Digital Money Creation and Algorithmic Stablecoin Run

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ABSTRACT

This study examines the downfall of Iron Finance's algorithmic stablecoin in June 2021 and draws parallels with the TerraUSD (UST) collapse in May 2022. Using transaction-level blockchain data, we dissect the events leading to Iron Finance's failure, unveiling algorithmic stablecoins' inherent vulnerabilities. We highlight the disproportionate impact on retail investors, a pattern also mirrored in UST, where confidence erosion led to a similar destabilizing 'bank run.' Our analysis contributes to the broader understanding of the fragility of DeFi ecosystems and sheds light on the risks of adopting permissionless blockchains and algorithmic stablecoins as payment infrastructures and forms of digital money.

Keywords: digital money, algorithmic stablecoin, DeFi, bank run, regulation

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ABSTRACT

This study examines the downfall of Iron Finance's algorithmic stablecoin in June 2021 and draws parallels with the TerraUSD (UST) collapse in May 2022. Using transaction-level blockchain data, we dissect the events leading to Iron Finance's failure, unveiling algorithmic stablecoins' inherent vulnerabilities. We highlight the disproportionate impact on retail investors, a pattern also mirrored in UST, where confidence erosion led to a similar destabilizing 'bank run.' Our analysis contributes to the broader understanding of the fragility of DeFi ecosystems and sheds light on the risks of adopting permissionless blockchains and algorithmic stablecoins as payment infrastructures and forms of digital money.

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1. Introduction

Stablecoins are digital tokens on blockchain networks. They are designed to peg their exchange rates to currencies, drawing comparisons to traditional money. With the global reach of permissionless blockchains, stablecoins issued on these open networks promise to revolutionize payments. In June 2019, Facebook unveiled its plan to create Libra, a digital currency on its blockchain network.[1] The rise of stablecoins and blockchain-based digital money alarmed monetary authorities, who are concerned about the potential impact on global financial stability and the risks of 'liquidity runs' that stablecoin issuers face (G7 Working Group on Stablecoins, 2019; ECB Crypto-Assets Task Force, 2020; Liao and Caramichael, 2022).

Tokens, digital information created by developers, can be programmed to specify their creation (minting), transfer, or destruction (burning). Typically, issuers can 'guarantee' token creation and redemption at a fixed exchange rate (e.g., $1 per unit), classifying them as stablecoins. These creations and redemptions are primary market transactions, and when secondary market prices differ from the peg, arbitrage opportunities exist.

A stablecoin is a new, privately issued money. In a paper that relates stablecoins to pre-Civil War U.S. private banknotes, Gorton, Ross, and Ross (2022) began by quoting Hyman Minsky: "Everyone can create money; the problem is to get it accepted." Thus, stablecoin issuers face two challenges. First, their mechanisms must ensure peg stability. Second, they must create demand for their stablecoins.

Stablecoins that require self-issued tokens to create/redeem are called 'algorithmic stablecoins,' and notable examples include TerraUSD (UST) on Terra and Frax on Ethereum. Other issuers may back their stablecoins with off-chain assets (e.g., USD Coin, Tether, Pax Dollar) or involve collateralized loans (e.g., Dai, Liquity USD) in the process (Li and Mayer, 2022; Lyons and Viswanath-Natraj, 2023). Brunnermeier, James, and Landau (2019) state that money issuers offer some level of convertibility to other payment instruments, and reserve backing helps maintain money's value. Algorithmic stablecoins are fragile, as backing by self-issued tokens is almost like no backing, making them more vulnerable to depeg.

Iron Finance is a decentralized finance (DeFi) protocol developed by an anonymous team that issues IRON algorithmic stablecoin on Polygon.[2] The protocol was short-lived: it began on May 29, 2021, grew rapidly to almost $800 million by June 16, and collapsed on June 17, in under three weeks. Its similarity to money and banking led crypto media to liken its demise to a 'bank run.'[3]

Iron Finance's failure did not deter algorithmic stablecoins issuers. Frax and UST continued to grow, reaching $2.9 billion and $18.8 billion in early 2022. However, UST's collapse on May 9, 2022, led to discussions of algorithmic stablecoin risks. For example, a draft U.S. stablecoin bill in September 2022 sought to ban new algorithmic stablecoins for two

[1] See, for example, https://www.cnbc.com/2019/06/17/facebook-announces-libra-digital-currency-calibra-digital-wallet.html.

[2] For more details and discussions on decentralize finance (DeFi), see Schär (2020), Aramonte, Huang, and Schrimpf (2021), and Carapella et al. (2022)

[3] See, for example, https://www.coindesk.com/markets/2021/06/17/in-token-crash-postmortem-iron-finance-says-it-suffered-cryptos-first-large-scale-bank-run/.

years,[4] while the EU banned algorithmic stablecoins in its 2023 Markets in Crypto-Assets Regulation (MiCA).[5]

Researchers have explored UST's failure theoretically (Uhlig, 2022; Badev and Watsky, 2023) and empirically (Briola et al., 2023; Liu, Makarov, and Schoar, 2023). While Briola et al. (2023) stated that the fall of TerraUSD is very similar to Iron Finance, academic evidence on Iron Finance is limited to the FEDS Notes by Adams and Ibert (2022). We contribute by documenting the collapse using transaction-level blockchain data.

We provide an overview of Iron Finance, examining its tokens through a balance-sheet perspective, and highlight the innate fragility of algorithmic stablecoins. We demonstrate how the 'death spiral' (like TerraUSD) unfolded and show that sophisticated users were more likely to exit, exit faster, and exit more profitably. Our work complements Liu, Makarov, and Schoar (2023), who also use blockchain data and reach similar conclusions for TerraUSD. In addition, we highlight the potentially confusing and distortionary practice of 'governance token' issuance and distribution.

2. Iron Finance's Algorithmic Stablecoin

2.1 How IRON stablecoins work.

To purchase IRON, Iron Finance's algorithmic stablecoin, users must provide $1 worth of USD Coin (USDC) and TITAN, a 'governance token' issued by Iron Finance. More details on this will be provided later. However, it does not fully rely on a self-issued token and incorporates USDC. The ratio of USDC per IRON created is called the Target Collateral Ratio (TCR).

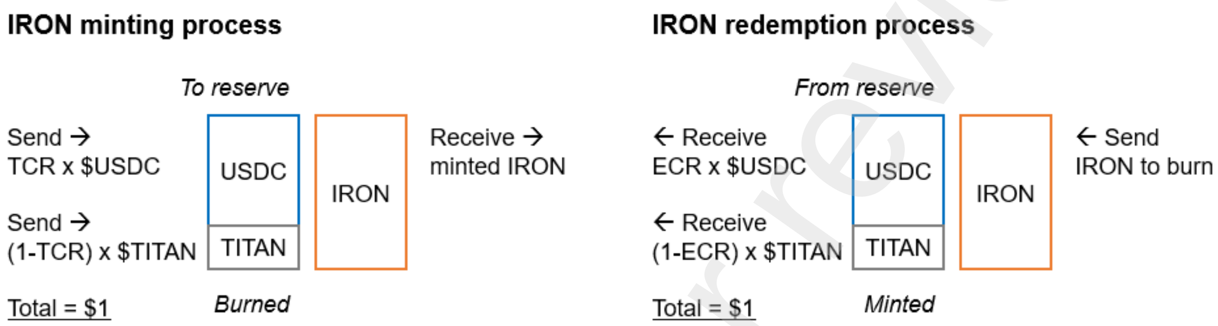
Iron Finance also allows users to sell one unit of IRON in exchange for $1 worth of USDC and TITAN. The ratio of USDC per IRON redeemed is called the Effective Collateral Ratio (ECR). The smart contract looks up prices and determines the quantities of USDC and TITAN to receive and send. The USDC received is held in reserve and is disbursed upon redemption. The process is shown in Figure 1.

[4] https://www.bloomberg.com/news/articles/2022-09-20/house-stablecoin-bill-would-put-two-year-ban-on-terra-like-coins

[5] https://www.esma.europa.eu/esmas-activities/digital-finance-and-innovation/markets-crypto-assets-regulation-mica

Figure 1: IRON Stablecoins Minting and Redemption

Users send the smart contract a basket of tokens under the pre-specified rule to receive a stablecoin minted by the smart contract. The smart contract can also redeem the stablecoin for a basket of tokens (potentially different from those sent). The process is often referred to as burning. Stablecoins (and tokens generally) can only be minted and burned in the originating smart contract. For Iron Finance, users are required to send USDC (another stablecoin) and TITAN (Iron Finance's governance token) to receive IRON (Iron Finance's stablecoin), and the ratio of USDC to one unit of IRON created (minted) is called the Target Collateral Ratio (TCR). Users can send IRON to receive USDC and TITAN, and the ratio of USDC to \$1 worth of IRON redeemed (burned) is called the Effective Collateral Ratio (ECR). Creation and redemption prices of IRON are fixed at \$1 per unit in the smart contract, and the algorithm will determine the amount of TITAN required in the transaction (hence algorithmic stablecoin). Arbitrage opportunities exist when there are price discrepancies between IRON in primary and secondary markets.



An extreme algorithmic stablecoin design (e.g., UST) relies solely on self-issued tokens (LUNA). The incorporation of external assets like USDC in Iron Finance's model can enhance the credibility of its peg.[6] The system requires less USDC per IRON if the price of IRON is above \$1 over time.[7] Figure 2 shows that IRON traded above \$1 in most periods (shaded blue), so TCR (USDC sent) was always less than ECR (USDC received), relying less upon external USDC.[8]

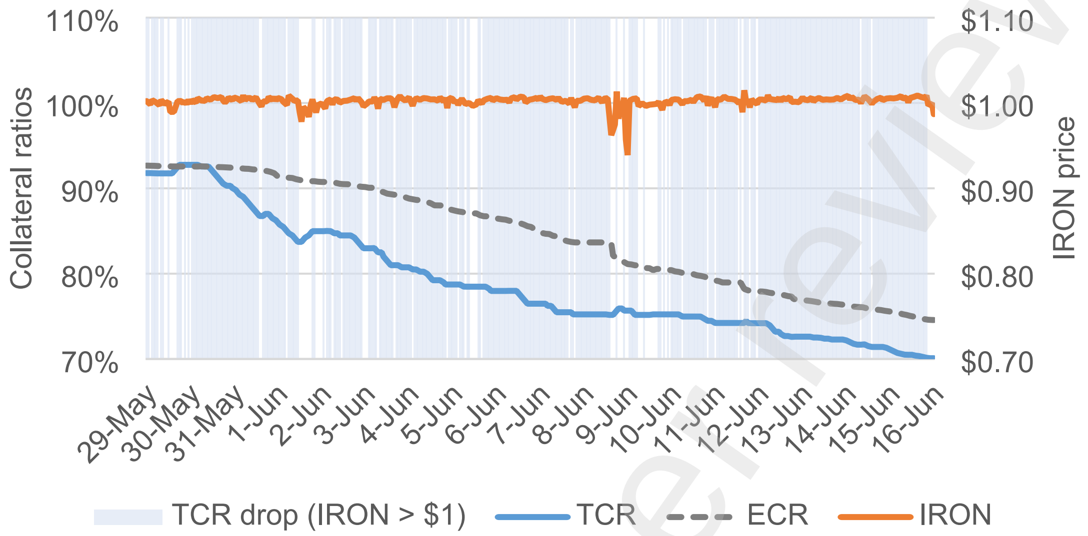
[6] The USDC used by Iron Finance is not native to the Polygon blockchain but is bridged across from the Ethereum blockchain. It was not until October 2023 that Circle, the issuer of the 'original' USDC, offered 'native' USDC on the Polygon blockchain. Thus, the USDC used by Iron Finance is called the USD Coin (PoS) (symbol: USDC.e), while Circle's USDC is called the Native USDC (symbol: USDC). Both are distinct crypto assets created in two separate smart contracts. As a comparison, USDC.e is like a depositary receipt (DR) of USDC. In this paper, we refer to USDC.e as USDC for convenience.

[7] Details of the codes can be found in the Treasury smart contract https://polygonscan.com/address/0x376b9e0Abbde0cA068DeFCD8919CA73369124825#code and the CollateralRatioPolicy smart contract https://polygonscan.com/address/0xDE3BaA1e28740e7fDbdBf65E78efcb3aA994b110#code.

[8] Frax is also designed in a similar way, also requiring USDC in addition to FXS (its governance token) to create FRAX stablecoin. The collateral ratio is also adjusted depending on FRAX's price on the open market and the amount of FXS liquidity available. For algorithmic stablecoins with extreme design such as UST, the collateral ratio is zero. The mechanism to decrease the reliance on external crypto assets to back issued stablecoins was likely first used by the Saga protocol, and not using any external crypto asset to back at all was first used by the Basis protocol. Both are discussed in Eichengreen (2019).

Figure 2: Collateral Ratios During Normal Times

This figure plots the hourly Target Collateral Ratio (TCR) and Effective Collateral Ratio (ECR) between 8:00 am on May 29 and 8:00 am on June 16. TCR determines the proportion of USDC necessary to mint IRON, while ECR determines the proportion of USDC participants will receive upon IRON redemption. TCR is reduced if the time-weighted average price of IRON over the last hour is greater than $1, and vice versa. ECR depends on the ratio of USDC in the protocol to outstanding IRON. The shaded regions are buckets where the price of IRON is above $1, likely to trigger a reduction in TCR (labeled TCR drop).



2.2 Why do users need the IRON stablecoin?

The raison d'être for stablecoins in DeFi is to create a nominal anchor to facilitate payments and exchanges, like national currencies. Without clear monetary authorities, the exchange rates for crypto assets (like Bitcoin or Ether) are unstable, making them unsuitable for payment mediums (Yermack, 2015; Baur and Dimpfl, 2021). In addition, stablecoin competition is like competition in money or payment networks, as the issuer can benefit from seigniorage if the face value (e.g., $1) of stablecoin in this form is less than its production cost.[9] Profits from money creation are alluring, as Eichengreen (2019) affirms that "monopoly over seigniorage is a source of political power."

So, why do users need another stablecoin? After all, IRON borrows credibility from USDC, so why not use USDC instead?[10] If credit card issuers can attract customers with reward points, stablecoin issuers can also reward their users with tokens. A popular protocol strategy

[9] Recall that algorithmic stablecoins are created from self-issued tokens. Developers can issue tokens to themselves at minimal cost. Do Kwon, the developer of the UST stablecoin stated in his 2018 blog post that "At Terra we see seigniorage as fuel with the potential to make stable-coin applications fundamentally superior to fiat-based counterparts. If we can find a way to bootstrap steady demand for Terra and capture healthy seigniorage, Terra could finance fiscal spending of its own and subsidize its [decentralized application]." https://medium.com/terra-money/scaling-seigniorage-a72356a118ae

[10] In fact, many other stablecoins exist on many other blockchain networks. For example, in addition to Ethereum and Polygon, USDC is also available on Algorand, Avalanche, Flow, Hedera, Solana, Stellar and TRON. Tether USD (USDT) also supports tokens on many blockchains, and each blockchain network has its own rules of engagement. Without necessary safeguards, users may wonder whether a USDC on Ethereum is comparable to a USDC on Polygon (we also saw earlier that there are USDC.e and USDC on Polygon). Thus, the modern competition of money and payment networks (especially on blockchain) is quite nuanced.

to bootstrap demand is to 'emit' tokens to users interacting with their protocols.[11] Codes can be written to emit tokens for any behavior, such as providing liquidity in decentralized exchange pools (Lehar and Parlour, 2021), lending pools (Saengchote, 2023), or freely 'airdropped' to generate marketing interest (Allen, Berg, and Lane, 2023). DeFi reward distributions are associated with terms such as 'staking reward' and 'yield farming' and can lead to incentive distortion as users reach for yield (Saengchote, 2023).

Iron Finance rewards two users.[12] First, it rewards users who provide liquidity in the four exchange pools involving their tokens (IRON and TITAN), as they are not traded in centralized exchanges like Binance. With deeper liquidity, swap prices have lower slippages (Lehar and Parlour, 2021). Second, it rewards users who lock TITAN in the single-staking contract. The staked TITANs have no economic function beyond reducing free float. Rather than emitting governance tokens, TerraUSD incentivizes users by Anchor, a deposit and lending protocol for UST with heavily subsidized deposit rates (Liu, Makarov, and Schoar, 2023).

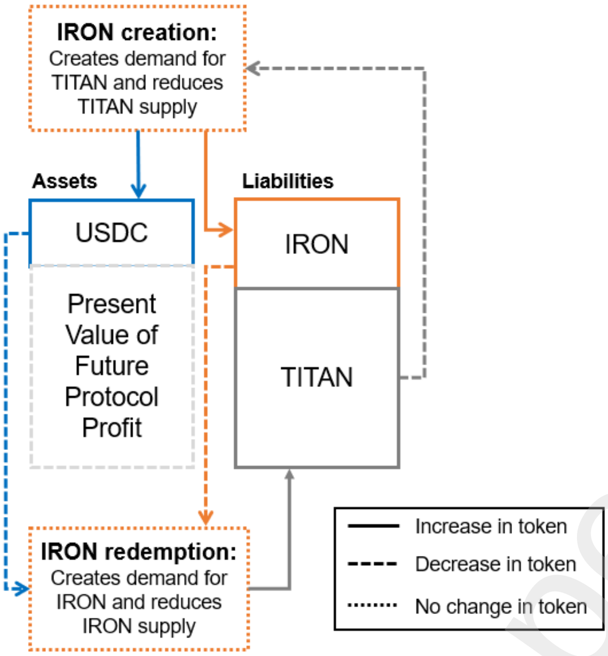
If Iron Finance were a financial institution, its market value balance sheet might look like Figure 3 Panel A. The USDCs received are assets, the issued IRONs are debt-like obligations like e-money,[13] and the issued TITAN are residual claims on the protocol, like equity. Iron Finance had no revenue model upon launch but could share profits with TITAN holders.

[11] In June 2020, the lending protocol on Ethereum called Compound began to reward users who deposited (staked) collateral and borrowed tokens with COMP, its governance tokens. Unlike credit card points, COMP can be sold freely and easily. Deposit and borrow activities in Compound rose sharply as a result. Saengchote (2023) found that the net borrowing costs (inclusive of rewards) for many assets were negative, and many users were recursively borrowing to engage in 'leveraged yield farming'.
[12] The distribution of the TITAN reward is managed by the 'MasterChef' smart contracts, originally developed by SushiSwap, an Ethereum-based decentralized exchange protocol that distributed its governance token as reward to attract users from Uniswap, the-then leading decentralized exchange protocol. Because blockchain transparency, codes written in smart contracts can be easily forked by other developers. Even if codes can be protected by software copyright, the anonymity of developers on permissionless blockchains can complicate legal enforcements.
[13] Gorton et al. (2022) refer to stablecoins as non-interest-bearing perpetuities with embedded put options to redeem at par from the issuer". Liu, Makarov, and Schoar (2023) refer to UST as "infinite convertible debt with a face value of $1 backed by LUNA". Here, IRON is backed by USDC and TITAN.

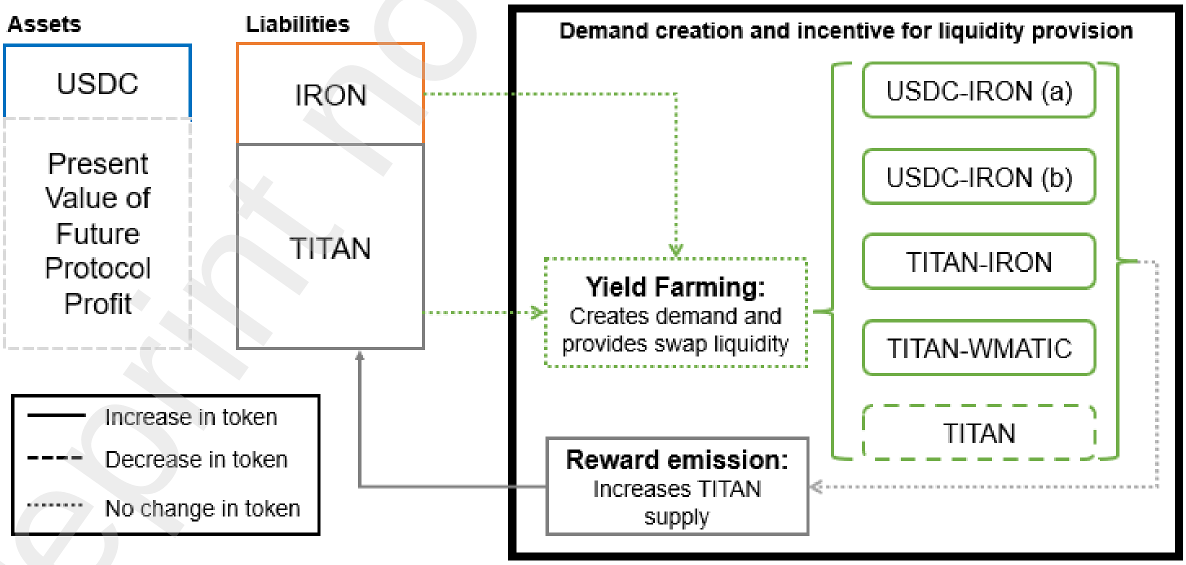
Figure 3: Overview of Iron Finance Protocol

This figure illustrates the schematics of how different tokens in Iron Finance are created (minted), redeemed (burned), and used to provide a decentralized financial service (DeFi) via smart contract codes. IRON is the stablecoin, TITAN is the governance token, and USDC is another stablecoin not issued by the Iron Finance protocol. Panel A presents IRON's creation and redemption process from the protocol's view of asset liabilities. Panel B illustrates how IRON and TITAN can earn yield in the form of TITAN rewards, which in turn creates demand for IRON and TITAN.

Panel A: IRON creation and redemption



Panel B: The uses of TITAN and IRON



DeFi protocols tend to call their residual tokens 'governance tokens.' This is because the U.S. Securities and Exchange Commission dictates that any arrangement with characteristics of an 'investment contract' (The 'Howey' Test) are securities and are subject to federal securities laws.[14] Developers typically proceed without regulatory approval. Because of this, TITAN's cash flow rights are unclear. Instead, developers allow holders to vote on future directions of the protocol (thus, governance), but voting rights and adherence to voting results are not formalized like corporate laws.

The roles of IRON and TITAN are summarized in Figure 3 Panel B. Swap pools need liquidity: yield farming provides liquidity and creates demand for IRON and TITAN. The single-staking contract creates demand for TITAN and reduces selling pressure. Arbitrage traders will restore the peg if IRON's price deviates from $1. If TITAN's price continues to increase, the protocol mechanism remains intact.

3. The Anatomy of the IRON Bank Run

3.1 The collapse of the IRON stablecoin.

This section analyzes the collapse by analyzing aggregated IRON creations, redemptions, and contract interactions (staking, unstaking, and token swapping). Token price data is obtained from swap pools and supplemented with CoinGecko's data API as necessary.

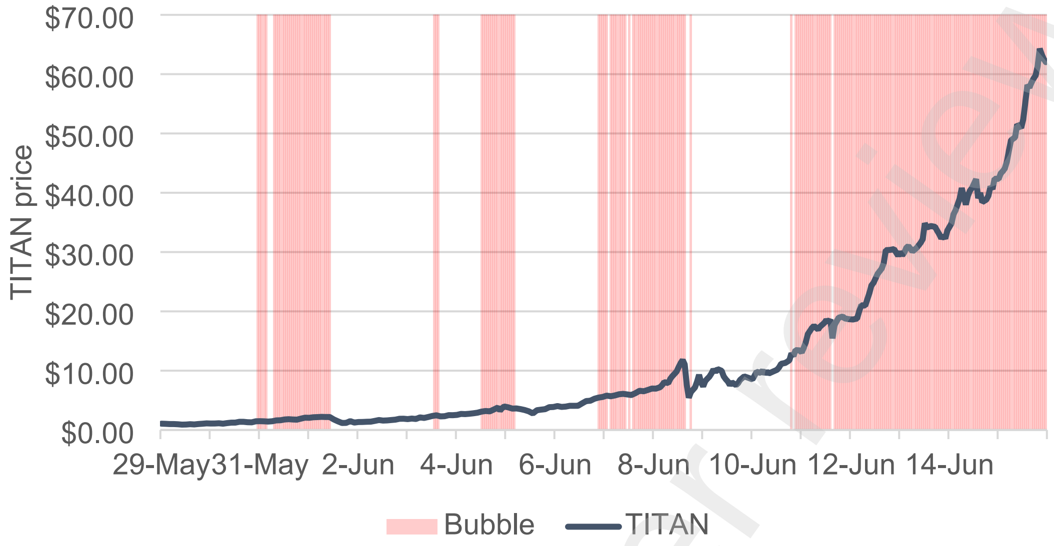
When IRON trades below $1, arbitrageurs can buy IRON in the secondary market and redeem it for USDC and TITAN at $1 per unit. The increased demand for IRON should restore the peg. While arbitrageurs may sell TITAN to realize profits and the price may fall, the mechanism will work if TITAN remains in demand. Figure 2 shows a brief period of large depeg (around -6%) on June 9, but the peg was shortly restored. Figure 4 shows that TITAN dropped from $11.74 to $5.58 (-52%) but continued to increase afterward.

Instead, TITAN's price rose rapidly. We used the Phillips et al. (2015) algorithm, which Bouri et al. (2019) used to identify bubbles in the cryptocurrency market, and found that TITAN experienced multiple bubble episodes over this period. This is likely because TITAN is required to earn yield via the single-staking contract (that reduces free float) or used to create IRON to earn yield in the stablecoin USDC-IRON liquidity pools. Generous emission schedules, even for stablecoin pairs, and rapid price appreciation made rewards more valuable and reflexively made IRON and TITAN more sought after, like a flywheel.[15]

[14] See the U.S. SEC Framework for "Investment Contract" Analysis of Digital Assets at https://www.sec.gov/files/dlt-framework.pdf. Activities such as profit-sharing arrangements, dividend distributions, or token buybacks can qualify as an investment contract.
[15] See, for example, a recommendation made by Mark Cuban (a celebrity investor) on June 13, 2021. https://blogmaverick.com/2021/06/13/the-brilliance-of-yield-farming-liquidity-providing-and-valuing-crypto-projects/.

Figure 4: Bubble-like appreciation of TITAN

This figure plots the hourly closing prices of TITAN computed from Iron Finance's swap pools using on-chain data between 8:00 am UTC on May 29 and 2:00 am UTC on June 16. The shaded regions are hourly buckets that are stamped as bubbles using the methodology of Phillips et al. (2015), also used by Bouri et al. (2019). During the 3-week window, there are multiple episodes of bubble-like price runups.



However, around 9:00 am on June 16, large amounts of TITAN and IRON were withdrawn from swap pools. Figure 5 shows that the magnitude was significant: across the three pools containing IRON, 455.9 million were withdrawn in one day – the largest on record – and 40% of the transactions had at least 1 million sizes. Because TITAN and IRON were only tradeable in these pools, the liquidity reduction led to large price impacts as swaps occurred. TITAN dropped from $63.74 to $33.51 (-47%) while IRON dropped to $0.911 (-8.9%), the largest depeg so far. Briola et al. (2023) also documented UST and LUNA's "remarkable selling pressure" before TerraUSD's collapse.

Because blockchain transactions are transparent, transactions of large users may be overinterpreted. DeFi users can react to non-material information and unintentionally trigger a run (Saengchote, Putniņš, and Samphantharak, 2023).

Figure 6 shows the hourly activities of IRON. For June 9, while the depeg was followed by a small wave of IRON sales and redemptions (Panel A), IRON's circulating supply was still increasing (Panel B). However, the depeg of June 16 was followed by massive sales and redemptions, plunging circulating supply from a high of 781.83 million to 15.94 million in just two days.

TITAN plummeted, and Iron Finance entered a 'death spiral'. Figure 7 shows that from 5:00 am on June 16 to midnight, TITAN fell from $63.74 to $0.000000672, and its circulating supply increased from 104.68 million to 922.16 billion, exceeding the intended maximum supply of 1 billion specified in the White Paper. By 6:00 am on June 17, the circulating supply reached 34 trillion. Iron Finance suspended operation until 5:00 pm on June 17. Once it reopened, waves of redemptions resumed as IRON continued to trade below or close to $0.7467 (remaining USDC).

Figure 5: Withdrawals from Iron Finance-Linked Swap Pools

This figure plots the daily withdrawals from the three swap pools for IRON between May 28 and June 18. The three pools are the TITAN-IRON SushiSwap, the USDC-IRON SushiSwap, and the USDC-IRON QuickSwap pools. Units reported are millions of IRONs aggregated between midnight UTC of each day.

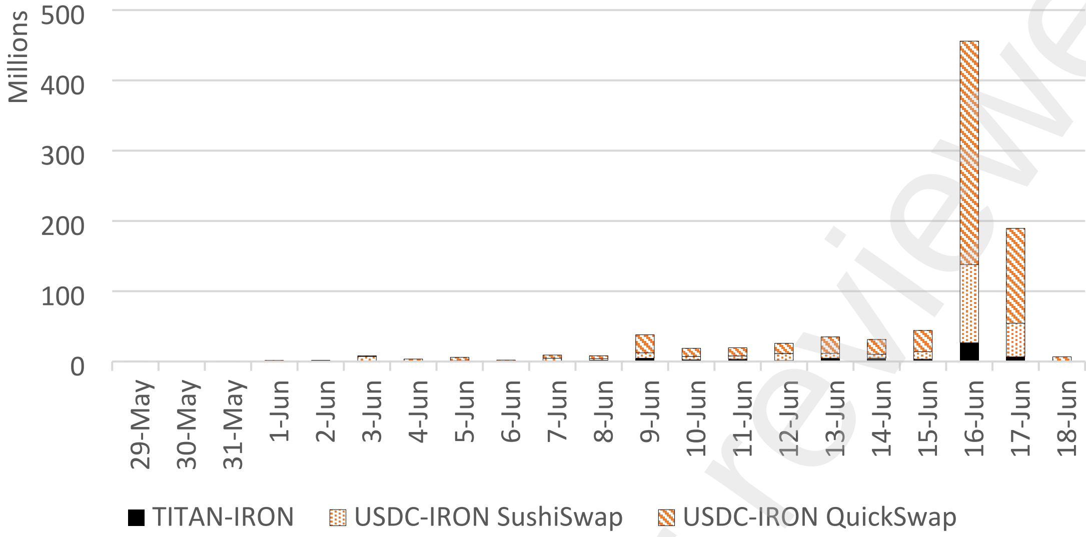
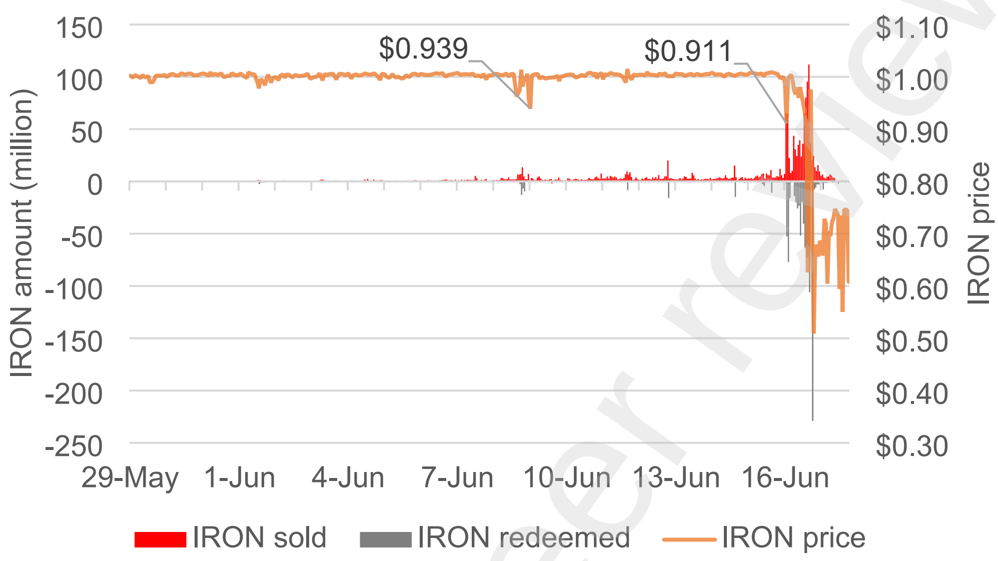


Figure 6: IRON Stablecoin Run

This figure plots the hourly activities of Iron Finance extracted from on-chain data between 8:00 am UTC on May 29 and 2:00 am UTC on June 18. Panel A plots the hourly price of IRON computed from Iron Finance's swap pools and the amount of IRON sold (red positive bars) via swap pools and redeemed (grey negative bars) to the protocol in exchange for USDC and TITAN. Panel B plots the hourly circulating supply of IRON (which can be interpreted as outstanding currency or debt, depending on the viewpoint) and hourly price.

A: IRON sale and redemption waves



B: IRON circulating supply

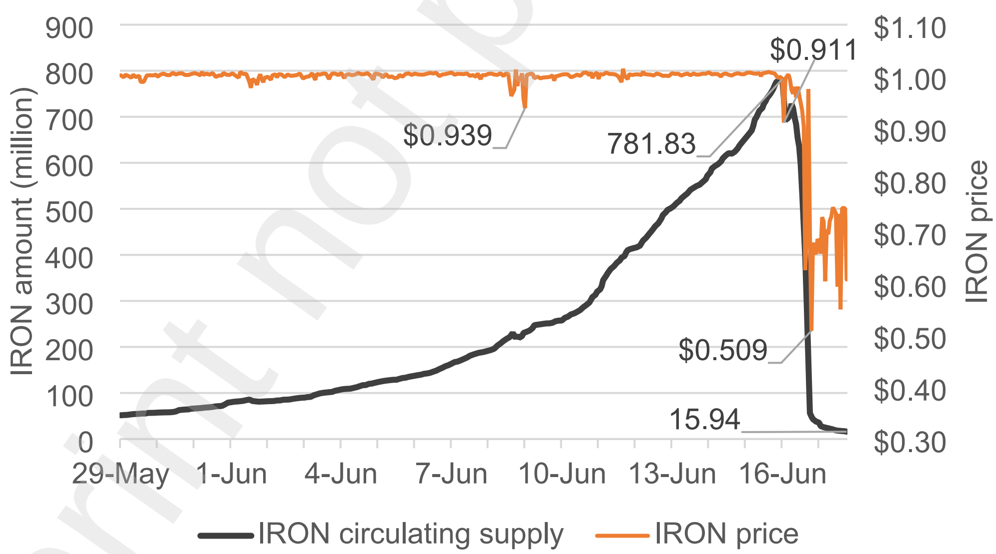
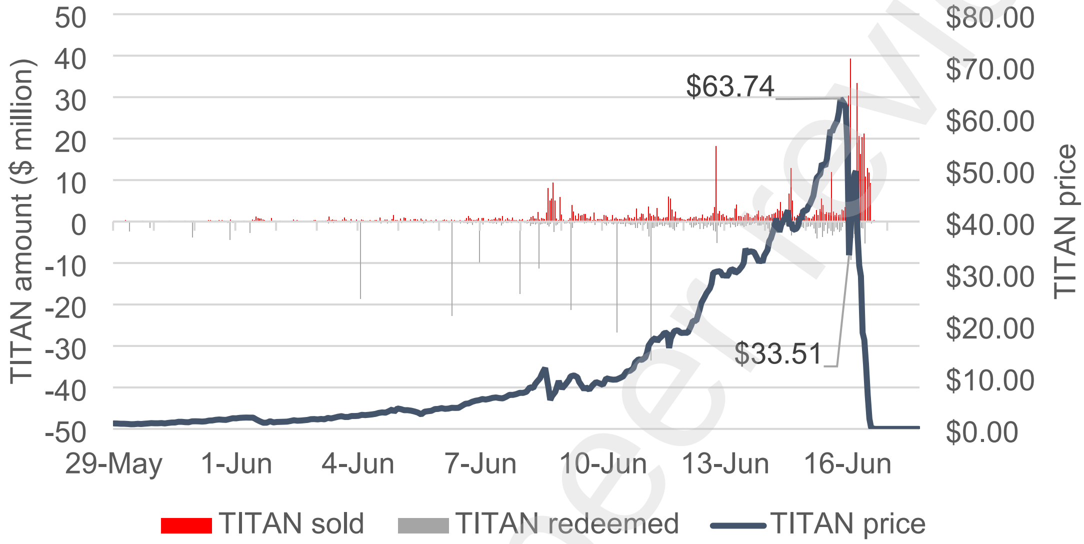


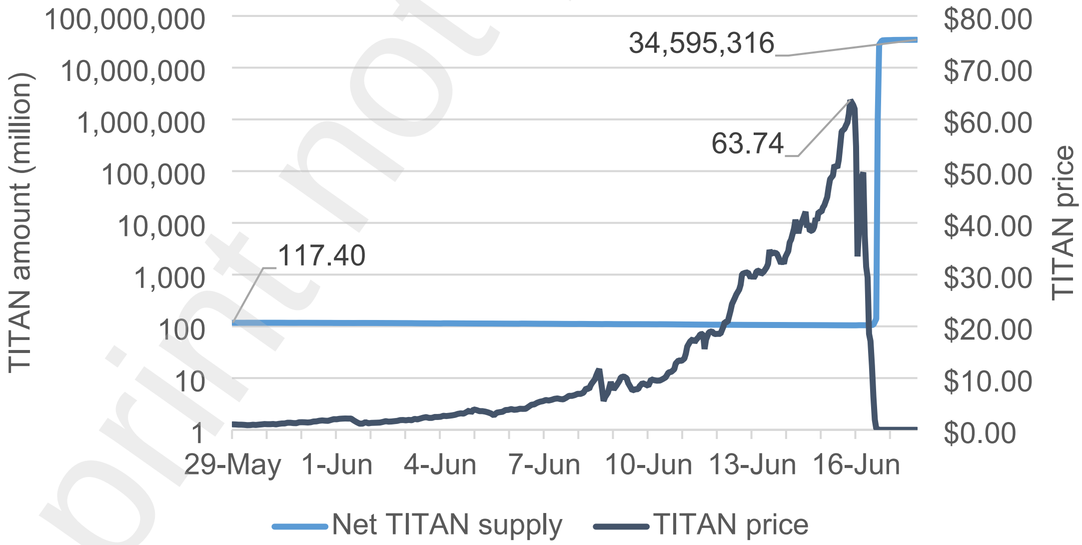
Figure 7: Governance Token Inflation Spiral

This figure plots the hourly activities of Iron Finance extracted from on-chain data between 8:00 am UTC on May 29 and 2:00 am UTC on June 18. Panel A plots the hourly closing prices of TITAN computed from Iron Finance's swap pools and the amount of TITAN sold (red positive bars) via swap pools and redeemed (grey negative bars) to the protocol and USDC in exchange for IRON. Panel B plots the hourly circulating supply of TITAN (which can be interpreted as outstanding government securities or outside money, depending on the viewpoint) and hourly price. The circulating supply is reported using a log scale on the primary axis.

A: TITAN sale and redemption waves



B: TITAN circulating supply



3.2 The microstructure of the Iron Finance run.

This section uses address-level data to investigate how users reacted to the collapse. We analyze (1) whether the user exited IRON, (2) if exiting, then how fast, and (3) how they exited (redeeming versus selling IRON). We conjecture that sophisticated participants are more likely to exit, exit faster, and redeem their stablecoins rather than selling.[16]

To proxy for user sophistication, we consider (1) address size (large addresses transacted more than 50,000 IRON), (2) time on the protocol (measured in days), (3) how IRON was first acquired (minting versus buying), and (4) proportion of IRON acquired by minting versus buying. Small addresses are like retail investors; users with a longer time on protocol likely have more experience; minting IRON is more complicated than buying. As reported in Table 1 Panel B, these proxies are not significantly correlated, except for *began as minter*, which is highly correlated with *% IRON minted*.

Overall, 42,074 unique addresses interacted with Iron Finance, and 27,532 (65.4%) exited within two days of the run. The summary statistics are reported in Table 1. On average, users who exited before June 20 were larger, had longer time on protocol, were more likely to begin as minter, and were more likely to mint than buy, suggesting they are more sophisticated.

We estimate a logistic model of exit on proxies of sophistication and report the results in Table 4. Column 1 suggests that sophisticated addresses are significantly more likely to exit. The marginal effects for large addresses are 13.4%, and for minters, 12.6%. For each day of experience, the address is 0.5% more likely to exit. All effects are statistically significant at the 1% level. In Column 2, we replace the minter indicator with the share of IRON minted due to high correlation, and the result remains similar.

Next, for those who exited by June 20, we estimate a logistic redemption model on proxies of sophistication and report the results in Columns 3 and 4. Sophisticated addresses are more likely to exit via redemption than sales, which can be more profitable because the token basket is likely worth more than the depegged price. The marginal effects for large addresses are 7.6% and for minter 15.0%. For each day of experience, the address is 0.37% more likely to exit via redemption.

Finally, we regress reaction time on proxies of sophistication and report the results in Table 3. Sophisticated addresses reacted faster. The average is 19.1 hours, so large addresses reacted more than 34% faster. Addresses that exited via redemption reacted more slowly than sales. It is possible that users who sold IRON preferred a complete exit, as IRON can be sold for USDC but redeemed for a basket of USDC and TITAN, which needs to be sold again.

Although the transparency of blockchain can, in principle, allow everyone to see and engage equally under the same rules, our evidence suggests that retail investors are, in practice, disadvantaged. Combined with the findings of Liu, Makarov, and Schoar (2023) that large and sophisticated users suffered smaller losses, the results point to the necessity of regulation and coordination mechanisms to ensure money stability.

[16] There are various ways of classifying sophistication. For example, Liu, Makarov, and Schoar (2023) classify addresses based on usage of complex protocols (such as bridges) or complex transaction strategies.

Table 1: Summary statistics

This table reports summary statistics of addresses that interacted with Iron Finance. There are 42,074 unique addresses, 27,532 of which reacted within two days of the run. Panel A reports the summary statistics of all addresses. We aggregate the IRON interactions for each address between the protocol's inception and 8:00 am on June 16 and classify large addresses as those with cumulative interactions of more than 50,000 IRON. Time on the protocol (in days) is calculated as the first date and time an address minted or bought IRON until 8:00 am on June 16 as a proxy for experience. We also classify whether the first IRON acquisition is minting or buying and calculate the share of IRON minted (rather than bought) relative to all IRON acquired. Panel B reports correlation coefficients between the variables in Panel A. Panel C restricts the sample to those who have reacted by either selling or redeeming IRON before June 20 and calculated the same statistics as Panel A, with the addition of reaction time, calculated as hours between 8:00 am on June 16 to the time they first reacted, the method used for the first reaction (IRON sale or redemption), and the share of IRON sold relative to all exit modes. Panel D reports the summary statistics for those who did not react by midnight on June 20.

Panel A: All users (N = 42,074)

	Mean	Std Dev	p5	p50	p95
Size of IRON interaction (unit)	42,067	1,247,119	6.20	877	58,776
Large address (> 50k)	5.69%	23.2%	0	0	0
Time on protocol (days)	5.95	6.09	0.21	4.06	19.59
Began as minter	16.6%	35.4%	0	1	1
% IRON minted (vs bought)	11.9%	32.4%	0	1	1

Panel B: Correlation

	Large address	Time on protocol	Began as minter
Time on protocol (days)	0.1869		
Began as minter	0.1215	0.0547	
% IRON minted (vs bought)	0.1563	0.0506	0.8584

Panel C: Users who exited before June 20 (N = 27,532)

	Mean	Std Dev	p5	p50	p95
Size of IRON interaction (unit)	54,593	1,516,816	46.98	1,495	78,622
Large address (> 50k)	7.1%	25.6%	0	0	1
Time on protocol (days)	6.30	6.13	0.22	4.56	20.16
Began as minter	19.5%	39.6%	0	1	1
% IRON minted (vs bought)	20.9%	37.6%	0%	100%	100%
Reaction time (hours)	19.05	14.15	1.86	16.57	42.34
First exit as minter	19.2%	38.6%	0	1	1
% IRON redeemed (vs sold)	19.6%	37.6%	0%	100%	100%

Panel D: Users who did not exit by June 20 (N = 14,542)

	Mean	Std Dev	p5	p50	p95
Size of IRON interaction (unit)	18,352	378,435	0.91	229	25,025
Large address (> 50k)	3.1%	17.3%	0	0	0
Time on protocol (days)	5.29	5.98	0.19	2.97	18.83
Began as minter	11.1%	31.4%	0	1	1
% IRON minted (vs bought)	11.1%	29.7%	0	1	1

Table 2: Logistic models of sophisticated addresses

This table reports the results of logistic models to classify addresses during the stablecoin run. In Columns 1 and 2, the dependent variable is an indicator variable for addresses that reacted during the window of 8:00 am on June 16 to midnight on June 20. Large addresses had cumulative interactions of more than 50,000 IRON between the protocol's inception in May and 8:00 am on June 16 (pre-run). Time on protocol (in days) is calculated as the first date and time an address minted or bought IRON until 8:00 am on June 16. An address is classified as minter if the first interaction is minting and the share of IRON minted (rather than bought) is calculated relative to all IRON acquired. The analysis of the minter indicator variable and % IRON minted are conducted separately because of the high correlation between the two coding schemes. In Columns 3 and 4, the dependent variable is whether the address exited via IRON redemption (hence redeemer), and the analysis is conditional on the address reacting before midnight on 20 June. Standard errors are computed using the Huber-White procedure and reported in parenthesis. Stars correspond to the statistical significance level, with *, **, and *** representing 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	Exit	Exit	Redeemer	Redeemer
Large address (> 50k IRON)	0.668***	0.599***	0.468***	0.365***
	(0.06)	(0.06)	(0.05)	(0.05)
Time on protocol (days)	0.023***	0.023***	0.026***	0.029***
	(0.00)	(0.00)	(0.00)	(0.00)
Began as minter	0.607***		0.885***	
	(0.03)		(0.04)	
% IRON minted (vs bought)		0.008***		0.012***
		(0.00)		(0.00)
Constant	0.988***	0.349***	-1.93***	-2.04***
	(0.03)	(0.03)	(0.02)	(0.00)
Observations	42,074	42,074	27,532	27,532
Pseudo R-squared	0.0168	0.0212	0.0334	0.0469

Table 3: OLS model of reaction time

This table reports the results of OLS regressions of reaction time (in hours) on address characteristics. Large addresses had cumulative interactions of more than 50,000 IRON between the protocol's inception in May and 8:00 am on June 16 (pre-run). Time on protocol (in days) is calculated as the first date and time an address minted or bought IRON until 8:00 am on June 16. An address is classified as minter if the first interaction is minting and the share of IRON minted (rather than bought) is calculated relative to all IRON acquired. An address is classified as redeemer if the first reaction is redemption, and the share of IRON redeemed (rather than sold) is calculated relative to all IRON exited. In Column 1, address characteristics are coded as indicator variables (minter, redeemer), and in Column 2, they are coded as continuous variables (% IRON minted, % IRON redeemed). The analyses are conducted separately because of the high correlation between the two coding schemes. Standard errors are computed using the Huber-White procedure and reported in parenthesis. Stars correspond to the statistical significance level, with *, **, and *** representing 10%, 5%, and 1% respectively.

	(1)	(2)
Large address (> 50k IRON)	-6.66***	-6.61***
	(0.26)	(0.26)
Time on protocol (days)	-0.214***	-0.222***
	(0.01)	(0.01)
Began as minter	-1.44***	
	(0.21)	
First exited as redeemer	9.35***	
	(0.28)	
% IRON minted (vs purchased)		-0.024***
		(0.00)
% IRON redeemed (vs sold)		0.102***
		(0.00)
Constant	19.4***	19.5***
	(0.12)	(0.13)
Observations	27,532	27,532
Adjusted R-squared	0.083	0.089

4. Conclusion

While digital money can potentially transform trade and commerce, policymakers are loath to embrace algorithmic stablecoins. This is not surprising, as they rely on users believing that self-issued tokens are valuable, making algorithmic stablecoins themselves bubble-like (Brunnermeier and Niepelt, 2019) and thus inherently fragile.

Iron Finance is not the first to fail. Eichengreen (2019) discussed the Basis stablecoin (similar to UST) and expressed concerns about its viability and the potential for a 'self-reinforcing spiral' leading to its collapse.[17] Because permissionless blockchains are open, unregulated networks, there is a likelihood of another algorithmic stablecoin emerging from potentially anonymous developers. These developers may issue governance tokens with no cash flow rights (to avoid violating U.S. securities laws) as a reward to bootstrap demand for their protocols.[18] As large users take profits, blockchain transparency may catalyze a run, leaving retail investors to bear the brunt of the damages.[19] History is likely to repeat itself, even over a short span.

Such is the nature of permissionless blockchains and algorithmic stablecoins, which may not be the best payment infrastructures or forms of digital money.

[17] Its white paper is titled "A Price-Stable Cryptocurrency with an Algorithmic Central Bank". Despite being backed by high-profile investors, Basis never launched due to regulatory concerns, such as unregistered sale of securities and compliance with transfer restrictions to accredit investors. They decided to shut down and return investors' capital in December 2020. (See https://www.basis.io/). However, Basis's design inspired Empty Set, another algorithmic stablecoin protocol launched in August 2020, and an anonymous team of developers forked Basis' code and launched as Basis Cash at the end of November 2020 (https://www.coindesk.com/tech/2020/11/30/basis-cash-launch-brings-defunct-stablecoin-into-the-defi-era/). Both Empty Set and Basis Cash already failed by the time Iron Finance launched.

[18] In February 2023, U.S. SEC brought charges against Terraform Labs and Do Kwon, the team behind TerraUSD failed to register LUNA and UST as securities and thus violated U.S. securities law. In December 2023, U.S. District Judge Jed Rakoff in Manhattan agreed with the SEC and said there was "no genuine dispute" that Terraform Labs' crypto assets (including LUNA and the UST stablecoin) were securities under U.S. law (https://www.reuters.com/legal/terraform-labs-sold-unregistered-securities-us-judge-rules-sec-case-2023-12-28/).

[19] Governance token emission in some protocols is in thousands or tens of thousands percentage points when annualized. For example, OlympusDAO employs the single-staking contract (reduce free float) and distributes staking yield of 7,000% by minting its governance token, leading to crypto media comparing it to a Ponzi scheme (https://www.coindesk.com/policy/2021/12/05/olympus-dao-might-be-the-future-of-money-or-it-might-be-a-ponzi/). It also inspired protocols forks that distribute yields of more than 621,000% (https://coinmarketcap.com/academy/article/a-deep-dive-into-the-eight-most-popular-ohm-forks). OlympusDAO spearheaded the 'DeFi 2.0' wave in late 2021, which was roughly equivalent to "doing whatever it took", including incurring recursive leverage, to maximize yield disbursed as governance tokens with no cash flow rights. Many of these DeFi 2.0 protocols suffered because of the UST collapse in May 2022. By the end of 2022, 'real yield' emerged as new DeFi narrative, calling for yield "generated from tangible sources of revenue and are not solely reliant on inflationary token emission" (https://www.binance.com/en/research/analysis/emergence-of-real-yield).

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