Stablecoin Devaluation Risk

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Abstract

We construct a market-based measure of stablecoin devaluation risk using spot and futures prices for Tether. We estimate an average probability of devaluation over one year of 60 basis points, rising to 200 basis points during the March 2020 "Black Thursday" Cryto crash and the March 2022 Terra-Luna crash. Interest rates on stablecoins at DeFi lending protocols are not well connected to interest rates on conventional financial instruments; deviations from covered interest parity are pervasive. Nor do stablecoin interest rates respond to Federal Reserve policy announcements in the manner of conventional market interest rates. We suggest explanations for these disconnects, including market segmentation, lack of term structure in DeFi interest rates, lack of arbitrage capital in cryptocurrency markets, and transaction costs of arbitrage.

Keywords: Cryptocurrency, stablecoins, futures, bank runs, Tether, Bitcoin

JEL Classifications: E5, F3, F4, G15, G18

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1 Introduction and Motivation

Stablecoins are popular onramps and offramps for purchases and sales of a variety of units in the cryptocurrency universe. They are widely utilized as vehicles for transactions in popular cryptocurrencies such as Bitcoin (BTC), for example. They find some use for remittances and other cross-border transactions (Luckner, Reinhart, and Rogoff 2021; Adams et al. 2023). Their advocates suggest that they will gain broader acceptance for use in financial and commercial transactions.

The dominant stablecoins rely on a centralized custodian of assets held as collateral or reserves, where these assets are held off-chain. Sometimes such assets, or a portion thereof, are less liquid than the custodian's liabilities – that is, than the stablecoin itself. This resembles the liquidity mismatch that characterizes the balance sheet of a bank whose business is maturity transformation. Consequently, it gives rise to a problem of run risk like that to which banks are subject. Relatedly, there is an analogy between a run on a central bank seeking to maintain a set value for a national currency (seeking to defend a currency peg), something that if sufficiently intense can result in that currency's devaluation, and a run on a centralized custodian seeking to maintain a set value for a stablecoin against a national currency, something that if sufficiently intense can force that set value to be abandoned.

We show that stablecoin devaluation risk can be priced using futures contracts in much the same way that the risk that a national currency will be devalued on foreign exchange markets can be priced using forward foreign exchange contracts. The analysis focuses on Tether, the most actively traded stablecoin and the only stablecoin with traded futures. We use these futures to construct a measure of devaluation risk, which we define as the probability of a speculative attack on the stablecoin peg.

We show that Tether futures regularly trade at a discount to spot prices. On average, Tether devaluation risk implicit in that discount is priced at approximately 60 points in annualized terms. But there is significant time variation in the implied probability of default: the peak annualized default probability through mid-2022 was 200 basis points.

We show that this devaluation risk is increasing with Bitcoin volatility. An increase in volatility may induce more transactions by investors who have taken BTC positions on margin, and those transactions may cause them to close out their positions in the stablecoin. In turn this will require the centralized custodian to liquidate collateral. Since liquidating collateral may be easier said than done, this need, and the associated uncertainty, show up as an increase in the perceived default probability.

Network characteristics such as investor concentration and trading velocity (the rate of turnover of the stablecoin) are also associated with an increase in devaluation risk. Increased velocity may indicate that investors are paying more attention to the centralized custodian's balance sheet and trading in response. Increased concentration may intensify contagion effects and the risk that individual investors, in touch with one another or observing one another's transactions, will launch a concerted attack on the stablecoin.[1]

We trace the impact of market sentiment on devaluation risk using a measure of market sentiment constructed from news articles. Negative sentiment in the media is negatively associated with Tether futures prices; hence it is positively associated with devaluation risk. This suggests an analogy with "self-fulfilling" bank runs (Diamond and Dybvig 1983) and so-called "second-generation" models of speculative attacks on pegged exchange rates (Obstfeld 1996), where negative sentiment leads to a run/attack that justifies the negative sentiment ex post (and where it underscores the fragility of the underlying construct).

We further document these relationships with three case studies. Our first case study is "Black Thursday," March 12th, 2020, when the price of BTC fell by 40% in one day. This led to Tether trading at a premium in the spot market, as investors in BTC scrambled to obtain Tether for their transactions, and consequently to a widening futures-spot basis. This wider basis was indicative of an increase in the perceived risk of systemic collapse of the cryptocurrency market, which would have reduced the utility of stablecoins such as Tether that are used to purchase and sell BTC and other cryptocurrencies without intermediation and dollar settlement. We thus see contagion from the collapse of BTC prices to the perceived risk of stablecoin devaluation.

A second case study is the TerraUSD crash of May 9th, 2022, when Tether's price fell to 95 cents in intra-day trading. We document an increase in the probability of Tether devaluation to 200 basis points. We observe an increase in market concentration and velocity as some investors exited the crypto market and others re-balanced their portfolios toward other cryptocurrencies.

The third case study is USDC stablecoin de-pegging when Silicon Valley Bank went bankrupt in March 2023. This event raised concerns about whether USDC was still fully backed, given that USDC held some of its reserves at SVB. At one point, USDC fell to 87 cents. This rise in perceived devaluation risk was accompanied by increased concentration of USDC wallets and a rise in monetary velocity, just as in the TerraUSD crash (our second case study). USDC stabilized when it successfully transferred cash reserves held at SVB to other banking partners. Redemptions in the weeks following the event helped stabilize the coin's secondary market value.

We turn next to the behavior of interest rates in stablecoin markets. We construct a shadow risk-free interest rate from the Tether futures discount. We show that futures trading at a discount is equivalent to the shadow-risk free rate being above conventional money market rates such as the USD 3 month OIS rate. This premium leads to an interpretation of stablecoin rates: they command an inconvenience yield, since they are

1. For example, depositor concentration is alleged to have facilitated the run on Silicon Valley Bank (Vo and Le 2023).

imperfect substitutes to money.

We next compare money market rates to lending rates on stablecoins at DeFi lending protocols. Even after hedging exchange rate risk using futures, stablecoin interest rates are systematically higher than money market rates. There are systematic deviations from covered interest parity, in other words. We suggest some reasons for the disconnect: market segmentation, lack of term structure in DeFi interest rates, lack of arbitrage capital in cryptocurrency markets, and costs of arbitrage such as gas fees charged to validate transactions on the blockchain.

Further evidence of this interest-rate disconnect can be seen in the impact of Federal Reserve announcements on stablecoin prices, interest rates and issuance. While interest rates on conventional money market instruments respond to changes in the Fed funds rate on announcement days, stablecoin interest rates do not. Eventually, however, stablecoin issuance responds. A rise in the Fed funds rate on monetary announcement days is followed by a decline in stablecoin issuance, as if investors move over time from stablecoins to alternative money-market instruments, attracted by higher money-market rates. This is effectively a reduction in the demand for private money (in the form of Tether), which is necessary for the maintenance of its stable peg to the Fed's government-issued fiat currency.

Finally, we study the operation of Tether's redemption mechanism. For example, during the TerraUSD de-pegging event on May 9, 2022, Tether also traded at a discount, as if investor confidence in the stablecoin was adversely affected. In the face of this negative shock, peg redemption mechanisms should operate so as to return the price to par. Using local projections, we confirm that redemptions had a stabilizing impact on Tether's price. With the decline of Tether in circulation as a result of redemptions, the price of Tether recovered. A priori, one could imagine the opposite: that investors observing redemptions might lose confidence in the peg, leading to additional redemptions and a still wider discount. However, this is not what we find.

In concluding we offer suggestions for managing stablecoin risks. One response to devaluation and custodial risk would be real-time audits conducted using a proof-of-reserve system provided by companies like Chainlink. These protocols can detect reserve or backing shortfalls and provide early notice of custodial problems. The result would might be a healthy increase in market discipline, but also possibly an increase in run risk if and when custodial problems are detected. Adding a smart contract (auto-executing code on the blockchain) that allows for minting new tokens only when Chainlink verifies that reserve balances held at escrow accounts have increased would increase the odds of a stabilizing effect.

Another possible response would be for regulatory authorities to license stablecoin platforms, impose capital and liquidity requirements, and conduct regular audits of their balance sheets, in much the manner that they regulate banks. In the limit, stablecoin providers could be required to hold reserves in the form of central bank digital currency or a regular deposit account at the central bank. In return, the authorities could extend deposit protection to holders of the stablecoin in question up to a prescribed limit.

The remainder of the paper is structured as follows. Section 2 reviews the related literature. In section 3 we introduce a taxonomy of stablecoin risks, outline our data sources and construct a market-based measure of run-risk from spot and futures data. In section 4 we analyze the determinants of run-risk, marshaling both econometric and case-study evidence, and present evidence on the behavior of stablecoin interest rates at DeFi lending protocols. Section 5 discusses the pros and cons of possible solutions to minimize devaluation risk, such as using a proof of reserve system or using a CBDC to back stablecoin assets. Section 6 concludes.

2 Related Literature

We contribute to a growing literature on stablecoin markets. On the empirical side, this includes analyses of stablecoin properties and comparisons with markets in traditional financial assets (Eichengreen 2019; Berentsen and Schär 2019; Bullmann, Klemm, and Pinna 2019; Dell'Erba 2019; Arner, Auer, and Frost 2020; Frost, Shin, and Wierts 2020; Force et al. 2020; Barthelemy, Gardin, and Nguyen 2021), arbitrage in stablecoin and cryptocurrency markets (Lyons and Viswanath-Natraj 2020; Makarov and Schoar 2019, 2020; Borri and Shakhnov 2018; Pernice 2021; Kozhan and Viswanath-Natraj 2021; Ma, Zeng, and Zhang 2023), intraday price changes that support stablecoins' role as safe havens (Baur and Hoang 2020; Hoang and Baur 2021, 2020; Baumöhl and Vyrost 2020; Wang, Ma, and Wu 2020; Bianchi, Iacopini, and Rossini 2020; Gloede and Moser 2021), and the macroeconomic, financial stability and political economy implications of stablecoins (Cong and Mayer 2021; Catalini and Gortari 2021; Catalini and Shah 2021; Allen, Gu, and Jagtiani 2022; Gorton and Zhang 2021; Gorton, Ross, and Ross 2022; Murakami and Viswanath-Natraj 2021; Barthelemy, Gardin, and Nguyen 2021; Kim 2022; Liu, Makarov, and Schoar 2023). Within this literature, our paper is most closely related to the concept of a stablecoin inconvenience yield introduced in Gorton and Zhang (2021) and Gorton, Ross, and Ross (2022). This inconvenience yield is stablecoins effectively requiring higher interest rates as they are an imperfect substitute for money. We complement their findings by showing that stablecoins like Tether typically trade at a discount in futures, and use this to construct a measure of devaluation risk. Importantly, our devaluation risk is equivalent to constructing a shadow risk-free rate that lies above equivalent USD money market rates.

On the theoretical front, studies focus on the price dynamics of stablecoins, including the effects of solutions such as reserve buffers and over-collateralization to avoid speculative attacks and peg discounts (Routledge and Zetlin-Jones 2018; Li and Mayer 2021; Cong, Li, and Wang 2021; Kwon et al. 2021; d'Avernas, Maurin, and Vandeweyer 2022; Bertsch 2022; Uhlig 2022).[2] Routledge and Zetlin-Jones (2018) adapt a model of fixed exchange rates to stablecoins and point out the potential for centralized stablecoin regimes to collapse due to expectations of insufficient backing of reserves. Li and Mayer (2020) and d'Avernas, Bourany, and Vandeweyer (2022) consider reserve management and over-collateralization as potential solutions to avoid speculative attacks and peg discounts.

Within this literature, our paper is most closely related to understanding the determinants of stablecoin devaluation risk (Bertsch 2022). Our findings complement theoretical work in that we find stablecoin devaluation risk is related to speculative demand by investors, characteristics of the stablecoin network such as the concentration and velocity of trading, and measures of market volatility such as Bitcoin volatility.

3 Definitions and Data

3.1 Stablecoin taxonomy

Stablecoins operate on the blockchain and are pegged at parity to the US dollar (for present purposes we ignore stablecoins pegged to other currencies). They reached a peak of nearly 160 USD Billion marketcap in late 2021, and are dominated by stablecoins Tether, USDC, Binance USD, and DAI (Figure 1). They serve as vehicles for trading crypto assets generally, due to the reduction in intermediation costs owing to the fact that they, like other crypto assets, operate on the blockchain.[3] Specific use cases include providing a vehicle currency on Uniswap (an open source protocol through which tokens can be traded without trusted intermediaries) and on DeFI lending protocols for leveraged trading. In addition, there is some, relatively limited use of stablecoins for remittances and cross-border payments, and residents of developing countries may use stablecoins to evade capital controls and avoid high domestic-currency inflation.

Stablecoins typically follow three designs (Figure 2). The first type, as in the case of Tether, is backed by collateral (typically dollar collateral) held off chain by a custodian. In Tether's case, the custodian is centralized. It is responsible for managing Tether's fixed peg to the dollar, and can be thought of analogously to the Hong Kong Currency Board, which manages a fixed currency peg to the dollar. The second-largest stablecoin,

2. These models folllow an earlier literature on fixed exchange rate regimes (Krugman 1979; Eichengreen, Rose, and Wyplosz 1995; Morris and Shin 1998; Chamley 2003; Cukierman, Goldstein, and Spiegel 2004).

3. Stablecoins are widely used in the cryptocurrency market due to the added intermediation costs when trading cryptocurrencies against dollars and their usability across a greater cross-section of crypto exchanges. For example, total trading volume between Bitcoin and Tether surpassed the trading volume of Bitcoin/USD in 2019.

USDC, has a more decentralized governance system, under which multiple custodians provide and redeem tokens. Dollar collateral backing USDC is held entirely in the form of deposits at FDIC-insured banks.[4] In other cases, not all dollar reserves are held in the form of cash or cash-equivalents. Historically, Tether and USDC's balance sheets have included commercial paper and other assets, including other cryptocurrencies, that may become illiquid during risk-off events.

A second design is decentralised, crypto (over)collateralized, and custodian free, as in the case of MakerDAO's DAI. Investors deposit Ethereum into a collateralized position that allows them to borrow DAI. The number of DAI they can borrow is limited by a smart (i.e., auto-executing) contract.[5] A drawback of this approach is that it is capital inefficient, since positions are over-collateralized.

A third design is algorithmic. In this case there may be is zero collateral. The algorithm managing the system is supposed to increase and reduce the supply of the stablecoin as its value rises and falls relative to parity. A leading algorithmic stablecoin is TerraUSD, which reached a peak market capitalization of 40 USD billion in April 2022. TerraUSD is entirely backed by Luna, the native token of the Terra blockchain. Users can create 1 USD worth of TerraUSD stablecoins by burning 1 USD of Luna. The Luna token is used to pay fees for validating transactions on the blockchain, for staking tokens in governance votes, and for earning yields on DeFi lending protocols.

This third approach is capital efficient (since there is no capital) but prone to speculative attack, as evident in the large discounts at which algorithmically collateralized stablecoins sometimes trade. An example is when the TerraUSD peg was broken on May 12, 2022, triggering a loss of confidence in the Terra blockchain and governance token. This triggered a spiral of falling Luna and TerraUSD prices; on May 12, 2022 the ratio of the value of Luna to the circulating supply of TerraUSD declined to approximately 0.1.[6] The arbitrage mechanism of redeeming TerraUSD at 1 USD and buying Luna tokens failed as investors lost confidence in the peg-stabilising mechanism. Compared to alternative systems, such as dollar-backed stablecoins like Tether and over-collateralized

4. See https://www.binance.com/en/blog/ecosystem/understanding-busd-and-binancepeg-busd-5526464425033159282. Paxos issues BUSD and the article states *In accordance with strict custody regulations enforced by the New York state regulators, Paxos' BUSD reserves are only held in FDIC-insured, bankruptcy-remote bank accounts or US Treasury instruments.*

5. The contract liquidates underlying Ethereum collateral if the value of that collateral is less than 150% of the corresponding DAI-borrowing value. Agents therefore have an incentive to scale back borrowing by redeeming DAI when Ethereum prices fall in order to prevent their collateral from breaching the 150% level.

6. The spiral in Luna and Terra prices observed in May 2022 was in part due to a decline in demand for TerraUSD on Anchor. Anchor is a lending protocol that offers users the ability to deposit Luna as collateral ("staking" Luna) and borrow TerraUSD tokens, creating a demand for TerraUSD. The negative sentiment on Terra-Luna led to a decline in the demand for TerraUSD on the protocol. As users redeem TerraUSD and mint Luna tokens, the price of Luna depreciates. This in turn causes a decline in the amount of Luna deposited in the protocol, leading to less borrowing of TerraUSD, and a downward spiral of TerraUSD and Luna prices.

crypto-backed coins like as DAI, algorithmically-backed stablecoins such as TerraUSD suffer from absence of an effective arbitrage mechanism between primary and secondary markets. The governance token Luna is unsuitable as collateral backing, since it is systemically dependent on the value of the TerraUSD token and hence on the growth of the Terra blockchain.

3.2 Stablecoin risks

We identify four types of risk associated with stablecoins: custodial risk, devaluation risk, systemic risk, and payments risk.

- **Custodial Risk**: This can arise when a centralised issuer responsible for reserve management absconds with funds.
- **Devaluation risk**: This can arise when reserves or backing are less than 100 percent of the value of issuance or less than perfectly liquid.
- **Systemic risk**: Stablecoins used in crypto derivative markets can increase risk exposures of financial intermediaries. Because stablecoin issuers hold traditional assets, a run on stablecoins can lead to systemic risks to the financial sector and financial intermediation, for example when they are forced to engage in fire sales of commercial paper and other assets.
- **Payment risk**: Payment risk derives from the role of stablecoins as a medium of exchange. If a firm has receivables denominated in stablecoins, its flows are subject to devaluation risk.[7] This is similar to the foreign exchange rate risk that occurs when firms denominate liabilities in foreign currency and are subject to a revaluation of foreign debt when the local currency depreciates (Eichengreen, Hausmann, and Panizza 2007).

We can illustrate these risks in the context of Tether, the stablecoin that is the focus of our empirics. Since May 13th 2021 Tether has provided a breakdown of its reserves, which are subject to quarterly attestation reports by accounting firm BDO. Tether's first statement of May 2021 revealed that it was only 75.6 per cent backed by cash or cash equivalents (less liquid asset categories such as commercial paper, fiduciary deposits and treasury bills).[8] In the latest quarterly attestation at the time of writing in Q1 2023, Tether had scaled down its commercial paper to zero. However, it still has only 84.65 per

7. Other use cases for stablecoin payments are in cross-border flows or as a hedge against macroeconomic risk

8. Quarterly statement released by Tether Ltd on breakdown of reserves. Statement issued on May 13th,2021 on Tether's twitter account. Available at https://twitter.com/Tether_to/status/1392811872810934276

cent of its assets in cash or cash-equivalents. The remaining 15.35 per cent are in less liquid assets such as corporate bonds, precious metals, and cryptocurrencies like Bitcoin (Table 1).

In the absence of 100 percent liquid reserves, Tether can be susceptible to bank-run-like problems. If demands to redeem Tether exceed available liquid reserves, Tether must suspend redemptions or sell less liquid assets. By way of analogy, at the height of the Global Financial Crisis in 2008, money market funds were forced to "break the buck" when the value of their commercial paper holdings fell. A difference here is that redemption pressure on Tether may not be linked to a decline in the value of underlying assets; instead it may just be linked to lack of full collateralization. Even if the stablecoin is 100 percent collateralized, however, when commercial paper markets are illiquid the issuer may be unable to meet redemption requests, triggering a speculative attack.

A specific issue is Tether's holdings of Bitcoin. While these constituted a small fraction (1.8 per cent) of Tether's balance sheet on March 31st, 2023, they make Tether's backing subject to market volatility. A crash in the value of risky cryptocurrencies such as Bitcoin can reduce the value of Tether's assets. And a decline in the value of Tether's assets relative to tokens in circulation can trigger a run and mass redemptions. We study the role of this market risk in Section 4.2.

Another issue is opacity and lack of auditing requirements. Because Tether's assets are kept off-chain, investors are unable to confirm that the Tether balance sheet is fully collateralized in real time. Attestations, while useful, are done only once a quarter. We study an alternative proof of reserve system that can offer audits in real-time in Section 5.

Finally, while our study focuses on Tether, we show that concerns about the valuation of assets and the degree of collateralization are relevant to other stablecoins in the ecosystem. In Section 4.2.3, we highlight the role of Silicon Valley Bank's collapse in triggering a USDC de-pegging event that occurred in March 2023, when the bank, which held cash reserves for USDC, went bankrupt.

3.3 Data

3.3.1 Spot and futures

Table 2 presents summary statistics for variables used in the analysis. For USDT spot and futures prices, we draw data from Coinapi https://www.coinapi.io/. Coinapi offers a monthly subscription with access to their data api, which gives historical cryptocurrency OHLCV (Open, High, Low, Close and Volume) data. Prices for Tether futures are available from the now notorious FTX exchange from May 2020. Spot prices are available earlier; the earliest historical series for Tether is obtained from the Kraken exchange, which is the most liquid exchange for spot USDT/USD trading.

Figure 3 plots spot and futures prices and the basis, which is defined as the difference between the futures and spot rate. The basis is typically negative, and is consistent with investors pricing devaluation risk. For a measure of market volatility risk, we use a measure of intra-day volatility of Bitcoin, calculated as the square root of the daily average sum of squared returns over hourly intervals.

3.3.2 Lending and borrowing rates

For interest rates on Tether we use lending rates from the Compound protocol. These rates are compounded every block (approximately every 15 seconds on the Ethereum blockchain, resulting in approximately continuous compounding) and are determined by the utilization percentage in the market, which is the percentage of the asset supplied to the protocol that is borrowed.[9] For money market rates, we use the 3 month USD OIS rate obtained from Bloomberg. The 3 month maturity matches the term structure of 3 month futures on USDT/USD contracts.

3.3.3 Network measures

Our network measures are from coinmetrics, a blockchain data company that specializes in measures of transfer value and network characteristics for major cryptocurrencies. We classify transactions that are "sent" as deposits, and transactions when the Treasury receives Tether as redemptions. Importantly, we only consider Tether circulation net of supply held by the Treasury, this is labeled as the free float supply in the coinmetrics database. We construct the measure of Tether in circulation for three blockchains that account for over 95% of Tether creation: Omni, Ethereum and Tron. For each platform, we utilise data on the transactions of the Tether Treasury with secondary market wallets. Figure 4 plots the total Tether supplied on each blockchain. While Tether was initially issued on the Omni blockchain, the two primary blockchains since 2019 have been Ethereum and Tron. Tether's move to the Ethereum and Tron blockchain is driven by several factors, including the ability to serve a larger number of cryptocurrency investors, facilitate exchange with Ethereum (ERC20) and Tron (TRX) tokens, enable faster arbitrage opportunities, and reduce transaction costs.[10] For example, cryptocurrency exchanges like

9. For example, the interest rate model for borrowing rates is given by the piece-wise equation (1). a_0 is the base rate, and is the rate corresponding to zero utilization. The slope parameter b_0 measures the sensitivity of interest rates to utilization. Typically the threshold is set at 0.8.

$$r = \begin{cases} a_0 + b_0 u, u \leq \bar{u} \\ a_0 + b_0 \bar{u} + b_1 (u - \bar{u}), u > \bar{u} \end{cases} \tag{1}$$

10. ERC20 and TRX are standards which provide features including the transfer of tokens from one account to another, measuring the current token balance of an account, and measuring the total supply of the token available on the network. It deploys smart contracts, auto-executing code on the blockchain,

Bittrex and Huobi recognize the benefits of the Ethereum blockchain for Tether.[11]

In addition to measures of Tether in circulation, We employ a measure of the concentration of addresses on the network known as the network distribution factor (NDF), which measures the ratio of supply held by addresses with at least one ten-thousandth of the current supply. We also use a measure of velocity, which is the ratio of value transferred in the trailing year divided by the current supply at the end of the period. This can be thought of as turnover – as the number of times that an average native unit has been transferred in the past year. In Figure 5, we plot the velocity and concentration for Tether across all 3 blockchains, as well as a value-weighted measure. As the value of the Omni network declined, so did the velocity of transactions. In contrast, we see an increasing trend in velocity on the Tron blockchain, which drives the increase in the value-weighted measure. There has been a downward trend in the value-weighted measure of blockchain concentration mainly driven by Tron blockchain. While it starts with a concentration of nearly 1 in early 2020, it falls to 0.75 at the end of our sample in June 2022, converging to the concentration of Ethereum which has been stable, ranging between 0.65 and 0.75 over our sample.

3.4 Sentiment

We also build a measure of market sentiment from news articles. The goal here is to extract the most prominent topic from each article. Conventional topic modeling methods extensively used in the literature, Latent Dirichlet Allocation and Latent Semantic Indexing, rely on bag-of-word representations of documents, meaning that word ordering and semantics are overlooked. In contrast, the Bidirectional Encoder Representations from Transformers (BERT) modeling approach is a state-of-the-art topic modeling structure developed to overcome these shortcomings (Devlin et al. 2018). It is our choice of algorithm to explore the topics of our corpus.

The input required for BERT topic modeling is the corpus, in our case a set of stablecoin-related news articles. In the first step, Sentence Transformers are used to extract document embeddings. The pre-trained model we use to extract document embeddings is RoBERTa, developed by Liu et al. (2019). Documents are embedded to create representations in vector space that can be compared semantically.

The next step is to apply the UMAP algorithm of McInnes, Healy, and Melville (2018) to the document embeddings. This reduces dimensions and clusters semantically similar documents.

The last step is topic creation based on a class-based variant of TF-IDF (Term Frequency–Inverse Document Frequency) (i.e., c-TF-IDF). All documents in the same cluster

to perform these various functions.

11. Huobi exchange statement on the migration to the Tether blockchain, https://prn.to/2ZkPzw0

are treated as a single document, and c-TF-IDF, a score indicating the importance of a word for a particular cluster, is constructed based on the following equation:

$$c - TF - IDF_i = \frac{t_i}{w_i} \times log \frac{m}{\sum_j^n t_j} \tag{2}$$

where t_i is the frequency of term t in cluster i, which is divided by the total number of words in the cluster w_i. This is multiplied by the logarithmically-scaled fraction of the total number of n documents across all clusters m divided by the sum of occurrences of term t in all those documents. Words with highest c-TF-IDF in each cluster enable us label that cluster.

The output generated for our corpus consists of 9 topics and the top 30 keywords for each topic. We summarize the keywords for the topic we identify as having derivatives content in Figure 6. Words capturing derivatives include futures, contracts, options, leveraged, transfers, spot, withdrawal, and derivatives.

BERT also gives us a sample of news articles classified as having derivatives content. This enables us to calculate the sentiment of such articles. Specifically, we count the number of positive and negative words in Loughran and McDonald (2011) dictionary. Sentiment takes the following form:

$$Sent = \frac{\text{Number of negative words}}{\text{Number of negative words+Number of positive words}}$$

Examples of stablecoin derivative articles are in Appendix B. For example, sample sentences that mention Tether in relation to derivatives are *"Crypto derivatives exchange platform ByBit is set to airdrop Tether (USDT) tokens to its users following the platform's recent unveiling of its perpetual contracts for the popular stablecoin"*. An example of a negative sentiment sentence is on the role of Tether in market manipulation *"Despite multiple legal troubles for Tether and Bitfinex, the popular stablecoin has remained the de facto liquidity provider for most of the crypto trading market. USDT has also been at the center of price manipulation claims with some critics alleging that Tether was being used to control the Bitcoin (BTC) price action"*.

Finally, articles contain passages relating to concerns on the collateral being used to back stablecoin pegs. Sample sentences include *"A primary issue of concern is transparency and quality of collateral for stablecoins. If doubts about the securities backing the coins trigger a rush of redemptions, that could damage the entire payments mechanism as well as the prices of assets such as Bitcoin and Ethereum with a combined market capitalisation of more than \$1.5tn. Tether, the stablecoin leader with about \$75bn in coins, has been accused in the past of making misleading claims about the assets backing them"*.

The article also mentions previous litigation surrounding the claims that Tether were backed one-for-one with cash or cash equivalent assets, *" Last month it agreed to pay a \$41m penalty to resolve a charge by a regulator that it had falsely represented that its digital tokens were fully backed by dollars"*, and *"Earlier this year Tether and a linked exchange Bitfinex also agreed to pay an \$18.5m penalty after New York attorney-general accused them of covering up a massive financial losses"*.

Figure 7 plots the 1 month rolling average of the sentiment measure on the futures topic. The sentiment scores are persistently positive with an average of 0.22 over our sample. A positive sentiment measure indicates higher pessimism about stablecoins and their role as a vehicle currency in the cryptocurrency market. Therefore our sentiment measure can be used by investors to price Tether devaluation risk.

4 Model and Evidence

4.1 Model of Devaluation Risk

To motivate the empirical analysis, we set out a simple model of devaluation risk. Define s_t, f_t as the spot and futures rates, expressed as the dollar price of a unit of Tether. Assume that the price dynamics of the peg follow an AR(1) process with mean-reversion coefficient ρ in equation (3).

$$s_{t+1} = 1 + \rho(s_t - 1) + \epsilon_{t+1}, 0 < \rho < 1 \tag{3}$$

Stability of the system requires $\rho < 1$. The coefficient ρ provides an estimate of the half-life of the system.[12] The reduced form dynamics of the peg capture an arbitrage mechanism through which peg-price deviations are reduced and eliminated.

This AR(1) process allows for a direct mapping between the spot price today and the spot price at expiry. Iterating equation (3) forward, we obtain an expression for the peg-price deviation at expiry $t+h$ of the contract in equation (4). This is equal to the current deviation discounted by the mean-reversion coefficient ρ, in addition to a discounted sum of Tether-specific shocks ϵ_{t+s}.

$$s_{t+h} = 1 + \rho^h(s_t - 1) + \sum_{s=1}^{h} \rho^{h-s}\epsilon_{t+s} \tag{4}$$

The spot rate at expiry follows equation (5). With probability $\mathcal{P}$, the stablecoin regime collapses because the issuer absconds with funds or as a result of a run creating

12. To measure the half-life, we run an auto-regressive process of order 1 on the deviations, $\Delta = \rho\Delta_{t-1} + u_t$. The half-life, or the time it takes for a shock to dissipate by 50%, is $T = \frac{log(0.5)}{log(\rho)}$.

an inability to meet remaining redemption requests. In this scenario, the spot rate approaches zero. With probability $1 - \mathcal{P}$, the spot rate is equal to an exponential decay of peg-price deviations, reflecting a series of shocks that are discounted by the mean reversion coefficient ρ.

$$s_{t+h} = \begin{cases} s_{t+h} = 1 + \rho^h(s_t - 1) + \sum_{s=1}^{h} \rho^{h-s}\epsilon_{t+s}, \text{ with probability } 1 - \mathcal{P} \\ 0, \text{ with probability } \mathcal{P} \end{cases} \tag{5}$$

Under the expectations hypothesis, the futures price for a contract expiring h periods from now is equal to the expectation of the spot rate h periods from now. The futures contract at expiry is given by equation (6).

$$\begin{aligned} f_t &= \mathbb{E}_t[s_{t+h}] && (6) \\ &= (1 - \mathcal{P}) \times (\mathbb{E}_t[s_{t+h}]|\text{No Default}) + \mathcal{P} \times (\mathbb{E}_t[s_{t+h}]|\text{Default}) && (7) \\ &= (1 - \mathcal{P}) \times \big(1 + \rho^h(s_t - 1)\big) && (8) \end{aligned}$$

Utilizing the probabilities of the 'default' and 'no-default' states, we can show that stablecoin futures equal the expected price.

The probability of a run is captured by equation (9).

$$\mathcal{P} = 1 - \frac{f_t}{1 + \rho^h(s_t - 1)} \tag{9}$$

This probability can be estimated based on observable spot and futures rates. It is decreasing in the futures rate and increasing in the spot rate. It is inversely related to the futures-spot basis $f_t - s_t$. As the horizon of the futures contract $h \to \infty$, the equation simplifies to $\mathcal{P} = 1 - f_t$.

We show our measure of devaluation risk (equivalently, default risk) in Figure 8.[13] There is significant time variation in the implied default probability, with a peak of 2 per cent (annualized). The two local peaks correspond to major events in the cryptocurrency market. The first one is the 'Black Thursday' March 12th, 2020 Crypto crash, when the prices of major currencies such as Bitcoin fell by 50 per cent. The second one is the TerraUSD crash on May 9th, 2022, when investors priced an increase in the probability of a Tether-de-pegging event. We discuss further the dynamics of these two events in section 4.2.

13. To compute the default probability, we first estimate the auto regressive parameter ρ in equation (3). and use an average estimate of $\rho = 0.77$ over the full sample. In calculating the annualized probability, we use the estimate of ρ and assume a horizon $h = 90$ of the futures contract.

4.2 Correlates of run risk

We test for the determinants of the probability of a stablecoin run using equation (10). Explanatory variables include network measures such as the concentration of Tether addresses and rate of turnover (also referred to as monetary velocity). Proxies for market volatility include measures of intra-day volatility and returns on Tether and Bitcoin. Finally, we consider interest rates on both Tether and in money markets, as well as a variable capturing periods of net redemptions of Tether, that is, periods when the supply of Tether (net of Treasury) falls.

$$\mathcal{P} = \beta_0 + \sum_i \beta_i X_i + \epsilon_t \tag{10}$$

As shown in Table 3, an increase in concentration is associated with an increase in the probability of default. Statistically, a 1 per cent increase in concentration leads to an approximately 0.1 basis point increase in the annual default probability. Our results thus support theoretical work Bertsch (2022) suggesting that risk in stablecoin markets arises when there exist more large holders with market power and the ability to trigger a run. In contrast, a more dispersed network of addresses is more resilient to runs insofar as each investor is marginal.

Velocity is positively associated with devaluation risk. An interpretation is that investors are re-balancing the coin in their portfolios because there are concerns that the coin is overvalued, or that investors are panicking and seeking redeem the coin at par on secondary exchanges.

In addition, devaluation risk is responsive to periods of high Bitcoin volatility and BTC returns. Periods of high Bitcoin volatility and negative Bitcoin returns can increase devaluation risk due to investor concerns about the role of Tether as a vehicle for transactions in Bitcoin and related cryptocurrencies.

These results broadly support the findings of theoretical models of stablecoin devaluation risk (Bertsch 2022; Routledge and Zetlin-Jones 2018; Li and Mayer 2021; d'Avernas, Maurin, and Vandeweyer 2022). In these models, cryptocurrency-related fundamentals matter for stablecoin devaluation risk. For example, a decline in the value of stablecoins as a means of payment, through an increase in market volatility or in the concentration of the network, can heighten the susceptibility of a stablecoin run. If investors believe the expected value of Bitcoin and similar cryptocurrencies will fall, this will lead to an increased probability of states where investors redeem stablecoins in order to reduce their holdings of cryptocurrencies. Another potential reason why Bitcoin volatility and returns impact devaluation risk is the possibility that Bitcoin is held as part of Tether's assets. In 2021, up to 4 per cent of Tether's assets were used to make collateralized loans in Bitcoin.

A decline in the value of Bitcoin can therefore have valuation effects on the balance sheet and lead to an under-collateralized peg.[14]

Devaluation risk is also affected positively by lending rates on USDT. Lending protocols in decentralized finance are primarily used for leveraged trading. For example, an investor can take a long leveraged position on ETH by depositing ETH in the lending protocol and borrowing stablecoins to buy more ETH in the secondary market. This increase in demand for borrowing stablecoins to finance long leveraged positions puts upward pressure on stablecoin interest rates. Higher deposit rates, all else equal, imply higher speculative demand for cryptocurrencies. Insofar as stablecoins facilitate leveraged demand for speculative currencies, investors price a greater systemic risk of stablecoin de-pegging events.

In contrast, we find no evidence that devaluation risk is positively affected by money market rates as proxied by the 3 month USD OIS rate. This disconnect between stablecoin prices and USD money market rates is further explored in section 4.3. In Appendix C, we document the effects of each fundamental on the basis (difference between futures and spot), spot and futures prices.

Finally, we explore the relationship between sentiment and devaluation risk. Negative sentiment in news articles on the immediately preceding day is associated with a significant increase in devaluation risk. Intuitively, this pessimism can stem from direct concerns about devaluation risk arising from insufficient reserves, and/or from pending litigation related to solvency and alleged market manipulation of stablecoin issuance. In addition, negative sentiment can indirectly amplify devaluation risk by contributing to market volatility. In a bearish (negative sentiment-dominated) market, stablecoins are less likely to be used in futures trading, where they serve as collateral for investors taking long or short positions in high-risk cryptocurrencies. Consequently, pessimism about cryptocurrencies as a speculative asset can reduce the role of stablecoins as vehicle, thereby increasing the likelihood of scenarios where investors redeem stablecoins to reduce their holdings of cryptocurrencies, potentially increasing devaluation risk (when, for example, collateral is less than perfectly liquid).

4.2.1 Case study: The March 12th, 2020 'Crypto Crash'

To better understand why BTC volatility is a robust predictor of stablecoin default risk, we consider a case study of the cryptocurrency market on March 12th, 2020, when BTC prices fell by 40 per cent.

Figure 9 shows the behavior of stablecoin futures and spot prices and of select deter-

14. For further information, refer to https://www.ft.com/content/0035016c-29ad-4e6f-9163-2a17df490aa5 In the December 2022 attestation report conducted by accounting firm BDO, Tether reports up to 5.8 USD Billion of its total 67 USD Billion (8.7 per cent) are in the category of "Secured loans" which can include loans collateralized with Bitcoin and other risky cryptocurrencies.

minants of devaluation risk around this event. An interesting observation highlighted by the figure is that stablecoins traded at a premium in the spot market for much of the period (Lyons and Viswanath-Natraj 2020; Liao and Caramichael 2022). Despite these temporary "safe haven" effects, however, we also observe a widening futures-spot basis. The widening basis implies a rise in our measure of devaluation risk. The increase in devaluation risk appears to have stemmed from sharp decline of the cryptocurrency market generally, as opposed to circumstances affecting USDT specifically. Evidently, investors felt that if increased cryptomarket volatililty persisted, this would reduce the utility of stablecoins used as vehicles for crypto transactions, and specifically of Tether's role as a vehicle for facilitating the buying and selling of units such Bitcoin. In the appreciation of spot USDT but the simultaneous emergence of a futures discount, we see a distinction between the short-term safe haven benefits of a stablecoin in periods of increased market volatility, and the long-term effect of investors pricing states of the world in which the cryptocurrency market shrinks, resulting in a permanent decline in the demand for stablecoins as vehicle currencies.

This crypto crash was a temporary event; risky cryptocurrency prices returned to pre-crash levels within days. Their unusually high volatility subsided. Hence the rise in perceived devaluation risk was similarly temporary.

We also observe a transitory increase in the volatility of USDT/USD, an increase in the supply of Tether, and a decline in its velocity. The increase in Tether supply is in part due to investors arbitraging premia in the spot price in the secondary market. Investors can make a simple arbitrage trade by buying Tether from the Treasury at par and selling it at the prevailing market rate (above par). Measures of concentration fell, as a larger number of investors started using stablecoins as a vehicle currency and buying the dip in cryptocurrency markets. This response may have been facilitated by the growing number of retail traders, as recipients of COVID-19 stimulus checks put their funds to work in crypto markets (Divakaruni and Zimmerman 2021) and as other traders sought to hedge against inflation risk. Velocity then fell once crypto prices recovered and volatility declined.

In sum, the March 2020 crypto crash led to a temporary increase in USDT devaluation risk. However, once high volatility in the crypto sphere subsided, devaluation risk declined back to earlier levels, and there was a renewed demand for the stablecoin as a vehicle currency.

4.2.2 Case study: The May 9th, 2022, TerraUSD crash

TerraUSD is an algorithmic stablecoin backed by Luna, the native token of the Terra blockchain. (In other words, TerraUSD is not collateralized by dollar reserves. The TerraUSD treasury holds reserves of Bitcoin for use in extremis, but only limited amounts.)

TerraUSD is pegged to 1 USD through a simple arbitrage mechanism. When the TerraUSD price is above par, an investor can sell 1 USD worth of Luna and buy TerraUSD for 1 USD. He or she can then sell TerraUSD in the secondary market for an arbitrage profit. Conversely, when the dollar price of TerraUSD is below one, an investor can buy TerraUSD at the exchange and sell TerraUSD for 1 USD worth of Luna tokens.

The arbitrage mechanism is not risk-free: investor profits are driven by expectations of the valuation of the governance token. It follows that algorithmic stablecoins such as TerraUSD are prone to speculative attacks (Briola et al. 2023; Liu, Makarov, and Schoar 2023; Ma, Zeng, and Zhang 2023; Uhlig 2022). An instance of this problem was in May 2022, when TerraUSD was subject to a speculative attack, leading it to trade at large discounts relative to the peg. This in turn triggered a loss of confidence in the blockchain and governance token, resulting in a spiral of falling Luna prices and falling TerraUSD prices. The TerraUSD treasury's Bitcoin reserve was fully depleted during the attack.

Although these design features affecting the TerraUSD peg were not shared by other stablecoins such as Tether, Tether fell to 95 cents USD intra-day on May 12th, 2022, three days after the initial TerraUSD collapse. This contagion may indicate investor expectations of reduced utility of stablecoins generally for cryptocurrency transactions. In addition, Liao (2022) document a shift from Tether toward USDC, an alternative stablecoin with more transparent and ample backing, suggestive of investor preferences for increased transparency and security in this uncertain environment.

Figure 10 shows the dynamics of Tether spot and futures prices, the implied probability of default, and network measures on May 12th. While there was a decline in spot prices, futures prices declined by more and did not rebound as quickly following the event. The implied probability of Tether default rose to 200 basis points (annualized). The basis (futures less spot) took weeks to recover to levels prevailing prior to the TerraUSD collapse.

In terms of blockchain characteristics, there was an increase Tether velocity, an increase in the volatility of USDT/USD, and an increase in concentration of wallets holding USDT. Some investors exited, and rRedemptions were required to stabilize the peg. The increase in velocity presumably reflects the tendency for investors to rebalance their portfolios toward other stablecoins such as USDC, consistent with the narrative in Liao (2022).

4.2.3 Case study: March 11th, 2023, The USDC De-pegging event

A third case study is the USDC de-pegging event that occurred in March 2023, when Silicon Valley Bank, which held cash reserves for USDC, went bankrupt. USDC reportedly held some 3.3 USD Billion of cash reserves at SVB. The run on SVB created investor concern about whether these reserves would be lost, since they far exceeded the cap on

Federal deposit insurance, and speculation about whether or not the coin was still fully backed. USDC fell to 87 cents on March 11th, before prices stabilized on March 13th after the FDIC had announced that all deposits at SVB would be fully guaranteed and available, and USDC transferred its cash reserves to other banking partners (Figure 11).[15]

While we do not have futures data for the USDC stablecoin, we can use this case study to test the external validity of our interpretation of the behavior of other variables around episodes of heightened devaluation risk. We again observe an increase in velocity and in the concentration of wallets holding USDC. Evidently, efforts to exchange the USDC for USD reserves lead an increase in secondary market trading, which shows up as a rise in velocity. Some of these investors liquidated their holdings of USDC; the resulting decline in the number of investors using USDC as a vehicle currency in the cryptocurrency market results in increased concentration in large wallets. We then observe redemptions in the weeks following the event: the free float supply of USDC decreased from 40 USD Billion to 32 USD Billion over the 4 weeks since the de-pegging event. These redemptions were necessary for maintenance of the peg. By removing USDC from circulation, they put upward pressure on prices and helped maintain the peg's secondary market value at par.

In sum, these patterns suggest a narrative consistent with the Tether de-pegging event discussed earlier.

4.3 Determinants of stablecoin interest rates

4.3.1 Shadow risk-free rate

An alternative measure of default risk can be derived from differences in risk-free rates on USD and stablecoins, such as Tether. We estimate a shadow risk-free rate on Tether based on the futures-spot basis. As a money market rate, we use the USD 3 month OIS rate obtained from Bloomberg.

The resulting rate is derived as:

$$i^{*}_{USDT,t} = \left(\frac{s_t}{f_t}(1 + i_{\$,t}\frac{h}{360}) - 1\right) \times \frac{360}{h} \times 100 \tag{11}$$

We plot our shadow risk-free rate and the money market rate in Figure 12. The shadow-risk free rate is persistently higher than the money market rate. This result is mechanical in the sense that futures regularly trade at a discount. We can therefore interpret our devaluation risk measure as a stablecoin inconvenience yield. This is in line with related literature documenting that stablecoins are imperfect substitutes for money (Gorton,

15. For a full account of USDC's reserve composition and the de-pegging event, we refer readers to https://www.circle.com/blog/an-update-on-usdc-and-silicon-valley-bank

Ross, and Ross 2022; Gorton et al. 2022).

4.3.2 Covered interest rate parity

Previously, we found that default/devaluation probabilities are affected by stablecoin lending rates but not by conventional money market interest rates. This points to a possible disconnect between interest rates and futures prices in the stablecoin market on the one hand, and conditions in financial markets more broadly on the other. In this subsection we analyze this disconnect directly.

Decentralized finance lending protocols such as Compound report borrowing and lending rates on Tether. We can use them to construct the risk premium of holding Tether instead of the USD after hedging the exchange rate risk using a futures contract. This in turn allows us to consider deviations from covered interest parity (CIP), computed as in equation (12). The CIP deviation is expressed as the difference between a synthetic dollar rate $i_{\$,t}^{synthetic}$ and a direct dollar rate $i_{\$,t}$. The synthetic dollar rate can be constructed by converting dollars to Tether at spot rate s_t, lending Tether at $i_{usdt,t}$, and then re-converting Tether to dollars at maturity at the forward rate f_t.

CIP serves as a benchmark of market efficiency of stablecoin interest rate markets. In a frictionless setting, we expect interest rates to be equalized across currencies after hedging exchange rate risk using a futures contract. Therefore, the benchmark for efficient interest rate markets suggests that the CIP deviations are zero or within bounds governed by transaction costs such as gas fees on the Ethereum blockchain.

$$
\begin{aligned}
CIP_t &= i_{\$,t}^{synthetic} - i_{\$,t} && (12)\\
&= \left(\left(\frac{f_t}{s_t}(1 + i_{usdt,t}\frac{h}{360}) - 1\right) \times \frac{360}{h} - i_{\$,t}\right) \times 100 && (13)
\end{aligned}
$$

Figure 13 plots the CIP deviation, along with the synthetic dollar interest rate and direct dollar rates. Deviations are persistently positive. These indicate the existence of a risk premium embedded in stablecoin rates even after controlling for exchange risk using a futures contract. The CIP deviation derives mainly from high stablecoin lending rates on the Compound protocol. Note that the deviation narrows somewhat in the second half of the sample period.

One can think of a number of reasons for the disconnect between money market rates and stablecoin rates even after controlling for devaluation risk. One possibility is market segmentation. While money market rates reflect the relative supply of savings and demand for investment projects in the real economy, stablecoin rates reflect leveraged trading in financial markets that are largely disconnected from that real economy. (Gorton et al. 2022; Chaudhary, Kozhan, and Viswanath-Natraj 2023). Interest rates on decentralized finance protocols are determined by the utilization of assets, which is the percentage of an asset that is borrowed. Stablecoin interest rates therefore reflect the demand by speculators for long leveraged positions in risky cryptocurrencies.

Interest rates on lending protocols have no term structure; interest accrues in block time, which is approximately every 15 seconds on the Ethereum blockchain. Because interest rates on Tether are not fixed at 3 months like USD money market rates, there is no risk-free arbitrage profit in a basic CIP trade. To construct the synthetic dollar interest rate, an investor must lock their funds in Tether for 3 months, before re-converting to dollars at a forward rate. Investors will have to base their profit on the expected interest rate over the 3 months duration. Part of the positive premium on stablecoin rates over money market rates reflects this interest-rate risk.

A third issue is that arbitrage between stablecoin interest rates and money market rates involves transaction costs, given the need to move capital from financial intermediaries to decentralized finance platforms. These costs include gas fees. Gas is a measure of the amount of ether (ETH) a user pays to perform a given activity, or batch of activities, on the Ethereum network. These transaction costs are analogous to commissions on exchanges. However in this case these costs are paid to the miners who authenticate the transactions on the Ethereum blockchain.

A final cost is that of supporting an off-ramp from Tether to USD in order to conduct a round-trip arbitrage trade. Retail investors need to access spot markets in USD/USDT on centralized cryptocurrency exchanges like Bitfinex. Processing lags for withdrawals of dollars on these exchanges are substantial, and fees are imposed when dollar withdrawals are frequent or large.[16]

4.3.3 Interest rate disconnect

Determinants of Tether borrowing and lending interest rates are shown in Tables 4 and 5. These interest rates are correlated with the network properties of Tether and respond positively to Bitcoin returns. In contrast, there is no evident correlation with USD money market rates.

To shed light on this disconnect, Table 6 investigates the impact of Federal Reserve policy rate announcements on stablecoin prices, borrowing and lending rates, and issuance. We estimate Equation (14), regressing USDT spot price changes on a $FOMC_{dummy}$. This variable takes a value equal to 1 on FOMC announcement days, and 0 otherwise. Δi_{USD} is the change in USD interest rate, and $FOMC_{dummy} {}^* \Delta i_{USD}$ is the interaction

16. For more information, refer to the following announcements by Bitfinex: https://bit.ly/2NEzITW and https://www.bitfinex.com/posts/311. Bitfinex states that it takes investors 7 to 15 days to make dollar withdrawals from their platform in order to comply with intermediation procedures. Bitfinex has also introduced a transaction cost of 3% for investors who make more than two dollar withdrawals a month, or for withdrawals of more than $1 million in a given month.

variable between $FOMC_{dummy}$ and Δi_{USD}.

$$s_{t+1} - s_t = \beta_0 + \beta_1 FOMC_{dummy} + \beta_2 \Delta i_{USD} + \beta_3 FOMC_{dummy} \times \Delta i_{USD} \tag{14}$$

Stablecoin markets do not respond to money market rates on announcement days. In specifications (1) to (5), we find no effect of FOMC announcements on USD/USD spot prices, borrowing rates or lending rates, consistent with the hypothesis that stablecoin rates are disconnected from conventional financial markets. We do however find, in specification (6), that issuance responds to interest rates. An increase in the Federal funds rate on monetary announcement days is followed by a decline in stablecoin issuance. This is consistent with higher interest rates causing a portfolio rebalancing by investors toward high yielding interest-bearing assets. This results in a decline in stablecoin demand, requiring a fall in issuance to stabilize the peg.

4.4 Redemption mechanisms and peg resilience

Over our sample period, deposits were more common than redemptions on all three platforms, accounting for some 80 per cent of transactions on the Ethereum and Tron blockchains. Only 20 per cent of days experienced negative net flows. The excess of deposits over redemptions is indicative of how the demand for cryptocurrencies was growing.

The primary market is the rate at which the Treasury is willing to exchange Tether for dollars. The primary market rate is 1 USDT:USD, with asymmetric transaction costs for deposits and redemptions. While deposits of dollars at the Treasury come with a flat fee of 0.1 per cent, redemptions incur a minimum cost of 1000 USD or 0.1 per cent of the trade. [17] Starting in April 2017, the first secondary market for Tether/Dollar trading was introduced on the Kraken exchange.

In accordance with Lyons and Viswanath-Natraj (2020) and Ma, Zeng, and Zhang (2023), we posit a decentralized arbitrage mechanism for maintaining the stability of the Tether/USD peg that is driven by the actions of arbitrageurs who exploit differences between primary and secondary market prices. If the secondary market price of Tether is above one dollar, an investor can buy Tether from the Treasury at a one-for-one rate and sell it at the prevailing market rate to profit, resulting in a flow of Tether from the Treasury to the secondary market. Conversely, when the dollar price of Tether is below 1, an investor can buy Tether at the exchange and sell it to the Tether Treasury.[18]

Therefore, peg stability requires that Tether redemptions put upward pressure on

17. For example, refer to https://tether.to/fees/ for details.

18. Ma, Zeng, and Zhang (2023) identify key wallets that are necessary for the arbitrage to work, and find top shares of participants necessary for arbitrage are concentrated. The top 5 wallets that process redemptions typically account for over 90 per cent of total redemptions of Tether.

prices when Tether trades at a discount. Conversely, when Tether trades at a premium, an increase in deposits and Tether creation should put downward pressure on prices.

To test this arbitrage mechanism, we use local projections (based on Jordà 2005) of the value of changes in Tether supply on deviations from Tether's parity peg. To carry out this analysis, we denote $\Delta ffs_t = ffs_t - ffs_{t-1}$, which is the change in the free float supply as calculated by Coinmetrics. This is the change in the Tether supply net of changes in Treasury holdings. As discussed in Lyons and Viswanath-Natraj (2020), this is the economically relevant object when examining the price effects of Tether issuance.

In equation (15), the change in the Tether dollar price, $P_{t+h} - P_{t-1}$, is projected on the change in free float supply, allowing for feedback effects using lagged prices and flows as controls. We are interested in whether the arbitrage mechanism works both when there are net deposits ($\Delta ffs_t > 0$) and net redemptions ($\Delta ffs_t < 0$). Denote $D_{redemption}$ as days when there are negative changes in free float supply. We hypothesize a negative coefficient β_h for positive changes in free float supply, which suggests that positive flows to the secondary market push Tether prices downward. Conversely, negative changes in free float supply, which are consistent with investors redeeming Tether tokens, exert upward pressure on Tether price dynamics. Therefore we hypothesize positive coefficient γ_h for negative changes in free float supply.

$$P_{t+h} - P_{t-1} = \alpha + \beta_h |\Delta ffs_t| \times (1 - D_{redemption}) + \gamma_h |\Delta ffs_t| \times D_{redemption} + \text{controls} + u_t \qquad h = 0, 1, 2, ... \quad (15)$$

In the top panel of Figure 14. we show the coefficients β_h, which are the price effects of positive changes in free float supply. In the bottom panel, we trace the coefficients γ_h, which are the price effects of negative changes in free float supply. Changes in free float supply are measured in USD Billion. Consistent with our hypothesis, arbitrage flows from investors have a stabilizing effect on the Tether/USD price. A 1 USD Billion deposit and redemption have approximately a 5 basis point price impact that persists for up to one month.

Interestingly, our results show similar price impacts of positive and negative changes in free float supply. This confirms the stabilizing role played by redemptions during de-pegging events of Tether and USDC. It suggests that these effects work to stabilize the peg.

5 Stablecoin risk management solutions

5.1 Private sector solutions

One possibility for minimising devaluation risk is real-time audits by a third party proof-of-reserve system. Third party verification of stablecoin collateral at a block-time frequency would provide more transparency on the value of collateral. Real-time auditing can also mitigate the risk of an issuer absconding with funds held off-chain by providing an early alert.

An example is the proof of reserve system provided by the blockchain firm Chainlink.[19] Chainlink conducts automated audits designed to help prevent systemic failures in DeFi applications. A stablecoin that uses Chainlink's proof of reserve is TrueUSD. On February 23rd, 2023, TrueUSD (TUSD) partnered with Chainlink to verify its minting of new stablecoin tokens in real-time.

A schematic is shown in Figure 15. First, Network Firm (an accounting firm) initiates a call for USD-reserve data from TUSD's escrow bank accounts. Network Firm is an oracle, an entity that brings data from off the blockchain (off-chain) data sources, such as the reserves held by TrueUSD in bank accounts. It then transfers it onto the blockchain for use by smart contracts, which are auto-executing code. The use of oracles is necessary because smart contracts running on the Ethereum blockchain cannot access information stored outside the blockchain network.

Once the new balance of reserves held in escrow accounts is verified, Chainlink triggers an update on the blockchain. The TrueUSD smart contract, which is auto-executing, mints new tokens based on the value of reserves it receives from Chainlink's proof of reserve. Minting of new tokens can only occur once Chainlink verifies that the reserve balances held at the escrow accounts have increased.

This proof of reserve system addresses at least some of the fundamentals creating stablecoin devaluation risk. First, it ensures that the minting of new tokens is tied to reserves, and enforces full collateralization at all times. There can still be a run on the stablecoin if investors want out, but there will now be sufficient reserves to meet all redemption requests at par in all states of the world. And since reserves are sufficient to meet all redemption requests, the risks of a run are likely to be less.

Second, this is a significant improvement over the existing transparency measures of the largest stablecoins Tether and USDC, which provide attestation reports at a monthly or quarterly frequency. Auditing of assets by a proof-of-reserve system is at a much higher frequency in block-time.

Third and finally, investors can more easily verify the liquidity and riskiness of the assets held by the issuer. If the issuer holds U.S. Treasury securities, the CUSIPs of those

19. https://chain.link/proof-of-reserve

individual Treasuries can be verified by the oracles.

A concern is oracle risk, in other words, insufficient quality or misreporting of data received by the oracle on reserves held in escrow accounts. Chainlink requires multiple oracles to achieve consensus on the value of reserves held by the issuer.[20] At the time of writing in May 2023, 16 different companies (and oracles) validate the reserves held by TrueUSD. Chainlink only updates the level of reserves held by TrueUSD when there is consensus among all of the oracles on the network.

Third-party auditing is only as a reliable as the third-party auditor, in this case Chainlink. Questions about the reliability of such auditors, and whether they might create "market-for-lemons" problems, have given rise to calls for government regulation, to which we now turn.

5.2 Government policies

Recent analysis by the Bank of England recommends a regulatory framework for mitigating stablecoin devaluation risk (BOE 2021).[21] First, the framework suggests a need for capital requirements, for the issuer to maintain a sufficiently high fraction of high-quality liquid assets (HQLA) in their portfolio. Second, it suggests that the central bank can provide liquidity support to meet deposit redemptions. This can be provided through access to the central bank discount window facilities used by banks. Third, central banks can provide arrangements for stablecoin users to access their funds in the event that a stablecoin fails. This can be through providing full or partial insurance of customer holdings.

One suggestion is for issuers to meet the capital requirements imposed by Basel regulations (Catalini and Shah 2021; Liao 2022). For example, Liao and Caramichael (2022) show that USDC has a historically high level of HQLA based on liquidity coverage ratio calculations. The authors find that USDC has at least two times the amount of HQLA as traditional banks, when benchmarked against historical gross outflows over a 30-day ahead period.

In addition, the Bank of England describes a scenario where the stablecoin issuer holds central bank digital currency (CBDC), the ultimate HQLA, as reserves. In return for granting a stablecoin issuer access to reserves held in a central bank account, the central bank would be entitled to regularly audit the stablecoin provider's balance sheet and impose additional capital requirements as appropriate. If stablecoin providers are holding a certain percentage of their liquid reserves at the central bank, this would increase the

20. In technical parlance, Chainlink introduces the concept of decentralized oracle networks. This avoids the risk of a centralized entity controlling an oracle or potentially manipulating the smart contract. For more details we refer readers to https://blog.chain.link/what-is-the-blockchain-oracle-problem/

21. For more information, refer to the BOE report on stablecoins https://www.bankofengland.co.uk/paper/2021/new-forms-of-digital-money

likelihood that they had sufficient funds to process redemptions while maintaining the value of the stablecoin at par against the value of the CBDC. If reserves of CBDC proved inadequate to meet immediate needs, the stablecoin issuer might be authorized to borrow at the discount window against other high-quality but illiquid collateral. Its customers might have their holdings guaranteed up to a specified limit.

In this scenario, the central bank would effectively be regulating the stablecoin issuer in the same way it regulates banks. This is effectively the recommendation of Gorton and Zhang (2023). But if it was regulated as a narrow bank, it is not clear that it could compete with existing fractional reserve banks. If it was regulated like existing fractional reserve banks, it is not clear how it would differ from the latter, aside from having a different deposit base and using a different transactions technology.

6 Conclusion

Stablecoins are an important element of the cryptocurrency ecosystem. They provide a way of buying and selling cryptoassets more efficiently than can be done using national currencies, and serve as (currently limited) vehicles for remittances and other cross-border transactions. Popular stablecoins rely on a centralized custodian of assets held off-chain. When collateralization is partial, or when the collateral is less than fully liquid, this arrangement is vulnerable to mass withdrawals, resulting in the suspension of convertibility and collapse of the peg.

This paper has provided a market-based measure of the probability of default using futures for Tether, the dominant stablecoin. Under the expectations hypothesis, the futures-spot basis is inversely related to Tether's perceived default probability. On average, Tether default is priced at approximately 60 basis points in annualized terms. There is significant time variation in this implied default probability, which at times can spike to a multiple of this average.

We identified several factors associated with devaluation risk. These include factors capturing market risks such as BTC volatility and interest rates on stablecoins in lending markets. They include network fundamentals such as the concentration of addresses and the velocity of transactions. Increases in the concentration and velocity lead to an increase in devaluation risk. An increase in pessimism about stablecoins as captured by our textual analysis of news articles also leads to an increase in devaluation risk.

Our analysis documents a disconnect between stablecoin interest rates and money market interest rates. Stablecoin rates are systematically higher even after hedging exchange rate risk using futures contracts; covered interest parity is violated, in other words. We point to several reasons for this disconnect, including market segmentation, lack of term structure in DeFi interest rates, and transaction costs in arbitrage.

Our findings have implications for investors, regulators, and policymakers, who need to be aware of the risks and potential impacts of stablecoins on the crypto and the broader financial systems. They point to the need for more transparency and regulatory oversight of stablecoins to ensure the stability and integrity of digital assets.

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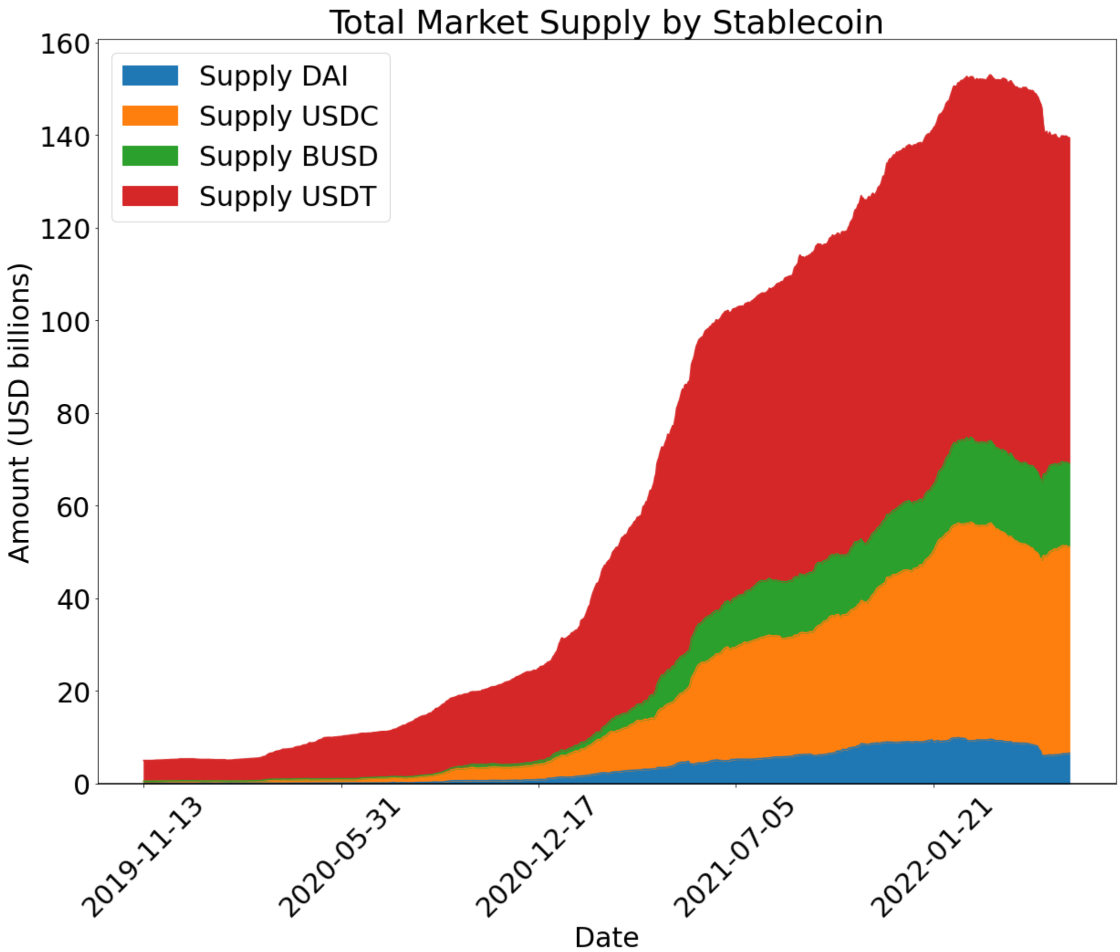
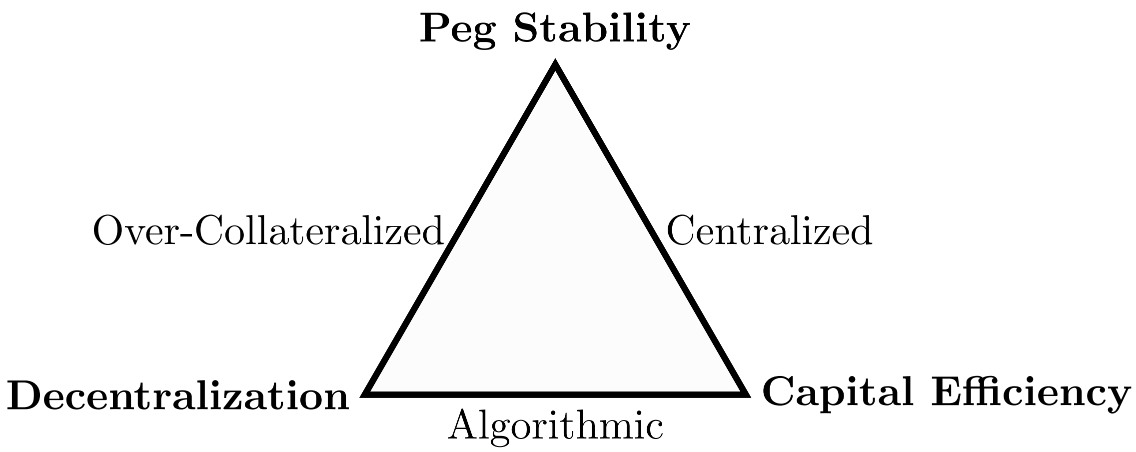
Figures

Figure 1: Stablecoins Total Supply



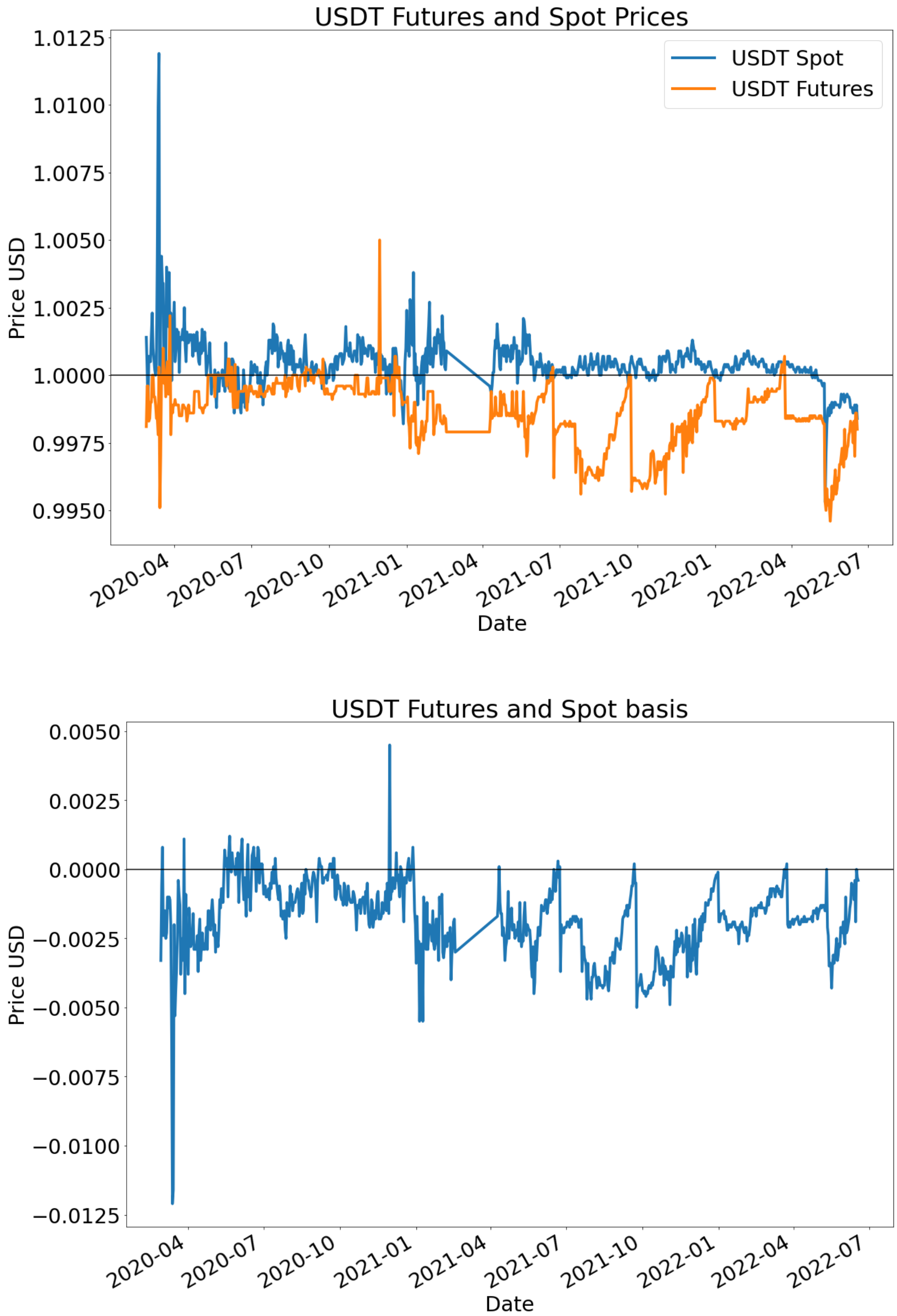
Note: Top panel: total supply of DAI, USDC, BUSD, and USDT. Bottom panel: total supply of Tether across blockchains Omni, Tron and Ethereum.

Figure 2: Stablecoin trilemma



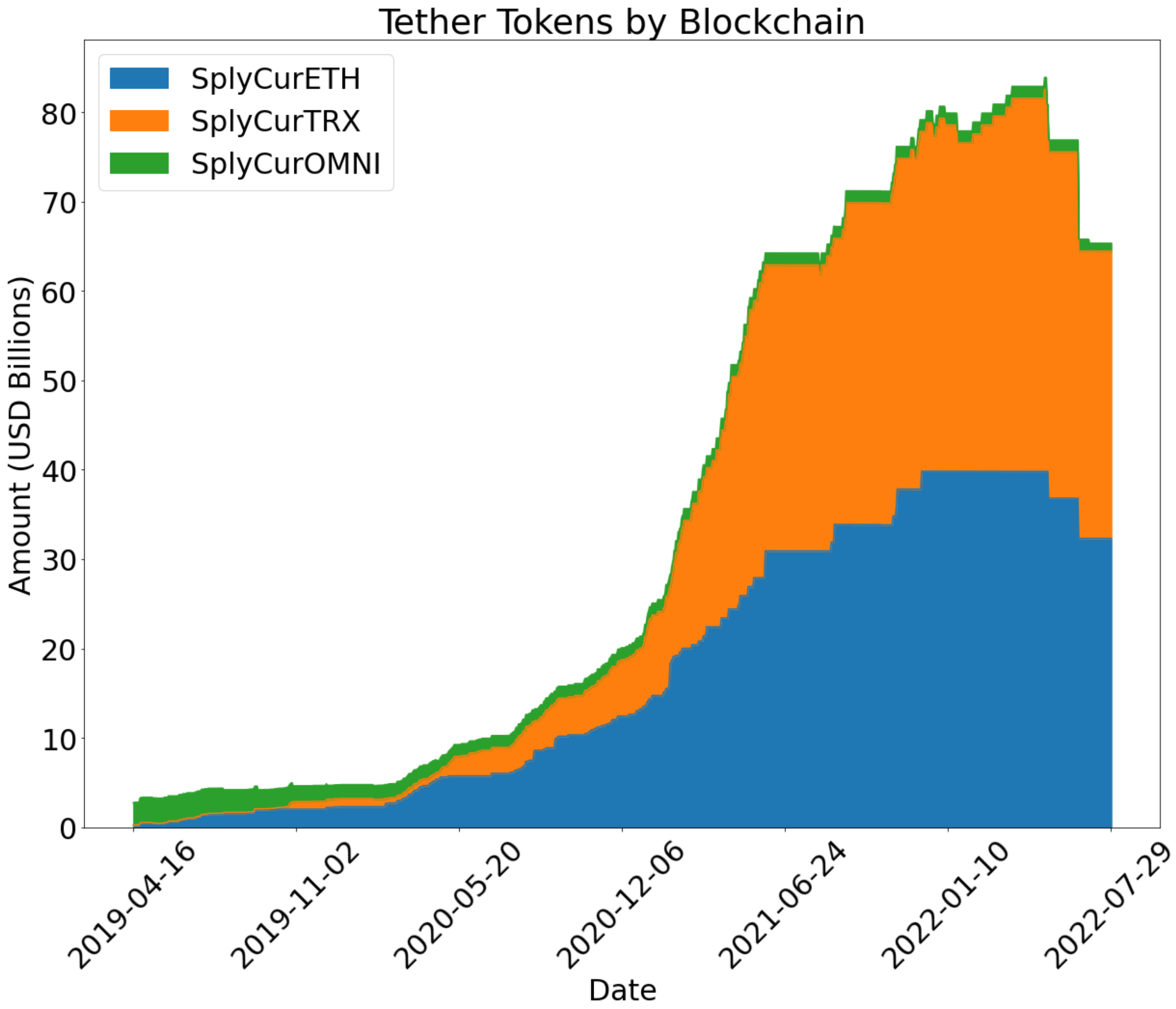
Note: The trilemma states that stablecoins face a trade-off between three objectives: peg stability, decentralization and capital efficiency. Stablecoin designs can be categorized into centralized, over-collateralized (decentralized) and algorithmic stablecoins based on which objectives it achieves.

Figure 3: USDT Futures and Spot Prices on FTX Exchange



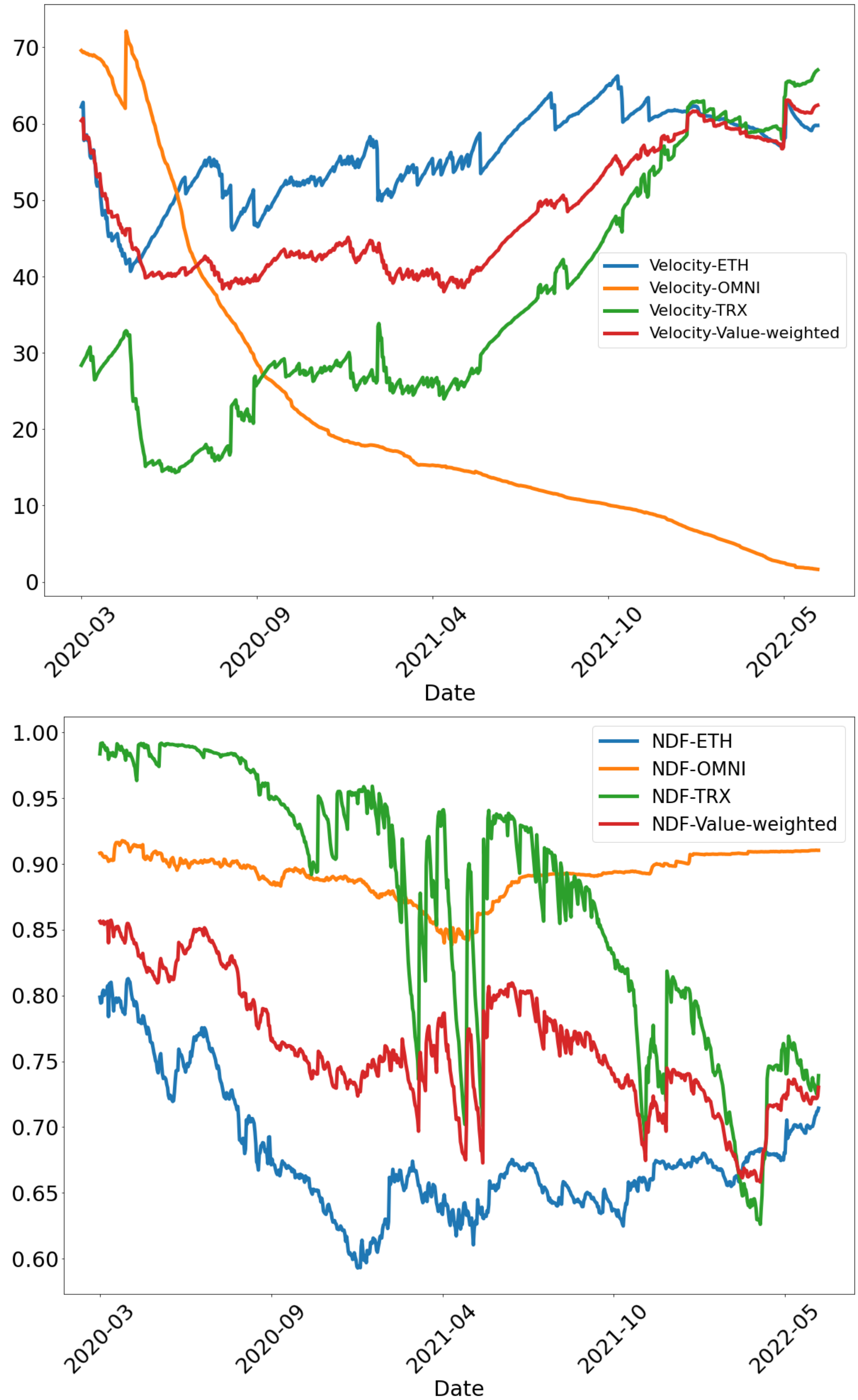
Note: Top panel: futures and spot prices on the FTX exchange. Bottom panel: Difference between futures and spot prices.

Figure 4: Stablecoins Total Supply: by Tether blockchain



Note: Total supply of DAI, USDC, BUSD, and USDT. Bottom panel: total supply of Tether across blockchains Omni, Tron and Ethereum.

Figure 5: USDT Network measures on FTX Exchange

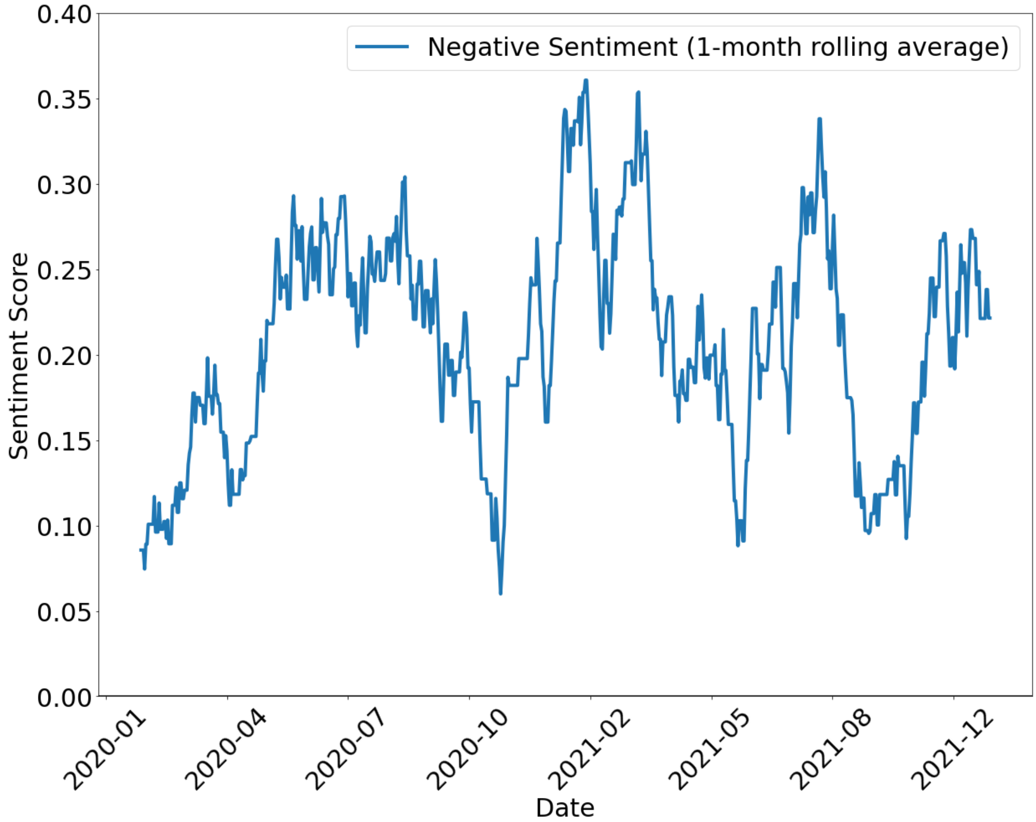


Note: Top panel: Velocity (The ratio of the value transferred (i.e., the aggregate size of all transfers) in the trailing 1 year divided by the current supply up to the end of that interval. Bottom panel: Network distribution factor (The ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply).

Figure 6: Wordcloud for Futures topic from BERT topic modelling

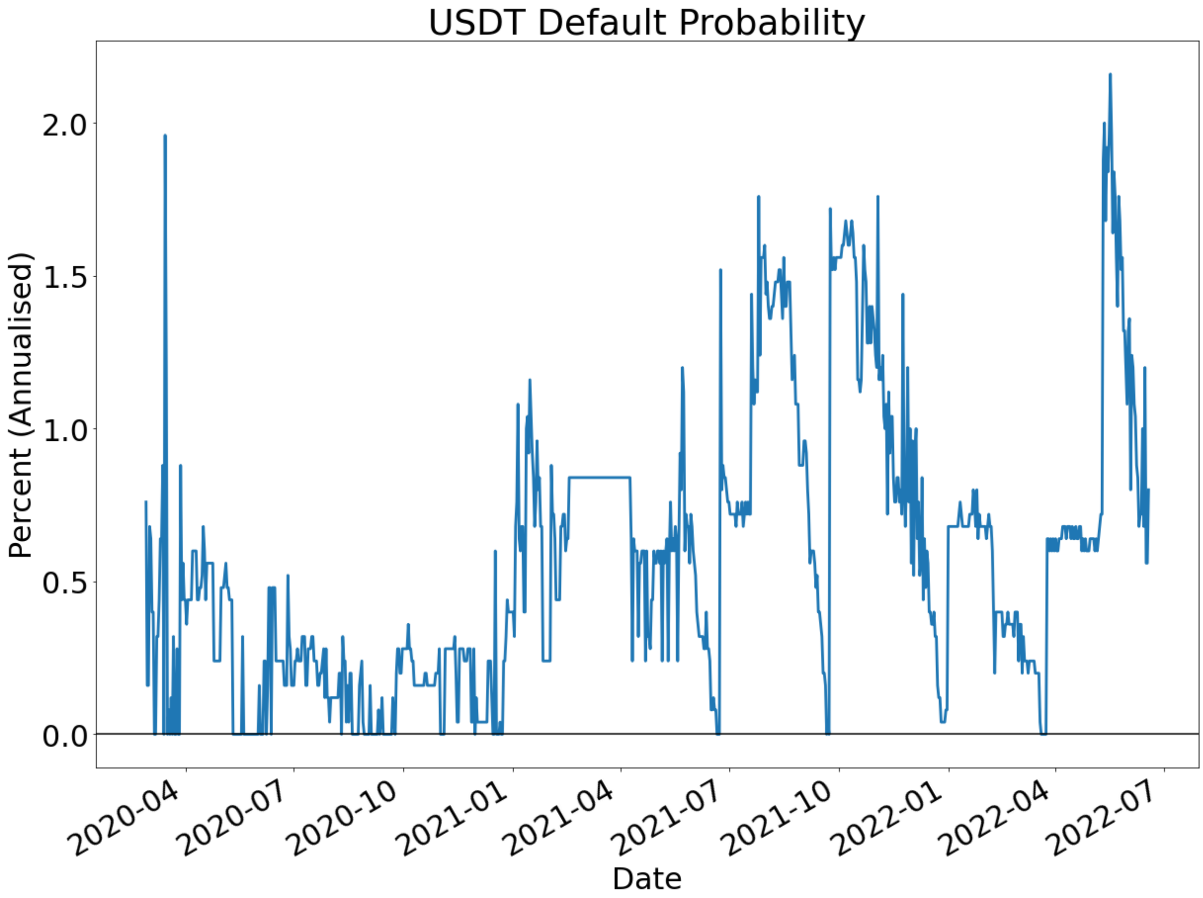
Note: Keywords for Futures topic from BERT.

Figure 7: Negative Sentiment Score from Futures Topic



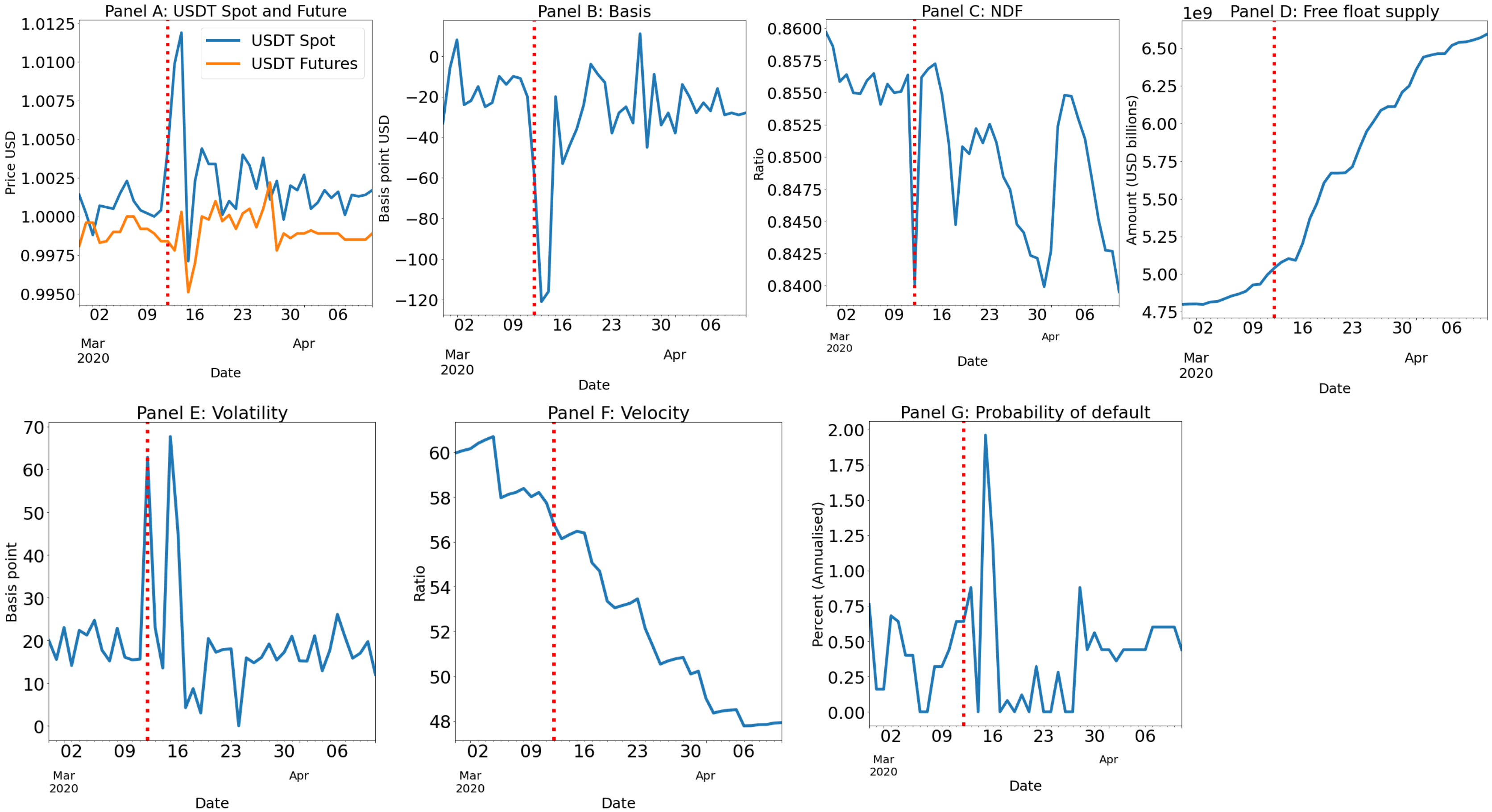
Note: Negative Sentiment Score from Future topic.

Figure 8: Estimate of probability of default $\mathcal{P}$



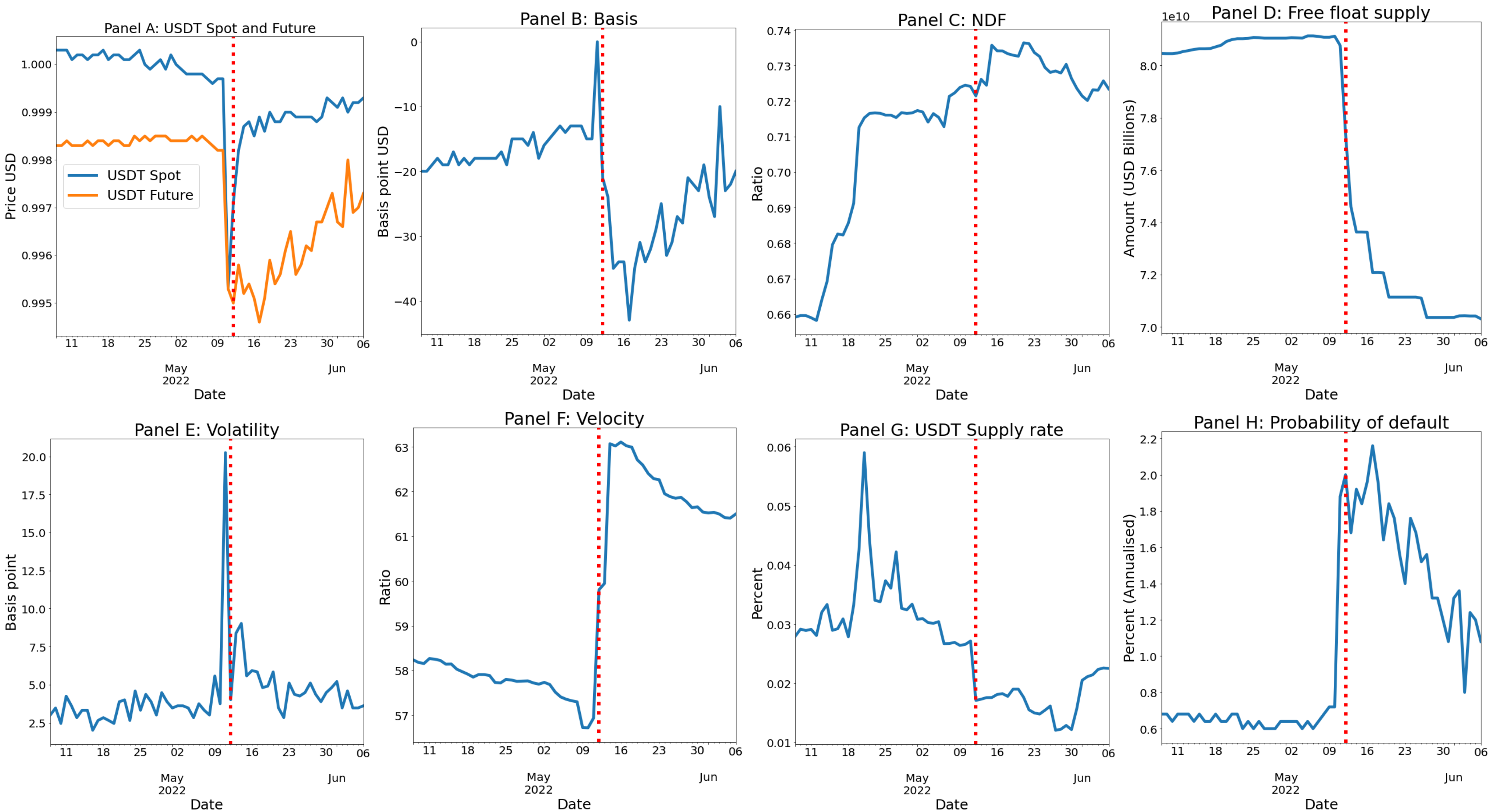
Note: Implied default probabilities based on spot, futures prices and the average mean reversion coefficient.

Figure 9: Event Study: 'Black Thursday' Crypto Crash March 2020



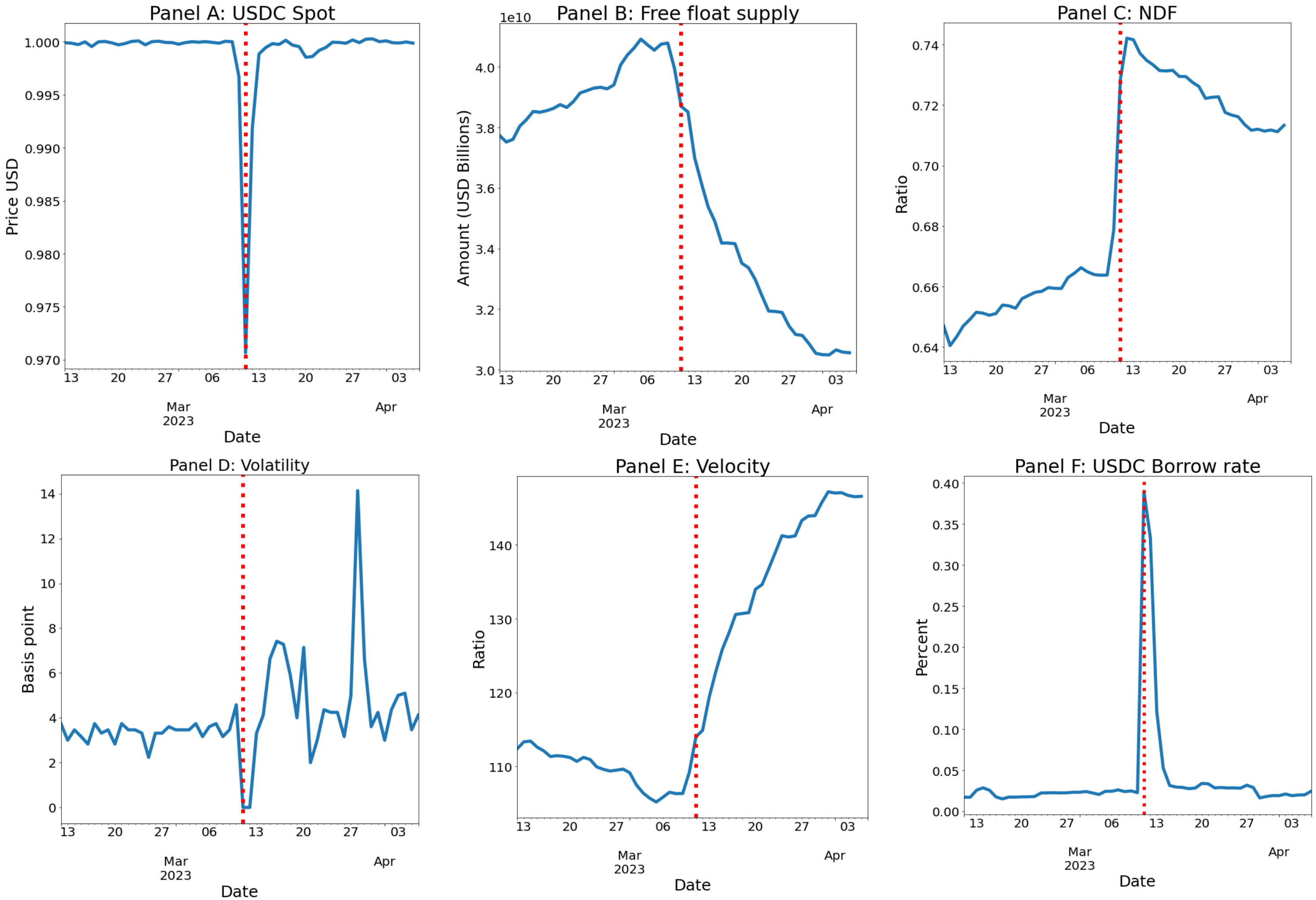
The graph reports event study for various variables during the 1 month window before and after USDT peg collapse in March 2020. The vertical line is the day of USDT peg collapse, which is 12th March 2020.

Figure 10: Event Study: USDT Peg Collapse May 2022



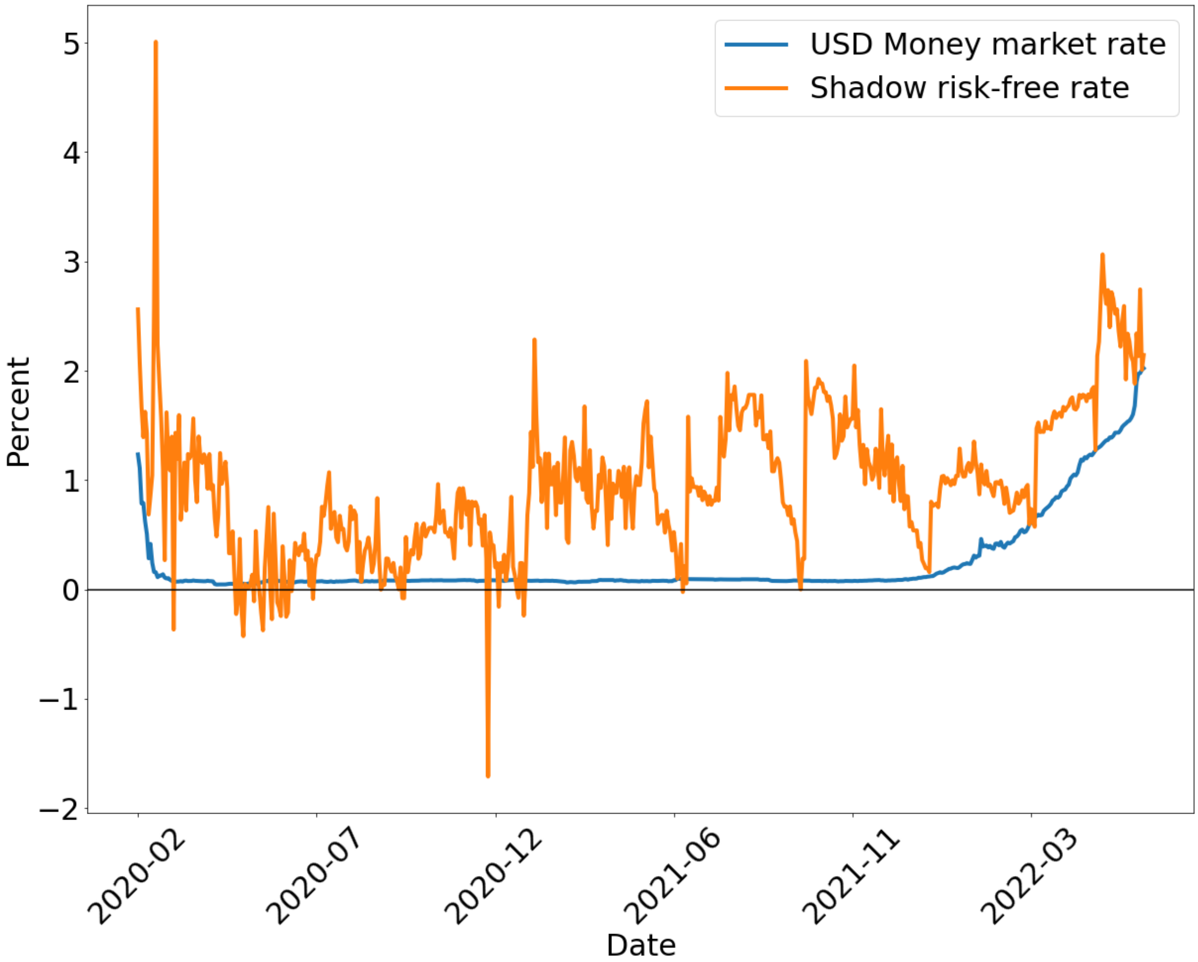
Note: The graph reports event study for various variables during the 1 month window before and after USDT peg collapse in May 2022. The vertical line is the day of USDT peg collapse, which is 12th May 2022.

Figure 11: Event Study: USDC Crash March 2023



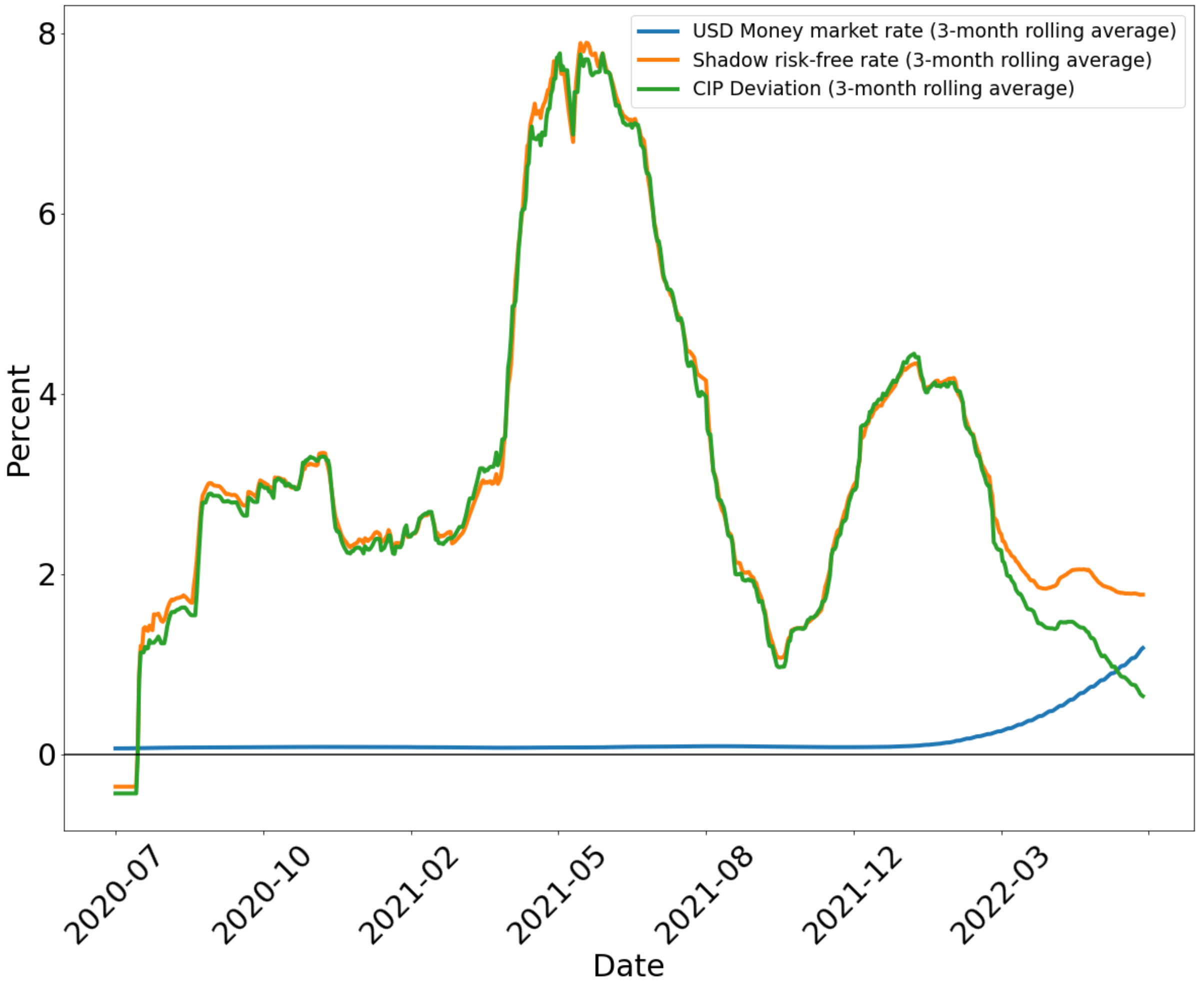
The graph reports event study for various variables during the 1 month window before and after USDC peg collapse in March 2023. The vertical line is the day of USDC peg collapse, which is 11th March 2023.

Figure 12: Interest rates in money markets.



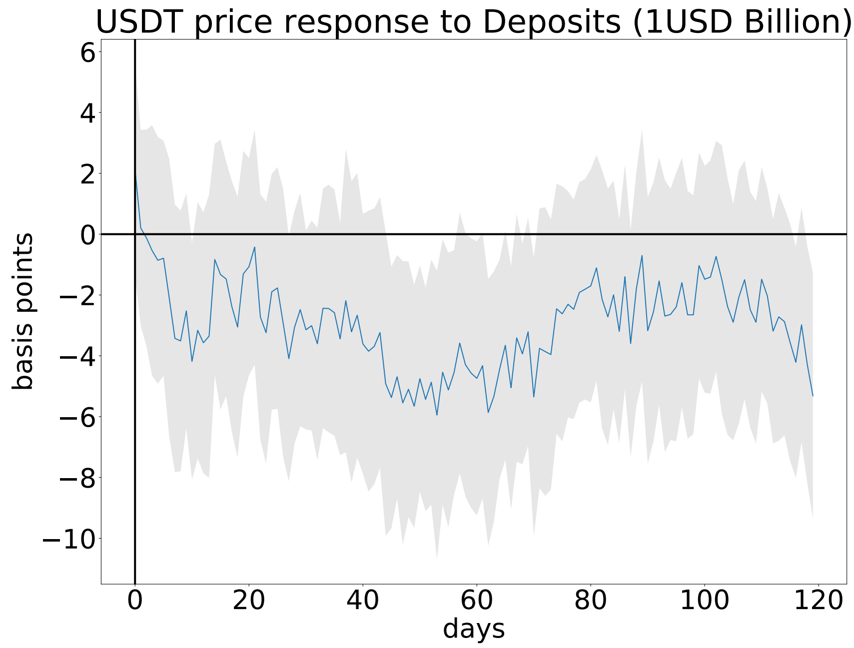
Note: USD Money market rate and shadow risk-free rate.

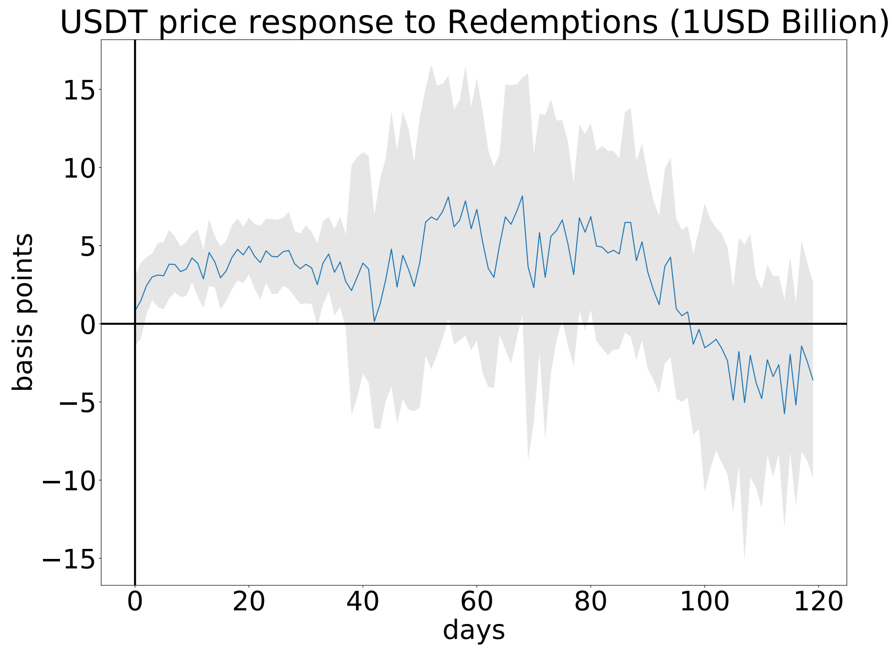
Figure 13: CIP Deviations between money market and stablecoin rates



Note: Top panel: USD Money market rate and shadow risk-free rate. Bottom pannel: CIP deviation.

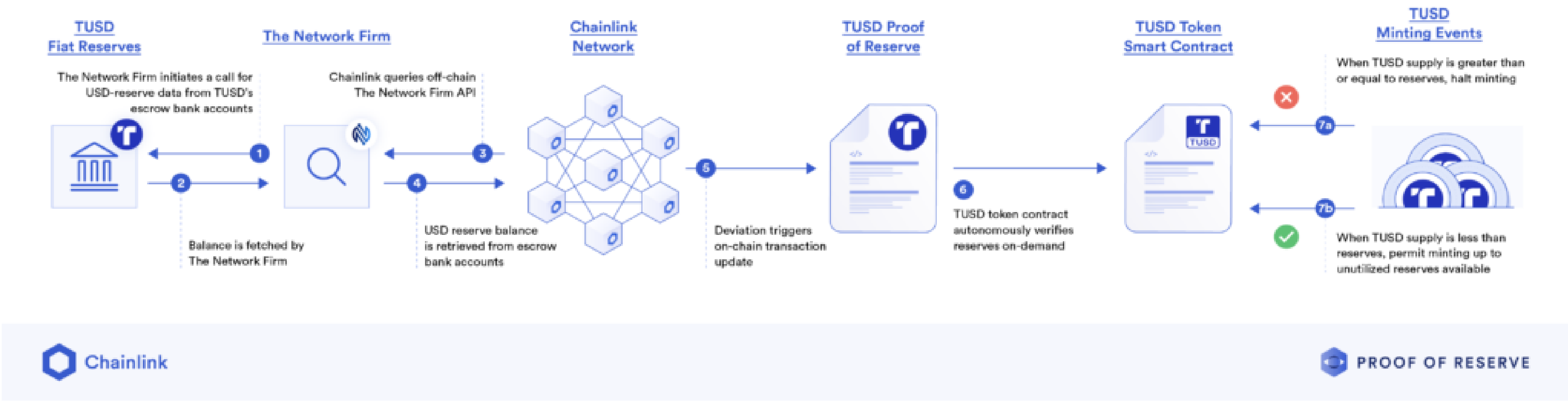
Figure 14: Tether price changes in response to 1 USD Billion deposits (top panel) and 1 USD Billion redemptions (bottom panel)





Note: Figure documents the effect of a 1 USD Billion shock in secondary-market flows on the price of Tether/USD. Top panel traces the effect on prices when there are positive flows of Tether (deposits), the bottom panel traces price effects when there are negative flows (redemptions). Data for issuance is based on changes in free float supply constructed by coinmetrics. Price data for the USDT/USD pair is from Kraken. 1 lag is included in the baseline specification. Gray area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

Figure 15: Chainlink Proof of Reserve



Note: Schematic documents the proof of reserve for TUSD minting events. In the first step, the Network Firm (An accounting firm) initiates a call for USD-reserve data from TUSD's escrow bank accounts. Chainlink queries the Network Firm API to determine the balance from escrow bank accounts. This triggers an update on the blockchain. The TrueUSD smart contract is hard wired to only mint TUSD tokens when the supply is less than reserves held off-chain.

Tables

Table 1: Q1 2023 Tether Attestation: Consolidated Reserves report

Assets	**Amount (USD Billion)**	**% Balance Sheet**
US T-Bills	53.04	64.78%
Overnight Reverse Repo Agreements	7.50	9.17%
Term Reverse Repo Agreements	0.79	0.97%
Money Market Funds	7.45	9.08%
Cash and Bank Deposits	0.48	0.59%
Non-U.S. T-Bills	0.05	0.06%
Cash or Cash Equivalents Sub-Total (1)	69.31	84.65%
Corporate Bonds	0.14	0.17%
Precious Metals	3.39	4.14%
Bitcoin	1.50	1.83%
Other investments	2.14	2.62%
Secured loans	5.35	6.54%
Non-Cash or Cash Equivalents Sub-Total (2)	12.52	15.35%
Total (1)+(2)	81.83	100.00%

Note: Table presents Tether attestation by accounting firm BDO for Quarter 1 2023. Balance sheet breaks down all assets held by Tether into categories. For more details and the full attestation, see https://tether.to/en/tethers-latest-q1-2023-assurance-report-shows-reserves-surplus-at-all-time-high-of-244b-up-148b-in-net-profit-new-categories-for-additional-transparency-reveals-bitcoin-and-gold-allocations/ for Tether's press release.

Table 2: Summary statistics

	Mean	Std	25%	50%	75%	Min	Max	Count
s_t	1.000	0.001	1.000	1.000	1.001	0.995	1.012	791
f_t	0.999	0.001	0.998	0.999	0.999	0.995	1.005	791
$f_t - s_t$	-0.0018	0.0014	-0.0026	-0.0017	-0.0009	-0.0121	0.0045	791
P	0.5627	0.4672	0.2202	0.4809	0.7219	-0.0000	2.1776	791
Concentration	0.762	0.050	0.729	0.755	0.801	0.658	0.860	791
Velocity	48.562	7.818	41.581	46.181	56.726	38.000	63.105	791
i_{supply}	0.039	0.033	0.020	0.028	0.043	0.000	0.248	633
σ_{USDT}	8.190	6.051	4.120	6.325	10.671	0.000	67.681	791
σ_{BTC}	330.263	197.823	208.961	295.865	400.646	0.000	1659.943	791
R_{btc}	0.001	0.042	-0.018	0.002	0.021	-0.480	0.178	844
i_{USD}	0.002	0.004	0.001	0.001	0.001	0.000	0.020	602
Sply_{ETH}	32.948	245.572	-0.963	0.000	33.154	-1691.673	2320.195	788
Sply_{OMNI}	-0.327	18.999	-0.000	0.000	0.000	-311.850	368.260	788
Sply_{TRX}	30.599	298.519	0.000	15.204	77.250	-3576.693	1168.998	788
Sply_{AGG}	63.219	263.637	0.000	24.861	100.059	-3357.5	1128.997	788
$\mathrm{Redemption}_{dummy}$	0.193	0.395	0.000	0.000	0.000	0.000	1.000	791
Negative Sentiment	0.222	0.299	0.000	0.000	0.885	0.000	0.935	332

Table 3: Determinants of probability of default

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Velocity	0.025***	0.024***	0.034***	0.036***	0.031***	0.032***	0.029***	0.029***	0.043***
	(13.32)	(11.30)	(12.12)	(9.58)	(8.42)	(8.45)	(6.40)	(6.24)	(8.57)
i_{supply}		0.526	0.829**	0.872**	0.473	0.538	0.813	0.832*	-0.091
		(1.41)	(2.14)	(2.20)	(1.16)	(1.31)	(1.63)	(1.66)	(-0.16)
Concentration			3.904***	4.045***	3.800***	3.802***	4.178***	4.252***	1.520*
			(6.50)	(6.33)	(6.36)	(6.30)	(5.87)	(5.70)	(1.95)
σ_{USDT}				0.344	-1.056*	-0.998*	-1.101*	-1.114*	-2.997***
				(0.79)	(-1.96)	(-1.85)	(-1.78)	(-1.79)	(-4.71)
σ_{BTC}					0.053***	0.054***	0.052***	0.053***	0.067***
					(4.41)	(4.46)	(3.80)	(3.82)	(4.77)
$\mathrm{R}_{btc} BTCreturn$						0.746*	0.884*	0.854*	0.838
						(1.66)	(1.83)	(1.73)	(1.48)
i_{USD}							0.086	0.090	-16.397***
							(1.31)	(1.38)	(-4.24)
$\mathrm{Redemption}_{dummy}$								-0.022	0.025
								(-0.42)	(0.35)
Lag Negative Sentiment									0.169**
									(2.26)
Observations	791	633	633	633	633	633	452	452	332
R^2	0.18	0.15	0.21	0.21	0.24	0.24	0.25	0.25	0.38

Note: This table regresses probability of default on a set of independent variables. Velocity is the velocity of current supply. i_{supply} is the supply rate of USDT. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 4: Determinants of USDT supply rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Velocity	-0.001***	-0.001***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(-9.34)	(-8.15)	(-6.35)	(-6.51)	(-6.50)	(-4.38)	(-4.59)	(-3.42)
Concentration		-0.089**	-0.129***	-0.139***	-0.139***	-0.197***	-0.214***	-0.342***
		(-2.06)	(-2.89)	(-3.15)	(-3.12)	(-3.97)	(-4.19)	(-4.63)
σ_{USDT}			-0.094***	-0.169***	-0.172***	-0.169***	-0.165***	-0.203***
			(-2.84)	(-3.66)	(-3.71)	(-3.09)	(-2.97)	(-2.99)
σ_{BTC}				0.003***	0.003***	0.002**	0.002**	0.003**
				(3.14)	(3.10)	(2.51)	(2.14)	(2.17)
R_{btc}					-0.059*	-0.078**	-0.070**	-0.075
					(-1.79)	(-2.23)	(-1.99)	(-1.56)
i_{USD}						-0.010***	-0.011***	-0.014
						(-3.26)	(-3.48)	(-0.06)
$Redemption_{dummy}$							0.005	0.008
							(1.55)	(1.61)
Lag Negative Sentiment								-0.001
								(-0.18)
Observations	726	726	633	633	633	452	452	332
R^2	0.09	0.09	0.07	0.09	0.09	0.11	0.12	0.09

Note: This table regresses USDT supply rate on on a set of independent variables. Velocity is the velocity of current supply. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. Basis is f-s. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 5: Determinants of USDT borrow rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Velocity	-0.002***	-0.002***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(-14.79)	(-10.80)	(-9.90)	(-8.93)	(-8.92)	(-6.55)	(-6.67)	(-5.15)
Concentration		-0.036	-0.107**	-0.105**	-0.104**	-0.163***	-0.177***	-0.299***
		(-0.76)	(-2.21)	(-2.16)	(-2.13)	(-2.98)	(-3.13)	(-3.51)
σ_{USDT}			-0.113***	-0.097*	-0.102**	-0.104*	-0.101	-0.135*
			(-2.91)	(-1.89)	(-1.97)	(-1.71)	(-1.64)	(-1.80)
σ_{BTC}				-0.001	-0.001	-0.001	-0.001	-0.002
				(-0.62)	(-0.79)	(-0.98)	(-1.11)	(-1.18)
R_{btc}					-0.077**	-0.090**	-0.084**	-0.100*
					(-2.09)	(-2.33)	(-2.15)	(-1.89)
i_{USD}						-0.004	-0.005	-0.069
						(-1.19)	(-1.38)	(-0.27)
$\text{Redemption}_{dummy}$							0.005	0.006
							(1.18)	(0.93)
Lag Negative Sentiment								-0.004
								(-0.52)
Observations	725	725	632	632	632	632	452	332
R^2	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20

Note: This table regresses USDT borrow rate on on a set of independent variables. Velocity is the velocity of current supply. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. Basis is f-s. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 6: USDT Spot change and FOMC announcements

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ USDT Spot	Δ USDT Spot	Δ USDT Spot	Δ USDT Supply rate	Δ USDT Borrow rate	USDT Net supply
$FOMC_{dummy}$	-0.000	0.000	0.000	-0.116	-0.051	-0.000
	(-1.06)	(0.43)	(0.45)	(-0.53)	(-0.27)	(-0.27)
Δi_{USD}	-0.001			-0.498	-0.276	-0.008*
	(-1.10)			(-1.17)	(-0.82)	(-1.65)
$FOMC_{dummy}{*}\Delta i_{USD}$	0.002			-0.260	-0.281	-0.046**
	(1.19)			(-0.12)	(-0.15)	(-2.42)
Δi^{USDT}_{supply}		0.000				
		(0.30)				
$FOMC_{dummy}{*}\Delta i^{USDT}_{supply}$		0.000				
		(1.12)				
Δi^{USDT}_{borrow}			0.000			
			(0.55)			
$FOMC_{dummy}{*}\Delta i^{USDT}_{borrow}$			0.000			
			(1.40)			
Observations	714	682	682	390	390	663
R^2	0.003	0.001	0.002	0.001	0.001	0.019

Note: This table regresses USDT spot price changes on on a set of independent variables. $FOMC_{dummy}$ is the dummy variable, which takes value equal to 1 if it is a day with FOMC announcement, and 0 otherwise. Δi_{USD} is the change in USD interest rate. $FOMC_{dummy}{*}\Delta i_{USD}$ is the interaction variable between $FOMC_{dummy}$ and Δi_{USD}. The sample runs from January 14th, 2019 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Internet Appendix to
“Stablecoin Devaluation Risk”

by

Barry Eichengreen My T. Nguyen Ganesh Viswanath-Natraj

(Not for publication)

Appendix

A Data

Table A1: **Variable descriptions**

This table reports descriptions of variables used in the paper.

Variable descriptions

Variable	Description
S	Closing spot price of USDT.
F	Closing future price of USDT.
Basis	The difference between spot and future price of USDT.
ρ	The probability of default of USDT.
Concentration (NDF)	The ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply.
Velocity	The ratio of the value transferred (i.e., the aggregate size of all transfers) in the trailing 1 year divided by the current supply up to the end of that interval. It can be thought of as a rate of turnover – the number of times that an average native unit has been transferred in the past 1 year.
i_{supply}	USDT supply rate.
σ_{USDT}	USDT volatility.
σ_{BTC}	BTC volatility.
R_{BTC}	BTC return.
i_{USD}	USD Libor interest rate
$Redemption_{dummy}$	Takes value of 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise.

B Examples of Stablecoin Derivatives Articles

Some articles identified as Stablecoin Derivatives articles are listed.

<u>Stablecoin Derivatives Article 1</u>

"Investment Weekly News 2020 MAY 16 (VerticalNews) – By a News Reporter-Staff News Editor at Investment Weekly News – ***Overbit.com, a leading bitcoin margin exchange, has enabled deposits in USD Tether****. The leveraged trading platform that allows its users to trade cryptos, forex, and commodities using bitcoin without delivery of the assets, will be amplifying its offer to appeal to a wider net of traders. Adding deposits in Tether, the company believes, will help it to establish a leadership position in the space. The importance of stablecoins for traders:* ***As the first stablecoin, Tether (USDT) is the most popular in the cryptocurrency industry and is listed on most major spot exchanges****. It has the largest market capitalisation of all stablecoins, currently at around \$6.3bn making it the fourth-largest cryptocurrency. Adding a stablecoin deposits option will give Overbit users the ability to reduce their risk, particularly in times of high volatility, and hold their assets in Tether, the most established and widely-used stablecoin. Overbit believes that with this new feature, spot traders will have another platform to migrate to margin trading for their Tether deposits where they can take advantage of leverage up to 100X. CEO and founder Chieh Liu commented, "Adding Tether deposits is a smart move for Overbit and will give traders the chance to counter market volatility. We believe that we will appeal to more professional and advanced traders who prefer to store their assets in USDT." Overbit research shows advanced traders prefer to hold assets in USDT Overbit surveyed a total of 2500+ traders from 90 different countries.* ***According to its findings, professional traders prefer to hold more of their assets in Tether (USDT). As such, Tether (USDT) is the third most popular crypto asset for advanced traders and professional traders after Bitcoin and ETH. In addition to the launch of USDT deposits, Overbit has recently revamped its platform to offer new features, such as cross and isolated margin, and the fees or spread trading modes."***

(Sentiment Score: 0.17)

<u>Stablecoin Derivatives Article 2</u>

*"****Crypto derivatives exchange platform ByBit is set to airdrop Tether (USDT) tokens to its users following the platform's recent unveiling of its perpetual contracts for the popular stablecoin****. Bybit is one of the participants in Singapore's growing cryptocurrency derivatives scene as pundits expect more institutional inflows into the derivatives market. Given the popularity of crypto*

derivatives trading, regulators in jurisdictions like Japan have come out with robust regulators to govern the market. However, their counterparts in the UK have expressed a desire to ban cryptocurrency derivatives due to perceived risks to retail traders. ***ByBit's USDT Airdrop Campaign In a press release shared with Blockonomi, the Singapore-based crypto derivatives exchange announced plans for a 1,000 USDT airdrop to its customers. As previously reported by Blockonomi, Bybit launched USDT perpetual contracts in May 2020.*** *According to the details in the Bybit press release, traders with a wallet balance of at least 0.5 BTC by 10 am (UTC) on April 13, 2020, stand a chance of receiving up to 50 USDT. Customers with wallet balances of at least 50 USDT by 10 am (UTC) on April 16, 2020, could receive coupons of 60 USDT. The Bybit press statement also revealed that active traders on the platform could receive up to 1,000 USDT depending on their trading volume and wallet size with early-bird registration opening the door for users to claim an additional 20% bonus rewards. Commenting on the decision to carry out the airdrop campaign, Ben Zhou, CEO of the exchange, remarked: 'The launch of the USDT perpetual contracts on Bybit is a cause for celebration, and this airdrop will incentivize traders to hold the most liquid and trusted stablecoin on the market. Small traders, as well as big players, will be rewarded according to their activity, giving all Bybit users an incentive to get involved.* ***Despite multiple legal troubles for Tether and Bitfinex, the popular stablecoin has remained the de facto liquidity provider for most of the crypto trading market. USDT has also been at the center of price manipulation claims with some critics alleging that Tether was being used to control the Bitcoin (BTC) price action.*** *As part of the airdrop campaign, Bybit says users can sign up to become MVFs (Most Valuable Feedbackers) ' providing reviews on the USDT perpetual contracts trading experience on the platform. Members of the MVF club also stand a chance to win 500 USDT in additional bonus rewards. Evolving Crypto Derivatives Scene Back in 2019, the explosion of crypto derivatives saw many pundits stating that the market would be the conduit for greater institutional investment in cryptocurrencies. Intercontinental Exchange (ICE) launched Bakkt which after a slow start began to set trading volume records. CME Bitcoin futures also saw increased appetite from traders despite months of sideways price action in the spot market. Bakkt, on the back of its successful physically-delivered BTC futures, launched an Options product in Singapore. New entrants like Phemex also entered the scene, promising to deliver novel features as competition in the crypto derivatives scene picked up in 2019. With volume on the rise, the UK' Financial Conduct Authority revealed that it was looking to ban cryptocurrency derivatives. In response, organizations like the World Federation of Exchanges declared that the FCA's move would be a bad idea. The UK government even came out to state that it would not interfere in the FCA's plan to*

outlaw cryptocurrency derivatives. Outside the UK, regulators in Germany and Japan have made efforts to legitimize crypto derivatives with the former officially recognizing them as investment instruments. In Japan, the newly created Financial Instruments and Exchange Act (FIEA) officially creates a regulatory platform for cryptocurrency derivatives trading in the country. The post Crypto Derivatives Exchange Bybit Announces USDT Airdrop appeared first on Blockonomi. "
(Sentiment score: 0.72)

<u>Stablecoin Derivatives Article 3</u>

"Explosive growth in tokens raises concerns over broader stability of financial system. The writer is an economics professor at Rutgers University. One of the great misnomers in the crypto world is stablecoins. These digital assets are meant to provide a safer exposure to crypto, with coins pegged to stores of value such as the dollar or gold to limit price fluctuations and facilitate transactions. But they are far from stable. My research has shown 2016 and 2019 vintages of new stablecoins had failure rates of 100 per cent and 42 per cent respectively. The problem for broader financial stability is that even the successful coins that have seen explosive growth have flaws. The Biden administration has recognised the risks and a working party advising the US government this month issued a series of recommendations it says are urgent given the rapid expansion of the sector. There are five stablecoins with market capitalisations of more than $5bn â€" Tether, USD Coin, Binance USD, Dai and TerraUSD. Overall, there are about $140bn of stablecoins outstanding. If ranked purely by asset size, the market would be equivalent to a top 30 US bank. Stablecoins were used in $1.77tn of transactions in the second quarter of 2021. While this turnover is still less than 10 per cent of the $18.4tn of payment volumes in the same quarter through Automated Clearing, the main system for US electronic fund transfers, stablecoin transactions have grown more than 1,100 per cent year over year. A primary issue of concern is transparency and quality of collateral for stablecoins. If doubts about the securities backing the coins trigger a rush of redemptions, that could damage the entire payments mechanism as well as the prices of assets such as Bitcoin and Ethereum with a combined market capitalisation of more than $1.5tn. ***Tether, the stablecoin leader with about $75bn in coins, has been accused in the past of making misleading claims about the assets backing them.*** *Last month it agreed to pay a $41m penalty to resolve a charge by a regulator that it had falsely represented that its digital tokens were fully backed by dollars.* ***Earlier this year Tether and a linked exchange Bitfinex also agreed to pay an $18.5m penalty after New York attorney-general accused them of covering up a massive financial losses.*** *The backing of USD Coin, a stablecoin leader launched by a consortium including cryptocurrency exchange Coinbase and technology firm Circle, has also come under scrutiny. The Coinbase website has*

claimed in the past that each coin was backed by dollars held in government-backed US depository institutions. It now says its coins are backed by fully reserved assets. Dai backs its stablecoin with collateralised debt positions in Ethereum network assets but, according to data from CoinMarketCap, it appears to have deviated from its peg during rapid changes in Ether prices. Dai, which should trade at par with equivalent of $1 of asset backing fell below $0.97 on February 20 2020 and rose as high as $1.11 on March 13 2020. The Biden administration report recommends that stablecoin issuers become institutions covered by insurance from the US Federal Deposit Insurance Corporation. While a few coins such as Binance USD are partially collateralised by bank deposits backed by FDIC, current law may only protect the issuers, not the coin holders. There are additional risks to the stablecoins aside from collateral. ***Turbocharged by high-frequency trading, there is more than $100bn in daily turnover of Tether on exchanges.*** *That is a level comparable with the trading volume of the NYSE. Unfortunately, the infrastructure for stablecoin trading is not as robust as some might hope. The two largest exchanges, Binance and Coinbase, had platform outages on May 19 when China banned most crypto payments and Bitcoin prices fell more than 30 per cent. Investors have little regulatory protection from the fallout of such incidents. There are also risks as the number of stablecoin blockchains diversifies. Most stablecoins originated on the Ethereum network. But fee rises on that are spurring the migration of tokens on to other platforms.* ***Median fees for transferring holdings on the network have risen more than 3,500 per cent for Tether year over year.*** *This is because fees are priced in Ethereum, and its price jumped from $226.31 to $2,274.55 in the year to June 30. The payments mechanism needs to be modernised and blockchain technology that underpins cryptocurrencies made more secure and cheaper. A central bank issued digital currency with major financial institutions as intermediaries can accomplish these goals. ”*
(Sentiment score: 0.72)

C Additional Tables

Table 2: Determinants of future spot basis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Velocity	-0.471***	-0.309***	-0.449***	-0.490***	-0.394***	-0.425***	-0.609***	-0.656***	-1.015***
	(-8.56)	(-5.84)	(-6.01)	(-5.63)	(-4.46)	(-4.78)	(-5.33)	(-5.51)	(-7.50)
i_{supply}		-34.308***	-38.334***	-39.443***	-30.721**	-34.296***	-30.299**	-32.602**	-12.499
		(-3.03)	(-3.23)	(-3.32)	(-2.52)	(-2.83)	(-2.16)	(-2.27)	(-0.81)
Concentration			-51.879***	-55.467***	-50.116***	-50.200***	-52.508***	-61.303***	-12.004
			(-3.14)	(-3.40)	(-3.25)	(-3.20)	(-2.85)	(-3.19)	(-0.53)
σ_{USDT}				-8.743	21.814	18.667	21.261	22.901	62.275***
				(-0.69)	(1.43)	(1.22)	(1.24)	(1.32)	(3.48)
σ_{BTC}					-1.147***	-1.215***	-1.310***	-1.418***	-2.091***
					(-3.42)	(-3.60)	(-3.63)	(-3.85)	(-4.91)
R_{btc}						-40.879***	-41.880***	-38.379***	-38.465**
						(-3.08)	(-3.00)	(-2.70)	(-2.24)
i_{USD}							6.921***	6.493***	470.706***
							(4.58)	(4.35)	(4.62)
Redemption$_{dummy}$								2.691**	1.032
								(2.02)	(0.57)
Lag Negative Sentiment									-3.310
									(-1.56)
Observations	791	633	633	633	633	633	452	452	332
R^2	0.07	0.04	0.05	0.05	0.08	0.09	0.14	0.15	0.31

Note: This table regresses future spot basis on a set of independent variables. Velocity is the velocity of current supply. i_{supply} is the supply rate of USDT. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 3: Determinants of spot

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Velocity	-0.002***	-0.003***	-0.004***	-0.004***	-0.004***	-0.004***	-0.001**	-0.001*	-0.001*
	(-3.70)	(-9.01)	(-10.50)	(-5.97)	(-6.47)	(-6.30)	(-2.37)	(-1.85)	(-1.69)
i_{supply}		0.161**	0.121*	0.124*	0.139**	0.162**	0.045	0.062	0.075
		(2.34)	(1.89)	(1.91)	(2.09)	(2.45)	(0.63)	(0.91)	(1.04)
Concentration			-0.509***	-0.500***	-0.491***	-0.491***	-0.573***	-0.507***	-0.323***
			(-8.74)	(-7.17)	(-7.31)	(-7.39)	(-7.52)	(-6.81)	(-3.68)
σ_{USDT}				0.020	0.072	0.093	0.096	0.084	0.134
				(0.17)	(0.74)	(0.96)	(0.94)	(0.82)	(1.51)
σ_{BTC}					-0.002	-0.002	-0.000	0.001	0.004**
					(-0.88)	(-0.69)	(-0.14)	(0.24)	(2.28)
R_{btc}						0.269***	0.250***	0.223***	0.242***
						(3.92)	(3.72)	(3.25)	(2.85)
i_{USD}							-0.091***	-0.088***	-0.450
							(-12.08)	(-11.92)	(-1.51)
$\text{Redemption}_{dummy}$								-0.020***	-0.016**
								(-3.97)	(-2.21)
Lag Negative Sentiment									-0.004
									(-0.43)
Observations	791	633	633	633	633	633	452	452	332
R^2	0.01	0.15	0.20	0.20	0.20	0.23	0.43	0.44	0.21

Note: This table regresses spot value on on a set of independent variables. Velocity is the velocity of current supply. i_{supply} is the supply rate of USDT. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 4: Determinants of future

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Velocity	-0.006***	-0.006***	-0.009***	-0.009***	-0.008***	-0.008***	-0.007***	-0.008***	-0.011***
	(-13.16)	(-11.17)	(-11.79)	(-9.59)	(-8.44)	(-8.45)	(-6.42)	(-6.25)	(-8.54)
i_{supply}		-0.182*	-0.262**	-0.271**	-0.169	-0.181*	-0.258*	-0.264*	-0.050
		(-1.83)	(-2.49)	(-2.55)	(-1.55)	(-1.67)	(-1.93)	(-1.96)	(-0.34)
Concentration			-1.027***	-1.055***	-0.992***	-0.993***	-1.098***	-1.120***	-0.443**
			(-6.46)	(-6.34)	(-6.37)	(-6.32)	(-5.88)	(-5.72)	(-2.10)
σ_{USDT}				-0.067	0.291**	0.280*	0.309*	0.313*	0.757***
				(-0.58)	(2.03)	(1.94)	(1.85)	(1.87)	(4.41)
σ_{BTC}					-0.013***	-0.014***	-0.013***	-0.014***	-0.017***
					(-4.44)	(-4.48)	(-3.84)	(-3.86)	(-4.75)
R_{btc}						-0.139	-0.169	-0.161	-0.143
						(-1.14)	(-1.27)	(-1.18)	(-0.89)
i_{USD}							-0.022	-0.023	4.257***
							(-1.30)	(-1.38)	(4.39)
$\mathrm{Redemption}_{dummy}$								0.007	-0.005
								(0.48)	(-0.30)
Lag Negative Sentiment									-0.037*
									(-1.85)
Observations	791	633	633	633	633	633	452	452	332
R^2	0.16	0.14	0.20	0.20	0.23	0.23	0.24	0.24	0.37

Note: This table regresses the futures value on on a set of independent variables. Velocity is the velocity of current supply. i_{supply} is the supply rate of USDT. Network distribution factor is the concentration i.e., the ratio of supply held by addresses with at least one ten-thousandth of the current supply of native units to the current supply . σ_{USDT} is the volatility of USDT. σ_{BTC} is the volatility of BTC. R_{btc} is the return of BTC. $Redemption_{dummy}$ is equal to 1 if there is a decline in the free float supply of USDT compared to the previous day, and 0 otherwise. The sample runs from February 28th, 2020 to June 18th, 2022. White heteroscedasticity-robust standard errors are reported in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.