What Keeps Stablecoins Stable?

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Abstract

Using a rich dataset of trades between the stablecoin Treasury and private investors, we examine how arbitrage stabilizes the price of the dominant stablecoin, Tether. We identify the arbitrage mechanism through a unique natural experiment: the migration of Tether from the Omni to the Ethereum blockchain in 2019. This event led to an increase in investor access to arbitrage trades with the Tether Treasury, and reduced the absolute size of peg deviations by more than half. We also pin down the sources of stablecoin instability: Premiums are due to stablecoins' role as a safe haven; discounts derive from collateral concerns.

Keywords: Cryptocurrency, stablecoins, Tether, arbitrage, exchange rates

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

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Introduction and Motivation

Stablecoins peg to a national currency, typically the US dollar, and are used to transact in non-stable cryptoassets more efficiently than using national currencies. They operate on blockchains, distributed ledgers where payments are verified and recorded without need for centralized settlement. By maintaining a collateralized peg, stablecoins achieve much lower volatility than cryptocurrencies such as Bitcoin (BTC), whose volatility relative to the US dollar (USD) is roughly 10 times that between major national currencies (Yermack, 2015). The largest stablecoin is Tether, accounting for over 80 percent of stablecoin capitalization over the period we study. Unlike fixed-rate national currencies, stablecoin pegs like that for Tether are maintained wholly via private participants;[1] and unlike exchange-traded funds, there is no subset of private participants pre-authorized to do so.

Our focus is stablecoin issuance, and the role issuance plays in stabilizing prices, and identifying which stability mechanisms best account for issuance. For national currencies with fixed prices, central bank initiative is the mechanism: Foreign reserves are exchanged for domestic currency, adjusting supply to mute deviations from the peg (e.g., when domestic currency trades below the peg, the central bank intervenes to reduce supply by buying domestic currency for foreign reserves, and vice versa). Another mechanism, complementary to the first, is trades initiated by private investors that stabilize price. Suppose for example the price of Tether rises above the pegged rate of 1 USD. Private investors can deposit Tether with the Tether Treasury, receive 1 USD for each in return, and sell Tether in the market for more than 1 USD. The arbitrage increases circulating Tether supply, putting downward pressure on Tether's market price toward parity.

We test these stability mechanisms in two main ways. First, we exploit a unique natural experiment: The April 2019 migration of Tether from the Omni to the Ethereum blockchain. Introduction to the Ethereum blockchain was motivated in part due to its increased network of investors and Ethereum-based (ERC20) tokens, and its relative efficiency in processing payments. This resulted in a large increase in investor access to the Tether Treasury, made possible by the reduced transaction costs of operating on the Ethereum blockchain.[2] We find a significant subsequent increase in the number of unique addresses transacting with the Tether Treasury. Consistent with an hypothesis that decentralized arbitrage is responsible for keeping stablecoins stable, estimates show a resulting decline in the absolute size of price deviations from the peg of 50 basis points, and a decline in the half-life of deviations from 6 days to 3 days.

To sharpen our test, we employ a difference-in-differences design using a set of control-group

[1] Among traditional exchange rates, strong backing with USD reserves is most similar to the Hong Kong Currency Board where the central bank maintains dollar reserves to match every Hong Kong dollar in circulation.

[2] For more information on the event, we refer readers to https://www.prnewswire.com/news-releases/huobi-global-offers-deposit--withdrawal-in-tether-erc20-300803113.html.

stablecoins that share similar institutional features, but did not undergo a structural change of blockchain. This too produces a large and statistically significant reduction in peg deviations of 30 basis points relative to the control group, even after controlling for sampling intervals that might contain confounding events. The difference-in-difference estimates are robust to alternative specifications of the structural date, and a dynamic setting with quarterly dummies shows a peak efficiency gain occurring in the fourth quarter of 2019. This is consistent with a view that the migration to the Ethereum blockchain was gradual, as Tether creation on Ethereum surpassed that on Omni by October 2019.

Our second test of stability mechanisms focuses specifically on arbitrage flows to determine their stabilizing effect. Flows of Tether from the Treasury to private investors are equal to changes in the supply of Tether in circulation net of changes retained in the account of the Tether Treasury. These netted flows are the economically relevant object for determining price pressure on the secondary market. We estimate the effects of arbitrage flows on peg prices based on local projections as in Jordà (2005), a procedure that controls for feedback effects in price and flow. We find significant reductions in peg-price deviations due to changes in net flows, consistent with our proposed arbitrage mechanism.

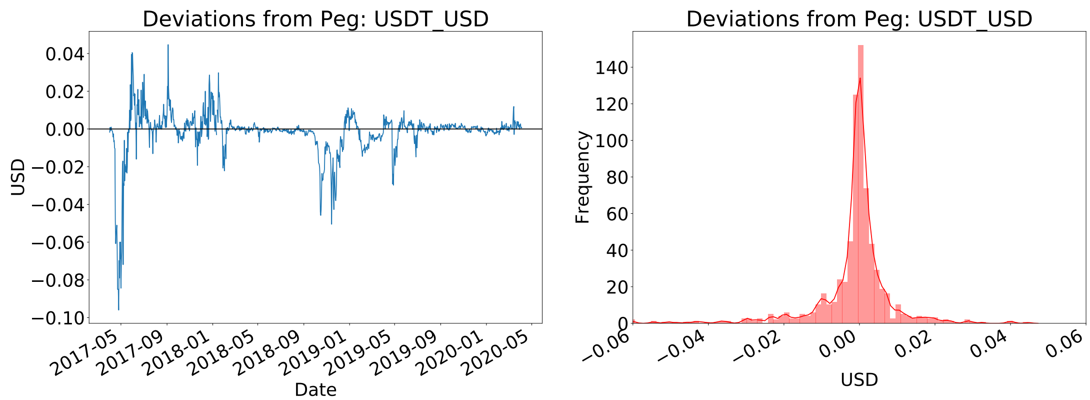
We also provide evidence on the profitability of arbitrage trades. We compute arbitrage profit based on an investor depositing dollars and obtaining Tether at a 1:1 rate, and then selling Tether at a premium in the secondary market. Matching the high-frequency timestamp of deposits with the Treasury with transaction prices, and adjusting for transaction costs (bid-ask spreads and price impact), we find that arbitrage profits are positive on average on both the Omni and Ethereum blockchains. Migration to the Ethereum blockchain resulted in a smaller deposit size, spreads, and profits. This is consistent with the "democratization" of access to arbitrage trades on the Ethereum blockchain leading to smaller spreads and profits per trade.

Beyond addressing the connection between arbitrage and issuance, we pin down more sharply where stablecoin price variation comes from in the first place, i.e., the fundamentals that explain premiums and discounts. An empirical difference between national-currency pegs and stablecoin pegs is that the distribution of stablecoin price deviations is two-sided (Figure 1),[3] whereas national currencies pegged to the dollar generally trade at discounts (due, e.g., to the risk of central-bank mismanagement). It is more difficult to rationalize why stablecoins so frequently trade at a premium.[4]

[3]Plots of peg-price deviations for other major stablecoins are provided in appendix E.

[4]To shed analytical light on these issues, we develop an illustrative model of stablecoin prices that generates a two-sided distribution and other testable implications, now contained in Appendix F. In the framework, an investor chooses to invest in a risky cryptoasset using dollars, stablecoins, or both. The investor's relative demand for each vehicle currency is dependent on the relative ease of transacting cryptocurrency. By imposing an increased intermediation cost for using dollars, the model describes how the stablecoin trades at a premium due to its relative benefit as a vehicle.

Figure 1: Tether/USD Deviations from Peg and Histogram of Deviations



Note: Figure plots the deviations of the Tether/USD price from parity (left panel). A positive deviation indicates Tether/USD trades at a premium. The right panel is a histogram of deviations of the Tether/USD peg. Data from Coinapi. Sample is April 1st, 2017 to March 31st, 2020.

Fundamentals of national-currency pegs include macroeconomic variables such as interest-rate misalignments, current-account deficits, government deficits, high inflation, and insufficient reserves (Eichengreen et al., 1994). Analogously, we can test which fundamentals impact stablecoin pricing. The first (proximate) fundamental we examine is order flow, which is the net of buyer-initiated trades less seller-initiated trades in the Tether-Dollar pair in the secondary market.[5] We use order-book data across multiple crypto exchanges in a Hasbrouck (1991) model and find that order flow has significant impact on secondary-market prices, with a positive shock to net buyer-initiated flows inducing an increase in the dollar price of Tether: One percent change in price per roughly $40 million in net order flows.

We then examine fundamentals such as the intensity of Bitcoin trading. We find that an increase in the intra-day price volatility of the BTC/USDT market leads to Tether-price premiums, evidence that Tether, and other stablecoins, serve as safe havens in the domain of cryptoassets. The effect is particularly pronounced in turbulent periods. For example, when the price of Bitcoin crashed in January of 2018, the Tether price averaged a premium of 5 cents. When Bitcoin crashed by 40% overnight during the COVID-19 economic shock, stablecoin premiums also increased. Stablecoin discounts, on the other hand, generally occur due to risk of insufficient collateral. We spotlight a speculative attack on Tether in October of 2018. In this episode, speculators were uncertain whether Tether was fully collateralized – due to a move by its partner exchange Bitfinex to suspend convertibility of dollar deposits.[6] Risk of an under-collateralized Tether Treasury poses a systemic risk to the Bitfinex exchange. This event

[5]Identifying the direction of a trade's initiation is crucial for getting the information economics right: all trades have a buyer and a seller – the informational "news" is in the direction of the initiator/aggressor.

[6]At the time of the speculative attack in 2018, the Bitfinex exchange was responsible for investing the majority of USD deposits with the Tether Treasury.

induces a decline in Tether's price and a sharp rise in bid-ask spreads.

Related literature The literature on cryptocurrencies is relatively new, with many papers focusing on how Bitcoin and other prices are determined (Abadi and Brunnermeier, 2018; Bolt and Van Oordt, 2020; Biais et al., 2020, 2019; Cong et al., 2020b, 2021; Catalini and Gans, 2016; Chiu and Koeppl, 2017; Easley et al., 2019; Schilling and Uhlig, 2019; Raskin and Yermack, 2018; Zimmerman, 2020; Sockin and Xiong, 2020), initial coin offerings (ICOs) (Catalini and Gans, 2018; Howell et al., 2018; Goldstein et al., 2019; Florysiak and Schandlbauer, 2019), economics of the blockchain (Cong and He, 2019; Cong et al., 2019; Garratt and van Oordt, 2019; Saleh, 2018; John et al., 2020; Hinzen et al., 2020; Amoussou-Guenou et al., 2020; Auer et al., 2021) and central bank digital currencies (Bordo and Levin, 2017; Benigno et al., 2019; Bindseil, 2020; Brunnermeier et al., 2019; Fernández-Villaverde et al., 2020; Kumhof and Noone, 2018; Keister and Sanches, 2019; Raskin and Yermack, 2018; Skeie, 2019). Topics include: Bitcoin having a dual role as a medium of exchange and speculative investment, the pricing of fees for mining, the costs and benefits of proof of work, proof of stake and committee blockchains, and the interaction of digital-currency deposits with monetary policy and central banking.

The cryptocurrency research most closely related to our paper focuses on market efficiency. Much attention has been paid to the potential for market manipulation, with evidence of pump and dump schemes (Gandal et al., 2018; Li et al., 2018; Dhawan and Putnins, 2020), crypto wash trading (Cong et al., 2020a), opportunities for speculation and arbitrage on crypto exchanges (Makarov and Schoar, 2019, 2020; Hale et al., 2018; Borri and Shakhnov, 2018) and determining a set of factors to explain cryptocurrency returns (Liu and Tsyvinski, 2018; Bhambhwani et al., 2019). There is a recent and growing literature investigating properties of stablecoins (Berentsen and Schär, 2019; Bullmann et al., 2019; BIS, 2019; Eichengreen, 2019; Dell'Erba, 2019; Routledge and Zetlin-Jones, 2018; Arner et al., 2020; Frost et al., 2020; Force et al., 2020; Bianchi et al., 2020; Klages-Mundt and Minca, 2020; Pernice, 2021). For example Eichengreen (2019) comments on stablecoins being backed by either national currencies or cryptocurrencies, and highlights that systems can be vulnerable to speculative attack if there is perception that the peg is under-collateralized. There is also recent work that looks at intra-day price changes to support the role of stablecoins as safe havens (Baur and Hoang, 2020; Baumöhl and Vyrost, 2020; Wang et al., 2020). Another strand of research examines the effects of stablecoin issuance on risky cryptoasset prices. The seminal research of Griffin and Shams (2020) document Tether's role of manipulation of Bitcoin prices during 2017 and 2018. A concurrent study by Wei (2018) tests the effect of Tether issuance on Bitcoin by examining total changes in Tether circulation and finds no effect on the price of Bitcoin. More recent studies using aggregate stablecoin issuance find insignificant effects of stablecoin issuance on cryptoasset prices, pointing instead to evidence of stablecoin issuance being driven by periods of market downturns in Bitcoin (Ante et al., 2020; Kristoufek, 2021; Lyons and Viswanath-Natraj, 2021).

We extend existing work on stablecoins in several ways. Most broadly, we push beyond past work focusing on prices only and address quantities, in particular by analyzing trades between the Tether Treasury and private investors. Within this literature, we are the first paper to identify an arbitrage mechanism that is dependent on decentralized private-investor deposits (withdrawals) of dollars with the Treasury when the stablecoin trades at a premium (discount), i.e. changes in relative supply that push prices back toward one. We are also the first paper to model fundamentals that drive stablecoin premiums and discounts.

Stablecoins are fixed exchange rates: There are many studies of how fundamentals can affect fixed rates, such as relative money supplies, interest rates, capital flows, financial frictions, and commodity prices (Eichengreen et al., 1994; Engel and West, 2005; Gabaix and Maggiori, 2015; Itskhoki and Mukhin, 2017; Chen and Rogoff, 2003). In this setting a peg can collapse due to fundamentals that are sufficiently weak (Krugman, 1979; Flood and Hodrick, 1986; Obstfeld, 1984), including instances where currency crises are potentially self-fulfilling (Eichengreen et al., 1995; Morris and Shin, 1998; Chamley, 2003; Cukierman et al., 2004). Our paper also relates to the role of central bank intervention in maintaining pegs (Fratzscher et al., 2019a,b; Sarno and Taylor, 2001; Ferreira et al., 2019; Flood and Jeanne, 2005; Vitale, 1999). Empirical evidence in Fratzscher et al. (2019b) shows that central banks typically "lean against the wind" by actively counteracting the private trades of market participants, which has a stabilizing effect.[7]

It is an empirical question whether the stabilizing mechanisms behind national-currency-based stablecoins include these central-bank-like behaviors, or instead generate stabilization through decentralized arbitraging of peg-price deviations, akin to the mechanism that keeps exchange-traded funds trading at prices close to their net asset values, or both (Aldridge, 2016; Marshall et al., 2013). Stablecoins are fundamentally different in that for ETFs the arbitrage process is not decentralized by design, being conducted instead by a preset group of institutions serving as *authorized participants* that conduct all "creates" and "redeems." It is not clear a priori how the process works to keep stablecoins stable – is it actively managed centrally by the stablecoin treasury? Or is it decentralized private investors that are arbitraging the peg? Our natural experiment of Tether migration to the Ethereum blockchain is compelling evidence of the latter: an increase in arbitrage access leads to a significant increase in peg efficiency.

The remainder of the paper is structured as follows. In section 1 we summarize the properties and performance of the major stablecoins. In section 2 we address Tether issuance and define the measure of Tether flows to the secondary market and the arbitrage mechanism. In section 3

[7] There are differences between the decentralized structure of stablecoins and forex interventions by a central bank. For example, a central bank is typically concerned with macroeconomic fundamentals like preserving low interest rates and inflation, and is targeting an exchange rate that is based on a set of fundamentals that are macroeconomic. A stablecoin issuer has no equivalent policy function. Secondly, investors can often deposit dollars directly with the stablecoin issuer. In contrast, investors cannot typically initiate trades, or directly deposit currency, with the central bank.

we exploit the migration of Tether from the Omni to Ethereum blockchain as an empirical test of the arbitrage mechanism. In section 4 we test for the stabilizing properties of arbitrage flows, and estimate a measure of arbitrage spreads and profits of Tether deposits and redemptions. In section 5 we test hypotheses about which fundamentals drive stablecoin peg-price deviations and volatility. Section 6 concludes.

1 Stablecoins: Properties and Performance

We note two institutional features that explain the growing role of stablecoins as a store of value and medium of exchange. The first is added intermediation costs when trading cryptocurrencies against dollars: On some exchanges, for example, there are longer processing lags for dollar withdrawals; fees are also often imposed when dollar withdrawals are frequent or large.[8] A second institutional feature favoring stablecoins is their usability across a greater cross-section of crypto exchanges: Of the exchanges that have "trusted volume" according to a report filed with the SEC, two of them, Binance and Poloniex, do not provide investors with any on-ramp for trading dollars, and only accept stablecoins as a medium of exchange.[9] For perspective, total trading volume between Bitcoin and Tether – the latter accounting for more than 80% of the stablecoin market – exceeded the trading volume of Bitcoin/USD in 2019.

The collateral systems adopted by the six largest stablecoins by market capitalization are presented in Table 1.[10] Stablecoins are typically backed by either dollar collateral or crypto collateral. Of the top six coins by market cap, five are backed by dollar deposits, the exception being DAI, which is backed by Ethereum.[11] The methods of how dollar collateral itself is managed includes a central issuer in the case of Tether, which acts analogously to the Hong Kong Currency Board. The second-largest stablecoin, USDC, has a more decentralized system of governance, with multiple issuers that have a license to provide USDC tokens. The other three stablecoins managed with dollar collateral, Binance USD Coin, Paxos, and TrueUSD, focus on concerns over the risk of issuer default: In the case of Binance USD coin and Paxos, dollar collateral is backed by FDIC-insured banks, whereas TrueUSD dollar collateral is backed

[8]For more information, refer to the following announcements by Bitfinex: `https://bit.ly/2NEzITW` and `https://www.bitfinex.com/posts/311`. Bitfinex states 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.

[9]For a report on trusted exchanges, see `https://www.sec.gov/comments/sr-nysearca-2019-01/srnysearca201901-5164833-183434.pdf`.

[10]The top six coins by market share in April 2020 capture over 95% of the stablecoin market.

[11]Since November 16, 2019, investors holding single-collateral DAI have transferred their holdings to multi-collateral DAI. Multi-collateral DAI is also based on Ethereum collateral at present, with a view to extend to different types of collateral in the future. For the purposes of our analysis, we address single-collateral DAI as it has a longer time series.

by escrow accounts.[12] The sixth largest coin, DAI, operates a system under which 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.[13]

An equally important institutional detail is how these coins' collateral is audited. Tether publishes its balance sheet daily,[14] which provides a breakdown of the value of its assets (dollar deposits) and liabilities (Tether in circulation on blockchain platforms). While Tether liabilities are accounted for based on the record of transactions on the blockchain, there is a need to audit issuers to verify that the holdings of dollar deposits are secure. For full solvency, the dollar value of assets held in the issuer's accounts must at least equal the dollar value of its liabilities. Audit reports for these top coins assert that they are sufficiently collateralized. We review audit accountability and transparency measures in Appendix B.

Table 1: Top 6 Stablecoins – System of Collateral

Coin	Symbol	Blockchain	System of Collateral
Tether	USDT	Omni and Ethereum	100% USD Deposits held in centralized Tether Treasury
USD Coin	USDC	Ethereum	100% USD Deposits in decentralized (private) accounts.
Paxos Standard	PAX	Ethereum	100% USD Deposits held by FDIC-insured banks
Binance USD Coin	BUSD	Ethereum	100% USD Deposits held by FDIC-insured banks
True USD	TUSD	Ethereum	100% USD Deposits held in escrow accounts
Multi Collateral DAI	DAI	Ethereum	Ethereum held in CDO with value of >150% DAI borrowed

The table lists properties of the top-six stablecoins by market capitalization as of April 1st, 2020. Blockchain refers to the platform on which the history of transactions is recorded. System refers to method of collateral; for dollar-collateral-based systems this means there is, as a stated principle, 100% backing of dollar deposits.

Table 2 presents summary statistics on the deviations from peg prices as of March 31st, 2020. (For details on the source of price data, see the data appendix A.) The first observation is the high ratio of total reported trading volume to the market capitalization, also referred to as daily velocity.[15] This daily ratio is typically over five for Tether, the largest coin, and is similarly above one for other national-currency-backed coins Paxos (PAX) and TrueUSD

[12]Escrow accounts offer a novel security design. For example, suppose an investor wants to deposit one USD for one TrueUSD token. They first deposit their dollar in a protected escrow account. TrueUSD then provides the escrow account 1 token. Only upon receipt of the token, and once the token is sent to the investor, the escrow account transfers the dollar deposit to TrueUSD. This system minimises settlement risk on both sides.

[13]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.

[14]See https://wallet.tether.to/transparencyformoredetails.

[15]The reported 24H Volume in Coinmarketcap and other vendors includes all transactions verified on the blockchain. The volume of trading on exchanges trusted by the SEC is less likely to be inflated for the purpose of feigning activity and liquidity. For more details on crypto wash trading in unregulated exchanges, see Cong et al. (2020a).

(TUSD). For perspective, the daily turnover in spot foreign exchange markets involving the USD as one leg of the transaction is $1.7 trillion over the period 2016-2019, compared to a total supply in circulation of approximately $15 trillion. This implies a daily USD velocity of one tenth, an order of magnitude smaller than stablecoin velocities. A takeaway is that stablecoins derive intensive use as vehicle currencies.

Table 2: Top 6 Stablecoins – Peg Price Deviations

Sample	Symbol	Market Cap	24H Volume	Mean	SD	Min	Max	Half-Life (days)
04/17-03/20	USDT	$6,400M	$40,000M	-20.5	128.9	-960	571	6.4
01/20-03/20	USDC	$705M	$692M	6.9	25.0	-21	100	0.8
01/19-03/20	PAX	$245M	$911M	7.8	29.6	-100	200	0.5
10/10-03/20	BUSD	$187M	$49M	1.4	6.1	-10	50	0.3
06/18-03/20	TUSD	$136M	$466M	6.7	59.2	-170	990	0.4
04/18-03/20	DAI	$79M	$12M	42.5	128.7	-391	800	4.7

Note: Market capitalization for all coins is based on total value of stablecoins in circulation; 24H Volume is total reported trading volume, from Cryptoslate (as of April 10th, 2020, https://cryptoslate.com/cryptos/stablecoin/). Summary statistics for price deviations from the parity peg are expressed in basis points (100 basis points here equals 1 US cent). Half-Life is in days. Price data are sourced from Coinapi, which reports data from trusted exchanges Bitfinex, Bittrex, and Kraken.

Examining the summary statistics in Table 2, we observe that stablecoins typically have two-sided distributions, with maximum deviations both below and above the one-to-one parity exceeding 500 basis points (five percent) for Tether (USDT), and of similar magnitudes for the other coins. We also observe deviation persistence, measured by the half-life of price departures from the peg. The half-lives for all coins range from 1 to 10 days.[16] Persistence of deviations is evidence that the stabilizing mechanisms of these coins are not without frictions or risk.

2 Tether Issuance

Tether distribution on Omni and Ethereum blockchain

Analogous to a currency board, every Tether issued is in principle backed by a dollar deposit, so that in the event of a run, all investors could redeem their Tether for an equivalent in dollars. To construct the Tether balance sheet, we use three databases, Omniexplorer, Etherscan, and Tron.[17] These are blockchain platforms on which the entire history of on-chain transactions

[16] 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 $T = \frac{log(0.5)}{log(\rho)}$.

[17] These are the three largest blockchain platforms on which Tether is traded, and account for over 99% of Tether in circulation as of April, 2020.

involving transfers of Tether is recorded.[18] These platforms contain an api that allows users to access an entire history of Tether transactions, with details on the size, timestamp, and the type of transaction. Tether tokens are created through a "grant" when new Tether tokens are minted. Tether tokens are destroyed through a "revoke" when Tether tokens are redeemed. Transactions between the Treasury and secondary market recipients are recorded as a "simple send", with counter parties listed on the "send" and "receive" sides of the transaction. Transactions are recorded in a series of blocks, and can be retrieved using the Omniexplorer and Etherscan api. For more detail on the databases, including how the flows are constructed from the addresses of the issuer, see appendix A.

Starting in October 2014, Tether issuance is initially only on the Omni blockchain. The left panel of Figure 2 presents the distribution of Tether across the Omni blockchain. We observe a significant concentration of Treasury flows on Omni going to a single address: the Bitfinex cryptocurrency exchange.[19] For example, Bitfinex first deposits dollars with the Tether Treasury. The newly created Tether tokens are then distributed by Bitfinex to other exchanges for trading in the secondary market.

The distribution of Tether fundamentally changed in 2019 with a migration of Tether to the Ethereum blockchain as the principal blockchain for Tether in circulation. Tether's migration to the Ethereum blockchain is motivated by several factors. First, Tether could now be used more directly as a vehicle for a large number of cryptocurrency investors that use the Ethereum blockchain. Similarly, Tether's value as a vehicle increases by being used as a medium of exchange for a large number of ERC20 tokens that only circulate on the Ethereum network. Second, the Ethereum blockchain also enables higher-frequency arbitrage, with 15-second blocks (the corresponding set of transactions processed by miners on the blockchain) for Ethereum versus 10 minutes for Omni, which has mining times based on the Bitcoin protocol. Third, cryptocurrency exchanges such as Bittrex and Huobi also cite the Ethereum blockchain as enabling a reduction in transaction costs in Tether withdrawals and deposits.[20] To tap into the benefits of an increased client base and efficiency in payments processing, cryptocurrency exchanges engaged in a chain swap of Tether from the Omni to Ethereum blockchains. This is a special type of transaction that moves a cryptocurrency from one blockchain to another.[21] As we note in Appendix C, we record up to $1.0 billion of Tether holdings rebalanced from the Omni to the Ethereum blockchain by the Binance exchange through chain swaps from August 2019 to March 2020.

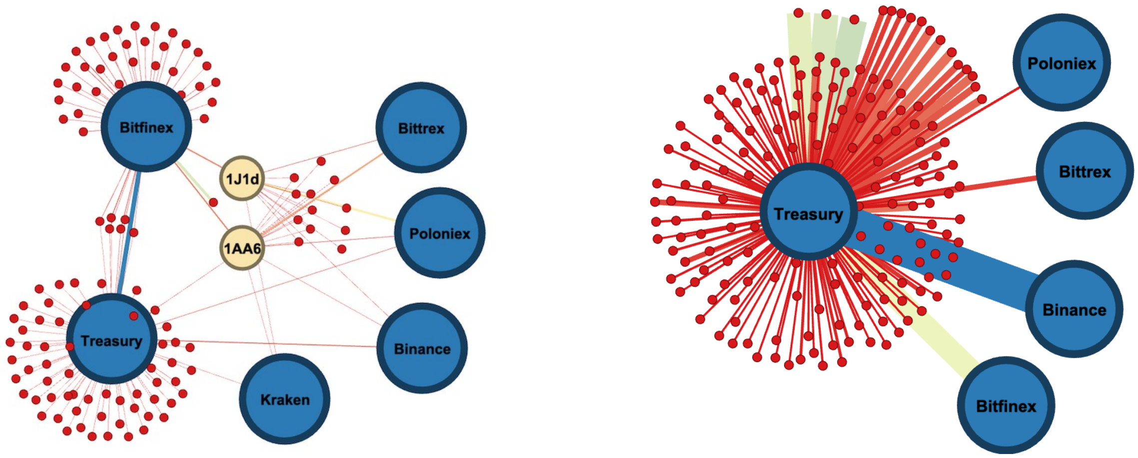
[18] Off-chain transactions, such as transactions within a cryptocurrency exchange, are not recorded.

[19] For more details on the concentration of Bitfinex on the Omni blockchain, we refer the reader to appendix C.

[20] For more details see statements from Bittrex https://bittrex.zendesk.com/hc/en-us/articles/360031291791-Support-for-ERC20-based-Tether-USDT-Deposits-and-Withdrawals and Huobi https://prn.to/2ZkPzw0.

[21] For more information on chain swaps, see https://tether.to/explained-chain-swaps/.

Figure 2: Distribution of Tether on the Omni and Ethereum Blockchains



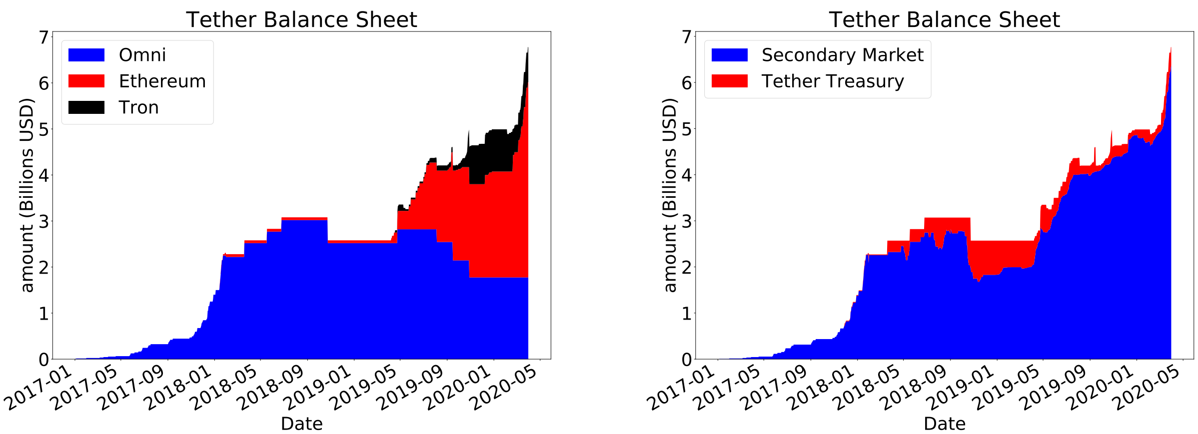
Note: Figure presents the network of transactions from the Tether Treasury to all wallets on the Omni blockchain recorded from October 8th, 2014 through to March 31st, 2020. Transaction history is obtained from https://omniexplorer.info/ for the Treasury wallet address "1NTMakcgVwQpMdGxRQnFKyb3G1FAJysSfz". The plot also records absolute flows from Bitfinex to other wallets (only wallets with an absolute transaction value greater than $100 million USD are included to minimize the number of nodes from Bitfinex). Right Figure presents the network of transactions from the Tether Treasury to all wallets on the Ethereum blockchain recorded from January 30th, 2019 through March 31st, 2020. Transaction history is obtained from https://etherscan.io/ for the Treasury wallet address "0x5754284f345afc66a98fbb0a0afe71e0f007b949". All identified wallets (cryptocurrency exchanges) are labeled. The line thickness between wallets and the Treasury indicate the magnitude of absolute flows, which we measure as the sum total of inflows and outflows of Tether from the Treasury to each wallet. Addresses are labeled based on publicly available information on the Tether rich list https://wallet.tether.to/richlist and https://etherscan.io/.

Tether Balance Sheet

We construct the aggregate stock of Tether, $Q_{Agg,t} = \sum_{i=1}^{N} Q_{i,t}$ as the sum of Tether created across the three principal blockchains, Omni, Ethereum, and Tron, which account for up to 99% of total Tether creation over the sample period from October 8th, 2014 to March 31st, 2020. We also record the amount of Tether created but retained by the Tether Treasury as reserves. The total amount of Tether Reserves on each blockchain is then equal to $Q_{T,t} = \sum_{i=1}^{N} Q_{T,i,t}$. The usefulness of the Treasury's reserves can be seen as analogous to the accumulation of foreign exchange reserves by a central bank. This provides the stablecoin issuer a one-sided potency against stablecoin premiums; in the event of a secondary market price above one USD, the Tether Treasury can sell its Tether reserves in the secondary market to restore parity of the peg.[22] The total amount of Tether held by private wallets and exchanges is equal to the total Tether creation net of Tether held in the Treasury's account, given by $Q_{EX,t}$ in equation 1.

[22]The accumulation of Tether reserves helps guard against stablecoin premiums, but not stablecoin discounts. For example, if Tether trades at a discount, then the Tether Treasury would require investors to redeem their dollar deposits and withdraw Tether from circulation.

Figure 3: Left panel: Tether/USD Balance Sheet – By Blockchain, Right panel: Tether/USD Balance Sheet – Tether held by the Treasury and Other Accounts



Note: The figure plots total Tether supply, divided by blockchain (left), and divided into holdings in the secondary market (by investors and exchanges) and holdings by the Tether Treasury as reserves (right). Flows of Tether to the secondary market, measured using transaction data of the Tether Treasury on the Omni, Ethereum, and Tron blockchains respectively.

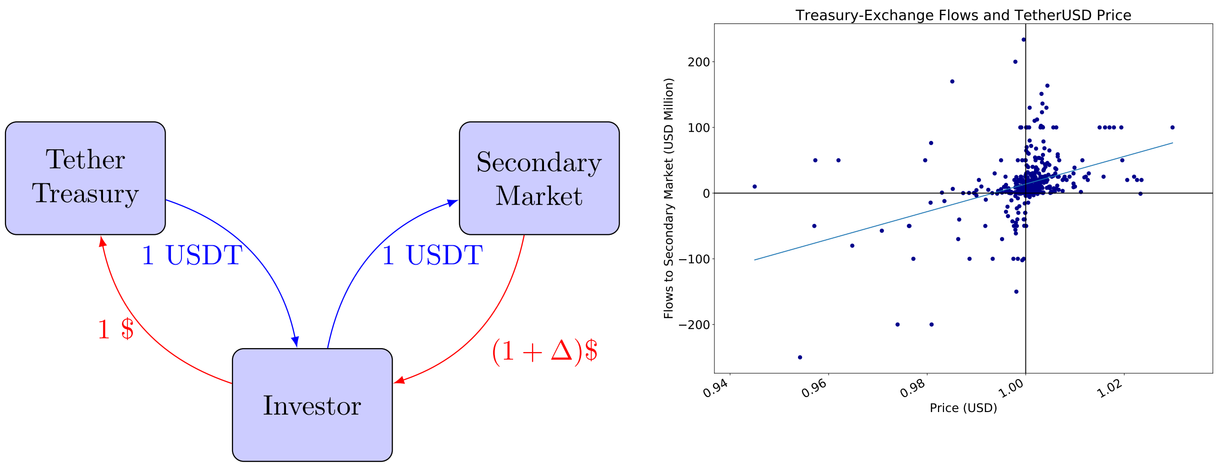
$$Q_{EX,t} = Q_{Agg,t} - Q_{T,t} \tag{1}$$

Figure 3 (left) plots the breakdown of Tether by blockchain. While Tether was exclusively created on the Omni blockchain from 2014 through to 2018, there is a gradual migration of Tether from the Omni to Ethereum blockchains starting in April, 2019. Within three months of Tether's introduction to the Ethereum blockchain, we note that it overtakes the Omni blockchain in Tether creation by October 29th, 2019. Figure 3 (right) plots the total Tether supply, with the division of total Tether held by the Treasury and the secondary market, which included balances held at crypto exchanges, retail investors, and institutional investors. While balances held at the Treasury are typically a small fraction of total Tether in circulation, they reached almost $1 billion USD in 2018, which equates to 25% of total Tether supply.

To construct a proper aggregate measure of net Tether issuance, take first differences of equation 1, and define flows from the Treasury to the secondary market, $Flow_{T \to EX,t} = \Delta Q_{EX,t}$, as the change in total Tether net of changes in the Treasury account (equation 2). This controls for changes in Tether that are retained at the Treasury, which do not constitute Tether in circulation for trading by private wallets and exchanges.

$$Flow_{T \to EX,t} = \Delta Q_{Agg,t} - \Delta Q_{T,t} \tag{2}$$

Figure 4: Left: Arbitrage Flows when Tether Price in Secondary Market is Trading at a Premium; Right: Scatter Plot of Daily Flows from the Tether Treasury to the Secondary Market, and the Tether/USD peg



Note: Left: Schematic illustrates an arbitrage trade where the secondary-market price of Tether trades at a premium. An investor makes a dollar deposit with the Tether Treasury, obtains a Tether token (at an exchange rate of 1 Tether per 1 USD), and then sells Tether tokens in the secondary market for a round-trip profit of Δ. Right: The figure illustrates scatter plot of flows of Tether to the secondary market, and the corresponding Tether/USD price, measured using daily data on secondary-market flows from Omni and Etherscan. Price data are from Coinapi, and use transaction data from trusted crypto exchanges Bitfinex, Bittrex, and Kraken. Sample is April 1st, 2017 to March 31st, 2020.

Tether Arbitrage Mechanism

In contrast to national exchange rate pegs, stablecoins are not managed by a national central bank.[23] The issuer of Tether has formally stated that it does not intervene in secondary markets to stabilize the market rate.[24] In the absence of central bank intervention, we posit a mechanism driven by the actions of arbitrageurs that exploit price departures from the unity peg. If the market price of Tether is above one dollar, an investor can buy Tether from the Treasury at a one-for-one rate, and sell Tether at the prevailing market rate to profit, resulting in a flow of Tether from the Treasury to the secondary market (Figure 4, left). Conversely, when the dollar price of Tether is below 1, an investor can buy Tether at the exchange and sell to the Tether Treasury, resulting in a flow in the opposite direction – from the secondary market to the Tether Treasury. Stability of the Tether/USD peg is maintained here through the actions of investors.

[23]In national exchange rate pegs, the central bank is committed to maintaining the peg by buying the domestic currency and selling foreign-currency reserves when the domestic-currency value falls below the peg level, and conversely selling domestic currency when the domestic-currency value rises above the peg level.

[24]In a statement released on its website, Tether Inc states: (i) Tether does not represent a country or oversee a banking system; (ii) The USDT supply is dictated by consumer demand (all issued USDT has been bought by a consumer at a 1:1 ratio); (iii) Tether does not set or manage any interest rates anywhere; (iv) Tether does not oversee – and is not responsible for – a banking or exchange sector, and does not claim to do so. For full reference, see https://tether.to/a-commentary-on-tether-chainalysis/.

Arbitrage by secondary-market participants offers a solution to exchange-rate stability that is decentralized.[25]

In the right panel of Figure 4, we plot daily flows between the Treasury and the secondary market against the Tether price. These flows are more frequent when the Tether price is above the peg. More relevant, the regression line has a clear positive slope, evidence – albeit suggestive – that flows between the Tether Treasury and the secondary market serve to maintain the Tether/USD peg.

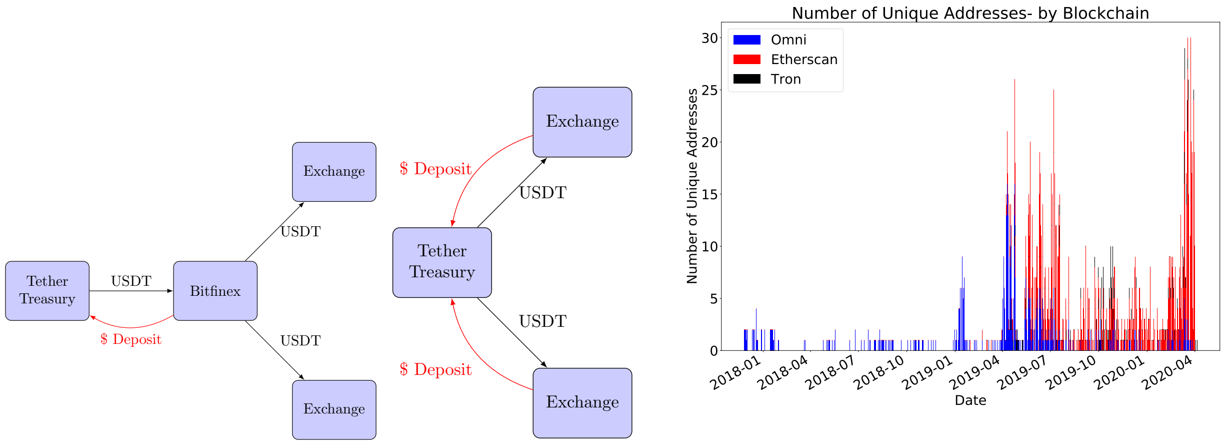
3 Testing the Arbitrage Mechanism: Tether Migration from Omni to Ethereum

We identify the migration of Tether to the Ethereum blockchain as a pseudo natural experiment in Tether Treasury access. Tether distribution fundamentally changed following introduction to the Ethereum blockchain in April 2019. On the Omni blockchain, the Bitfinex exchange had primary access to deposit dollars with the Tether Treasury to create newly minted Tether tokens, which were then distributed to other exchanges for trading. Increased access to the Treasury includes Tether distribution through multiple crypto exchanges that deposit dollars with the Treasury to create Tether tokens (Figure 5, left). Critically, migration to the Ethereum blockchain enabled increased access by investors of all kinds for depositing dollars directly with the Treasury. The right panel of Figure 5 shows the daily number of unique wallet addresses transacting with the Treasury on the three primary blockchains, Omni, Ethereum, and Tron. Note the sharp increase in unique addresses transacting with the Treasury in 2019. Judging from the count of unique addresses using Tether on the Omni and Ethereum blockchains, the Ethereum network begins to dominate Omni starting in April, 2019.[26] Transactions with the Treasury on the Ethereum blockchain is much less concentrated, with an average of 4.0 unique addresses transacting with the Treasury daily, compared to 1.4 on the Omni blockchain.

[25] The arbitrage mechanism we outline is taking advantage of a law-of-one-price deviation in currency markets, and follows a line of reasoning similar to arbitrage conditions in foreign exchange markets such as covered interest-rate arbitrage (Akram et al., 2008) and triangular arbitrage of cross-rates in forex (Foucault et al., 2017).

[26] See https://news.bitcoin.com/erc20-tether-transactions-flip-their-omni-equivalent/ for more details on the change in number of users on Omni and Ethereum blockchains.

Figure 5: Left – Distribution of Tether to Secondary Market on the Omni and Ethereum blockchains; Right – Number of Unique Addresses transacting with the Tether Treasury on Omni, Ethereum, and Tron Blockchains



Note: Left figure illustrates the creation of Tether on the Omni and Ethereum blockchains. On the Omni blockchain, Bitfinex deposits dollars into the Tether Treasury. The Tether Treasury then issues Tether tokens at parity (1:1 exchange rate). The newly created tokens are then distributed to other investors and exchanges in the secondary market. On the Ethereum blockchain exchanges directly deposit dollars with the Tether Treasury to create newly minted tokens. Right Figure plots the daily number of unique investor addresses transacting with the Tether Treasury on each blockchain. Data records trades between the Tether Treasury and private investors, obtained from the Omni, Ethereum, and Tron Blockchains. Sample is November 2017 through March 2020.

We hypothesize that an increase in access to the primary market should translate to increased effectiveness of arbitrage in sustaining the peg. For example, if Bitfinex is the only investor that has access to the primary market, then this impairs the ability of private investors to arbitrage peg deviations. We first partition our sample of Tether prices into the pre and post periods according to the first week in which we observe a jump in transactions between the Treasury and addresses depositing dollars directly with the Treasury on the Ethereum blockchain, which we identify as April 9th, 2019.[27] Table 3 presents summary statistics. The average size of peg deviations falls substantially, and in particular, note a significantly lower half-life of deviations, measuring 6.5 days in the pre Ethereum blockchain sample, versus 3.3 days in the post period.[28]

[27] The first recorded transaction with the Tether Treasury occurred on January 30th, 2019. We note that there are 6 transactions prior to April 9th, 2019. In the week of April 9th, 2019, we note a jump in the number of addresses transacting with the Ethereum blockchain by 24, which corresponds to the jump in April 2019 plotted in Figure 5.

[28] Tether, in its white paper, states that investors are allowed to deposit dollars directly to obtain Tether tokens at the 1:1 pegged rate (Tetherinc. (2016)).

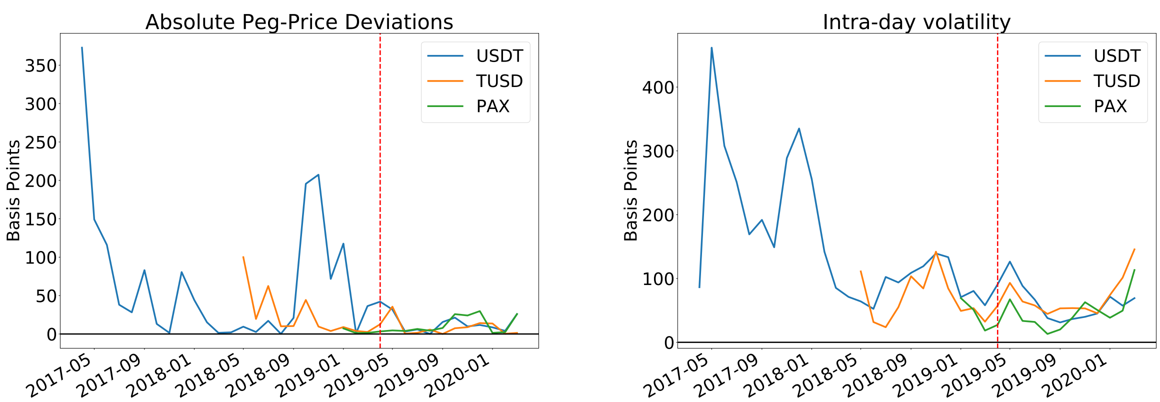
Table 3: Summary Statistics of Tether/USD Deviations, pre and post introduction of Tether on the Ethereum Blockchain

Period	Mean	SD	Min	Max	Half-Life (days)
Pre Ethereum Blockchain	-28.2	97.2	-505	298	6.5
Post Ethereum Blockchain	-0.9	47.2	-298	119	3.3

Note: Summary statistics for deviations from the peg are expressed in basis points (100 basis points = 1 US cent). Secondary-market price is based on daily data that averages prices from the Bitfinex, Bittrex, and Kraken exchanges, all three being trusted exchanges, sourced from Coinapi. Sample is divided into 04/17 to 04/19 in the pre period and 04/19 to 03/20 in the post period, with the post date starting on April 9th, 2019. The post period corresponds to when investors can directly transact with the Tether Treasury on the Ethereum blockchain.

Difference-in-Difference specification: pre-trends

Figure 6: Left panel: Absolute peg-price deviations; Right panel: intra-day volatility



Note: This figure plots average monthly stablecoin prices and intra-day volatility for the treatment (USDT) and the control group stablecoins. The treatment stablecoin is Tether (USDT). The control stablecoins are TrueUSD (TUSD) and Paxos (PAX). The red dotted line indicates the structural change date of April 9th,2019 used in the baseline specification. Price data for USDT consolidates trade data from three trusted exchanges: Bitfinex, Bittrex, and Kraken. Price data for the control group comes from Bittrex. Sample is January 10th, 2019 through to March 31st, 2020.

Increased efficiency of the Tether peg from April 2019 to March 2020 could be unrelated to the migration to the Ethereum blockchain. Other possible causes include, for example, increased liquidity across cryptocurrency exchanges, technological changes (such as an increased efficiency of mining), or changes in the global demand for cryptocurrencies that use stablecoins as the primary vehicle currency. To rule out alternative hypotheses, we adopt a difference-in-differences design. The set of control currencies we use in our sample are national-currency-backed stablecoins, Paxos and TrueUSD. These stablecoins are closest in design to Tether, with the critical difference being institutional features employed to mitigate counterparty risk.[29]

Figure 6 plots the stablecoin prices and intra-day volatility for Tether, TrueUSD, and Paxos. To calculate intra-day volatility, we use transaction data at 5-minute intervals to construct 5-minute returns. We then calculate the average sum of squared returns over 5-minute intervals over the trading day, and take the square root. A visual inspection of Figure 6 shows that Tether peg-price deviations and intra-day volatility are larger than the control group, with no evidence of pre-trends in the preceding 2 months leading to Tether migration to the Ethereum blockchain.[30]

Our purpose in using these stablecoins as a control is twofold. First, any common sources of shocks to the stablecoin class as a whole should be captured within the control group. This could be due to investors' transactional demand for crypto investments, the return and volatility structure of cryptocurrencies, and technological advances in crypto markets (new crypto exchanges) that will affect demand for all stablecoins. All stablecoins in the control group operate only on the Ethereum blockchain, providing a suitable control for testing the causal effect of Tether's structural transformation of its currency from the Omni to Ethereum blockchain.

We now test the specification in equation 3, where the outcome variable Y_t is either the absolute level of peg deviations, $|p_t - 1|$, or the intra-day volatility of peg deviations σ_t, both measured in basis points. The indicator for treatment T_i takes on a value of 1 for Tether and 0 for the control-group currencies. Indicators for Paxos and TrueUSD are given by $\mathbb{1}_{PAX}$ and $\mathbb{1}_{TUSD}$ respectively. The coefficient δ measures the net impact of the structural change on Tether net of any trends observed in the control group. The identifying assumption of our analysis is that δ measures the efficiency gain of Tether in migrating to the Ethereum blockchain. The results are summarized in Table 4. In columns (I) and (II), we impose a standard structural break test by regressing the absolute size and volatility of Tether peg deviations on a post dummy, which takes a value of 1 in April 2019 when Tether issuance migrated to the Ethereum blockchain. We observe on average a 62.5 basis point decline in the absolute level of peg deviations, and a decline in intra-day volatility of 97.5 basis points.

[29] For example, TrueUSD uses a system of escrow, whereas Paxos is insured by FDIC deposits. For more on the technical details of alternative stablecoins, please see Section 1. We do not include USDC and DAI in our control group due to institutional differences. USDC is different in that it does not have a centralized issuer, with multiple issuers being able to grant USDC tokens. DAI, in contrast, is a crypto-collateralized stablecoin, typically backed by Ethereum, and has an independent structure of stability mechanisms.

[30] A reasonable concern that we address in our design is the significance of Tether peg-price deviations in October 2018. Tether experienced large discounts in excess of 500 basis points in response to a speculative attack which we outline in section 5. We present our results both for the full sample starting on April 1st, 2017, as well as a balanced panel starting on January 10th, 2019. The balanced panel is therefore robust to pre-trends of the full sample that includes the confounding event.

$$Y_t = \alpha_0 + \alpha_i \sum_{i \in PAX,TUSD} \mathbb{1}_i + \beta T_i + \gamma post_t + \delta post_t \times T_i + u_t \qquad (3)$$

Table 4: Tests of a structural break in Tether issuance: effects of a migration to the Ethereum blockchain in 2019 on the size and volatility of Tether peg deviations

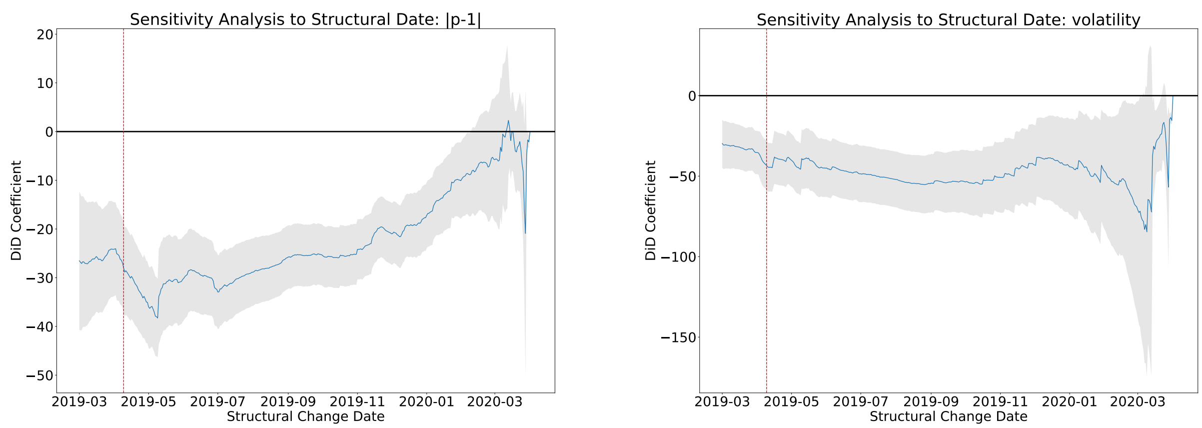
	I	II	III	IV	V	VI
	$\lvert p_t - 1\rvert$	σ_t	$\lvert p_t - 1\rvert$	σ_t	$\lvert p_t - 1\rvert$	σ_t
post	-62.46***	-97.45***	-10.90***	1.13	1.47	14.07***
	(7.16)	(5.80)	(3.44)	(4.32)	(1.73)	(4.06)
T			49.30***	91.27***	29.57***	33.98***
			(4.02)	(4.39)	(3.34)	(3.06)
post × T			-51.56***	-98.59***	-29.42***	-26.55***
			(6.16)	(7.24)	(4.89)	(5.77)
$\mathbb{1}_{PAX}$			-8.56***	-24.01***	-4.13**	-7.15**
			(2.14)	(3.26)	(1.71)	(2.97)
$\mathbb{1}_{TUSD}$			-5.88**	0.82	-5.37***	13.58***
			(2.40)	(2.67)	(1.57)	(2.55)
Intercept	84.16***	159.35***	34.86***	68.08***	20.08***	40.40***
	(4.09)	(5.38)	(1.96)	(2.19)	(1.21)	(1.83)
R-squared	0.07	0.12	0.11	0.19	0.07	0.04
No. observations	1095	1095	2122	2122	1276	1276
Sample	Full	Full	Full	Full	Balanced	Balanced

Note: Table presents regressions of the absolute level and volatility of deviations of the peg. The absolute level of deviations is denoted by $|p_t - 1|$, and σ_t is calculated based on a measure of intra-day volatility of the price, both measured in basis points. The post dummy $Post_t$ takes a value of 1 from April 9th, 2019. The Treatment dummy T takes a value of 1 for USDT, and 0 otherwise. Control-group currencies include TrueUSD, Paxos. Full sample for columns (I) through to (IV) is April 1st, 2017 to March 31st, 2020. Balanced panel for columns (V) and (VI) is from January 10th 2019 to March 31st 2020. Price data for currencies obtained from coinapi, and use closing prices from exchanges Kraken, Bitfinex, and Bittrex. White heteroscedasticity robust standard errors are used in estimation. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

The results of our differences-in-differences analysis for the full sample are reported in columns (III) and (IV) of Table 4. There is a net convergence in the stability of peg deviations in Tether during the post period, with a difference-in-difference coefficient on post × T of -51.6 basis points. This implies a decline in the absolute level of deviations of 51.6 basis points relative to the control-group currencies. Similarly, we observe a decline in intra-day volatility of Tether deviations relative to the control group of 98.6 basis points.

A reasonable concern of our full sample estimates is bias due to the presence of confounding events. We control for this by running our specification on a balanced panel for Tether and the control group that starts on January 10th, 2019. The results of the balanced panel are in columns (V) and (VI). Testing for effects using a balanced panel rules out the possibility that the result is driven by trends in Tether peg-prices in the earlier part of the full sample.[31] We still find a statistically significant difference-in-difference coefficient of -29.4 basis points for peg-price deviations and -26.5 basis-points for intra-day volatility. The balanced panel result therefore rules out the possibility that large Tether deviations witnessed in 2018 could be fully explaining the observed results.

Figure 7: Sensitivity Analysis of Difference-in-Difference Coefficients to a Change in the Structural Date



Note: This figure shows the difference-in-difference coefficient δ of the following design: $|p_t - 1| = \beta_t Post_t + \delta_t Post_t \times T_t$ by changing the structural change date $Post_t$. The outcome variable measures the absolute level of peg deviations on the left panel, and intra-day volatility of peg price deviations on the right panel. The treatment currency is Tether (USDT), and control-group currencies are TrueUSD (TUSD) and Paxos (PAX). The red dotted line indicates the structural change date of April 9th used in the baseline specification. White heteroscedasticity-robust standard error bands are reported at a 5% significance level. The sample is January 10th, 2019 to March 31st, 2020.

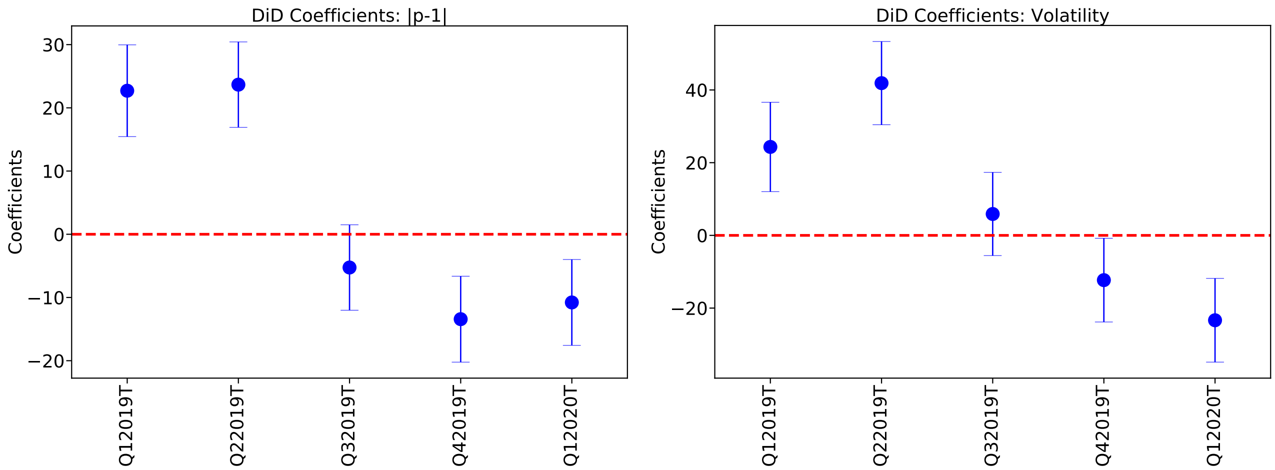
Difference-in-Difference Robustness test #1: sensitivity of migration date

The migration date in the baseline specification is April 9th, which is the first week in which at least 10 unique addresses transacted on the Ethereum blockchain. We conduct two robustness tests on the difference-in-difference specification. First, we test whether the reported regressions are sensitive to the choice of the migration date. For example, the full effects of

[31] In section 5 we document two sources of large peg-price deviations in 2018. In January and February of 2018, a crash of BTC led to Tether premiums due to its relative liquidity and stability benefits. Significant discounts in Tether in October 2018 were a response to collateral concerns due to the suspension of dollar deposits at the Bitfinex exchange.

migration are likely to be realized months after April 2019, as users only gradually transferred their Tether holdings.[32] In Figure 7, we perform a sensitivity analysis of the date of structural change by recording the difference-in-difference coefficients for alternative structural change dates. The presence of a treatment effect is robust to alternative dates: the peak treatment effect of -38 basis points occurs on May 8th, approximately a month after the structural change date of the baseline specification.

Figure 8: Difference-in-difference coefficients for dynamic panel specification



Note: Figure presents coefficients for a dynamic difference-in-difference specification with the absolute level of peg-price deviations (left) and intra-day volatility (right). Coefficients measure the effect of the treatment interacted with each quarter. Price data for USDT consolidates trade data from three trusted exchanges: Bitfinex, Bittrex, and Kraken. Price data for the control group of stablecoins comes from Bittrex. Sample is January 10th, 2019 through March 31st, 2020. White heteroscedasticity-robust standard-error bars are plotted to construct a 95 percent confidence interval around coefficient estimates.

Difference-in-Difference Robustness test #2: Dynamic time trend to the pre-post migration

We extend the specification to account for a dynamic trend in the post period in equation 4. The difference-in-difference coefficient δ traces the net effect of structural change across each quarter in the balanced sample, from 2019Q1 to 2020Q1. By tracing the net impact across quarters, we test the hypothesis that the structural change is not a step function, but reflects a gradual increase in arbitrage access. For example, we note that Tether creation on the Ethereum blockchain only exceeded Tether on Omni by the end of October 2019, months

[32] A potential concern with the post period is the April 30th, 2019 report on Tether backing being only 74% in the form of cash or cash equivalents. For details on the announcement, we refer the reader to https://www.coindesk.com/tether-lawyer-confirms-stablecoin-74-percent-backed-by-cash-and-equivalents. There was no visible market reaction to the April 30 report, with Tether continuing to have two-sided deviations. Tether asserts that they are backed by dollar reserves fully and releases a balance sheet daily showing Tether assets and liabilities match (with Assets>Liabilities suggesting earnings from interest-bearing assets). The definition of "cash or cash equivalents" does not include various interest-bearing assets on the balance sheet.

after the date of structural change. Cryptocurrency exchanges transferred Tether tokens from Omni to Ethereum for months through a series of chain swaps in which Tether holdings are rebalanced across blockchains.[33] Therefore we would not expect an immediate decline in peg deviations following the migration, but a gradual decline over a wider event window.

$$Y_t = \alpha_0 + \alpha_i \sum_{i \in PAX,TUSD} \mathbb{1}_i + \beta T_i + \gamma post_t + \sum_{q=1}^{Q} \delta_q Q_{t+q} \times T_i + u_t \quad (4)$$

Table 5 presents the results, and Figure 8 plots the difference-in-difference coefficients in columns (III) and (IV). Peg price-deviations relative to the control group is given by the coefficients of interest for each quarter interacted with the dummy for Tether. The coefficients document a trend increase in Tether efficiency. Tether peg-price deviations in 2019Q1 and 2019Q2 are 22.7 and 23.7 basis points higher relative to the control group. In contrast, Tether peg-price deviations decline relative to control group stablecoins during 2019Q4 and 2020Q1, with estimates of -13.4 and -10.8 basis points respectively. Intra-day volatility follows a similar qualitative pattern in efficiency. In 2019Q2, it is 42.0 basis points higher relative to the control group, the coefficient then declines to -13.0 and -24.4 basis points by 2019Q4 and 2020Q1 respectively. The results are consistent with a *gradual* increase in peg efficiency, with Tether migration to Ethereum occurring over a period of months following the date of structural change.

[33] We provide a list of major chain-swap events in appendix C.

Table 5: Difference-in-Difference Design: Dynamic Effects

	I	II	III	IV
	$\lvert p_t - 1 \rvert$	σ_t	$\lvert p_t - 1 \rvert$	σ_t
Q12019	23.16***	14.05***	6.40***	5.59
	(2.47)	(3.58)	(2.27)	(4.35)
Q22019	24.45***	52.43***	6.73***	28.35***
	(2.34)	(3.39)	(2.02)	(3.88)
Q32019	-10.65***	-9.38***	0.56	2.62
	(2.33)	(3.38)	(2.04)	(3.91)
Q42019	-6.53***	-14.40***	12.85***	16.57***
	(2.33)	(3.38)	(2.08)	(3.98)
Q12020	-7.58***	12.25***	9.16***	54.55***
	(2.34)	(3.39)	(2.06)	(3.94)
Q12019 × T			22.71***	26.40***
			(3.70)	(7.09)
Q22019 × T			23.67***	42.03***
			(3.45)	(6.60)
Q32019 × T			-5.26	5.94
			(3.44)	(6.60)
Q42019 × T			-13.43***	-13.02**
			(3.46)	(6.64)
Q12020 × T			-10.79***	-24.36***
			(3.46)	(6.64)
R-squared	0.29	0.31	0.12	0.14
No. observations	446	446	1274	1274

Note: Table estimates a dynamic difference-in-difference specification where the treatment is interacted with each quarter. The absolute level of deviations is denoted by $|p_t - 1|$, and σ_t is calculated based on a measure of intra-day volatility of the price, both measured in basis points. Price data for USDT consolidates trade data from three trusted exchanges: Bitfinex, Bittrex, and Kraken. Price data for the control group of stablecoins comes from Bittrex. Sample is January 10th, 2019 through March 31st, 2020. 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.

Testing direct arbitrage access: instrument variable estimation

The difference-in-difference test controls for factors that apply to all stablecoins, such as an increase in liquidity across all exchanges, or common network effects. The test is limited in dealing with confounding factors that are Tether specific. For example, an increase in peg efficiency during the post-migration period may have occurred due to idiosyncratic shocks to

Tether, such as an announcement on Tether audits, or by affecting expectations of Tether credibility. For example, Tether's migration to the Ethereum blockchain led to an overall increase in investor trust in Tether as an institution. This can anchor expectations and simultaneously cause more investors to transact with the Treasury. A second concern is that alternative channels of indirect arbitrage or stabilizing speculation can increase peg efficiency in the absence of access to the Tether Treasury.[34]

An instrumental variables specification that addresses Tether-specific confounding factors is stated in equations 5 and 6. Equation 5 is our first stage, and regresses the daily number of addresses transacting with the Treasury, $N_{USDT,T,t}$, on the proposed instrument N_{IV}. The instrument measures the daily total number of addresses transacting with a set of national-currency backed stablecoins, USDC, Paxos, and TrueUSD that operate on the Ethereum blockchain. In the second stage, we regress peg efficiency outcome Y_t on the instrumented number of addresses of the Tether Treasury as the explanatory variable of interest. The coefficient β_{IV} measures a plausibly exogenous increase in investor access attributed to increased users on the Ethereum network employing stablecoins as a vehicle to satisfy increased transactional demand.

$$N_{USDT,T,t} = \alpha_1 + \beta_1 N_{IV,t} + \epsilon_{USDT,t} \tag{5}$$

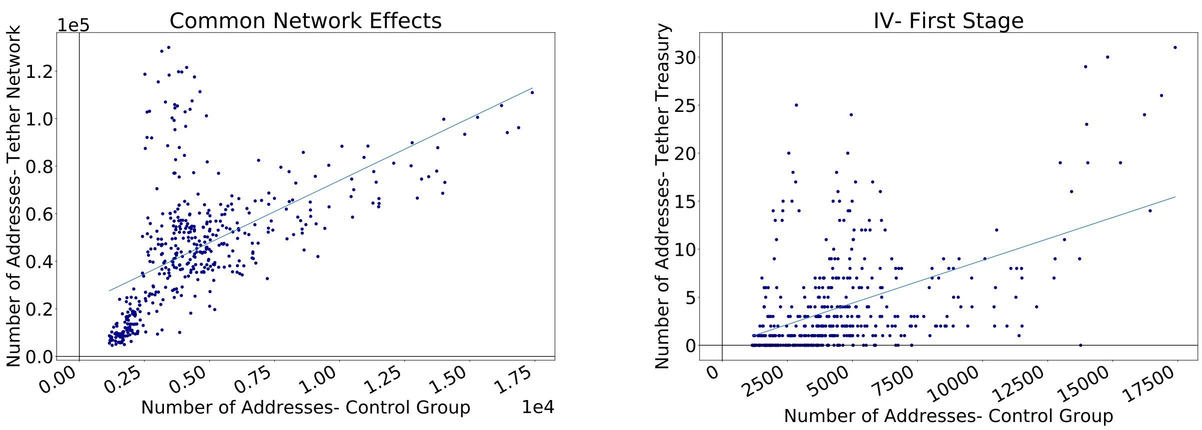
$$Y_t = \alpha_2 + \beta_{IV} \hat{N}_{USDT,T,t} + e_t \tag{6}$$

The two identifying assumptions needed are instrument relevance and exclusion listed in equations 7 and 8 respectively. Instrument relevance is satisfied due to common network effects: an increase in the value of the Ethereum network, or increased demand for ERC-20 tokens, will drive an increase in the number of holders using all stablecoins. Therefore we expect an increase in users of Tether on the Ethereum network to be correlated with an increase in users holding other stablecoins. A scatterplot of total users of Tether and other stablecoins in the left panel of Figure 9 confirms our hypothesis that demand for stablecoins has a common factor. The right panel of Figure 9 plots the number of addresses transacting with the Tether Treasury against our proposed instrument. The exclusion restriction states that the number of users holding a set of other stablecoins on the Ethereum network are plausibly exogenous to idiosyncratic shocks to the Tether peg, which we define accordingly as ϵ_{USDT}. Therefore, the identifying assumption is that the instrument leads to an increase in the number of addresses transacting with the Tether Treasury **only** through a channel of common network effects on the Ethereum blockchain.

[34] The point here is that migration to the Ethereum blockchain can facilitate alternative channels of arbitrage that do not rely on the primary market. An increase in peg efficiency may still occur due to the extended network of the Ethereum blockchain introducing opportunities for *indirect* arbitrage, by going short (long) Tether and taking a corresponding long (short) in another cryptocurrency when Tether is over (under)-valued with respect to the peg. Therefore, indirect arbitrage can cause the peg to stabilize even in the absence of access to the Tether Treasury. Indirect arbitrage may be limited however due to inherent risk and valuation effects of the investment currency.

$$cov(N_{USDT,T}, N_{IV}) \neq 0 \tag{7}$$
$$cov(N_{IV}, \epsilon_{USDT}) = 0 \tag{8}$$

Figure 9: Instrument Test: scatter plot of the number of daily addresses transacting with the Tether Treasury with the total number of wallets holding a control group of stablecoins



Note: Figure presents a scatter plot of the daily total users of Tether (left) and the number of unique addresses transacting with the Tether Treasury (right) against the corresponding number of addresses that hold a control group of stablecoins USDC, Paxos, and TrueUSD. The total number of addresses using each stablecoin are given by the $Network$ variable available on Coinmetrics. The number of addresses transacting with the Treasury is calculated using the history of Tether transactions available via the Omni, Ethereum, and Tron blockchains. Sample period is April 1st, 2017 to March 31st, 2020.

We now test whether the absolute level and volatility of peg deviations are directly impacted by the number of unique addresses transacting with the Treasury, $N_{USDT,T}$ in the columns (I) and (II) of Table 6. The reduced form estimates suggest a 1-unit increase in investor addresses transacting with the Treasury leads to a decline in peg deviations by 3.1 basis points, and a decline in volatility of peg deviations by 5.4 basis points.[35]

[35] We do not mean to suggest a 1:1 mapping from each unique wallet address to a unique investor. This may overstate the number of unique investors transacting with the Treasury if, for example, a single investor holds multiple unnamed wallet addresses. We provide the full extent of our information on the identity of wallets transacting with the Tether Treasury in Appendix C. While we note the Ethereum network has a significant number of unnamed wallets, we find an increased presence of multiple cryptocurrency exchanges transacting with the Treasury on the Ethereum blockchain.

Table 6: Effects of the number of unique addresses transacting with the Tether Treasury on the size and volatility of Tether peg deviations

	I	II	III	IV	V
	$\|p_t - 1\|$	σ_t	$N_{USDT,T}$	$\|p_t - 1\|$	σ_t
N	-3.07***	-5.36***		-9.17***	-15.41***
	(0.53)	(0.88)		(1.40)	(2.26)
N_{IV}			0.0009***		
			(0.0001)		
R-squared	0.01	0.02	0.42		
No. observations	1093	1093	1093	1093	1093
IV First Stage	No	No	Yes	No	No
IV Second Stage	No	No	No	Yes	Yes

Note: Table presents regressions of the absolute level and volatility of deviations of the peg. The absolute level of deviations is denoted by $|p_t - 1|$, and σ_t is calculated based on a measure of intra-day volatility of the price, both measured in basis points. $N_{USDT,T}$ measures the daily number of unique addresses transacting with the Tether Treasury on the blockchain platforms of Omni, Ethereum, and Tron. N_{IV} measures the total number of addresses transacting with a control group of stablecoins, USDC, Paxos, and TrueUSD. In columns (III) and (IV) we instrument $N_{USDT,T}$ with the daily number of addresses transacting with a set of control-group stablecoins, USDC, Paxos, and TrueUSD. Sample is April 1st, 2017 to March 31st, 2020. Price data for currencies obtained from coinapi, and use closing-price data from exchanges Kraken, Bitfinex, and Bittrex.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.

The results of our IV specification are documented in columns (III) through to (V) of Table 6. We first test instrument relevance in the first stage in column (III). A unit increase in the number of addresses holding control-group stablecoins predicts a 0.0009 increase in the number of addresses transacting with the Tether Treasury. A partial F statistic of 178.53 indicates a sufficiently strong instrument for the first stage. In columns (IV) and (V), we present the second-stage results on the effect of the instrumented number of Treasury addresses on peg-price deviations and volatility. A unit increase in the number of addresses transacting with the Treasury leads to decline in the absolute size of peg deviations of 9.2 basis points, and a decline in the intra-day volatility of peg deviations of 15.4 basis points. Based on our estimates, we can compute how much of the increase in peg efficiency from the introduction of the Ethereum blockchain is due to direct arbitrage. The Ethereum blockchain has an average of 4.0 addresses transacting daily, versus the Omni layer which averaged 1.4 addresses per day. The net decline in the absolute size of deviations due to direct arbitrage is then $9.2 \times 2.6 \approx 24$ basis points. Given an efficiency gain of approximately 52 basis points from the Omni to Ethereum blockchain as estimated in Table 4 (based on the full sample), approximately 50% of the efficiency gain is attributed to direct arbitrage access.

4 Stablecoin Prices and Issuance Flows

We have provided evidence of a decentralized mechanism for peg stability: migration to the Ethereum blockchain led to an increase in arbitrage access, and an increase in the efficiency of the peg. A testable implication of the arbitrage mechanism is that flows from the Treasury to the secondary market should be stabilizing, by moving peg price deviations toward zero. We conduct local projections (based on Jordà (2005)) of the value of net inflows from the Treasury to the secondary market on the level of deviations from Tether's parity peg. We denote $Flow_{T\to EX,h}$ as total flows from the Treasury to the secondary market, measured at a daily frequency.[36] The change in the Tether dollar price, $P_{t+h} - P_{t-1}$, is projected on the level of arbitrage flows of investors in equation (9), allowing for feedback effects using lagged price and flows as controls. We hypothesize a negative coefficient β_h, which suggests that positive flows to the secondary market have a stabilizing impact on price.

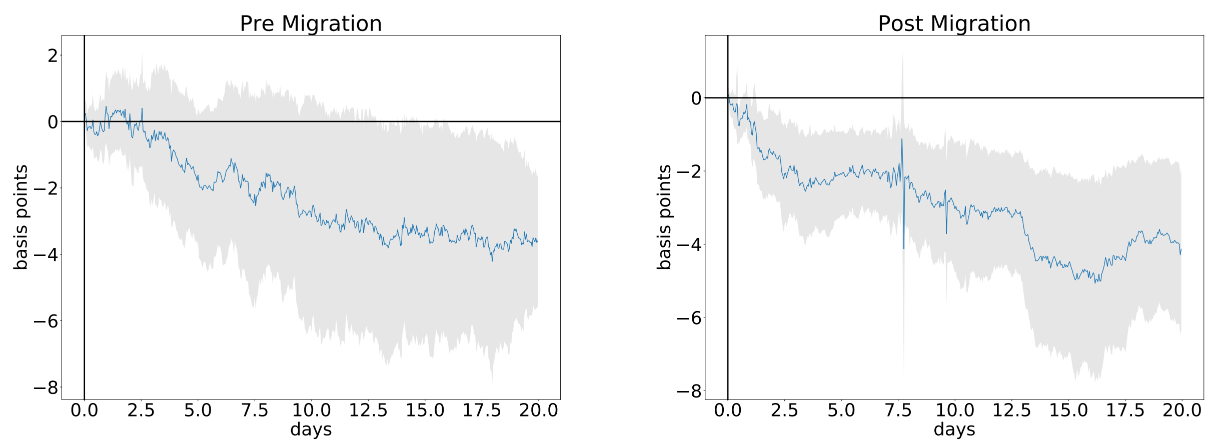
$$P_{t+h} - P_{t-1} = \alpha + \beta_h Flow_{T\to \text{EX},t} + \sum_{k=1}^{L} \delta_k Flow_{T\to EX,t-k} + \sum_{k=1}^{L} \gamma_k (P_{t-k-1} - P_{t-k-2}) + u_t \qquad h = 0, 1, 2, ... \quad (9)$$

Consistent with our hypothesis, arbitrage flows from investors have a stabilizing effect on the Tether/USD price. After dividing our sample based on the introduction of Tether to the Ethereum blockchain, we find a significant price impact of arbitrage flows in the post period, confirming that increased direct access of investors to the Treasury supports the arbitrage mechanism. In the period post migration to the Ethereum blockchain, we measure a price impact of approximately 5 basis points in response to a one standard-deviation shock in secondary-market flows (approximately 7.5 Million USD based on hourly data).[37]

[36] A positive flow to the secondary market is equivalent to a net positive deposit of dollars with the Tether Treasury, aggregated at a daily frequency.

[37] While our analysis in this section focuses on Tether, as it represents approximately 80% of the current stablecoin market, our analysis applies more generally to the class of national-currency-backed stablecoins. We provide data sources and analysis for other national-currency-backed coins in Appendix E.

Figure 10: Response of Tether/USD price to 1 standard deviation shock in flows to the secondary market; Left panel – Pre Ethereum blockchain; Right panel – Post Ethereum blockchain



Note: Figure documents the effect of a 1 standard-deviation shock to net secondary-market flows on the price of Tether/USD. Left and Right panels are for different sample periods based on the introduction of Tether to the Ethereum blockchain. Data for secondary-market flows are from Omniexplorer and Etherscan. Price data are from Coinapi, and take an average of trade-price data from the following trusted exchanges: Bittrex and Kraken. Sample is hourly data from April 1st, 2017 to March 31st, 2020. 24 lags are included in the baseline specification. Gray area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

Feedback trading and arbitrage profits

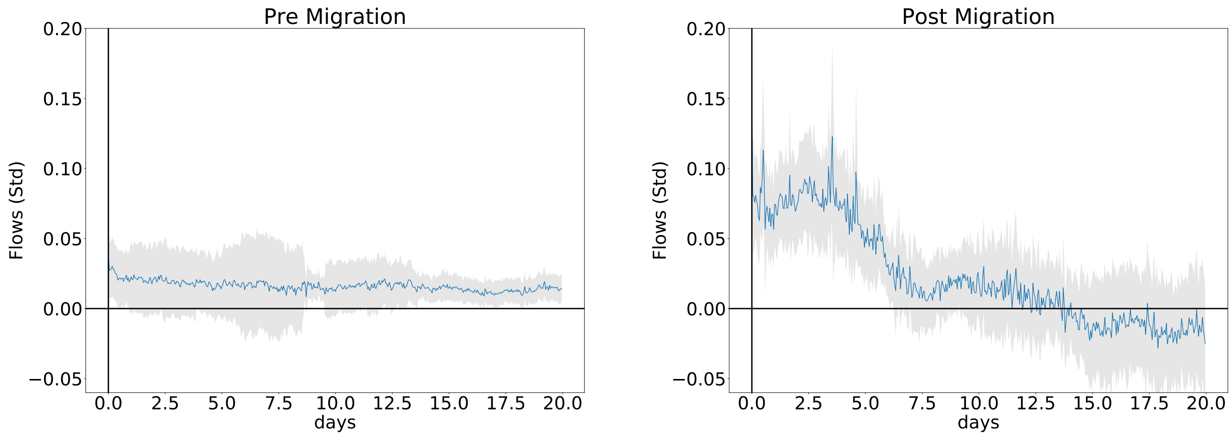
A principal assumption of arbitrage is a feedback mechanism: flows from the Tether Treasury to the secondary market are consistent with a premium. We can test for feedback effects from price to arbitrage flow through specification 10.

$$Flow_{T\to EX,t+h} = \alpha + \beta_h(P_{t-1} - 1) + \sum_{k=1}^{L} \delta_k Flow_{T\to EX,t-k} + \sum_{k=1}^{L} \gamma_k (P_{t-k-1} - 1) + u_t \qquad h = 0, 1, 2, ... \quad (10)$$

Consistent with our hypothesis, arbitrage flows from investors have a stabilizing effect on the Tether/USD price (Figure 11). After dividing our sample based on the introduction of Tether on Ethereum, we find a significant feedback effects from price to arbitrage flows in both periods. A 100 basis point increase in the Tether/USD price leads to a contemporaneous 0.03 and 0.08 standard deviation effect on Tether flows to the secondary market on the Omni and Ethereum blockchains respectively.[38]

[38]While our analysis in this section focuses on Tether, as it represents approximately 80% of the stablecoin market, our analysis applies more generally to the class of national-currency-backed stablecoins. We provide data sources and analysis for other national-currency-backed coins in Appendix E.

Figure 11: Response of Flows of Tether to the secondary market in response to a 100 basis point shock to the Tether-USD price; Left panel – Pre Ethereum blockchain; Right panel – Post Ethereum blockchain



Note: Figure documents the effect of a positive 100 basis point shock to the Tether price on standardized flows of Tether from the Treasury to the secondary market. Left and Right panels are for different periods based on the introduction of Tether to the Ethereum blockchain. Data for secondary-market flows are from Omniexplorer and Etherscan. Price data are from Coinapi, and take an average of trade-price data from the following trusted exchanges: Bittrex and Kraken. Sample is hourly data from April 1st, 2017 to March 31st, 2020. 24 lags are included in the baseline specification. Gray area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

Arbitrage Profits on the Omni and Ethereum Blockchains

Tether deposits

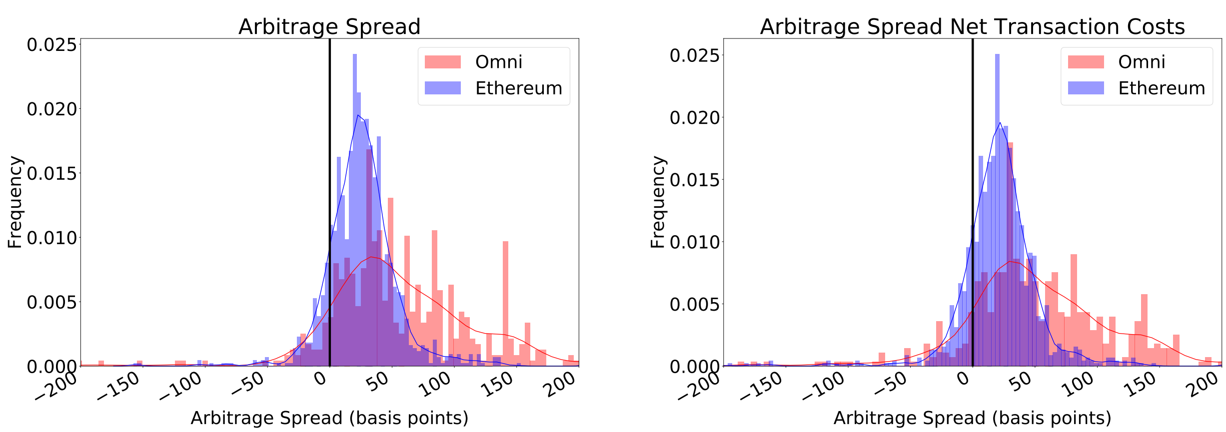
We provide additional evidence on the effects on feedback trading by computing a proxy for the profitability of arbitrage trades. We compute arbitrage profit based on an investor depositing dollars and obtaining Tether at 1:1, and then selling Tether at a premium in the secondary market. We match the timestamp of investor Treasury deposits with the secondary-market price of Tether based on minute-frequency price data from trusted exchanges Bitfinex, Bittrex, and Kraken, three of the most liquid exchanges in the Tether/Dollar market. We assume an arbitrage sequence where an investor deposits dollars with the Tether Treasury, and then contemporaneously sells Tether in the secondary market. The arbitrage spread is then defined, in USD, as the difference $p_{USDT} - 1$, where p_{USDT} is the dollar price of Tether at the exchange. The resulting profit we calculate, on a per-trade basis, is the amount deposited with the Tether Treasury multiplied by the arbitrage spread at that moment.

In constructing the arbitrage spreads and profits, we assume the transaction sequence is contemporaneous, and there are no delays in the processing of each transaction due to queuing or latency time of transactions. This measure of arbitrage profits is an upper bound due to the existence of transaction costs, such as bid-ask spreads, and slippage costs due to price impact.

We now control for transaction costs in two ways. Assuming the transaction price is at the mid-point between bid and ask, we subtract half the bid-ask spread. To estimate slippage costs, we use our prior estimates on the price impact of arbitrage flow, where we find a 1 standard deviation change in arbitrage flow to the secondary market (approximately 7.5 million USD) leads to a 5 basis point decline in the Tether price. For example, for a deposit of 1 million, the slippage cost is then calculated as $\frac{1}{7.5} \times 5 = \frac{2}{3}$ basis points. A histogram of arbitrage spreads (including a measure net of transaction costs) on the Omni and Ethereum blockchains is provided in Figure 12. The distribution of arbitrage spreads is more dispersed on the Omni blockchain, and both blockchains have a majority of deposits, 87% and 84% respectively, that coincide with a secondary-market price above the peg.

We summarise the statistics of arbitrage profits, deposits, and spread for the Omni and Ethereum blockchains in Table 7. Following the migration to the Ethereum blockchain, the average size of deposits fell from 7.6 to 4.0 USD million. Second, arbitrage spreads (net of transaction costs) shrink from an average of 57.1 basis points on Omni to 27.1 basis points on Ethereum. Consequently, median arbitrage profits (net of transaction costs) shrink from an average of 0.005 to 0.002 USD million. The bottom line: increased investor access on the Ethereum blockchain has reduced the extent of arbitrage opportunities. The corresponding decline in the average size of trades, spreads and profits is consistent with a "democratization" of access to arbitrage trades.

Figure 12: Arbitrage spreads calculated as the peg-price deviation $p_t - 1$ at the timestamp of the deposit (left). Arbitrage spreads net of transaction costs (right)



Note: Figure plots histograms of arbitrage spread of Tether deposits on the Omni and Ethereum blockchain (left), and spreads net of transaction costs (right). Spread, measured in basis points, is the difference between the secondary-market price of Tether and the pegged rate of 1. Secondary-market price is based on minute-frequency data that averages prices from the Bitfinex, Bittrex, and Kraken exchanges, sourced from Coinapi. Spread$_c$ is a spread net of transaction costs, which includes bid-ask spreads and an estimate of slippage cost due to the price impact of the trade. Sample is July 12th, 2018 (from which bid-ask prices on the Kraken exchange order book is available) to March 31st, 2020.

Table 7: Summary Statistics of Arbitrage spreads on the Omni and Ethereum Blockchains

	Omni					Ethereum				
	Deposit	Spread	Spread_c	Profit	Profit_c	Deposit	Spread	Spread_c	Profit	Profit_c
count	542	542	542	542	542	1364	1364	1364	1364	1364
mean	7.591	64.022	57.114	-0.012	-0.104	4.031	27.122	22.680	0.011	-0.009
std	36.272	77.834	86.437	0.577	1.425	16.424	35.325	36.649	0.038	0.274
min	0.002	-440.000	-594.333	-13.000	-29.717	0.000	-157.767	-196.700	-0.079	-5.901
25%	0.597	25.000	21.659	0.002	0.001	0.500	10.475	6.831	0.000	0.000
50%	1.498	50.000	47.441	0.007	0.005	1.698	24.708	20.997	0.003	0.002
75%	3.996	95.000	89.130	0.018	0.016	4.000	39.000	35.034	0.011	0.009
max	500.000	437.000	433.167	0.902	0.497	300.000	483.750	464.250	0.870	0.209

Note: Table records statistics on Tether Treasury deposit size, arbitrage spread, and profit (calculated as arbitrage spread times deposit size, trade-by-trade). Spread, measured in basis points, is the difference between the secondary-market price of Tether and the pegged rate of 1. Secondary-market price is based on minute-frequency data that averages prices from the Bitfinex, Bittrex, and Kraken exchanges, sourced from Coinapi. Spread_c is a spread net of transaction costs, which includes bid-ask spreads and an estimate of slippage cost due to the price impact of the trade. Profit is computed as the product of spread and deposit size, and is measured in USD Millions. Sample is July 12th, 2018 (from which bid-ask prices on the Kraken exchange order book is available) to March 31st, 2020.

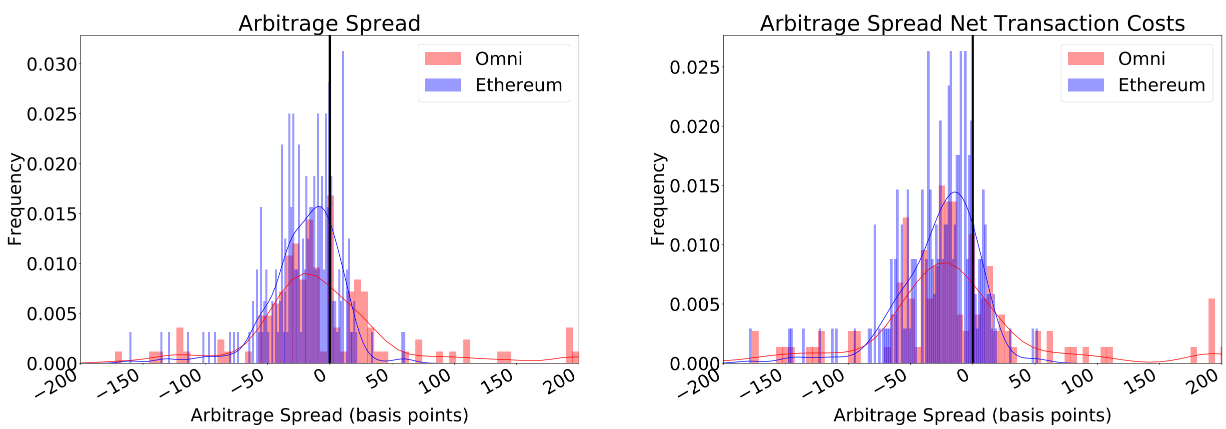
Tether Redemptions

Similar to our analysis of Tether deposits, we can also calculate arbitrage profits from redemptions of Tether to the Treasury. The arbitrage sequence is when an investor buys Tether contemporaneously in the market, and sell their Tether to the Treasury at a 1:1 rate. The arbitrage spread is then defined, in USD, as the difference $1 - p_{USDT}$, where p_{USDT} is the dollar price of Tether at the exchange. The resulting profit we calculate, on a per-trade basis, is the amount deposited with the Tether Treasury multiplied by the arbitrage spread at that moment. A histogram of arbitrage spreads of Tether redemptions (including a measure net of transaction costs) on the Omni and Ethereum blockchains is provided in Figure 13. Both blockchains have a minority of redemptions that earn a positive arbitrage spread, only 32% and 16% respectively, that coincide with a secondary-market price below the peg.

We summarise the statistics of arbitrage profits, deposits, and spread for the Omni and Ethereum blockchains in Table 8. In contrast to our results on Tether deposits, the majority of Tether redemptions earn negative arbitrage spreads and profits. Following the migration to the Ethereum blockchain, the average size of redemptions fell from 25.1 to 6.9 USD million. Second, arbitrage spreads (net of transaction costs) shrink from an average of -11.1 basis points on Omni to -29.3 basis points on Ethereum. Median arbitrage profits (net of transaction costs) slightly increase from an average of -0.005 to -0.003 USD million.

In analysing Tether deposits and redemptions, we find stronger evidence for an arbitrage motive based on deposits of Tether, but not for redemptions of Tether. One reason for this asymmetry may be due to idiosyncratic liquidity needs of the investor (i.e. they want to liquidate their holdings of Tether and other cryptocurrency investments into dollars, or alternatively liquidate Tether to hold deposits with an alternative stablecoin). Alternatively, redemptions may occur due to institutional features such as chain swaps, in which Tether tokens are transferred from one blockchain to another. For example, if the Binance cryptocurrency exchange transfers Tether from their Omni wallet to their Ethereum wallet, the chain swap will record a Tether redemption with Omni and a Tether deposit with Ethereum. These transactions are independent of the arbitrage mechanism we have outlined.[39] Finally, speculation on Tether and concerns on collateral risk may play a role. For example, investors may decide to liquidate their Tether holdings due to reports that Tether is not fully backed by reserves, for example in response to the April 30th, 2019 report on Tether being only backed by 74% cash or cash equivalents.

Figure 13: Arbitrage spreads calculated as the peg-price deviation $1 - p_t$ at the timestamp of the redemption (left). Arbitrage spreads net of transaction costs (right)



Note: Figure plots histograms of arbitrage spread of Tether redemptions on the Omni and Ethereum blockchain (left), and spreads net of transaction costs (right). Spread, measured in basis points, is the difference between the pegged rate of 1 and the secondary-market price of Tether. Secondary-market price is based on minute-frequency data that averages prices from the Bitfinex, Bittrex, and Kraken exchanges, sourced from Coinapi. Spread$_c$ is a spread net of transaction costs, which includes bid-ask spreads and an estimate of slippage cost due to the price impact of the trade. Sample is July 12th, 2018 (from which bid-ask prices on the Kraken exchange order book is available) to March 31st, 2020.

[39]For more detail on chain swap events, please refer to Appendix C

Table 8: Summary Statistics of Arbitrage spreads on the Omni and Ethereum Blockchains

	Omni					Ethereum				
	Redemption	Spread	Spread_c	Profit	Profit_c	Redemption	Spread	Spread_c	Profit	Profit_c
count	152.00	152.00	152.00	152.00	152.00	208.00	208.00	208.00	208.00	208.00
mean	25.090	7.384	-11.076	0.197	-0.006	6.879	-22.601	-29.333	-0.018	-0.033
std	48.603	142.850	137.955	1.074	1.189	12.315	36.457	39.704	0.054	0.084
min	0.000	-545.000	-547.989	-0.870	-6.915	0.000	-246.733	-276.233	-0.423	-0.797
25%	1.275	-33.250	-51.667	-0.023	-0.043	0.100	-33.300	-45.026	-0.014	-0.019
50%	7.808	-11.950	-20.667	-0.000	-0.005	2.000	-16.500	-20.833	-0.002	-0.003
75%	29.861	24.500	12.829	0.038	0.004	6.125	-1.567	-5.535	-0.000	-0.000
max	300.000	551.000	416.167	11.020	8.323	73.000	60.500	52.174	0.116	0.057

Note: Table records statistics on Tether Treasury redemption size, arbitrage spread, and profit (calculated as arbitrage spread times deposit size, trade-by-trade). Spread, measured in basis points, is the negative of the difference between the secondary-market price of Tether and the pegged rate of 1. Secondary-market price is based on minute-frequency data that averages prices from the Bitfinex, Bittrex, and Kraken exchanges, sourced from Coinapi. Spread_c is a spread net of transaction costs, which includes bid-ask spreads and an estimate of slippage cost due to the price impact of the trade. Profit is computed as the product of spread and redemption size, and is measured in USD Millions. Sample is July 12th, 2018 (from which bid-ask prices on the Kraken exchange order book is available) to March 31st, 2020.

5 Empirical Evidence: Fundamentals of Peg Deviations

In this section we test channels through which stablecoins trade at a premium or discount. We present evidence that premiums arise in times of increased volatility in non-stable cryptocurrency markets. Notable examples include the crash of Bitcoin in early 2018 and the COVID-19 crisis of 2020. We document an example of speculation on Tether in October 2018, when Bitfinex temporarily suspended convertibility of dollar deposits. This signalled to investors that Tether may not have been fully collateralized, and Tether traded at a discount of approximately 500 basis points, with significant increases in bid-ask spreads. All data used in this section, including transaction data used to construct order flow, are discussed further in the data appendix A. We rationalise stablecoin premiums and discounts in an illustrative model in appendix F.

Liquidity Fundamentals

We quantify factors that determine pricing in the Tether/USD market. We identify two such factors, order flow, which is a measure of net buying pressure, and cryptocurrency volatility. Determinants of Tether's value are difficult to model in traditional ways, e.g., with macroeconomic fundamentals such as inflation and interest-rate differentials. We draw instead from the medium-of-exchange role in monetary theory to posit that the price of Tether is driven by factors connected to Bitcoin- and Tether-market liquidity.

Order Flow

The first determinant of Tether returns we examine is order flow. Order flow is a measure of net buying pressure in the secondary market and, viewed through the lens of information models in microstructure theory, is the primary means through which dispersed information in the market is expressed and aggregated in price-setting. We construct a measure of order flow using transaction data provided by cryptocurrency vendor Coinapi. This includes a history of trades from a series of exchanges that trade in the Tether/USD pair.[40] This dataset provides the timestamp of each trade, together with the amount of underlying Tether in each trade, and a true-or-false variable *taker side sell* which we use to construct the sign of each transaction.

The exchange follows a maker-taker structure. The market maker is the provider of liquidity, and typically submits limit orders to the exchange with a specified bid and ask price. The takers are typically private investors who submit market orders for Tether, and are the aggressor of the transaction. When the *taker side sell* column reads true, this signifies that the taker is selling Tether and buying USD. The price they are willing to sell Tether is the bid price offered by the market maker. Conversely, when *taker side sell* is false, the taker is buying Tether and selling USD. They buy Tether at the ask price offered by the market maker. Using this signing convention we can construct a measure of order flow as the difference between buyer- and seller-initiated transactions, expressed in the following equation where T_k is the transaction, B indicates it is buyer-initiated, S indicates it is seller-initiated, and V_{T_k} is the amount of the transaction.

$$OF_t^{vol} = \sum_{k=t_0}^{k=t} V_{T_k} \left(\mathbb{1}[T_k = B] - \mathbb{1}[T_k = S] \right) \tag{11}$$

Volatility of Cryptocurrency Markets

We construct a measure of intra-day price volatility in the BTC/USDT market. To calculate intra-day volatility, we use transaction data of the BTC/USDT pair in the Binance exchange at 5-minute intervals to construct 5-minute returns. We then calculate the average sum of squared returns over 5-minute intervals over the trading day, and take the square root. This fundamental captures the safety premium of Tether; in market downturns, investors want to liquidate to a store of value. Stablecoins have lower intermediation costs and lower latency time of transactions, with bank wires taking significantly longer than a transaction executed on the blockchain. We hypothesize that this results in investors choosing to liquidate unstable cryptocurrencies to stablecoins, as opposed to dollars, causing Tether to trade at a premium in

[40]Exchanges that trade significantly in Tether/USD are Bitfinex and Kraken. For the baseline results we use the Kraken exchange as it has the highest volume of trades, and the earliest history (starting in April 2017).

times of increased risk in cryptocurrency markets.

Determinants of Tether premiums and discounts

Following Evans and Lyons (2002), we estimate equation (12), where $\Delta p_t = p_t - p_{t-1}$ measures the difference between the closing dollar price of Tether today and the prior day. OF_t measures the net of buyer-initiated trades for Tether over the concurrent 24 hours.

$$\Delta p_t = \alpha + \beta OF_t + u_t \tag{12}$$

We find that order flow conveys significant information (Table 9). A one standard-deviation change in order flow (which we measure as \$3.8 million based on our estimation period for combined trading in the Bitfinex, Bittrex, and Kraken exchanges) leads to an approximately 10 basis-point increase in the dollar price of Tether, where 100 basis points is \$0.01. Alternatively, a 100 basis-point move in the dollar price of Tether then requires an approximate \$40 million change in net trading. We then condition the order-flow equation on subsets of the sample. In column (II), we condition on the USDT price being within 1 standard deviation of parity. In columns (III) and (IV), we condition on the price being less than 1 standard deviation, and greater than 1 standard deviation respectively.

The estimated elasticity of price changes to order flow is significantly higher than estimates for national currencies, e.g., in Evans and Lyons (2002). Those authors find net trading of \$1 billion in the USD/Deutschemark market in 1995 led to a 50 basis point change in the exchange rate. Our estimates are significantly higher likely due to relative differences in liquidity between the stablecoin and national-currency forex markets.[41] The high elasticity of price to net trading in the stablecoin market is also due to the role of private investors in arbitraging deviations from parity.[42]

Finally, we show in column (IV) that order flow has much larger price impact when Tether trades at significant premiums. In this case, flows from the Tether Treasury to the secondary market begin to occur as a potential stabilizing mechanism. To the extent these arbitrage flows impact the order book in a systematic way, this explains the increased price impact of order flow. For example, in response to Tether trading at a premium, an investor deposits dollars with the Treasury, obtains an equivalent amount of Tether at a price of 1.0, and sells it at the

[41] Daily trading volume in USD markets in 1995 is approximately \$1 trillion according to BIS figures. In our sample, the daily average trading in the Kraken exchange is approximately \$5 million.

[42] Another related paper on order flow in fixed exchange rate regimes is (Killeen et al., 2006), which analyses the transition from fixed to floating of the currencies under the European Monetary System (EMS). They propose that under fixed exchange rates, the sensitivity of order flow goes to zero under a perfectly credible regime because the central bank stands ready to offset any private-sector order flow. Therefore order imbalances have price impact of zero. Alternatively, in our setting, stablecoin issuers are passive, and so even under a perfectly credible regime, private investors are required to initiate trades in the market to arbitrage peg deviations.

higher secondary-market price via a market order at the best bid. This results in an increase in seller-initiated transactions, meaning negative order flow, and price stabilizing toward the peg.[43]

Table 9: Price Impact estimates of Signed Order Flow

	I	II	III	IV
	Δp	Δp	Δp	Δp
OF	9.49***	9.19***	11.97	35.07***
	(1.73)	(1.34)	(11.60)	(11.07)
Intercept	-0.69	0.44	28.00*	-53.74***
	(1.73)	(1.31)	(15.81)	(9.79)
R-squared	0.03	0.05	0.01	0.13
No. observations	1104	956	78	70
Full Sample	Y	N	N	N
$\lvert p_{t-1} - 1\rvert < 1sd$	N	Y	N	N
$p_{t-1} - 1 < -1sd$	N	N	Y	N
$p_{t-1} - 1 > 1sd$	N	N	N	Y

Note: Table presents regressions of the daily change in the USD price of Tether on a measure of daily order flow. Order flow is constructed as the net of buyer-initiated transactions for the Tether/USD pair, where a buy transaction is reported as +1 when the buyer of Tether is the aggressor. Order flow and trade price data are from Coinapi. Sample is daily data from April 1st 2017 to March 31st, 2020, and consolidates trade data from three trusted exchanges: Bitfinex, Bittrex, and Kraken. 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.

Determinants of Tether premiums and discounts

We now regress the deviation of the Tether price from the peg, $p_t - 1$, on signed order flow OF_t, as well as a measure of intra-day price volatility of the BTC/USDT pair, $\sigma_{BTC,t}$, as expressed in equation 13.

$$p_t - 1 = \alpha + \beta_1 OF_t + \beta_2 \sigma_{BTC,t} + u_t \tag{13}$$

Table 10 provides evidence that liquidity fundamentals have an important role in explaining deviations from the peg. In column (I), we present the results of regression 13 for the full sample.

[43] If the investor is also a market maker (such as a crypto exchange), they could alternatively post competitive limit-order offers to sell. This action could have an opposing effect on measured order flow since it can trigger buyer-initiated trades.

We then condition on subsets of the sample in columns (II), (III), and (IV). In column (II) we condition on the USDT price being within 1 standard deviation of parity. In columns (III) and (IV) we condition on price being more than 1 standard deviation below parity, and greater than 1 standard deviation above parity respectively. We find positive effects of an increase in Bitcoin volatility on the Tether price. Based on column (I), a 1 per cent (100 basis point) increase in BTC/USDT intra-day price volatility raises the price of Tether by approximately 5 basis points, all else equal. This suggests a potential risk-hedging motive for holding Tether in periods of extreme Bitcoin volatility. One of Tether's features is its store-of-value function for crypto investors.

Table 10: Determinants of Tether/USD Price – Liquidity Fundamentals

	I	II	III	IV
	$p_t - 1$	$p_t - 1$	$p_t - 1$	$p_t - 1$
OF	21.98***	10.92***	13.22	22.31***
	(3.33)	(1.46)	(13.03)	(7.37)
σ_{BTC}	0.05***	0.03***	-0.01	0.03
	(0.01)	(0.01)	(0.05)	(0.03)
Intercept	-18.92***	-6.51*	-177.68***	112.35***
	(5.00)	(3.58)	(20.04)	(15.19)
R-squared	0.11	0.14	0.03	0.08
No. observations	953	802	70	79
Full Sample	Y	N	N	N
$\|p_{t-1} - 1\| < 1sd$	N	Y	N	N
$p_{t-1} - 1 < -1sd$	N	N	Y	N
$p_{t-1} - 1 > 1sd$	N	N	N	Y

Note: Table presents regressions of the deviation from parity in the USD price of Tether on variables capturing liquidity in the Tether/USD and BTC market. OF measures order flow and is constructed as the net of buyer-initiated transactions for the Tether/USD pair, where a buy transaction is signed positively when the buyer of Tether is the aggressor. σ_{BTC} is the intra-day volatility of the BTC/USDT price sourced from the Binance exchange, measured in basis points. Sample is April 1st, 2017 to March 31st, 2020 and consolidates trade data from three trusted exchanges: Bitfinex, Bittrex, and Kraken. 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.

Discussion of stablecoin premiums and discounts

Why do Tether and other stablecoins exhibit safe-haven properties? In periods of risk, investors need to liquidate into a store of value. Portfolio rebalancing toward Tether and other stablecoins provide this function with minimal intermediation costs. As noted, on some exchanges for example, there are long processing lags for dollar withdrawals to comply with intermediation procedures. Fees are also often imposed when dollar withdrawals are frequent or large.[44] We provide evidence of safe-haven demand with reference to two major risk-off events in Appendix D. During the first event in January 2018, BTC prices fell by 65%, and in the second event on March 12th, 2020, BTC prices fell by 50%. In response to these events, we document (i) significant stablecoin in excess of 200 basis points in the former and 500 basis points in the latter and (ii) a selloff of Bitcoin primarily in the exchanges that offer conversion to dollars, and (iii) negative cumulative order flow in the Bitcoin/stablecoin market. This evidence is suggestive of a rebalancing toward stablecoins during risk-off events for unstable cryptocurrencies.

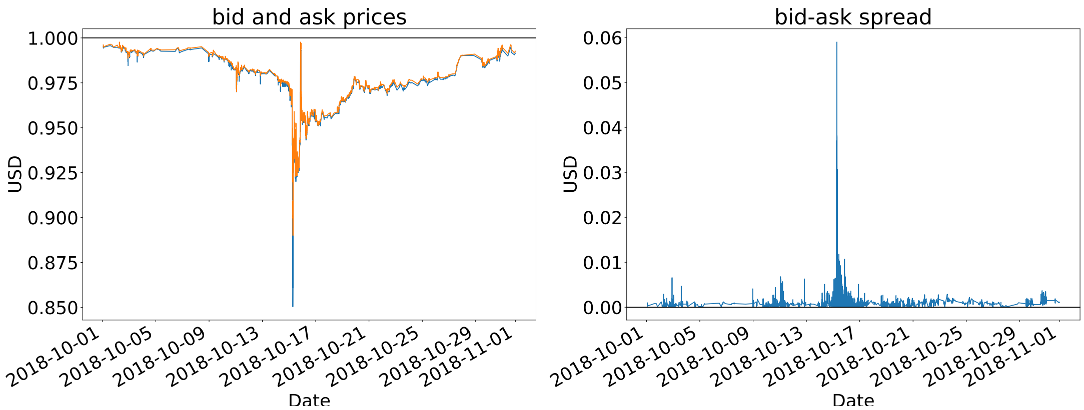
We rationalise stablecoin premiums in an illustrative model in appendix F. We model a stablecoin premium through added costs of using dollars as a vehicle to buy the model's risky asset. The premium arises due to institutional differences between exchanges that offer conversion to stablecoins, "crypto-to-crypto" exchanges, versus less liquid exchanges that offer conversion to dollars. Stablecoin premiums during risk-off events arise due to an increased preference to sell Bitcoin on exchanges that offer instantaneous settlement. Through the model, the preference for immediacy causes investors to transact in exchanges that offer conversion to stablecoins, and increasing its relative price.

Stablecoin discounts can be due to mismanagement by the issuer, a lack of collateral, or speculation. A speculative attack on Tether occurred on 11th October, 2018, by the exchange Bitfinex. On that day, Bitfinex decided to temporarily pause national-currency deposits (USD, GBP, EUR, JPY) for certain customer accounts in the face of processing complications.[45] Figure 14 shows the unfolding of this event on Tether's dollar price and on measures of bid-ask spreads. Tether transaction prices fall to 95 cents on October 15th. While the whole-sample average bid-ask spread is between 0.1 and 0.15 of a cent, with a standard deviation of 0.2 cents, there are evident spikes in bid-ask spreads, suggesting an information asymmetry in response to speculative events. In particular, the sharp fall in bid and ask prices corresponds to a spike in the width of the spread of 6 cents (600 basis points). Widening bid-ask spreads is consistent with a story of increased collateral risk as buyers and sellers of Tether are unsure of the fundamental trading price and whether others might have superior information.

[44] For more information, see announcements by Bitfinex: https://bit.ly/2NEzITW and https://www.bitfinex.com/posts/311. As noted previously, Bitfinex states it will take investors 7 to 15 days to make dollar withdrawals from their platform in order to comply with intermediation procedures. Bitfinex has also introduced transaction costs of a 3% fee for investors who make more than two dollar withdrawals a month, or for withdrawals larger than $1 million in a given month.

[45] See https://medium.com/bitfinex/fiat-deposit-update-october-15th-2018-18ddd276c3fd.

Figure 14: Tether/USD prices and Bid-Ask Spreads



Note: Schematic illustrates the movement in Tether/USD price and bid-ask spreads. Transaction, bid, and ask prices from Coinapi trade and order-book data. Volume data are from Cryptocompare. Sample is October 2018.

6 Conclusion

Focusing on issuance as the central object that keeps stablecoins stable, we identify which own-market stability mechanisms best account for issuance and addressed this in two ways. First, we exploit a unique natural experiment: The April 2019 migration of Tether from the Omni to the Ethereum blockchain, which resulted in a large increase in arbitrageur access to the Tether Treasury. We employed a difference-in-differences design using a set of control-group stablecoins that share similar institutional features, but did not undergo a structural change of blockchain. This too produces a large and statistically significant reduction in peg deviations. The second way we test the stability mechanism focuses specifically on arbitrage flows. We estimated the effects of arbitrage flows on peg prices based on local projections in a way that controls for feedback effects in price and flow. We find that a one standard-deviation change in net flows (approximately 7.5 Million USD based on hourly data) reduces peg-price deviations by up to 5 basis points, consistent with arbitrage being the central stabilizing mechanism.

A second contribution of this paper was to pin down the sources of stablecoin price variation in the first place, i.e., the fundamentals that explain premiums and discounts. A key difference between national-currency pegs and stablecoin pegs is that the distribution of stablecoin price deviations is two-sided, whereas distributions of national-currency pegs are generally one-sided toward discounts. The first (proximate) fundamental we examine is order flow. We use order-book data across multiple crypto exchanges and find a positive shock to order flow inducing an increase in the dollar price of Tether of roughly one percent per $40 million in order flow. We then examine fundamentals such as the intensity of Bitcoin trading based on Tether serving in the market as the principal vehicle currency for trading Bitcoin. An increase in the intra-day price volatility of the BTC/USDT market leads to Tether-price premiums, evidence more specifically that Tether and other stablecoins serve as safe-haven assets. The effect is particularly pronounced in turbulent periods such as the Bitcoin price-crash in January of 2018 and the COVID-19 economic shock in March of 2020. Stablecoin discounts, on the other hand, occur due primarily to risk of insufficient collateral. We spotlight a speculative attack on Tether in October of 2018 when investors were uncertain whether Tether was fully collateralized due to a move by Bitfinex to suspend dollar convertibility. This induced a decline in Tether's price and a sharp rise in bid-ask spreads.

Facebook announced in 2019 its intention to launch Libra – now called Diem – a global stablecoin. Our analysis sheds light on the mechanisms by which a global stablecoin like Diem can maintain its peg. Our findings indicate that a decentralized system supporting a peg can work well even when the primary issuer remains passive and depends on the actions of arbitrageurs to stabilize price around the peg. As stablecoins become even more widely used, new mechanisms for stabilizing price around the peg will inevitably arise. Introductions of forward and futures markets on stablecoins, for example, will attract arbitrage capital from regulated financial institutions, inducing still greater stability, so long as the pegs remain fully credible and collateralized.

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Appendices

We provide a roadmap of each section of our appendix.

1. Appendix A provides a summary of the datasets used in the analysis. This includes a description of Tether issuance data used to construct our flow measure, as well as price and transaction data.

2. Appendix B provides a summary of transparency and governance measures undertaken by stablecoins.

3. Appendix C provides statistics on Tether issuance on the Omni and Ethereum blockchains, including key wallets and concentration of flows.

4. Appendix D provides evidence of stablecoin premiums for the 6 largest stablecoins by market capitalization during the Covid panic of 2020.

5. Appendix E presents data and evidence on stabilizing mechanisms for other major stablecoins.

6. Appendix F presents an illustrative model to capture the two-sided distribution of stablecoin deviations.

A Data

We have four sources, each supporting a different aspect of our analysis.

1. **Coinapi**: Online subscription with access to open, high, low, close, and volume (OHLCV) trade data and order-book data from multiple crypto exchanges.

2. **Omniexplorer and Etherscan**: Blockchain explorers that contain transaction data of individual wallets, used to obtain new issuance/redemptions of stablecoin tokens to compute flows of these tokens to the secondary market.

3. **Cryptocompare**: Price and trading volume data for currencies (based on a representative list of crypto exchanges).

4. **Coinmetrics**: Provides fundamentals data on the network value, computing power of cryptocurrency mining, and number of unique addresses.

Coinapi

Coinapi offers a monthly subscription with access to their data api, which gives historical cryptocurrency OHLCV, trade, and order-book data. We outline in Table 11 the specific trading pairs, coin symbols, and types of data that we employ. To use the api, we followed `https://github.com/coinapi/coinapi-sdk`, which gives sample code for querying the api.[46] The trade data are used to construct order-flow data, as it has a boolean "taker_side_sell" variable that is a seller-initiated transaction if True, and buyer-initiated if False. Orderbook data for exchanges are also provided, useful for bid and ask prices. To construct bid-ask spreads, we take the highest bid and the lowest ask out of a set of 20 quotes for a specific time period, which gives us a lower bound for the effective bid-ask spread at any given point in time.

[46]Modifications were made to customize results; api requests are limited to 100,000 data points per day.

Table 11: Coinapi Data

Data Type	Coin Symbol	Exchange	Sample Period
OHLCV, Trade and Order-Book Data	USDT_USD	Kraken	04/17-03/20
OHLCV, Trade and Order-Book Data	USDT_USD	Bitfinex	12/18-03/20
OHLCV, Trade and Order-Book Data	USDT_USD	Bittrex	05/18-03/20
OHLCV	USDC_USD	Kraken	01/20-03/20
OHLCV	PAX_USD	Bittrex	01/19-03/20
OHLCV	BUSD_USD	Binance	10/19-03/20
OHLCV	TUSD_USD	Bittrex	06/18-03/20
OHLCV	DAI_USD	Bitfinex	04/18-03/20
OHLCV and Trade Data	BTC_USDT	Binance	08/17-03/20
OHLCV and Trade Data	BTC_USDC	Binance	12/18-03/20
OHLCV and Trade Data	BTC_PAX	Binance	11/18-03/20
OHLCV and Trade Data	BTC_BUSD	Binance	09/19-03/20
OHLCV and Trade Data	ETH_DAI	Coinbase	05/19-03/20

Where multiple cryptocurrency exchanges offer the same data, we choose the exchange that (i) has the longest time series and (ii) is one of ten exchanges that has "trusted volume" according to a report filed by the SEC.[47] The report tests exchanges for fraudulent activities (e.g., suspicious variability in bid-ask spreads, systematic patterns in histograms of transaction size) and finds that the exchanges listed in Table 12 do not have the telltale patterns in trading volume or spreads. We note that of the ten exchanges, two do not offer an onramp for trading national currencies, Binance and Poloniex. Similarly, two platforms, Itbit and Bitflyer, only accepted national currencies at the time the SEC report was written.

[47]See https://www.sec.gov/comments/sr-nysearca-2019-01/srnysearca201901-5164833-183434.pdf.

Table 12: Trusted Exchanges According to SEC Report

Exchange	National Currencies	Stablecoins
Binance	N	Y
Bitfinex	Y	Y
Bitstamp	Y	Y
Bittrex	Y	Y
Bitflyer	Y	N
Coinbase	Y	Y
Gemini	Y	Y
Itbit	Y	N
Kraken	Y	Y
Poloniex	N	Y

Omniexplorer and Etherscan

We use this dataset to construct net flows from the stablecoin issuer to the secondary market. The addresses of the issuers are listed in Table 15. We follow Wei (2018) in obtaining transactions of Tether grants (creation of new tokens) and revokes (redemptions) from the Omniexplorer api. Tether's ID is 31, and using the api call in Table 14, we retrieve the entire history of Grants and Revokes.[48] Etherscan is an explorer of all transactions recorded on the Ethereum blockchain, available at https://etherscan.io/. This includes transactions for Tether and other national-currency-backed coins. The history of token grants and revokes is exportable to a data-readable format.

For Etherscan, we first need the contract address of each coin, which one can find by searching the ticker ID of the coin (USDT, USDC, PAX and TUSD) in the search portal on https://etherscan.io/. The contract addresses are listed in Table 13. To find the Etherscan address, you need the contract address of the coin, followed by the wallet address to get the entire history of transactions for a given wallet. For example, the contract address for USDC is 0xa0b86991c6218b36c1d19d4a2e9eb0ce3606eb48, and the wallet address for Tether grants is 0x0000000000000000000000000000000000000000. Therefore, the Etherscan url for USDC grants is given by: https://etherscan.io/token/0xa0b86991c6218b36c1d19d4a2e9eb0ce3606eb48?a=0x0000000000000000000000000000000000000000. The addresses for Tether Grants/Revokes of tokens are listed in Table 14, and the Treasury addresses of four coins are listed in Table 15. (The only national-currency-backed coin that does not have a Treasury listed is TrueUSD.) We note that the addresses for Tether Grants for USDC, PAX, and TUSD are identical; when

[48]Please refer to https://api.omniexplorer.info/ on how to obtain transaction histories.

searching for transactions of the grant address, each coin has a different contract address and so it is a unique identifier. Using the following data, we compute net changes in Tether in circulation to the secondary market as the level of token grants less redemptions. Similarly, we measure net flows in and out of the Tether Treasury wallet. Subtracting net flows into Treasury from the net of grants and revokes of tokens gives a measure of total flows to the secondary market.

Table 13: Stablecoin Contract Addresses

Coin	Blockchain	Contract Address
USDT	Etherscan	0xdac17f958d2ee523a2206206994597c13d831ec7
USDC	Etherscan	0xa0b86991c6218b36c1d19d4a2e9eb0ce3606eb48
PAX	Etherscan	0x8e870d67f660d95d5be530380d0ec0bd388289e1
TUSD	Etherscan	0x97A9F6F941b54c373cec38b8Dc7565CcDBbE75C6

Table 14: Stablecoin Issuer Wallet Addresses

Coin	Blockchain	Wallet Address
USDT	Omni Explorer	https://api.omniexplorer.info/v1/properties/gethistory/31
USDT	Etherscan	0xc6cde7c39eb2f0f0095f41570af89efc2c1ea828
USDC	Etherscan	0x0000000000000000000000000000000000000000
PAX	Etherscan	0x0000000000000000000000000000000000000000
TUSD	Etherscan	0x0000000000000000000000000000000000000000

Table 15: Stablecoin Issuer Wallet Addresses

Coin	Blockchain	Wallet Address
USDT	Omni Explorer	1NTMakcgVwQpMdGxRQnFKyb3G1FAJysSfz
USDT	Etherscan	0x5754284f345afc66a98fbb0a0afe71e0f007b949
USDC	Etherscan	0x55fe002aeff02f77364de339a1292923a15844b8
PAX	Etherscan	0x5195427ca88df768c298721da791b93ad11eca65
TUSD	Etherscan	N/A

Cryptocompare

Cryptocompare provides public access to price and volume data based on volume-weighted averages of price quotes and trades from 150 cryptocurrency exchanges, available via their api https://min-api.cryptocompare.com/.[49] We use this resource to measure total traded volume in the Tether/USD and BTC/USD pairs. We also use cryptcompare to determine the daily closing price of non-stable cryptocurrencies BTC, ETH, XRP, BCH, and LTC.

Coinmetrics

We use coinmetrics for the following series, based on the data dictionary available at https://coinmetrics.io/data-downloads, using the tickers listed in Table 16.

Hash Rate: The mean rate at which miners are solving hashes in a give time interval. Hash rate is the speed at which computations are being completed across all miners in the network. The unit of measurement varies depending on the protocol.

Number of Unique Addresses: The sum count of unique addresses that were active in the network (either as a recipient or originator of a ledger change) in that time interval. All parties in a ledger change-action (recipients and originators) are counted. Individual addresses are not double-counted if previously active.

Following Bhambhwani et al. (2019), we use the hash rate and number of unique addresses as fundamentals to model price determination of non-stable cryptocurrencies such as BTC and ETH.

Table 16: Coinmetrics Indicators

Variable	Ticker	Pairs
Hash Rate	HashRate	BTC, ETH
Number of Unique Addresses	AdrActCnt	BTC, ETH,USDT,USDC,PAX,TUSD

[49]For more detail on how quotes and traded volume are calculated, see: https://www.cryptocompare.com/media/27010937/cccagg_methodology_2018-02-26.pdf.

B Governance and Transparency Measures

We provide here more institutional detail on the transparency measures undertaken by stablecoins. Tether Inc. acknowledges in its white paper that there are potential problems with the security of its dollar deposits. It lists the following five points (Tetherinc., 2016):

1. *We (Tether Inc.) could go bankrupt*
2. *Our bank could go insolvent*
3. *Our bank could freeze or confiscate the funds*
4. *We could abscond with the reserve funds*
5. *Recentralization of risk to a single point of failure*

Of the following points, Tether claims dollar deposits are still redeemable if Tether Inc. goes bankrupt or becomes insolvent. For the third and fourth point, they state that their bank is familiar with holding cryptocurrency deposits, and that absconding with funds is unlikely due to its public charter. The fifth point is the biggest issue with Tether: While Tether in circulation uses a decentralized system of exchange by being on the blockchain, all dollar deposits are held in a centralized issuer. There is settlement risk if the dollar deposits are vulnerable to attack from an outside party. One way for Tether to mitigate the central point of failure is by having sufficient reserves in its balance sheet. This point is tackled differently by newer stablecoins, e.g., Paxos, which has FDIC-insured deposits, and USDC tokens via decentralization of the issuer with multiple licenses to create tokens, and finally by protecting counterparty risk through the use of escrow accounts.

The main transparency measure undertaken by Tether is the publication of its daily balance sheet. As stated in the Tether White Paper (Tetherinc., 2016), Tether follows a "proof of reserves" process in which they account for all liabilities (Tether in circulation) on the blockchain. This includes all platforms Tether currently trades on, the three main platforms being Omni explorer, Ethereum, and Tron according to its balance sheet in April, 2020. Every Tether in circulation is backed, in principle, by a dollar deposit. Tether Inc. releases a daily balance sheet reporting their total dollar deposits. For example, on April 2nd, 2020, their balance sheet, according to `https://wallet.tether.to/transparency`, says the Total Assets, which is the bank deposits, is equal to $6,480,678,611.74, and total Tether in circulation is given by $6,349,160,932.47. The excess of assets over liabilities is $131,517,679.27. As a percentage of total assets, that is approximately 2%. We note that this matches very roughly what a risk-free rate would yield annually on fixed-income instruments.[50]

[50]While not explicit about their interest-bearing assets, the following article documents that Tether does earn interest on its dollar deposits: `https://cryptobriefing.com/tether-interest-stablecoins/`.

Audit Reports

Similar to Tether, we have monthly auditing reports for TrueUSD and USDC that are managed by accounting firms Cohen & Co and Grant Thornton respectively. For example, a typical audit report on TrueUSD, from the December 2019 statement, states the following: *"The issued and collateralized TrueUSD...do not exceed the balance of the escrow accounts reported above. The supply of TUSD tokens can be reconciled to transactions within the escrow accounts..."*.

Similarly, a statement on USDC's accounting firm Grant Thornton, December 2019 statement, asserts the following: *"USD Coin (USDC) tokens issued and outstanding = $519,628,995 USDC US Dollars held in custody accounts = $520,537,729...the issued and outstanding USDC tokens do not exceed the balance of the US Dollars held in custody accounts."*

Statements confirm that total assets exceed total liabilities and that the stablecoins are at least 100% collateralized.

Crypto-Collateralized Coins

The above discussion accounts for national-currency-backed coins; a different set of rules of transparency and accountability apply to the crypto-collateralized coin DAI. DAI is encoded on the Ethereum blockchain using a smart contract. This is a set of protocols that are enforced by computer code. In the case of DAI, the smart contract is designed to enforce liquidation of the collateral if the collateral ratio goes below 150% (the ratio of Ethereum collateral to total value of DAI borrowings), and will impose a liquidation penalty to the borrower. In contrast to national-currency-backed coins, there is no centralized risk of the issuer absconding with funds, as the smart contract means any Ethereum collateral deposited by the investors is locked in the contract.

Due to the nature of the Ethereum collateral, this currency requires additional features for stability of the secondary market price. One such tool is the DAI borrowing rate, which controls the level of borrowings of DAI, and by extension flows of DAI into the secondary market. This feature is controlled through a continuous voting process where voters can choose a DAI stability rate, with the weight of votes given by their share of total DAI borrowings. While the system consults all users on the stability rate, there are occasions where a "whale," an investor with significant market power, can manipulate the stability rate.[51]

[51] See https://bit.ly/2WoJRXY for more details.

C Tether Treasury Flows on Omni and Ethereum

In this section, we document in more detail specific wallet addresses that transact with the Tether Treasury on the Omni and Ethereum blockchains. Here is a summary of our analysis.

1. On the Omni blockchain, the main address transacting with the Tether Treasury is the Bitfinex exchange. Nearly all Tether (up to 90%) in circulation was channelled from the Treasury to Bitfinex in 2017 and 2018.

2. The Ethereum blockchain, in contrast, is much less concentrated, with a total number of 172 unique addresses transacting with the Treasury versus 71 on the Omni blockchain.

3. On the Ethereum blockchain, we find a shift in net flows from the Treasury toward other exchanges. For example, the Binance exchange is the largest recipient of net flows from the Treasury on the Ethereum blockchain in the sample (January 2019-March 2020).

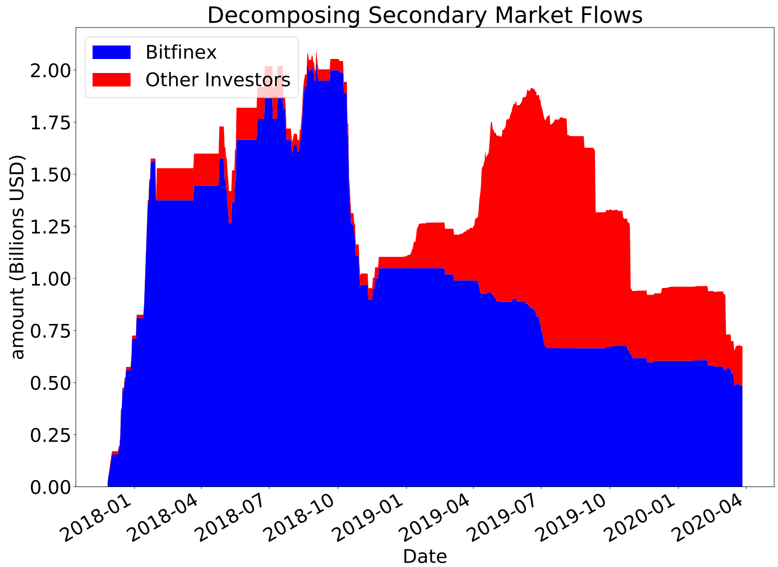
Treasury Transactions on Omni Blockchain

We have the entire history of Tether Treasury transactions on the Omni layer. Using the columns of "reference address" and "sending address" (where the sending address is transferring Tether tokens to the "reference address") we can construct a measure of net flows from the Treasury to each individual address. This provides a measure of bilateral flows from the Treasury to each investor.[52]

Over the entire sample (November 2017-March 2020), we record total net flows of Tether to each wallet address. We observe 71 unique addresses transacting with the Tether Treasury, Tables 17 and 18 record the largest positive and negative net flows respectively on the Omni blockchain. The key address transacting with the Omni layer is the Bitfinex exchange. While it only accounts for 26% of total positive net flows during the entire sample, prior to 2019 Bitfinex was the dominant address. For example, if we restrict our sample to the end of 2018, we observe only 11 unique addresses transacting with the Treasury, and Bitfinex accounted for 83% of outgoing flows from the Treasury during that period. In Figure 15 we plot the cumulative bilateral flows with respect to Bitfinex, and classify all other addresses as "Other Investors." We find that nearly all outgoing flows from the Treasury were distributed via Bitfinex until 2019. This is indicative of Tether distribution that begins with dollar deposits first deposited with Bitfinex, which then proceeds to distribute tokens to other exchanges for trading in the secondary market.

[52] The flows we report do not yield the final distribution of Tether holdings by each investor. For example, an investor that transacts with the Treasury may then distribute all of its tokens to other exchanges. Our focus on investor transactions with the Treasury is to identify the extent to which direct arbitrage with the Treasury matters for peg efficiency and stability.

Figure 15: Decomposing Flows to the Secondary Market via Bitfinex on the Omni Blockchain.



Note: Decomposes net flows to the secondary market from the Tether Treasury to private wallets on the Omni blockchain. Sample is November 2017 through March 31st, 2020. Up to the end of 2018, nearly all flows to the secondary market are to the exchange Bitfinex. In 2019 we see a shift in composition toward non-Bitfinex wallet addresses on the Omni Blockchain.

Table 17: Omni Explorer: Breakdown of Treasury Net Flows

Address	Net Flow (Tether)	Share	Cumulative Share	Identity
1KYiKJEfdJtap9QX2v9BXJMpz2SfU4pgZw	4.85E+08	0.260	0.260	Bitfinex
3LCx3zGC9wsaF5iLDg8do6TdwfJ9yCcwMn	2.11E+08	0.113	0.374	
1GjgKbj69hDB7YPQF9KwPEy274jLzBKVLh	2.00E+08	0.107	0.481	
16pj8cny6Doga428ZNKuz5eXBikLYf7YD1	1.08E+08	0.058	0.539	
16hvRK9Y7dUhzehy3nMHRfVGPq3vqKR33K	8.02E+07	0.043	0.582	
1GrZG61AoHVn8UZcHiX2gJgAkajRaTo1C3	7.07E+07	0.038	0.620	
1Kqn34iJnzTamYRV2ie2qsD1WEAy6BBhvF	6.79E+07	0.037	0.657	
3D2GQZ741GUiJebeTG2pyWQzHtuK6R9VS9	5.49E+07	0.030	0.686	
1KiJkugknjgW6AHXNgVQgNuo3b5DqsVFmk	5.21E+07	0.028	0.714	
1C9J4C8JwB4q7L97Uyqvo12Wo9xFoZ5aAC	4.70E+07	0.025	0.740	

Note: Table reports top-10 positive net flows of Tether to recipients. A positive net flow is defined as a net flow of Tether to the recipient address. Shares are calculated based on positive net flows only. Dataset records all trades between the Tether Treasury and private wallet addresses on Omniexplorer. We omit Tether grants (issuer) addresses in the list of recipients. Sample from November 2017 to March 31st, 2020. Identity of recipients is noted based on publicly available information on Omniexplorer and the Tether rich list, available at https://wallet.tether.to/richlist .

Table 18: Omni Explorer: Breakdown of Treasury Negative Net Flows

Address	Net Flow (Tether)	Share	Cumulative Share	Identity
1FoWyxwPXuj4C6abqwhjDWdz6D4PZgYRjA	-1.00E+09	7.36E-01	0.736	Binance
13TMLJdKgCnQLiv4Bx65DqpKvgnC2pdLLC	-1.34E+08	9.83E-02	0.834	
1RUBt5inB17W7kjg5ceRhLQa9GgrRtuXt	-1.00E+08	7.35E-02	0.908	
1DUb2YYbQA1jjaNYzVXLZ7ZioEhLXtbUru	-6.98E+07	5.13E-02	0.959	
1Po1oWkD2LmodfkBYiAktwh76vkF93LKnh	-3.70E+07	2.72E-02	0.986	Poloniex
15bQJVbQPsScK4mkjR7Pk2xt6guT2VTLEJ	-1.00E+07	7.35E-03	0.994	
1PktPwDM1h85GW4ab7Xgv83TALXJ71rXLt	-5.00E+06	3.67E-03	0.997	
3GyeFJmQynJWd8DeACm4cdEnZcckAtrfcN	-2.20E+06	1.62E-03	0.999	Kraken
33DunQKkUsvLr4GBTAtAj3KKYueyxeCYLR	-9.60E+05	7.05E-04	0.9995	
1zgmvYi5x1wy3hUh7AjKgpcVgpA8Lj9FA	-4.00E+05	2.94E-04	0.9998	

Note: Table reports top-10 negative net flows of Tether to recipients. Shares are calculated based on negative net flows only. Dataset records all trades between the Tether Treasury and private wallet addresses on Omniexplorer. We omit Tether grants (issuer) addresses in list of recipients. Sample from November 2017 to March 31st, 2020. Identity of recipients is noted based on publicly available information on Omniexplorer and the Tether rich list, available at https://wallet.tether.to/richlist.

Chain Swaps

We note there are some addresses that have net negative flows of Tether on the Omni blockchain, i.e., Tether redemptions. The largest negative net flow recorded is with the Binance exchange, with a total of approximately $1 billion worth of Tether redemptions. Many of the transactions between the Binance exchange and the Tether Treasury on Omni explorer can be explained as chain swaps.

This is a special type of transaction that moves a cryptocurrency from one blockchain to another.[53] In this case, many of the redemptions we see on the Omni blockchain are actually chain swaps; the Binance exchange is effectively transferring its Tether tokens to the Ethereum blockchain.[54] The two legs of the chain swap are:

1. On the Omni blockchain, Binance will redeem all Tether tokens, and Tether will burn these tokens, reducing the Tether supply.

2. The redemptions of Tether are directly offset by the Tether Treasury on the Ethereum blockchain sending tokens to Binance's address on the Ethereum blockchain.

The chain swap is neutral with respect to Tether supply. We identify the following chain-swap events based on public announcements by Tether, and record them in Table 19.

[53] For more information on chain swaps, see https://tether.to/explained-chain-swaps/.

[54] Motivation for chain swaps is driven by rebalancing of Tether across blockchains based on client demands. For example, if there is a larger network of clients on the Ethereum blockchain, cryptocurrency exchanges are incentivized to chain swap Tether from Omni to Ethereum in order to meet client demands on Ethereum.

Table 19: Chain Swaps of Tether from the Omni to the Ethereum Blockchain

Exchange	Date	Amount (million Tether)	Blockchain (Redemptions)	Blockchain (Creation)
Bittrex	August 5th, 2019	275	Omni	Ethereum
Binance	September 12th, 2019	300	Omni	Ethereum
Binance	October 29th, 2019	300	Omni	Ethereum
Binance	December 9th, 2019	200	Omni	Ethereum
Binance	February 20th, 2020	300	Tron	Ethereum
Binance	March 4th, 2020	200	Omni	Ethereum

Note: Table records all chain swaps from the Omni to the Ethereum blockchain. Public announcements are from Tether's tweets page https://twitter.com/Tether_to/. Sample from November 2017 to March 31st, 2020. Blockchain redemptions refers to the burning of Tether tokens, and represents a flow of Tether from the exchange to the Tether Treasury. Blockchain (creation) refers to an outgoing flow of Tether from the Treasury to the exchange on the new blockchain.

Ethereum Blockchain

Trades on the Ethereum blockchain are recorded on Etherscan, a block explorer and analytics platform for Ethereum. The block explorer data is of a similar format to Omni, with the "reference address" and "sending address" named "To" and "From" respectively. We aggregate net bilateral flows from the Treasury to each investor in our sample on Etherscan, which dates from January 2019 through March 31st, 2020. We find 172 unique addresses transacting with the Tether Treasury on Etherscan during our sample from January 2019 to March 31st, 2020. Based on Table 20, the largest positive cumulative flow to a single address is identified as belonging to the Binance exchange. The top-10 addresses account for up to 60% of the total positive net flows on the Ethereum blockchain. This drives home our point that on the Ethereum blockchain a larger set of investors are accessing the Treasury directly. In contrast, Bitfinex, which had a monopoly on distribution on the Omni layer, has negative flows with respect to the Tether Treasury. For two identified Bitfinex addresses, we observe negative net flows during our sample period, suggesting Bitfinex is burning tokens on the Ethereum network (Table 21). In our dataset, a large number of users transacting with the Treasury remain "unnamed" and the addresses therefore unidentified. A possible concern with our analysis is that the same decision-maker may hold multiple wallet addresses. This would violate our interpretation of a one-to-one mapping from unique addresses to unique investors transacting with the Treasury. But the one-to-one interpretation is not necessary for our analysis. Rather, what we have shown is that access to the Treasury was indeed democratized on the Ethereum blockchain, with multiple exchanges being able to deposit dollars directly with the Treasury and in fact doing so. As we discuss in the paper, reasons for Tether having migrated to the Ethereum blockchain and increasing access to arbitrage include: (i) efficiency in deposit/withdrawal process, (ii) arbitrage that is higher frequency, and (iii) increased network effects, with a larger client base and more tokens using the Ethereum blockchain.

Table 20: Ethereum Blockchain: Breakdown of Treasury Positive Net Flows

Address	Net Flow (Tether)	Share	Cumulative Share	Identity
0x3f5ce5fbfe3e9af3971dd833d26ba9b5c936f0be	8.00E+08	0.161	0.161	Binance
0xf44e17140b4c32ef1e9fab15cbcb14074bd832ee	5.00E+08	0.100	0.261	
0x0c7719f1d7ed41271cbba92ec153afa6610228f8	4.73E+08	0.095	0.356	
0x8bb00060531339d1bb24b804c2f1dd5ea84f6857	4.50E+08	0.090	0.447	
0xb1fa690155821bf9191d609593b556048aca517c	1.58E+08	0.032	0.478	
0xf2103b01cd7957f3a9d9726bbb74c0ccd3f355d3	1.55E+08	0.031	0.509	
0xeeb832aa50517d87a58926437b1a3fcfbdae8f6c	1.46E+08	0.029	0.539	
0xe0507a0e9fa4885a9c470567a342281627cdc7be	1.40E+08	0.028	0.567	
0x2db8a54c3d3b16146efaf7b9a776d94e259c8d80	1.37E+08	0.028	0.594	
0x3bfc9abd438306bb2830ae3fac0ad10348a2242c	1.32E+08	0.027	0.621	

Note: Table reports top-10 positive net flows of Tether to recipients. Data include all trades between the Tether Treasury and private investors. We omit Tether grants (issuer) addresses in the list of recipients. Sample from January 2019 to March 31st, 2020. Identity of recipients is provided where possible based on publicly available information in the Etherscan database.

Table 21: Ethereum Blockchain: Breakdown of Treasury Negative Net Flows

Address	Net Flow (Tether)	Share	Cumulative Share	Identity
0x742d35cc6634c0532925a3b844bc454e4438f44e	-3.84E+08	0.501	0.501	Bitfinex 2
0x876eabf441b2ee5b5b0554fd502a8e0600950cfa	-3.03E+08	0.396	0.898	Bitfinex 3
0xa910f92acdaf488fa6ef02174fb86208ad7722ba	-6.85E+07	0.089	0.987	Poloniex
0x0eebbb51cdee449fcfa9ed497c028a6f6080d962	-6.94E+06	0.009	0.996	
0x955cc527a36f125f367078db8b064f1b60df549f	-1.56E+06	0.002	0.998	
0xf9b4b3ad5ae1325579660959a39be343c4135027	-7.44E+05	0.001	0.999	
0xffec0067f5a79cff07527f63d83dd5462ccf8ba4	-5.00E+05	0.001	1.000	Nexo

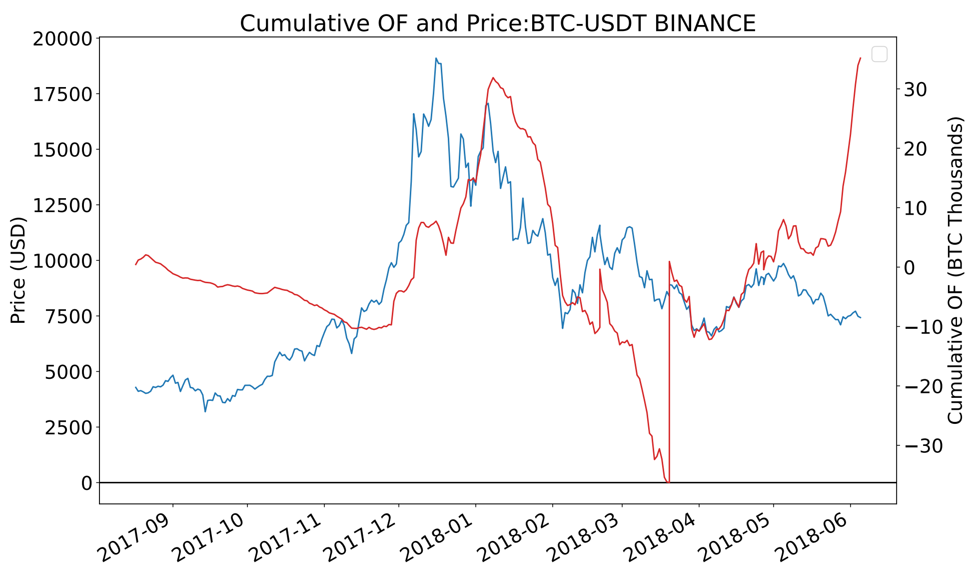
Note: Table reports top-10 negative net flows of Tether to recipients. Data include all trades between the Tether Treasury and private investors. We omit Tether grants (issuer) addresses in list of recipients. Sample from January 2019 to March 31st, 2020. Identity of recipients is provided where possible based on publicly available information in the Etherscan database.

D Stablecoins During Risk-Off events

Safe-Haven demand during January, 2018

To provide evidence of the safe-haven demand during the period from January 6 to February 6, 2018, we first note that there was a decline of up to 65 percent in the price of Bitcoin. While this necessarily implies a relative portfolio shift from Bitcoin to dollars purely from the valuation effect, we observe a similar rebalancing toward Tether during this period. We see clearly a decline in cumulative order flow for BTC during the period of January-February 2018 in Figure 16. Liquidation into Tether is intuitive given Tether is pegged to the dollar, and provides a natural hedge for crypto investors, and proxies as a risk-free cryptoasset. Liquidation into Tether is also the only option for exchanges such as Binance which do not allow conversion into national currencies directly.

Figure 16: Cumulative Order Flow and Price in BTC/USDT



Note: Figure plots cumulative order flow in the BTC-Tether market (red line) against the BTC-Tether price (blue line). Data from Coinapi, which provides trade data for BTC-USDT pair on Binance exchange. Sample is August 2017 to June 2018.

Safe-Haven demand during March, 2020

The COVID-19 economic crisis resulted in a collapse of the BTC market of approximately 40%, as it fell from approximately \$8,000 to \$5,000 from March 12th to 13th. Amidst the widespread sell-off in cryptocurrency markets, there were clear efforts by investors to liquidate into a store of value. To gauge investors incentive to liquidate into a store of value quickly, we use the Ether Network's gas prices. 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 these costs are paid to the miners who authenticate the transactions on the Ethereum blockchain. These prices are denominated in GWEI which is equivalent to one-billionth of one ETH, and they are typically an average of 10 GWEI per transaction. Critically, these units of GWEI provide a proxy for transactions' latency time. For example, on March 29th, 2020, the Ether gas station states that there is transaction cost of 8 units of GWEI for a transaction time less than 2 minutes, 5 units of GWEI for a transaction time less than 5 minutes, and 3 units of GWEI for a transaction time less than 30 minutes.[55]

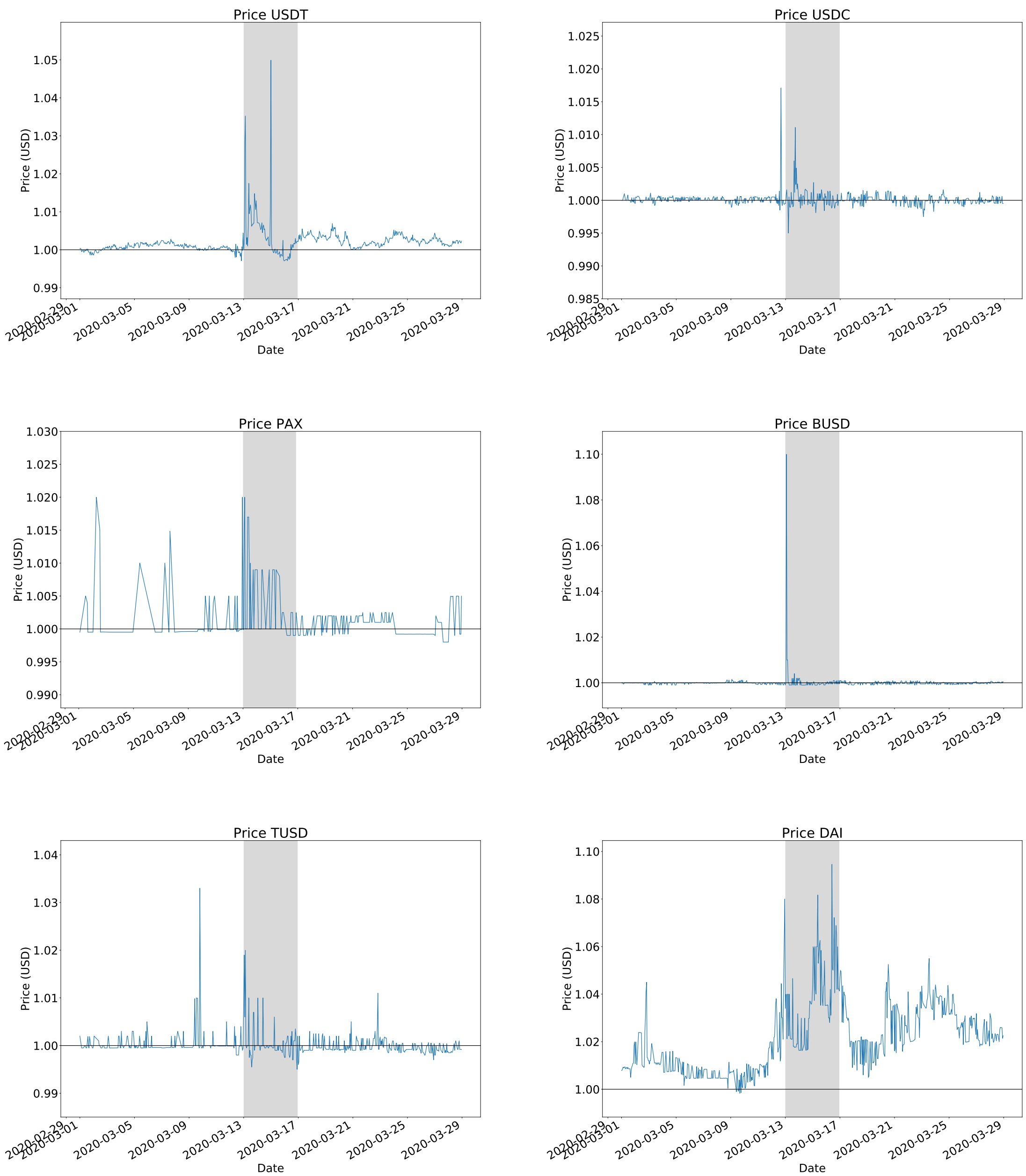
On March 12th, the average gas prices temporarily spiked to over 100 GWEI per transaction from the 10 GWEI average seen just one day prior. There was congestion on the Ethereum blockchain as investors wanted to liquidate unstable cryptocurrencies into stablecoins. The rise in gas costs reflected the cost of latency time; investors were willing to pay more gas costs to liquidate faster.[56]

We plot in Figure 17 the USD price response of the six largest coins by market cap, based on data in March 31st, 2020. Shaded areas indicate the period in which the price of Bitcoin fell by 50%. In all cases, we see a rise in the price of stablecoins of approximately 500 basis points. The largest increase is for BinanceUSD coin, the stablecoin issued by the Binance cryptocurrency exchange. A potential reason why BinanceUSD trades at a premium to the dollar is because Binance platforms do not allow conversion to national currencies directly. Therefore, for investors on the Binance exchange, converting to BinanceUSD is a good option for reducing latency time.

[55] Gas prices, as well as daily amounts of Ether Gas used, are provided in https://ethgasstation.info/.

[56] For more information see https://blockonomi.com/ethereum-gas-prices-surged/.

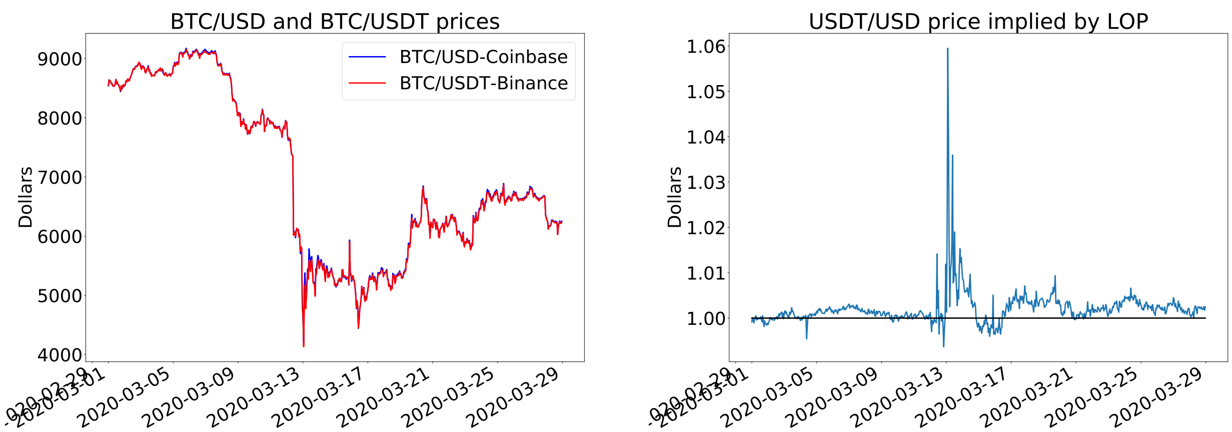
Figure 17: Response of stablecoin prices to negative price shock of Bitcoin in March, 2020



Note: Price (in USD) of 6 largest stablecoins by market cap during March 31st, 2020. Price data are from Coinapi and are hourly, available on cryptocurrency exchanges Binance, Bitfinex, Bittrex, and Kraken. Shaded areas indicate the period when the price of Bitcoin fell approximately 50% from March 12th to March 13th.

We rationalise stablecoin premiums through a model in Appendix F. In the model, stablecoins earn a premium due to the relative intermediation costs of using dollars to purchase cryptoassets. Investors choose to sell BTC during a market downturn on exchanges that offer conversion to stablecoins, like Binance, due to the immediacy of payments. This in turn leads to a price spread between BTC/USDT on stablecoin exchanges relative to BTC/USD on exchanges that offer conversion into dollar (eg. Coinbase). In the left panel of Figure 18, we note the relative difference in BTC/USDT prices and BTC/USD prices on Binance and Coinbase respectively during the market downturn of March 12th, 2020. Binance is a "crypto to crypto" exchange which does not offer conversion into dollars. In contrast, Coinbase is the most popular exchange for conversion into dollars. Using the law of one price, we impute the dollar price of Tether as the ratio of Bitcoin prices across the two exchanges in the right panel of Figure 18. We find significant premiums in excess of 500 basis points on March 12th, 2020, consistent with our narrative of investors demanding immediacy in payments.

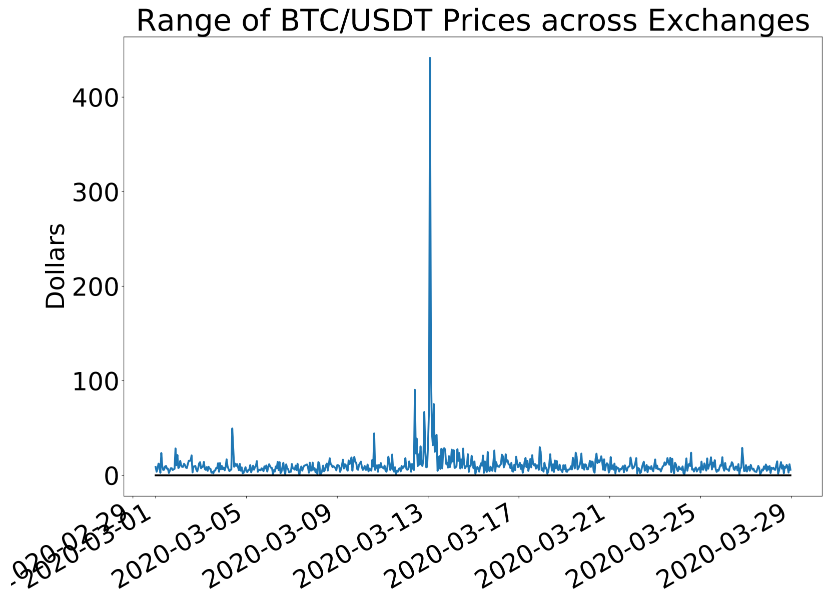
Figure 18: Left panel: Bitcoin prices on Binance (BTC/USDT) and Coinbase (BTC/USD), Right panel: USDT/USD price implied by LOP across two exchanges



Note: Left panel plots BTC/USDT prices and BTC/USD from the Binance and Coinbase exchanges. Right panel plots the dollar price of Tether based on the Law of One price holding across exchanges. Data is hourly and uses closing prices from coinapi for Binance and Coinbase. Sample is March 2020.

Another reason why stablecoins may be a dominant safe asset is that its immediacy in payments enables an investor to conduct arbitrage in the crypto market. We provide suggestive evidence that the Law of One Price (LOP) deviations open across exchanges during a market downturn, by plotting the spread in closing prices between major exchanges that offer the BTC/USDT pair during this period in Figure 19.

Figure 19: Range of BTC/USDT prices across cryptocurrency exchanges

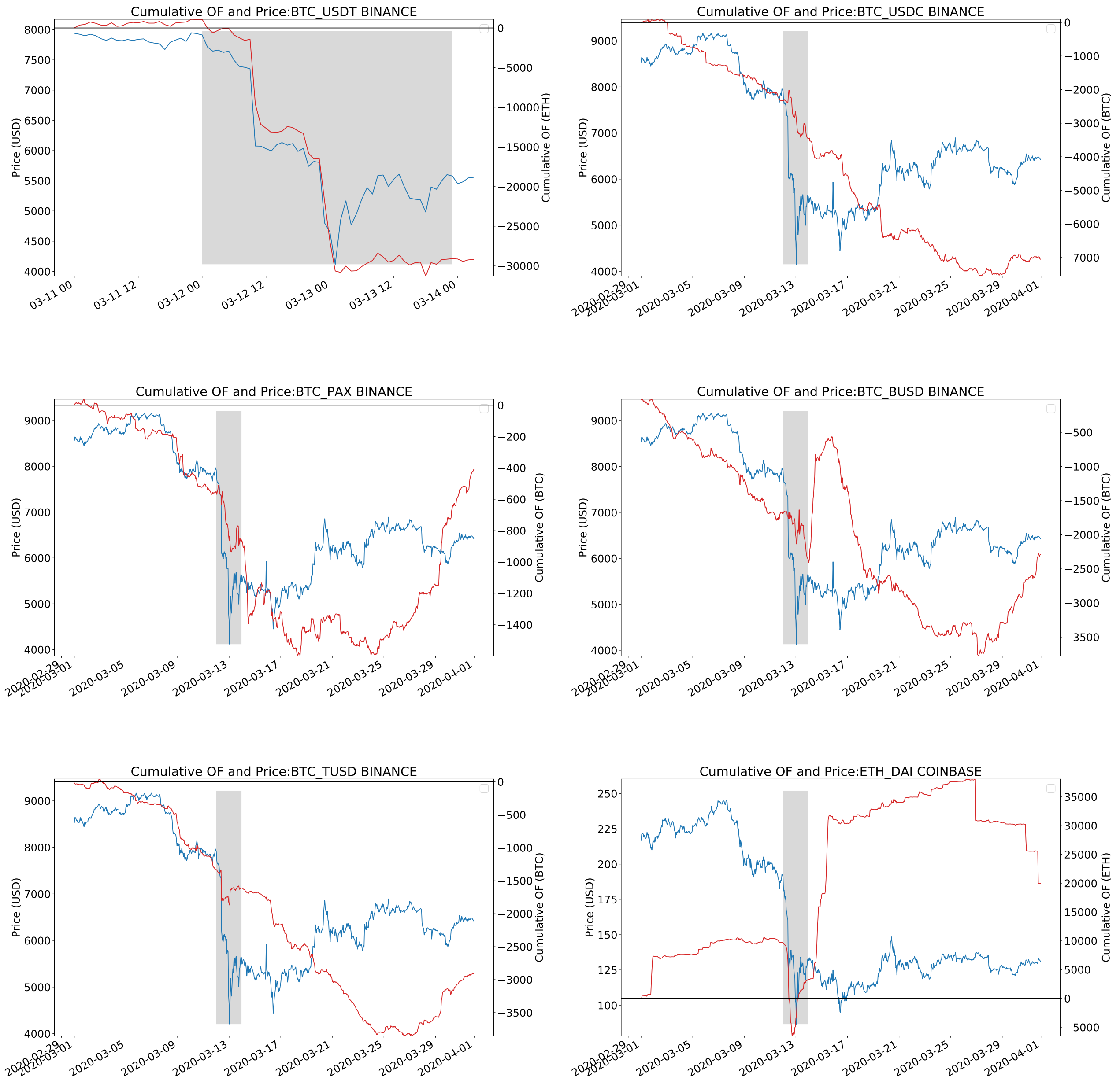


Note: Plot of the difference between maximum and minimum BTC/USDT prices for 4 liquid and trusted cryptocurrency exchanges, Binance, Poloniex, Bittrex, Bitfinex. Data is hourly and uses closing prices from coinapi for all exchanges. Sample is March 2020.

We provide final evidence of a Bitcoin sell-off in Figure 20, which plots cumulative order flow and price of BTC in terms of stablecoins for the five largest market-cap currencies. There is a significant sell-off of BTC during March 12th. For example, on the Binance exchange, there was an approximate 30,000 unit net selling pressure of BTC on March 12th. Similar trends of a decline in cumulative order flow for BTC in other stablecoin markets is evident. For the crypto-collateralized coin DAI, we examine the ETH/DAI market, and a similar trend collapse of the Ether price and decline in cumulative order flow on March 12th is evident; it is not as pronounced, however, as for the national-currency-backed coins.[57]

[57] We reason that as DAI is crypto-collateralized, investors use it more as a speculative investment. Therefore, investors that liquidate ETH into DAI will return to longer Ethereum positions once there is a greater expectation of rising Ethereum prices in the future; we do see a quick turnaround in order flow once the Ethereum price reaches its low.

Figure 20: Response of Bitcoin prices and order flow in BTC/Stablecoin markets, March 2020



Note: Blue line indicates BTC price (in terms of stablecoin), and red line indicates cumulative order flow in BTC. Trade data for BTC/Stablecoin are from Coinapi and is hourly, available on cryptocurrency exchanges Binance, for the national-currency-backed coins USDT, USDC, PAX, BUSD, and TUSD. For crypto-collateralized DAI, we plot the Ethereum price and cumulative order flow in ETH/DAI market on the Coinbase exchange. Shaded areas indicate the period when the price of Bitcoin fell approximately 50% from March 12th to March 13th.

E Data on Other Stablecoins

We provide first supplementary evidence on other national-currency-backed stablecoins. USDC, Paxos, and TrueUSD are among the largest 5 coins by market capitalization as of March, 2020, and are national-currency-backed like Tether. They differ from Tether: USDC decentralises the primary issuer to have multiple issuers with licenses to create USDC tokens; Paxos dollar deposits are insured by FDIC banks; and TrueUSD uses a system of escrow accounts in transactions between investors and the stablecoin issuer. All of these systems assert 100% backing by US-dollar collateral.

We subdivide this section into the following:

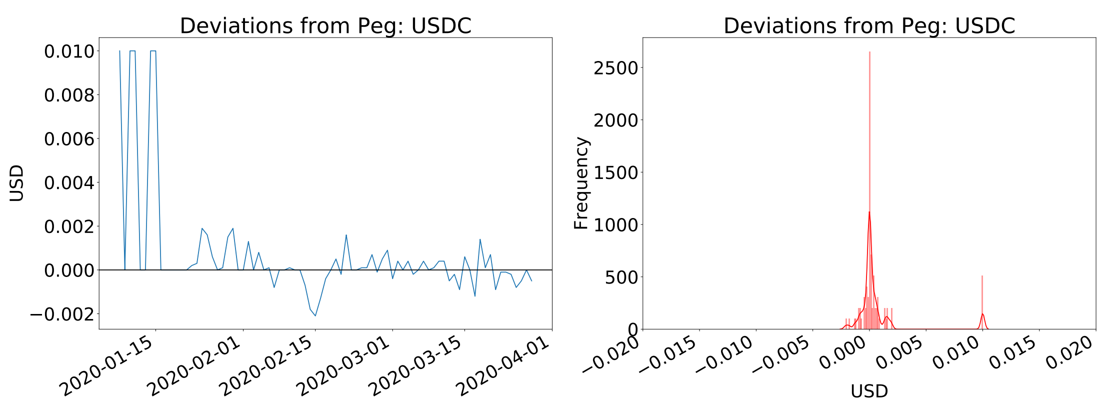
1. Transaction prices and histograms showing a two-sided distribution of deviations.

2. Balance sheets and secondary-market flows.

Transaction Price and Histogram of Deviations

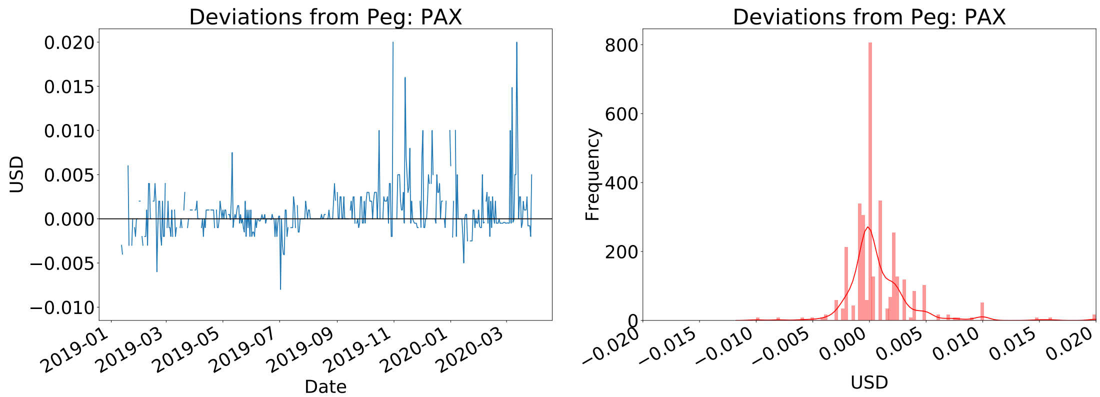
We plot transaction-price deviations from the peg for USDC, Paxos, and TrueUSD. Data are from Coinapi for all coins. We make two general observations based on the following Figures 21, 22, and 23. The first is that deviations are two-sided – these stablecoins trade at both premiums and discounts to the dollar parity peg. The second observation is that deviations are typically persistent, and as indicated in section 1, we note a half-life of deviations that ranges from 5 to 10 days for most coins.

Figure 21: USDC/USD Deviations from Peg and Histogram of Deviations



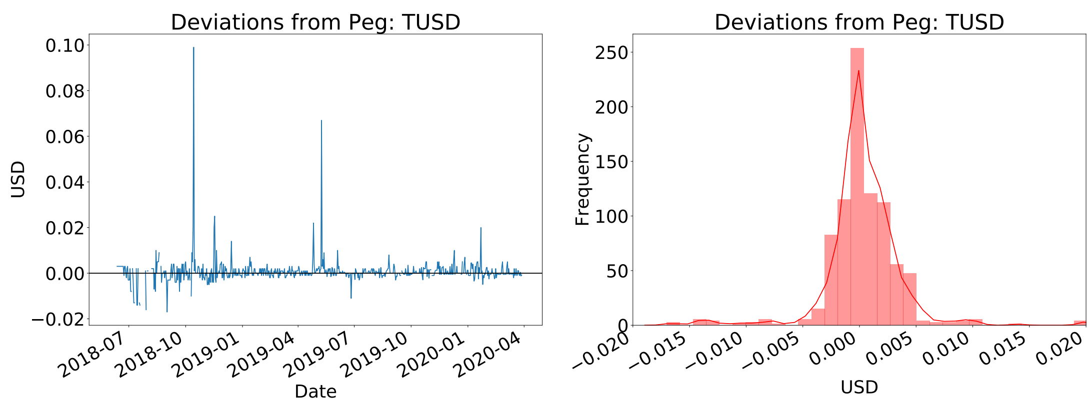
Note: Figure plots deviations of the USDC peg from parity (left panel). A positive deviation indicates USDC trades at a premium. Right panel is a histogram of deviations of the USDC peg. Data from Coinapi. Sample is January 10th, 2020 to March 31st, 2020.

Figure 22: PAX/USD Deviations from Peg and Histogram of Deviations



Note: Figure plots the Paxos deviations of the peg from parity (left panel). A positive deviation indicates Paxos trades at a premium. Right panel is a histogram of deviations of the Paxos peg. Data from Coinapi. Sample is January 2019 to March 31st, 2020.

Figure 23: TUSD/USD Deviations from Peg and Histogram of Deviations

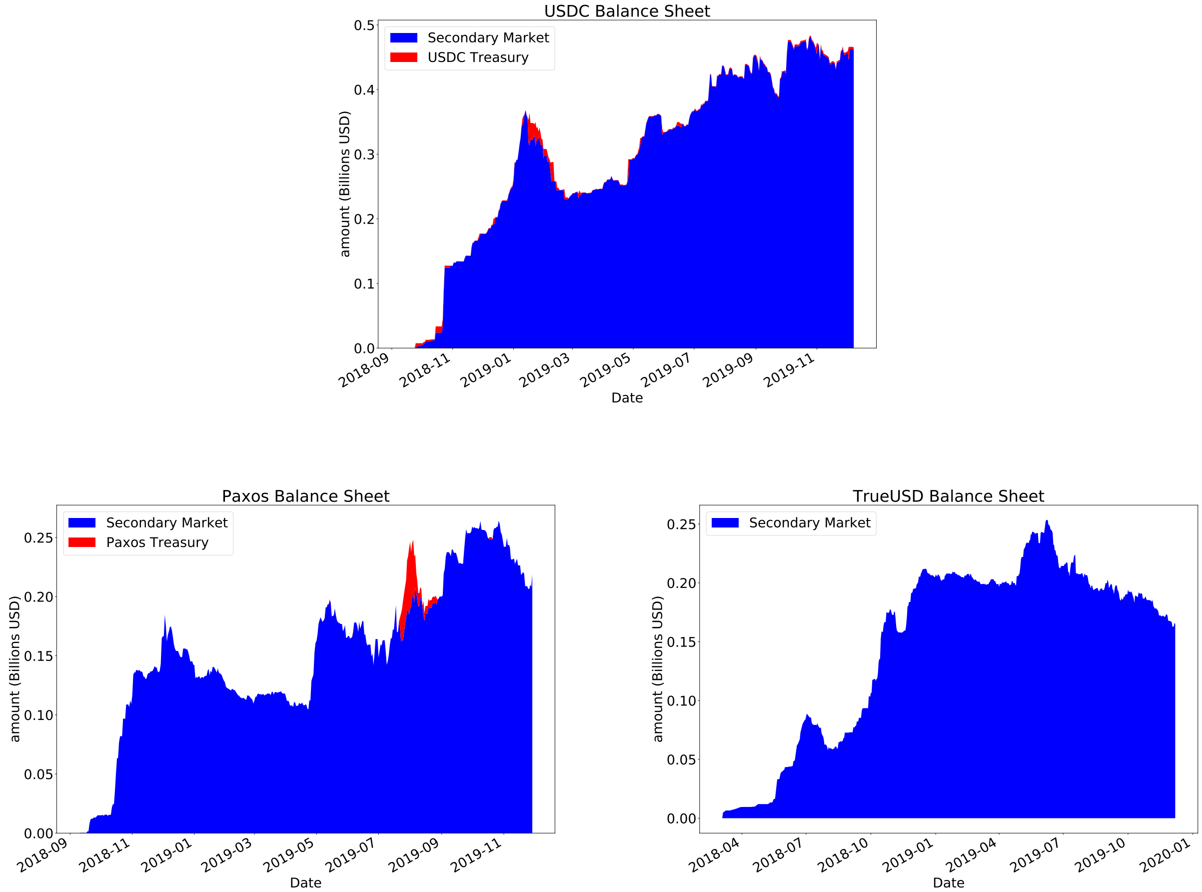


Note: Figure plots the deviations of the TrueUSD peg from parity (left panel). A positive deviation indicates TrueUSD trades at a premium. Right panel is a histogram of deviations of the TrueUSD peg. Data from Coinapi. Sample is June 2018 to March 31st, 2020.

E.1 Balance Sheets of Other Stablecoins

We plot here the balance sheets of other major stablecoins. The data platform we use is Etherscan, which records the entire set of transactions of a given stablecoin on the blockchain. To use Etherscan, we identify the wallet address of the issuer, and the wallet address of the Treasury (where applicable). We can then use the api to extract a set of transactions of a given wallet. Transactions are classified as a "from" or "to". The underlying assumption is that for the set of transactions involving the primary issuer, if the issuer is "from" this indicates a flow from the issuer to the secondary market. Conversely, "to" indicates redemptions and a withdrawal of stablecoin tokens from circulation. Sample period is from introduction of a given coin to Etherscan to November 2019.

Figure 24: Balance Sheet for USDC, Paxos, and TrueUSD



Note: Figure plots the balance sheet of USDC, Paxos, and TrueUSD. Balance-sheet data from Etherscan.

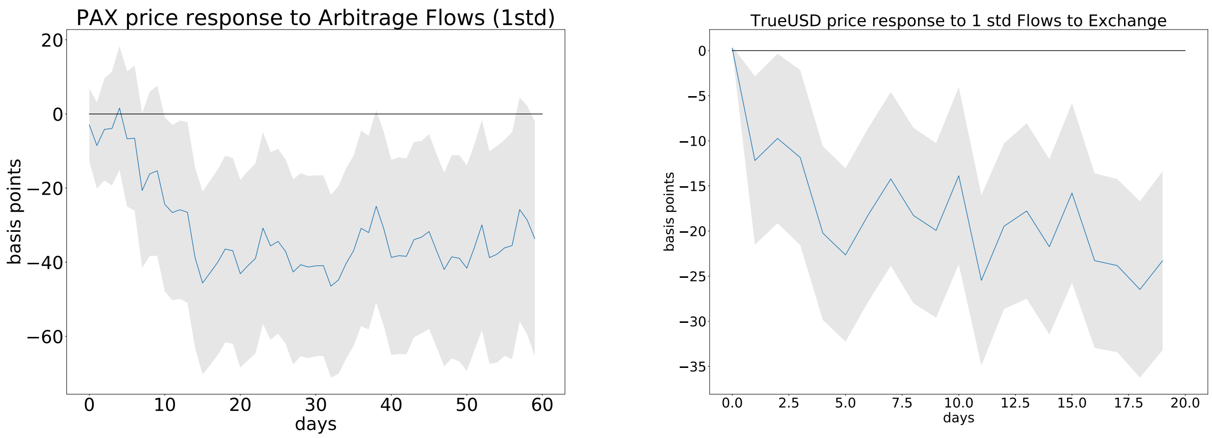
Arbitrage Flows

We estimate the following regression in equation 14 (h equals 0,1,2, ...) to test the stabilizing effect of arbitrage flows on the pegs. The results for Paxos and TrueUSD in Figure 25 suggest a stabilizing effect, on the order of 40 basis points for Paxos and 20 basis points for TrueUSD (for a one-standard-deviation shock in order flow).[58]

$$P_{t+h} - P_{t-1} = \alpha + \beta_h Flow_{T\rightarrow \text{EX},t} + \sum_{k=1}^{4} \delta_k Flow_{T\rightarrow EX,t-k} + \sum_{k=1}^{4} \gamma_k (P_{t-k-1} - P_{t-k-2}) + u_t \quad (14)$$

[58] We do not report results for USDC as our price data currently do not go back far enough, unlike the other two coins.

Figure 25: Response of Paxos (left panel) and TrueUSD (right panel) Prices to a Unit Standard Deviation of Flows to the Secondary Market

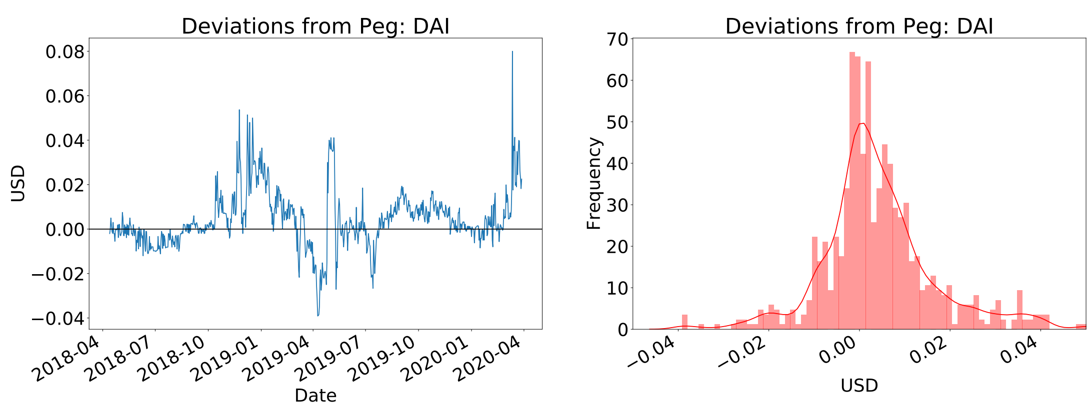


Note: Figure documents the effect of a 1 standard deviation shock to net secondary market flows on the price of Paxos and TrueUSD. Data for secondary-market flows from Etherscan. Price data from Coinapi. Sample is January 2019 to March 2020 in left panel, and June 2018 to March 2020 in right panel. Gray area denotes 95% confidence interval using White heteroscedasticity robust standard errors.

E.2 Crypto-Collateralized Stablecoins

We turn now to the stability mechanisms of DAI, a stablecoin backed by Ethereum collateral. Similar to other national-currency-backed coins, DAI exhibits a two-sided distribution of stablecoin prices, illustrated in Figure 26.

Figure 26: DAI/USD Deviations from Peg and Histogram of Deviations



Note: Figure plots the deviations of the DAI/USD peg from parity (left panel). A positive deviation indicates DAI/USD trades at a premium. Right panel presents a histogram of deviations of the DAI/USD peg. Data are Coinapi. Sample is April 2018 to March 31st, 2020.

The steps that increase DAI supply involve depositing a set amount of Ethereum collateral into a collateralized debt position. Based on the value of Ethereum collateral, the investor can borrow a fraction of their collateral as DAI tokens. There is a limit on how much DAI one can borrow. The safe ratio of collateral is considered by many market practitioners to be 300%. The minimum collateral ratio required is 150%. If the collateral ratio falls below 150%, the smart contract will trigger a liquidation.[59] In this event, the investor is required to repay the debt of DAI tokens using their remaining collateral, as well as pay a liquidation penalty. In general, investors are incentivized to maintain a stable collateral ratio of 300%. If the value of Ethereum prices fall, then an investor can either inject more Ethereum collateral, or alternatively redeem DAI, in order to maintain their level of collateral.

These incentives of the liquidation system and enforcement of smart contracts make it less likely that extreme price events in Ethereum will cause significant deviations from DAI/USD parity. An equally central question for stabilisation is what tools can be used when a coin like DAI trades systematically above or below parity. For national-currency-backed coins there is an arbitrage motive for investors in the event of a difference between the peg and the secondary market rate. However, in the case of DAI there is no similar arbitrage motive because the real-time value of the underlying collateral that would be released or absorbed is uncertain.

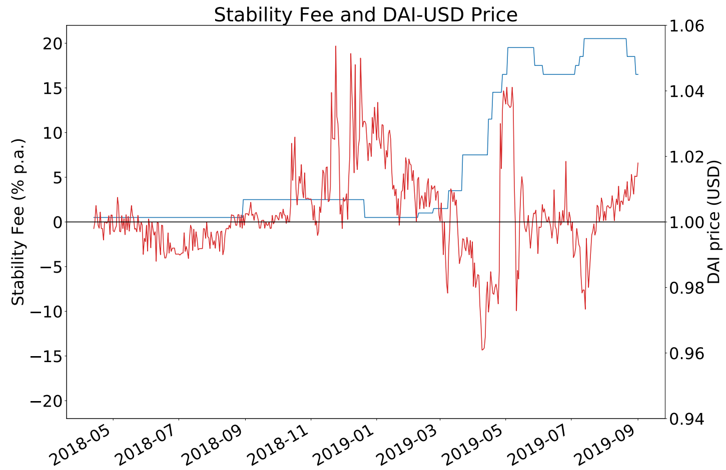
For example, suppose DAI trades at a dollar price above 1. If an investor buys Ethereum for dollars, then deposits that Ethereum as collateral and borrows DAI, then sells DAI in the secondary market for dollars, and finally closes out their position (by buying back DAI and exchanging that for their Ethereum collateral), they could lose money if the market value of Ethereum in dollars has fallen over the latency period. Given the market price of Ethereum against the USD exhibits considerable volatility, valuation losses on their Ethereum can easily dwarf deviations of the DAI secondary-market price from the peg.

Accordingly, crypto-collateralized coins use additional tools to maintain the peg. One tool that is used is the stability fee. Implemented by the MAKER DAO protocol, the stability fee is managed by the issuer of DAI tokens, and is effectively an interest rate on borrowing DAI tokens. This is analogous to a central bank managing interest rates. We document plots of the stability fee and the DAI/USD price in Figure 27 . A critical difference from a national central bank is the voting structure. While central banks typically have a centralised arrangement for setting rates, DAI has a decentralised, continuous-voting procedure for approval of a stability-fee (i.e., rate) change. Voters can choose from a range of options for the stability rate, and if the number of votes surpasses the number of votes for the prior decision, the stability rate will change.[60]

[59] A smart contract is a set of instructions in computer code that defines the conditions of the contract for each counterparty under different scenarios (default etc.). Being managed by computer code and visible on the blockchain, it can be verified publicly by all nodes on the blockchain.

[60] Voting can be influenced by whales, i.e. voters with market power. A recent stability-rate change in October 28, 2019, was influenced largely by one voter with a significant holding of DAI, and had a near 50% share of the total number of votes.

Figure 27: DAI Stability Fee (blue) and DAI/USD Price (red)



Note: Figure illustrates the stability fee (blue) and the DAI/USD price (red). Stability fee is expressed as a rate on borrowing DAI, sourced from Maker DAO api. DAI/USD data are from Coinapi. Sample is April 2018 to September 2019.

Given a higher DAI stability rate raises the cost of borrowing DAI, the intention of the stability rate is to reduce growth of DAI in circulation. This will be a combination of redemptions of existing DAI borrowed, and reductions in future growth of new Ethereum collateral by investors when generating DAI tokens. By reducing supply, all else equal, this will lead to a rise in the price of DAI.

On November 16th, 2019, MakerDAO introduced a multi-collateral DAI as well as retaining the single-collateral version (which has been renamed SAI and is planned to phase out by the end of 2020). Now investors can choose to diversify their basket of collateral to reduce idiosyncratic risk of a single cryptoasset, such as Ethereum. This is a natural direction for evolution in crypto-collateralization as future coins like Facebook's Libra consider pegging to currency baskets rather than a single currency such as the US dollar.

F Model of Stablecoin Prices

The purpose of the model is to shed light on the empirical observation of a two-sided distribution of stablecoin prices around their pegs. While a pegged currency trading at a discount can be explained by issuer mismanagement, a lack of collateral, or speculation against the peg, it is puzzling given past findings in exchange rate economics why stablecoins sometimes trade at a substantial premium. We model a stablecoin premium through added costs of using dollars as a vehicle to buy the model's risky asset. The premium arises due to institutional differences between exchanges that offer conversion to stablecoins, "crypto-to-crypto" exchanges, versus less liquid exchanges that offer conversion to dollars.

Liquidity across Crypto versus Fiat exchanges

We consider a form of intermediation costs that is based on relative differences in liquidity and crypto tokens across exchanges. For example, with a continuum of exchanges in [0,1], a fraction of exchanges $[0,\ell^*]$ have unit intermediation costs defined by $\phi(\ell) = \phi_0 - \frac{\phi_0}{\ell^*}\ell$, with $\phi_0 > 0$ and $\phi'(\ell) = -\frac{\phi_0}{\ell^*} < 0$. In contrast, crypto-to-crypto exchanges in the continuum $[\ell^*, 1]$ have zero unit intermediation costs, $\phi(\ell) = 0$. Equation 15 states the intermediation cost function. Intuitively, the function captures the empirical observation of significant fees for deposits and withdrawals that occur for dollar-crypto transactions. For example, the Bitfinex cryptocurrency exchange states that dollar withdrawals can take up to 15 days to comply with KYC/AML procedures. [61] In contrast, crypto-to-crypto exchanges (eg. Binance) are in the continuum from $[\ell^*,1]$, with all transactions settled instantaneously on the blockchain, $\phi(\ell) = 0$.

$$\phi(\ell) = \begin{cases} \phi_0 - \frac{\phi_0}{\ell^*}\ell, \ell < \ell^*. \\ 0, \qquad\qquad \ell \geq \ell^* \end{cases} \tag{15}$$

The model has two periods. A representative investor decides in period 1 the optimal choice for investing in a combination of the risk-free asset and the risky asset (e.g., Bitcoin or other non-stable cryptoasset). The investor faces a tradeoff between using the dollar and stablecoin as the vehicle currency. A fraction $\theta_{m,1}$ of wealth is invested in a combination of the dollar as the risk-free asset and the risky portfolio C across a set of exchanges that use dollars as the vehicle currency, $[0, \ell^*]$. The remaining fraction $1 - \theta_{m,1}$ of wealth is converted into a stablecoin S across the set of exchanges that offer stablecoins as a medium of exchange, $[\ell^*, 1]$, at the prevailing exchange rate $p_{m/s}$, which are then used to invest in the risky asset C. We now derive the optimal demand for the cryptoasset using dollars and stablecoins.

[61] For more information, refer to the following announcements by the Bitfinex exchange: https://bit.ly/2NEzITW and https://www.bitfinex.com/posts/311.

Dollar Chosen Case

Wealth is allocated to the risky cryptoasset and the risk-free asset, in this case the dollar. The cryptoasset has a final payout (cash flow) in dollars of $R_m \sim N(E[R_m], \sigma^2)$. The risk-free dollar asset has a non-negative return R_f. The investor has CARA utility over wealth, which yields mean-variance preferences. We can represent the dollar-investor problem by maximising equation (16) subject to the period 1 and period 2 budget constraints. In addition, a third constraint is due to liquidity preferences of the investor, they will only purchase cryptoassets on an exchange with sufficiently low intermediation costs, with $\ell > \underline{\ell}$. Expressing the investor's wealth W in dollars, they purchase the cryptoasset C up to a share of their wealth $\theta_{m,1}$ at the dollar price $p_{m/s}$.

$$\max_{C_{m\ell,1}} \qquad L = E[\theta_{m,1} W_2] - \frac{1}{2}\gamma Var(\theta_{m,1} W_2) \tag{16}$$

subject to:

$$\theta_{m,1} W_1 = p_{m/s,1} C_{m\ell,1} + M_1 \tag{17}$$

$$\theta_{m,1} W_2 = R_m C_{m\ell,1} + R_f M_1 - \phi(\ell) C_{m\ell,1} \tag{18}$$

$$\ell \geq \underline{\ell} \tag{19}$$

In period 1 the dollar investor chooses between the risk-free dollar asset M and the risky asset C. In period 2, returns are realized, and the investor incurs a cost of transacting in the exchange with a unit cost of $\phi(\ell)$. Solving for optimal investment in the risky cryptoasset purchased in the exchange ℓ in period 1 yields equation (20). This level of cryptoassets depends positively on the expected return, and negatively on the risk of the portfolio. In particular, the unit intermediation cost $\phi(\ell)$ has a negative effect on the optimal holdings of the cryptoasset.

$$C_{m\ell,1} = \begin{cases} \frac{E[R_m] - \phi(\ell)}{\gamma\sigma^2}, \underline{\ell} < \ell < \ell^*. \\ 0, \qquad\qquad \ell \geq \ell^* \end{cases} \tag{20}$$

The aggregate demand for crypto-assets by the investor across all exchanges that offer dollars as a vehicle currency is then given by equation 21.

$$\begin{aligned} C_{m,1} &= \int_{\underline{\ell}}^{\ell^*} \frac{E[R_m] - \phi(\ell)}{\gamma\sigma^2} d\ell \\ &= \frac{(\ell^* - \underline{\ell})(E[R_m] - \phi_0) + \frac{\phi_0}{2\ell^*}(\ell^{*2} - \underline{\ell}^2)}{\gamma\sigma^2} \end{aligned} \tag{21}$$

Stablecoin Chosen Case

The representative investor converts the remaining fraction of their period-1 wealth into the stablecoin at the exchange rate $p_{m/s,1}$ units of dollars per stablecoin. With CARA utility, we can represent the stablecoin investor problem by maximising equation (22) subject to the period 1 and period 2 budget constraint. The cryptoasset now has a final payout in stablecoins of $R_s \sim N(E[R_s], \sigma^2)$. Note that we express the allocations of wealth, cryptoasset and the risk-free asset in stablecoins. In contrast to using dollars, there is a zero risk-free rate on holding stablecoins, and so if the investor decides to use stablecoins as the vehicle currency, all stablecoins will be used to purchase the cryptoasset in period 1.

$$\max_{C_{s\ell,1}} \qquad L = E[\frac{\theta_{s,1} W_2}{p_{m/s,1}}] - \frac{1}{2}\gamma Var(\frac{\theta_{s,1} W_2}{p_{m/s,1}}) \tag{22}$$

subject to:

$$\frac{\theta_{s,1} W_1}{p_{m/s,1}} = C_{s\ell,1} \tag{23}$$

$$\frac{\theta_{s,1} W_2}{p_{m/s,1}} = R_s C_{s\ell,1} \tag{24}$$

$$\ell \geq \ell^* \tag{25}$$

Solving for the optimal cryptoassets in period 1 yields equation 26. As before, the optimal level of cryptoassets depends positively on the expected return, and negatively on the risk of the portfolio.

$$C_{s\ell,1} = \begin{cases} \frac{E[R_s]}{\gamma\sigma^2}, \ell \geq \ell^*. \\ 0, \qquad\qquad \ell < \ell^* \end{cases} \tag{26}$$

The aggregate demand for crypto-assets by the investor across all exchanges that offer stablecoins as a vehicle currency is then given by equation 27.

$$\begin{aligned} C_{s,1} &= \int_{\ell^*}^{1} \frac{E[R_s]}{\gamma\sigma^2} d\ell \\ &= (1 - \ell^*)\frac{E[R_s]}{\gamma\sigma^2} \end{aligned} \tag{27}$$

Equilibrium allocation of dollar and stablecoin portfolio shares

To choose an optimal weight $\theta_{m,1}$ of wealth to invest as the dollar investment and $\theta_{s,1} = 1 - \theta_{m,1}$ as a stablecoin investment, the representative investor equates the value of investment in dollars with the value of investment in stablecoins. We normalise the investments by the shares $\theta_{m,1}$ and $\theta_{s,1}$ to effectively equate the investment value per unit wealth invested. The fraction $\frac{E_1[p_{m/s,2}]}{p_{m/s,1}}$ measures the valuation effect of stablecoins over the investment horizon of the investor.

$$\frac{C_{m,1}}{\theta_{m,1}} = \frac{C_{s,1}}{\theta_{s,1}} \frac{E_1[p_{m/s,2}]}{p_{m/s,1}} \tag{28}$$

In the optimal allocation, the investor is indifferent between both methods.[62] Substituting the formulae for the total cryptoasset demand by stablecoin and dollar investors, we can then solve for the dollar price of the stablecoin, $p_{m/s}$, which yields equation (29):

$$p_{m/s,1} = E_1[p_{m/s,2}] \frac{1 - \theta_{s,1}}{\theta_{s,1}} \frac{(1 - \ell^*)E[R_s]}{(\ell^* - \underline{\ell})(E[R_m] - \phi_0) + \frac{\phi_0}{2\ell^*}(\ell^{*2} - \underline{\ell}^2)} \tag{29}$$

The relative price of stablecoins is a function of two ratios. The first ratio, $\frac{1-\theta_{s,1}}{\theta_{s,1}}$, captures the relative market share of the stablecoin. A rise in $\theta_{s,1}$ is equivalent to an increase in the relative supply of stablecoins in circulation, and equilibrium in the stablecoin/USD market requires the stablecoin price to fall to clear the market. The second ratio measures the relative return on cryptoassets using stablecoins and dollars as a vehicle.

We can further decompose the relative return on stablecoins through a stablecoin risk premium identified in equation 30. Defining the relationship between the risky-asset return in dollars, R_m, and in stablecoins R_s, the latter term $cov(R_s, \frac{p_{m/s,2}}{p_{m/s,1}})$ can be interpreted as a safety premium of the stablecoin. If stablecoins appreciate in periods of low risky-asset returns, then $cov(R_s, \frac{p_{m/s,2}}{p_{m/s,1}}) < 0$. This increases the relative return on using stablecoins as a vehicle currency.[63]

$$p_{m/s,1} = E_1[p_{m/s,2}] \frac{1 - \theta_{s,1}}{\theta_{s,1}} \frac{(1 - \ell^*)E[R_s]}{(\ell^* - \underline{\ell})(E[R_s] + cov\left(R_s, \frac{p_{m/s,2}}{p_{m/s,1}}\right) - \phi_0) + \frac{\phi_0}{2\ell^*}(\ell^{*2} - \underline{\ell}^2)} \tag{30}$$

While we have established a relationship between $p_{m/s,1}$ and $\theta_{s,1}$, we need another relation to close the model. We now turn to arbitrage flows as a stabilizing mechanism.

[62] In deriving an optimal allocation, we are making an assumption that the representative investor uses both vehicle currencies, yielding an interior allocation where $\theta_m > 0$ and $\theta_s > 0$. We exclude cases of $\theta_d = 0$ and $\theta_s = 0$ in our analysis as empirical evidence suggests both vehicle currencies are in use.

[63] To derive the risk premium, we denote the return on dollars and stablecoins are given by $R_m = R_s \frac{p_{m/s,2}}{p_{m/s,1}}$. Taking expectations, we obtain $E[R_m] = E[R_s]E\left[\frac{p_{m/s,2}}{p_{m/s,1}}\right] + cov\left(R_s, \frac{p_{m/s,2}}{p_{m/s,1}}\right)$

Arbitrage flows

The primary-market issuer is willing to supply stablecoins at a 1:1 exchange rate. This means departures of the stablecoin price from the peg result in incentives for arbitrage, and will cause endogenous investor flows. For example, if what we will call the "secondary-market price" $p_{m/s,1} > 1$, investors will buy stablecoins from the primary-market issuer with dollars at par. Conversely, investors will sell stablecoins to the primary-market issuer for dollars at par when the secondary-market price $p_{m/s,1} < 1$. Therefore the representative investor using stablecoins as the vehicle currency will, through arbitrage flows, cause $\theta_{s,1}$ to be a positive function of deviations from the peg. We illustrate this in equation 31. The speed of convergence parameter ω depends on the ability of private investors to transact with the stablecoin issuer directly via depositing dollars, obtaining an equivalent number of stablecoin tokens, and then selling them in the secondary market at $p_{m/s,1}$.

$$\Delta\theta_s = \omega(p_{m/s,1} - 1) \tag{31}$$

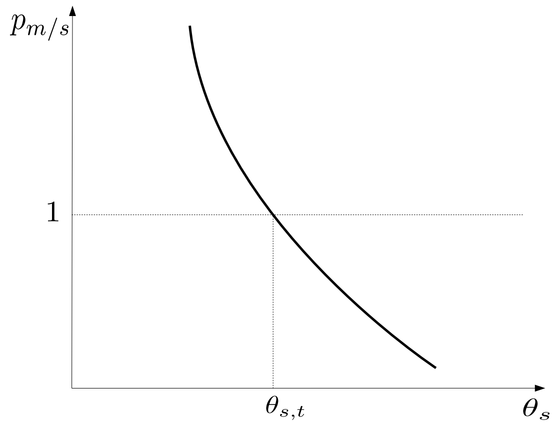
Equilibrium

The equilibrium is characterised by the following two equations 32 and 33. In characterising our equilibrium, we extend the two-period model to a multi-period model in continuous time to illustrate the dynamics of arbitrage flows in stabilizing the peg. The first equation represents the price that leads to a representative investor making an optimal allocation between dollars and stablecoins as a vehicle currency. The second equation represents the investor's incentive to arbitrage deviations from the peg, by increasing the relative share of stablecoin use when the secondary market trades at a premium to the peg. The equilibrium is plotted in Figure 28.

$$p_{m/s,1} = E_1[p_{m/s,2}]\frac{1-\theta_{s,1}}{\theta_{s,1}}\frac{(1-\ell^*)E[R_s]}{(\ell^*-\underline{\ell})(E[R_m]-\phi_0)+\frac{\phi_0}{2\ell^*}(\ell^{*2}-\underline{\ell}^2)} \tag{32}$$

$$\dot{\theta}_{s,t} = \omega(p_{m/s,t} - 1) \tag{33}$$

Figure 28: of Equilibrium



Note: This illustrates equilibrium, which in steady state will always be where $p_{m/s} = 1$, eliminating the incentive for arbitrage flows.

The model yields two key predictions.

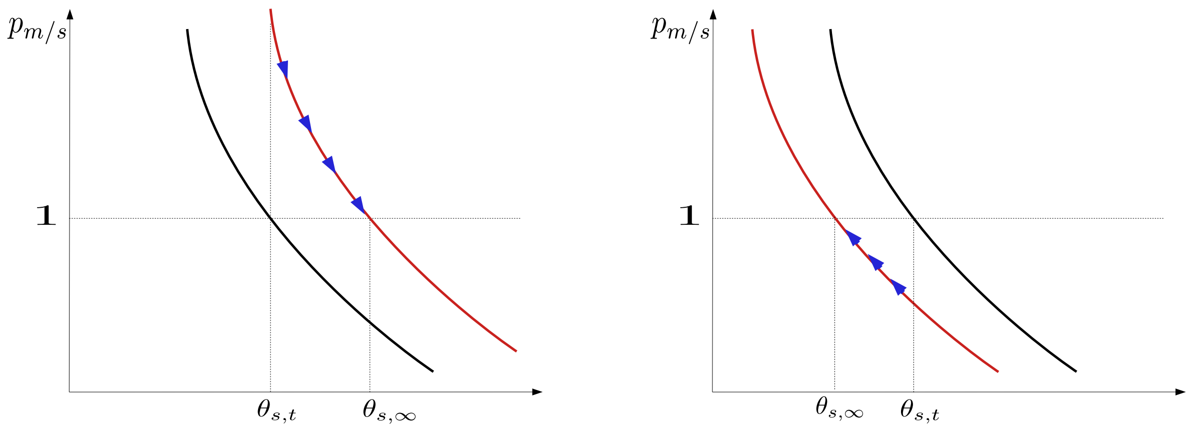
Prediction 1: Stablecoin premiums

An increase in a preference for crypto exchanges is represented by a reduction in the set of dollar exchanges the investor is willing to transact with $\underline{\ell} \uparrow$. *This reduces the amount of cryptoasset demand on dollar exchanges, causing an increase in the stablecoin price* $p_{m/s,t} > 1$, *all else equal. The representative investor then reallocates their portfolio toward stablecoins* ($\theta_{m,t} \downarrow$ *and* $\theta_{s,t} \uparrow$) *by depositing dollars with the stablecoin issuer, obtaining stablecoins at a 1:1 rate, and uses stablecoins to buy the risky cryptoasset. This causes the price* $p_{m/s}$ *to gradually return to its equilibrium pegged value of one as* $t \to \infty$.

Prediction 2: Stablecoin discounts

A decrease in the expected future spot price, $E_t[p_{m/s,t+1}]$, *decreases the current spot price* $p_{m/s,t} < 1$, *all else equal. The representative investor reallocates their portfolio toward dollars* ($\theta_{m,t} \uparrow$ *and* $\theta_{s,t} \downarrow$) *by withdrawing their dollar deposits with the stablecoin issuer, and using those dollars to buy the risky cryptoasset. This causes the price* $p_{m/s}$ *to gradually return to its equilibrium pegged value of one as* $t \to \infty$. We document both channels in Figure 29.

Figure 29: Left panel: Shock to preference for liquid crypto exchanges; Right panel: Speculative attack



Note: The left panel shows the transition dynamics for a shock to preferences over using crypto exchanges relative to dollar exchanges. This results in a temporary stablecoin price $p_{m/s} > 1$, and causes arbitrage flows to the secondary market, $\theta_{s,t} \uparrow$, to restore parity. The right panel shows the impact of an unsuccessful speculative attack (i.e., one that does not break the peg), which results in a decline in $E[p_{m/s}]$, and redemptions of stablecoins, $\theta_{s,t} \downarrow$, to restore parity.

The first prediction shows how an increase in the preference to purchase a cryptoasset on exchanges with sufficiently low intermediation costs can lead to stablecoin premiums. An increase in $\underline{\ell} \uparrow$ leads to a decline in the cryptoasset demand by dollar investors. This increases the relative benefits of using the stablecoin as the vehicle currency, and causes a temporary premium. The high secondary market price of the stablecoin will cause the representative investor to deposit dollars with the primary-market issuer, and sell stablecoins in the secondary market, causing a rise in the stablecoin share of wealth, $\dot{\theta}_{s,t} = \omega(p_{m/s,t} - 1) > 0$, until the price of stablecoins reaches a new long-run equilibrium at $p_{m/s} = 1$, and a higher vehicle-currency share for stablecoins, $\theta_s \uparrow$.We illustrate the dynamics in Figure 29, left. This prediction captures the dynamics of stablecoin premiums during crypto risk-off events. Investors desire immediacy of payment when selling Bitcoin during a risk-off event. The advantage of instantaneous settlement on the blockchain causes investors to gravitate toward exchanges that offer conversion to stablecoins.

The second key prediction is the effect of a speculative attack. In our model this closely corresponds to 2nd-generation currency-crisis models (e.g., Morris and Shin (1998)), which show how fixed exchange rates can be vulnerable to self-fulfilling attack from speculators who believe the currency is overvalued. Under this theory, we would expect deviations from the peg to be one-sided. For example, suppose speculators believe there is some positive probability $P > 0$ that the stablecoin will collapse. This necessarily implies that the expected value of the stablecoin price trades at a discount to the peg, $E_t[p_{m/s,t+1}] = P \times 0 + (1 - P) \times 1 < 1$. The low secondary market price of the stablecoin will cause the representative investor to redeem their stablecoins and withdraw dollar deposits from the primary-market issuer, causing a decline in the stablecoin share of wealth, $\dot{\theta}_{s,t} = \omega(p_{m/s,t} - 1) < 0$, until the price of stablecoins reaches a new long-run equilibrium at $p_{m/s} = 1$, and a lower vehicle-currency share for stablecoins, $\theta_s \downarrow$.We illustrate the dynamics in Figure 29, right.