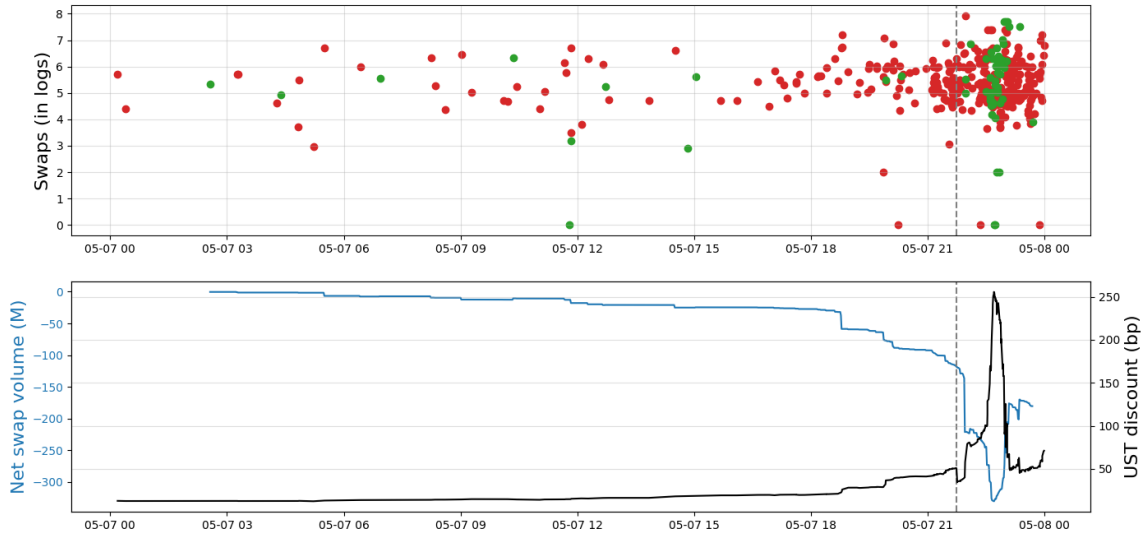


Figure 8: UST-3Crv swap transactions. The top panel shows the UST swap transactions price against three major stablecoins, USDT, USDC, and DAI on May 7, 2022. Swap transactions of UST into the other three stablecoins are in red, and swaps into UST in green. The y-scale is logarithmic. The bottom panel shows the net signed volume (blue) and the deviation of the UST price from \$1 in basis points (black).

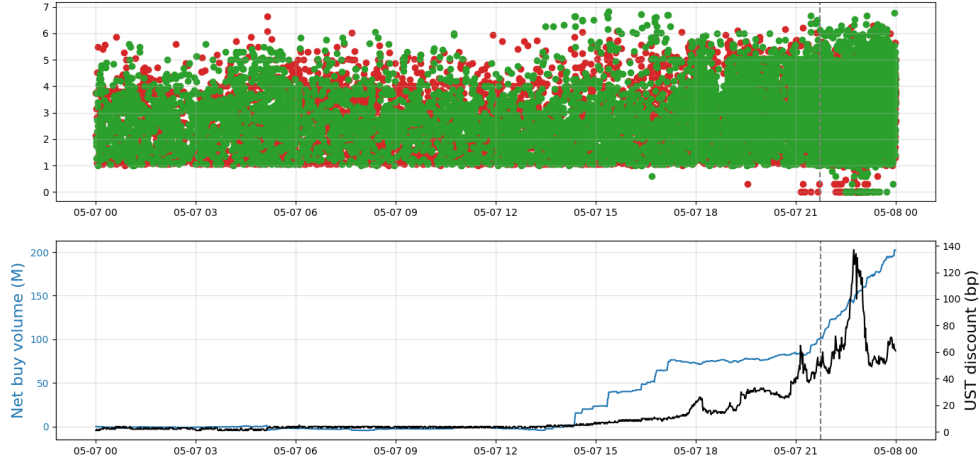


Figure 9: *Binance UST/USDT trades.* The top panel shows the UST/USDT trades on May 7, 2022. Sell-initiated trades are in red and buy-initiated ones in green. The y-scale is logarithmic. The bottom panel shows the net signed volume (blue) and the deviation of the UST price from \$1 in basis points (black).

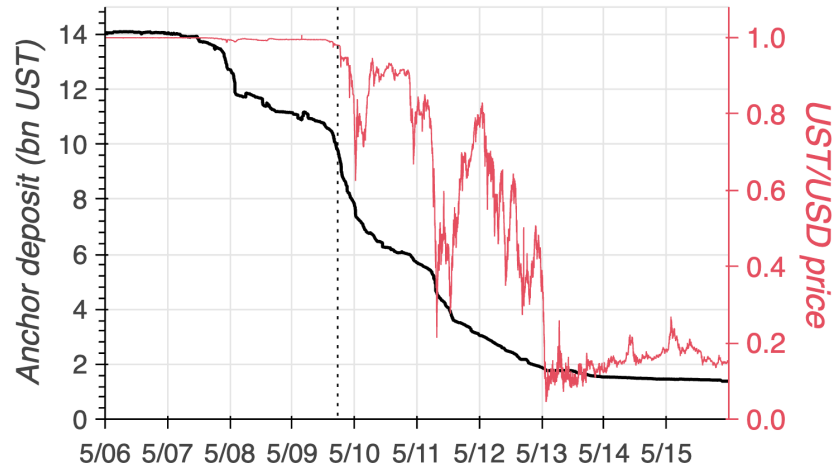


Figure 10: *Anchor outflows.* This figure shows the outstanding deposit balance in Anchor (black line, left axis) and the price of UST (red line, right axis) during the run in May 2022.

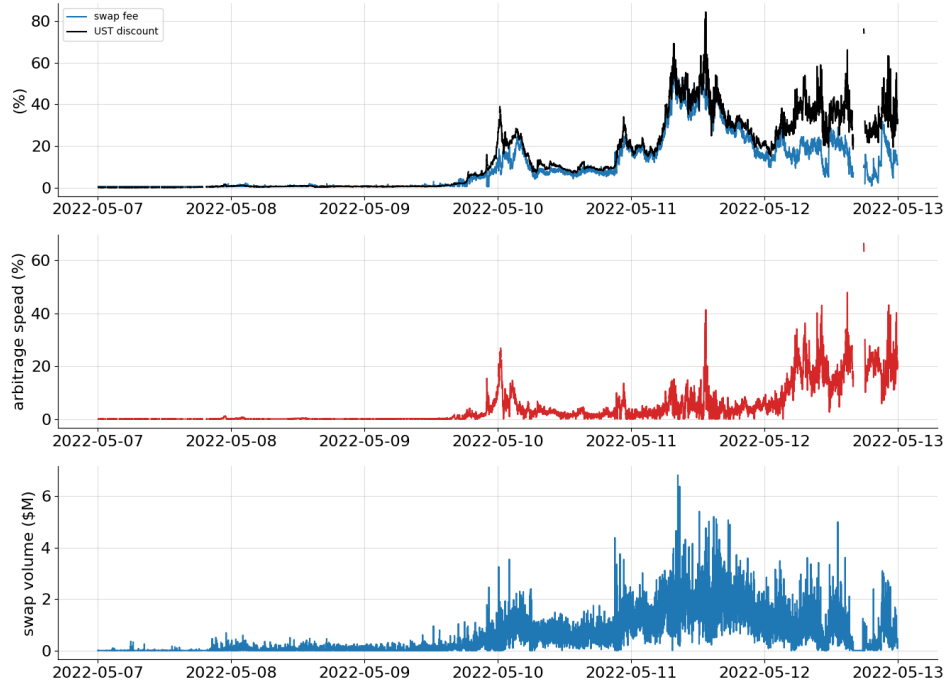


Figure 11: Swap arbitrage. This figure shows the trading activity on the native swap market. The top panel plots the UST discount and the swap fees over time. The middle panel shows the difference between the UST discount and the swap fees, which is a measure for the attractiveness of swapping UST for LUNA over selling UST at the market price. The bottom panel shows the dollar amount of UST that were swapped in a given minute.

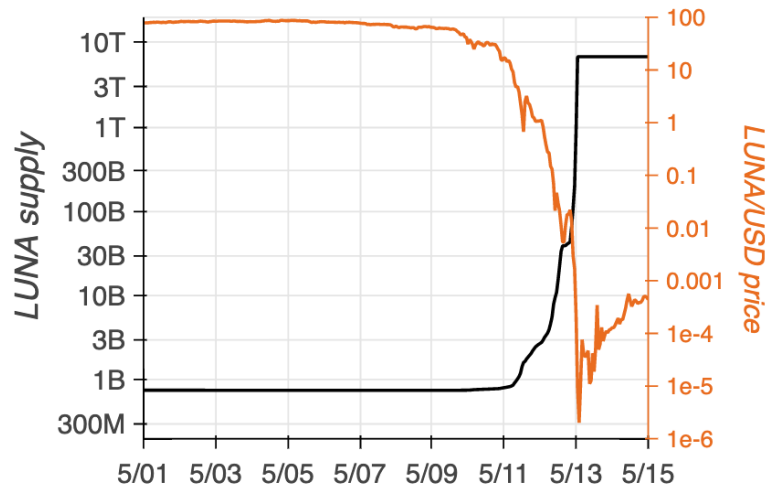


Figure 12: LUNA death spiral. This figure shows and the circulating supply (black line, left axis) and the price (orange line, right axis) of LUNA during the run, both in log scales. The convertibility between LUNA and UST was suspended on May 13.

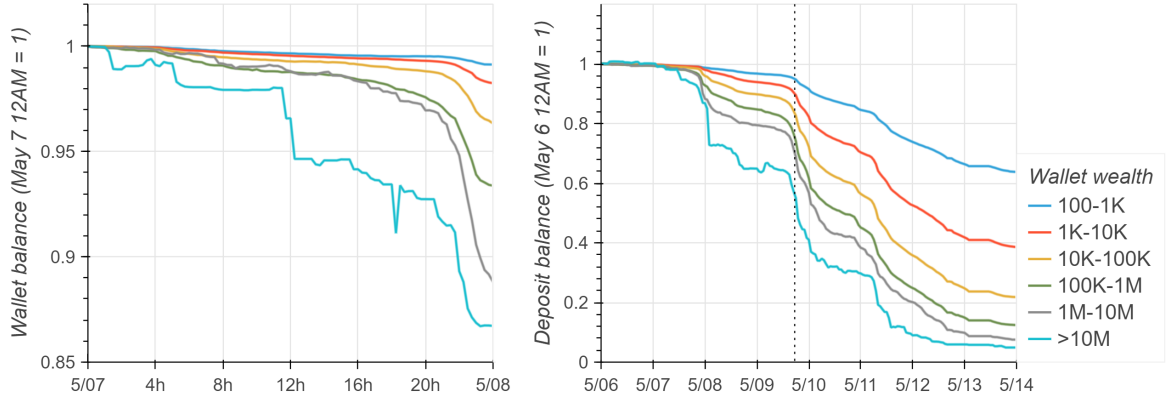


Figure 13: Anchor outflows by size. The left panel shows withdrawals from Anchor over the day of May 7, 2022, broken out by the size of the deposit balance of addresses as of May 6, before the run. The sample excludes any addresses held by intermediaries or large institutions and focuses on individual addresses. We also remove addresses with less than 100 UST in Anchor. The right panel shows the same analysis over the period from May 6 to May 14, 2022.

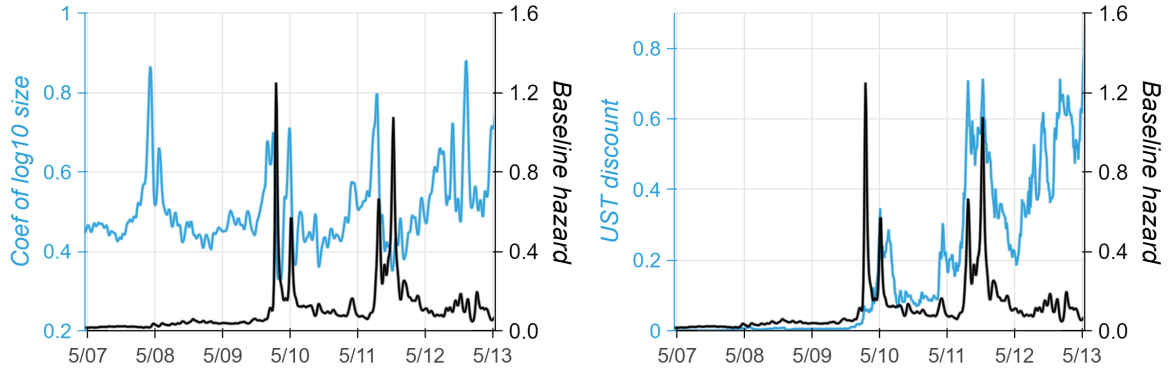


Figure 14: Cox model Anchor withdrawals. Figure 14 shows the results of the estimation of the Cox model described by equation (1). The left panel displays the estimates of the baseline hazard rate $\lambda_0(t)$ (black line, left axis) and the time-varying coefficient $\beta(t)$ (blue line, right axis). The right panel presents the baseline hazard rate (black line, left axis) and the UST discount (blue line, right axis).

Tables

Token	Volume (\$ Billion)	Transaction Count
UST	359.638	20272983
LUNA	216.698	9540155
aUST (Anchor UST deposit)	114.507	1581845
bLUNA (Anchor-bonded LUNA)	49.569	1548061
ANC (Anchor token)	13.161	2983677
bETH (Anchor-bonded ETH)	9.214	191050
Astroport ANC-UST LP	5.983	177590
Terraswap ANC-UST LP	5.068	170849
ASTRO (Astroport token)	3.988	1348552
VKR (Valkyrie token)	3.795	737877
SD (Stader token)	2.578	95102
MIR (Mirror token)	2.446	867647
Astroport ASTRO-UST LP	1.236	238299
PSI (Nexus token)	1.077	1175289
MINE (Pylon token)	1.065	593806

Table 1: *Token volume.* This table reports the volume (in billion US dollars) and the transaction count of the top 15 tokens on the Terra Luna network from September 30, 2021 to May 6, 2022. The volume is collected from transaction logs of type “transfer” and “send” in the network. We net any transfer of the same token between the same counterparties at the same time. The USD price is the closing price of the token on the day of transfer. The transaction count is the number of transactions that contain that token.

	Full Sample	Pre-Run Balance						Exited
	(1)	<1K	10K	100K	1M	10M	>10M	(8)
Address count	159669	43885	63360	40688	10397	1230	109	78859
Percent loss	59.31	76.49	60.05	46.29	36.74	31.85	26.58	
Age in months	4.56	4.06	4.43	5.01	5.58	6.10	6.92	
No. of CEXs	1.26	0.99	1.24	1.49	1.60	1.50	1.48	
Used bridges?	0.30	0.21	0.28	0.36	0.47	0.60	0.65	

Table 2: Summary statistics: individual addresses. This table reports the summary statistics for individual addresses prior to the run. We report the number of addresses, the percentage loss in the deposits on the address over the period of the run from May 6 to 13, Age in month is the number of months the address has been on the Terra blockchain, N of CEX is the number of centralized exchanges an address has traded with over the time of its existence, Used Bridges is a dummy for whether the address ever used Terra Shuttle or Wormhole Bridges. In Column (1) we show the full sample and in the remaining columns we break out the sample by the balance in the address on the day before the run.

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

Table 3: Percentage loss of Anchor depositors. This table reports the results from a regression of the loss in the value of an address experienced over the period of the run, from May 6 to May 13, on the size of the balance of the address before the run and measures of the financial sophistication of traders. Columns 1 and 2 report use the full sample. Columns 3 to 8 report subsamples by the size of the address.

Appendix

Name	Description
Admin	Addresses of network administration accounts and Terra insiders. This category includes addresses of the community pool, Terra’s native swap, the transaction fee collector, the native swap fee collector, LUNA staking master account, the Proposal 44 swap address, TFL’s main wallet, LFG’s main wallet, TFL and Do Kwon’s shadow wallets, TFL’s salary distribution wallet, TFL’s market marker wallet, and LFG’s reserve address.
TFL	Addresses that TFL, LFG, and Jump Trading used to issue UST and defend the peg.
CEX	Addresses of centralized exchanges are regular wallets that belong to a traditional cryptocurrency exchange. CEXs hold custody of cryptocurrencies. We cover 25 known exchanges: Binance, Bitfinex, Bithumb, Bitkub, Bittrue, Bittrex, Bkex, Bybit, Coinex, Coinone, Coinspot, Cryptex, Crypto.com, FTX, Gate.io, Gopax, Hotcoin, Huobi, Kraken, Kucoin, LBank, MEXC, Newton, Upbit, and Whitebit. We also identify some unknown exchanges by their transaction patterns and label them as CEXs.
DEX	Addresses of decentralized exchanges are smart contracts that allow traders to trade between pairs of tokens. Each token pair is a smart contract address. We cover trading pairs on Astroport, Terraswap, Loop, and Prism.
Anchor	Addresses that belong to Anchor, including Anchor’s UST money market account, Anchor’s UST yield reserve, bLUNA and bETH staking accounts, Anchor’s loan liquidation auctioneer, the ANC incentive payment account, the ANC airdrop account, the ANC repurchase account, Anchor’s community pool, and Anchor’s governance staking account.
Bridge	Addresses that connect Terra to other blockchains, including Wormhole and Shuttle bridges that connect to Ethereum. Terra users can send tokens to these bridges, and they issue tokens on Ethereum.
DeFi	Smart contract addresses that are not DEXs, bridges, or Anchor. This includes crowdfunding platforms, NFT marketplaces, and arbitrage bots.
Other	Addresses of regular users on the blockchain, including hedge funds, venture capitals, blockchain validators, and all unnamed regular accounts on Terra.

Table A.1: Categories of Terra addresses. This table reports the categories of Terra addresses in Figure 4 and their descriptions.

Internet Appendix

Anchor Protocol

This section provides details about the Anchor smart contract deployed on the Terra network.

Lending

The Anchor contract aggregated stablecoin deposits with matching denominations into pools called *markets*. Loans were drawn from these pools, and interest earned from them was shared pro rata across all units of stablecoin deposited. Deposits could be withdrawn at any time, unless all stablecoins in a market were borrowed.

When an address lent to Anchor, it transferred UST tokens to the Anchor UST market address. The Anchor UST market contract minted the appropriate amount of aUST and transferred it to the depositor’s address. aUST was a claim on UST held in Anchor. It was freely tradable and transferable. The conversion rate between aUST and UST was a function only of elapsed time, with the deposit rate embedded in the aUST/UST conversion rate. When an address wished to withdraw its UST from Anchor, it sent aUST tokens to the Anchor UST market contract, which burned the aUST and returned UST plus accrued interest. Interest earned equaled the difference between the aUST/UST conversion rates at deposit and withdrawal. The conversion rate stood at 1.000 at Anchor’s launch in March 2021 and reached 1.213 one year later in March 2022.

Borrowing

Borrowing on Anchor was overcollateralized. For the period we consider, Anchor allowed two types of collateral: bLUNA and bETH. These *bAssets* were liquid, tokenized representations of staked (bonded) assets on a proof-of-stake (PoS) blockchain. Since native tokens on a PoS blockchain can be staked to earn staking rewards, holding staked LUNA or ETH as collateral was more efficient than holding unstaked tokens. The main obstacle to using staked tokens as collateral was their illiquidity: staked tokens could be unstaked only with a delay because the Terra network imposed a lockup period of 21 days.

This built-in delay served an important function in the PoS protocol by providing validators and delegators with incentives to verify transactions on the blockchain. However, by restricting timely access to the token, the delay reduced its collateral value.

A solution was to create a derivative contract—a claim on staked tokens that could be freely traded. Lido implemented this solution through bAssets.²¹

When an address borrowed UST from the Anchor UST market, it first sent bLUNA (bETH) as collateral to the Anchor bLUNA (bETH) Custody Contract, which recorded the address and the amount of collateral provided. The borrowing limit depended on the value of collateral and could not exceed the maximum loan-to-value (LTV) ratio. The maximum LTV for bLUNA was initially set at 50%, raised to 60% in July 2021, and again to 80% in February 2022. The LTV ceiling for bETH was similarly raised to 75% at its peak. The borrowing limit fluctuated with the oracle-reported bAsset price. When a borrowing limit exceeded the maximum LTV, the position was liquidated. Liquidation was implemented via a *liquidation queue*, where liquidators bid in a first-price auction for the right to repay the loan and claim the collateral.

Anchor Rates

Anchor deposit and borrowing rates are described in Section 2.1.2 in the main text. Here we provide details on computing the net borrowing rate. The net borrowing rate is the sum of three components: the borrowing rate, the opportunity cost of posted collateral, and the ANC subsidy.

Borrowers were required to post LUNA as collateral, thereby forgoing the LUNA staking yield. LUNA staking yield derived from two main sources: (1) block rewards and (2) airdrops. Block rewards were the sum of swap fees and gas fees, less validator commissions. Airdrops—the practice of distributing tokens to active community members—is a popular marketing strategy in crypto markets to reward participants and promote awareness of new tokens.

LUNA delegators received three principal airdrops: ANC (Anchor token), MIR (Mirror token), and MINE (Pylon token). To compute the staking yield, we assume that delegators claimed all available airdrops of these three tokens weekly and sold them for LUNA. The left panel of Figure IA.1 shows LUNA staking yield by source. Through most of 2021, LUNA block rewards were stable but constituted less than 50% of staking rewards. The other half came from airdrops. The burning of LUNA for UST from the community pool in November 2021 (Terra Proposals 133 and 134), described in Section 2.1.2, led to a significant increase in staking yield.

To compensate borrowers for the opportunity cost of collateral, Anchor implemented a subsidy scheme which distributed Anchor native token ANC to borrow-

²¹Lido also offered a second derivative, stAssets. The distinction is not material for our purposes; details can be found in the Lido Terra documentation at <https://docs.terra.lido.fi/introduction/tokens>.

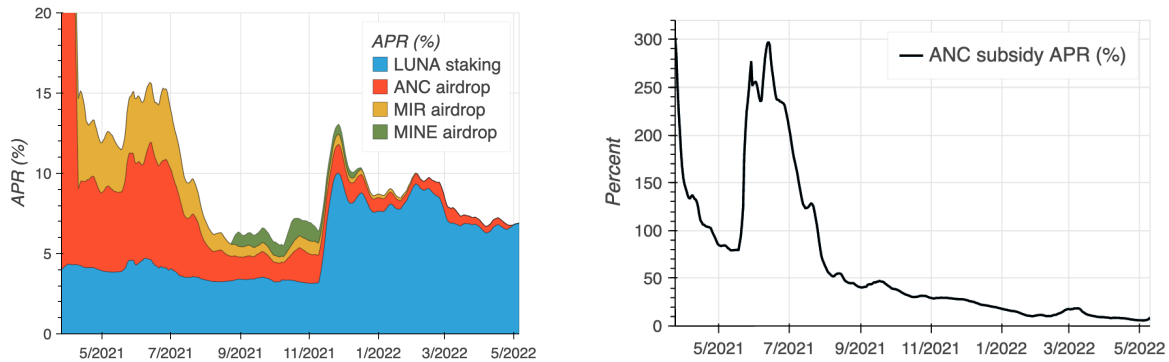


Figure IA.1: Anchor borrowing costs and incentives. The left figure shows the opportunity cost of LUNA collateral broken out by the source of the yield on LUNA tokens. The two main sources are block rewards and airdrops, which are token allocations to reward participants. To value the airdrops we assume a borrower sells weekly token airdrops during the week after receiving them. The right panel shows the annualized subsidy rate on Anchor, which was distributed to borrowers via ANC, Anchor native token. The series are smoothed with 7-day rolling averages.

ers. The protocol initially distributed 87,000 ANC per day pro rata to loan balances. Following the May 2021 de-pegging and the consequent sharp decline in LUNA’s price—which led to numerous liquidations over four days and a sharp decline in borrowing activity—the rate was dynamically adjusted by 50% per week until it reached the upper limit of 260,000 ANC per day on June 8, 2021, where it remained thereafter.

The right panel of Figure [IA.1](#) shows the annualized ANC subsidy rate, assuming borrowers sold the daily ANC distribution at market price. The subsidy rate reached 300% at inception, leading to a sharp rise in borrowing. As more investors borrowed from Anchor, the subsidy rate declined but remained around 80% in May 2021. After the de-pegging in May 2021, it increased again and then slowly decreased as borrowing activity recovered.

To compute the net borrowing rate, we assume a borrower took a loan at the maximum LTV. This would apply if users employed intermediary protocols like Nexus that were designed to maximize efficiency, constantly monitoring the LTV and ensuring that it remained below the liquidation threshold. Standalone users typically chose lower LTVs. For these users, the opportunity cost of borrowing was higher.

Anchor Governance

Like many other protocols on Terra, Anchor was organized as a decentralized autonomous organization (DAO) with its own governance token, ANC. Holders of ANC could stake their tokens to vote on or propose changes to the protocol, and their voting power was proportional to the amount of ANC staked. ANC tokens were designed to capture a portion of Anchor’s yield, scaling linearly with assets under management.

However, this design created a misalignment between ANC and LUNA token hold-

ers. Maintaining a high, subsidized deposit rate on Anchor benefited ANC holders by driving demand for ANC, increasing assets under management, and thereby increasing the fees accruing to ANC holders. But this also contributed to the risks building up in the system and reduced the going concern value of LUNA. ANC holders did not fully internalize the negative impact on the viability of the system. This misalignment became pronounced when ANC holders had to decide whether to reduce the subsidized deposit rate and bring it in line with the fees generated from borrowing.

Terra Run

Address	Vol (UST M)	Vol (\$M)	Transaction Count	Address Label
terra1cjjwzcer7qpx4uj9s70fcdwpz9lecrqsxmmtun	687	449	19122	unknown smart contract 12
terra139y02s9urkkyesukndrqdjmqj7gkk5dltd05v8	446	276	6513	unknown smart contract 5
terra1hz0q2qgsgetaqwxd95angslxfyvkpczfr4j9z	314	154	157	Alameda Research
terra14yzejwu639x5ntud98zsnl6caejqmns2vvfhs4	133	82	278	UST/LUNA arbitrageur
terra1ead9mws4efs64z4vz4sq2vp28q4wdsp3swpk4	119	70	134	UST/LUNA arbitrageur
terra1yvu32he5xprd5yea8dmagalaluases0z3x7dlv	122	68	184	UST/LUNA arbitrageur
terra1wlfagw79h0tushlz7uhvg3kxg5qq6zeg6axazf	86	66	2793	UST/LUNA arbitrageur
terra14tlthgtg6ep6xnqptyg8dp3gcq4jxvgqmskwkd	97	62	649	TFL bot/UST Peg Defender
terra1w92zvqhrplwalnj6ke7n28jfp8fwsdjlaivyv	83	57	2173	UST/LUNA arbitrageur
terra1zdm0cayj9y0vsvt4x60zp9eq9nh2uwxuht7jw0	78	55	7323	UST/LUNA arbitrageur
terra1jus3ldxzx4d42vzzw7yj5nzu2ghm6yz8k4c2t	90	54	1607	UST/LUNA arbitrageur
terra1wl5pwfj6zuqra2rhjs9eyufke3a0fjdckafxfu	96	51	304	UST/LUNA arbitrageur
terra1nexqdq252acp09m9eler7jhg9kd3rqfzkek9r0	83	50	526	TFL bot/UST Peg Defender
terra14ny376fe7hys2zqxwc87zp2achp9tju5q6jul4	81	50	504	TFL bot/UST Peg Defender
terra12qmfxcy8kahwt44tn4a4t6kdmtyer38xnrh7m	81	49	518	TFL bot/UST Peg Defender
terra1mer7nd843n5g3v37xxttd3hude6t5rf4cq3mnae	81	49	516	TFL bot/UST Peg Defender
terra1lewnh53gt0hzgjejrtdz8q7dennz09s6ds4k2	81	49	518	TFL bot/UST Peg Defender
terra1t8szgklntcwxyfyflucuq895gpjr8wn6tsqxye	80	49	505	TFL bot/UST Peg Defender
terra17p4mqd7yl9m0r7cfv0nf9s9zae3d3gm4tmyg2a	80	48	506	TFL bot/UST Peg Defender
terra1g5dmf4qpmdrcw77d3ty6djrgujt8r2n3lgyknj	81	48	529	TFL bot/UST Peg Defender
terra1v49w0m38fe87edhqdv30w96wq0pz6u6548q9gj	80	48	498	TFL bot/UST Peg Defender

Table IA.1: Top LUNA for UST swap addresses during the May 2022 Terra run.
This table reports the list of top addresses that swapped the largest amount of LUNA for UST over the period of the run, from May 7 to May 13.

De-pegging Event in May 2021

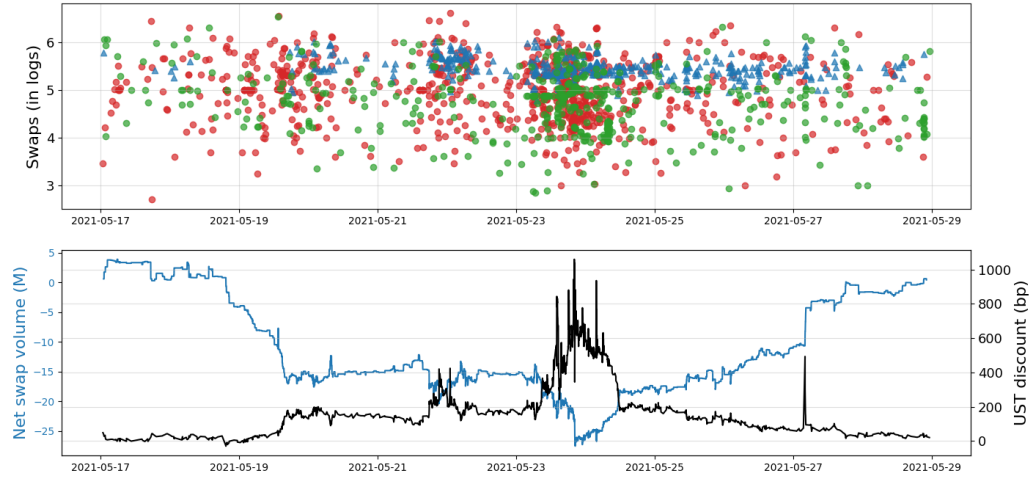


Figure IA.2: *UST-3Crv* swap transactions. The top panel shows the *UST* swap transactions price against three major stablecoins, *USDT*, *USDC*, and *DAI* on May 17–29, 2021. Swap transactions of *UST* into the other three stablecoins are in red, and swaps into *UST* in green and blue. The blue triangles are swaps into *UST* by four addresses: `0x5dd09afc9ca51b46d6cda2189478b505ace7f37b`, `0xe3bdda6413313ed58585e47441815e9662bdd818`, `0x2747363d886c7fdcc5187217f1ca493922aa4940`, and `0xaf7bbcfb1c1f987e0ae409c684289b332a425254`. The y-scale is logarithmic. The bottom panel shows the net signed volume (blue) and the deviation of the *UST* price from \$1 in basis points (black).

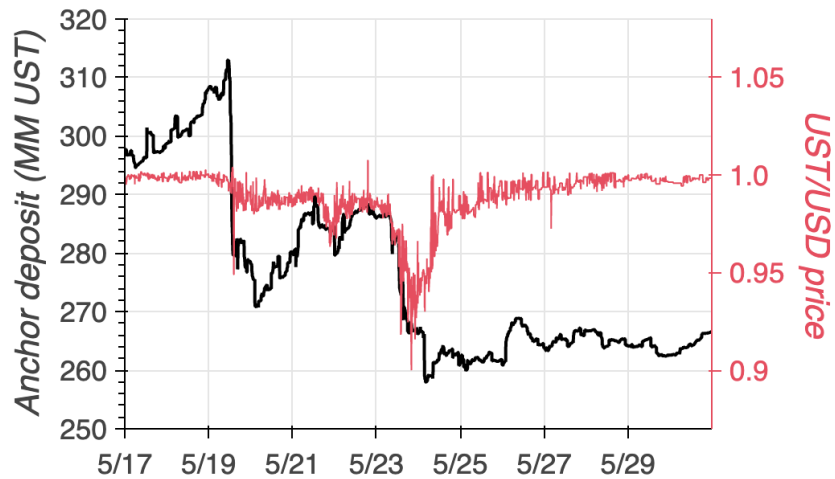


Figure IA.3: May 2021 De-pegging event. This figure shows the outstanding deposit balance in Anchor (black line, left axis) and the price of UST (red line, right axis) during the run in May 2021.

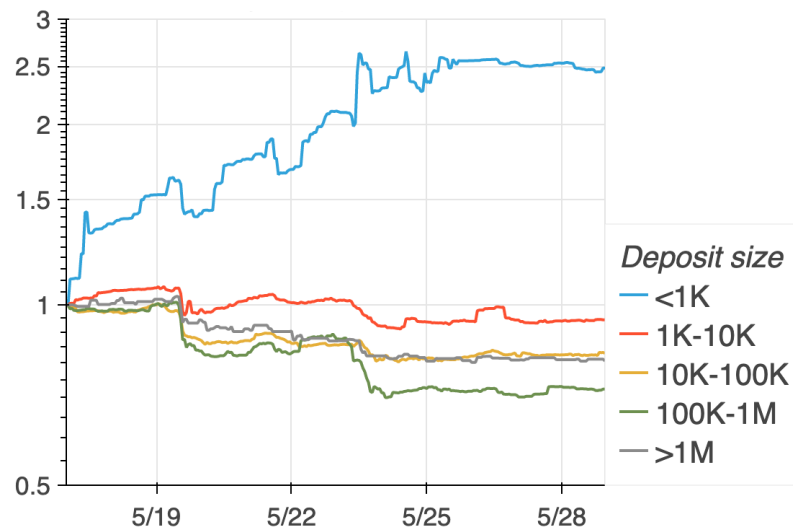


Figure IA.4: Anchor May 2021 outflows by size. The figure shows withdrawals from Anchor over the period of the first de-pegging event, May 17 to 28, 2021, broken out by the size of the deposit balance of addresses as of May 17th, 2021. The sample excludes any addresses held by intermediaries or large institutions and focuses on individual addresses. We also remove addresses with less than 100 UST in Anchor.

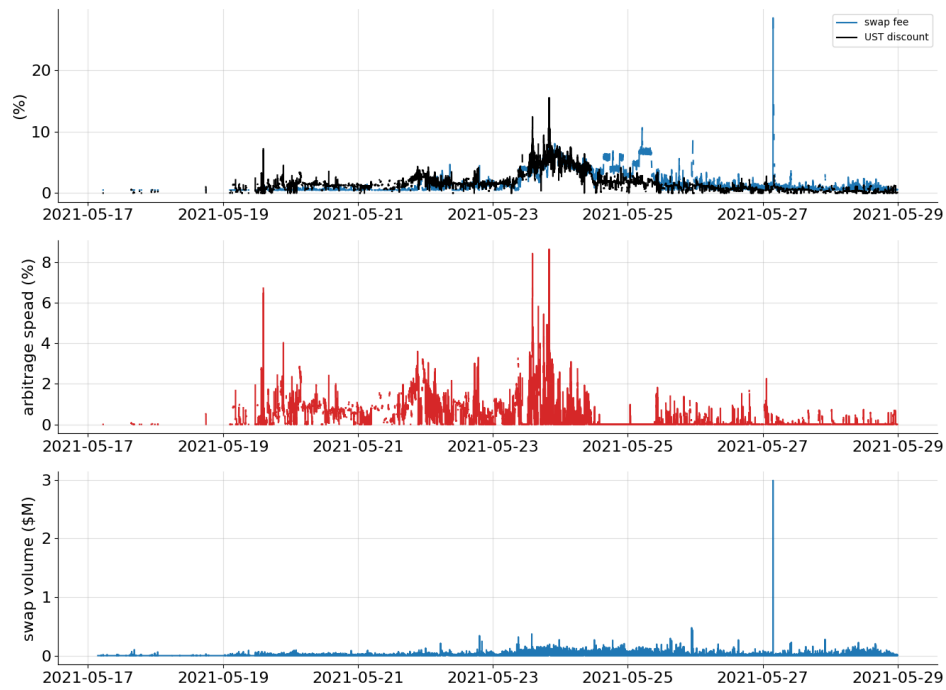


Figure IA.5: Swap arbitrage, May 2021. This figure shows the trading activity on the native swap market. The top panel plots the UST discount and the swap fees over time. The middle panel shows the difference between the UST discount and the swap fees, which is a measure for the attractiveness of swapping UST for LUNA over selling UST at the market price. The bottom panel shows the dollar amount of UST that were swapped in a given minute.

Address	Vol (UST M)	Transaction Count	Address Label
terra189gutrsl7dm47u5h4y7hsraxnr9q4dk2fhjs	63	11536	Jump/TFL swap addr
terra14ny376fe7hys2zqxwc87zp2achp9tju5q6jul4	9	214	TFL bot/UST Peg Defender
terra1lewnh53gt0hzgjeirtwdz8q7dennz09s6ds4k2	8	180	TFL bot/UST Peg Defender
terra1mer7nd843n5g3v37xxttd3hude6t5rf4cq3mnae	8	201	TFL bot/UST Peg Defender
terra1pemrznzc6kup38n294nd5q39k2c8qhl6lthet4	8	4988	UST/LUNA arbitrageur
terra1hsh3ve4vrqnluccws9gwh5sg4jchuc352md2kw	8	4713	UST/LUNA arbitrageur
terra1nexqdq252acp09m9eler7jhg9kd3rqfzkek9r0	7	180	TFL bot/UST Peg Defender
terra1v49w0m38fe87edhqdv30w96wq0pz6u6548q9gj	7	180	TFL bot/UST Peg Defender
terra12qmfxcy8kahwt44tn4aq4t6kdmtyer38xnrh7m	7	168	TFL bot/UST Peg Defender
terra1g5dmf4qpmdrw77d3ty6djrgujt8r2n3lgyknj	7	163	TFL bot/UST Peg Defender
terra17p4mqd7yl9m0r7cfv0nf9s9zae3d3gm4tmyg2a	7	164	TFL bot/UST Peg Defender
terra1t8szgklntcwxyfyflucq895gpjr8wn6tsqxye	7	160	TFL bot/UST Peg Defender
terra1cgq04kwfpckhlxvw3uw2ug43a5xur3shaxcl8e	7	2649	UST/LUNA arbitrageur
terra14tlthgtg6ep6xnqptyg8dp3gcq4jxvqgmskwkd	7	149	TFL bot/UST Peg Defender
terra1m3cxucxdkg2p8h7fk3ztwrwqw0fjnr07yxwvuf	5	1909	UST/LUNA arbitrageur
terra1pm37tvmac8khvfr500fzvuj7z0pu73d6mphepy	5	1743	UST/LUNA arbitrageur
terra1x04xgtwlw72gtfzrq7nfwmr6eexla8ecljw28z	4	2	TFL market making
terra1m2rylkksr05r3z7myzhldz59x9j0c5ffagzd5y	3	1281	UST/LUNA arbitrageur
terra1d6yuxj62qefw8wwmmskmfm8503g59fxdr0z8s	2	1185	UST/LUNA arbitrageur
terra10jycqs3qn6vlxkacqm9lyhzadwk0p03a6de8jm	1	393	UST/LUNA arbitrageur

Table IA.2: Top LUNA for UST swap addresses during the May 2021 de-pegging event. This table reports the list of top addresses that swapped the largest amount of LUNA for UST over the period of the May 2021 de-pegging event, from May 19 to May 27.