Macro-prudential Considerations for Tokenized Cash[*]

PRELIMINARY AND INCOMPLETE

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Latest draft here.

Abstract

This paper examines the systemic risks associated with tokenized cash, a subset of stablecoins fully reserved with cash and cash equivalents. Using a combination of on-chain data together with uniquely collected wallet addresses' labels we construct empirical measures of liquidity ratios and run off rates on the largest cash token, USDC, and characterize its users and their behavior. We find that less than 10% of tokenized cash is held by exchanges, while the majority of circulation is held in Externally Owned Accounts (EOAs) that include individual wallets and institutional custody wallets. Around 75% of these wallets hold balances of less than $100, highlighting its dispersed holdings. The overall circulation of tokenized cash seems to be largely insulated from crypto price movements, though price changes correlate with re-balancing between smart contracts and private wallets. A liquidity ratio calculation, similar in concept to Liquidity Coverage Ratio (LCR), indicates that tokenized cash has at least two times the amount of High-Quality Liquid Assets (HQLA) when compared to the worst observed *gross* outflow over 30-day ahead periods. We discuss the implications of tokenized cash on safe asset creation, credit supply, and monetary policy transmission.

Keywords: Tokenized cash, tokenized deposits, stablecoin, LCR, systemic risk

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1 Introduction

Stablecoins are cryptocurrencies designed to trade at par with a reference asset (typically the US dollar). Stablecoins have the potential to drastically improve the traditional payment system and financial services. Their cost structure may enable enhanced financial inclusion for populations otherwise excluded from traditional banking systems. Within the cryptocurrency ecosystem, they are used as a necessary base layer for decentralized finance protocols, facilitating lending and assets' exchange.

With their market growth, stablecoins are increasingly attracting regulatory attention and calls for prudential rules, when some equating stablecoins to wildcat banks (G. B. Gorton & Zhang, 2021). The collapse of an algorithmic stablecoin, Terra, has elevated run risks out of the realm of the hypothetical, highlighting potential spillover effects that can impact the ecosystem as a whole. Nevertheless, to date, discussions remain fairly theoretical as quantitative data and empirical evidence on how stablecoins are being used have largely been absent.

In this paper we rely on a combination of on-chain data together with uniquely collected wallet address labels to shed light on various key aspects of stablecoins usage. Specifically, we explore stablecoin usage and adoption, by understanding who are the stablecoin users, what are their main use cases and wallet balances, how are they reacting to market episodes with heightened run risks, while also studying their inflow (minting) and outflow (burning) velocity. We believe that using on-chain data to study stablecoin activity is paramount in making an assessment of their systemic impact.

We first highlight key design choices that differentiate between different types of stablecoins. Understanding these design choices is necessary to evaluate varying degrees of reserve backing, qualities of safety, liquidity, and run risks.

Moreover, we primarily focus on tokenized cash, a class of stablecoins backed by cash-equivalent assets such as Treasury bills, and offer one-to-one on-demand convertibility with fiat cash. Tokenized cash stablecoins are increasingly being prescribed as a potential path forward by regulators and policymakers[1].

Using on-chain data, we break down the holdings of the largest tokenized cash, USDC, into different wallet types. To our knowledge, this is the first comprehensive attempt to distill granular understandings of tokenized cash usage and holdings from blockchain data. We find that less than 10% of tokenized cash is held by exchanges, the majority of circulation is held in Externally Owned Accounts (EOAs) that include individual wallets and institutional custody wallets. About one-third of the tokenized cash is locked in smart contracts that support web3 developments. This breakdown possibly runs contrary to the narrative that stablecoins are primarily used to support speculation in digital assets. A further breakdown by wallet size indicates that around 75% of wallets holding tokenized cash have balances less than $100, which plausibly speaks to the wide adoption of tokenized cash by participants in the cryptocurrency ecosystem.

One of our key contributions is to provide a data-rich description of the dynamics of liability demand for tokenized cash (i.e. the demand for minting and burning of tokens). This exercise not only helps us understand run-off rates of tokenized cash but also enriches our understanding of liquidity demand more broadly in similar financial constructs such as deposit institutions and money market funds that do not typically report gross inflows and outflows.

Our analysis finds that both outflows and inflows increase meaningfully in times of market distress, with a slight net positive increase that plausibly reflects flight-to-safety behaviors among users. The observed max historical 30-day gross outflow is around 37%, which is far less than the observed gross inflow during the same period.

We also find a general lack of statistically significant relationship between digital asset price and tokenized cash demand, though there's a strong tendency of re-balancing of cash tokens holdings from smart contracts to EOAs when digital asset prices decline. This re-

[1]See, for instance, Lummis-Gillibrand Responsible Financial Innovation Act and New York State Department of Financial Services Virtual Currency Guidance

balancing behavior plausibly insulates the cash token issuers from the need to fulfill large net redemption demands. Holding of tokenized cash in exchange accounts also appears to be largely insulated from asset price movement.

We also propose several approaches to calculate the equivalent liquidity ratios proposed in Basel III but apply them to tokenized cash. Assuming the worst historical run rates, we find that tokenized cash has a liquidity ratio (ratio of High Quality Liquid Asset (HQLA) to 30 days ahead outflow) of over 200%.

Our study also examines the contagion effects of Terra stablecoin's collapse in May 2022. In contrast to the behavior of other stablecoins, the two major cash tokens experienced modest increases in balances during this volatile market event that led to the evaporation of the nearly $20 billion stablecoin and a more than 50% crash in major digital asset prices. Moreover, we find strong variations in the behaviors of tokenized cash balances for different wallet types — wallets that are associated with cross-chain bridging and supplying stablecoin liquidity saw large declines in balances while other wallets, particularly EOAs, drew in more tokenized cash. Overall, we conclude that the Terra episode highlighted that the safe asset backings of tokenized cash were critical in supporting stability and minimizing contagion risk.

Lastly, we contextualize the demand for safe assets by tokenized cash with similar demand stemming from government money market funds and discuss implications on lending and credit creation. To date, with less than $150 billion in circulation, stablecoins remain small relative to the over $4 trillion government money market fund complex. Historical examples of large demand shock in Treasury bills and contraction of credit provision, for instance during the 2016 money market fund reform, showed that the financial system can withstand still substantial growth of tokenized cash that provides payment and other utilities largely untapped[2].

[2] Anderson, Du, and Schlusche (2019) find that the U.S. money market mutual fund reform implemented in 2016 resulted in around $1 trillion of conversion from prime money market fund to Treasury money market fund. They find that the primary response of banks to the reform was a cutback in arbitrage positions that relied on unsecured funding, rather than a reduction in loan provision.

Literature review This paper relates to a growing literature on stablecoins that mostly has taken a qualitative approach to describe and evaluate stablecoin constructs. Catalini and de Gortari (2021) lay out economic fundamentals of stablecoins and Catalini and Shah (2021) describe different reserve frameworks for stablecoin design. Liao and Caramichael (2022) evaluate the opportunities and risks of stablecoins in the context of financial intermediation. And Lyons and Viswanath-Natraj (2020) explores factors that keep stablecoins pegged and finds a premium from a safe haven effect of stablecoins counterbalanced by a discount from illiquidity of reserve assets. Makarov and Schoar (2022) discusses the use of stablecoins in decentralized finance (DeFi) and provide an overview of the ecosystem. Relative to the literature, this paper focuses on the liquidity and systemic risks related to stablecoins.

A set of papers have also discussed stablecoins and compared them to earlier eras of banking. Among which, G. B. Gorton and Zhang (2021) equate stablecoins to state chartered banks under the Free Banking Era. Xu and Yang (2022) study the real effects of stable money in the context of the National Bank Act of 1864 and find that unstable money can hinder trade while stable currency improved market access and increased manufacturing output for places that gained access to stable money.

Our evaluation of liquidity and run risk for tokenized cash broadly relates to studies of money market turmoil in the years 2008 (G. Gorton & Metrick, 2012) and 2020 Eren, Schrimpf, Sushko, et al. (2020). The use of granular gross outflow and inflow data to estimate run-off rates is related to a similar attempt at dissecting deposit flows during bank distress (Martin, Puri, & Ufier, 2018).

Lastly, our discussions on the role of tokenized cash in the broader financial system relate to earlier studies of narrow bank proposals as ways to limit moral hazard and excess risk-taking concerns associated with government banking insurance and bailouts (Pennacchi, 2012). Recent proposals based on a narrow bank approach have also been a topic of active discussion (H. E. Jackson, Massad, & Awrey, 2022).

2 Stablecoin types and tokenized cash

The collapse of the Terra (UST) stablecoin highlighted that not all stablecoins are alike. Stablecoins differ in the quality and liquidity of their reserves, as well as their functionality and use case. Regulatory policies for stablecoins are also likely to be specific to a subset of stablecoin categories. With the objective of studying the systemic implications in mind, we describe and catalogue the current archetypes of stablecoins. Table 1 summarizes the different types of stablecoins currently in circulation. Note that, the categories and examples are not fixed as stablecoins continue to evolve and conform with exchange listing standards, regulatory requirements, and generally accepted principles by ecosystem participants.

This paper primarily focus on the type of stablecoins which are fully-reserved with cash and cash equivalent instruments. We refer to such stablecoins as tokenized cash. "Tokenized" due to the fact that the stablecoins are cryptographically secured through distributed ledger technology. "Cash" refers to the cash-like quality of the underlying reserve backing and near bearer instrument status.

This category of stablecoins is distinct from other types of stablecoins in the token's 1) high quality full cash-equivalent reserve backing, and 2) on-demand convertibility for fiat cash and cash equivalents through the issuer. The reserves are considered under U.S. generally agreed accounting standards (U.S. GAAP) and Financial Accounting Standard Board (FASB) as cash or cash equivalent, defined as "short-term, highly liquid investments that are readily convertible to known amounts of cash and that are so near their maturity that they present insignificant risk of changes in value because of changes in interest rates"[3]. For instance, cash equivalents assets include Treasury bills with maturities of less than 90 days. The convertibility criteria mean that holders of tokenized cash have the ability to redeem from the issuer rather than through the secondary market trading[4]. Such stablecoins rely on

[3]See Financial Accounting Standards Board Accounting Standards Codification ("FASB ASC") paragraph 305-10-20.

[4]Redemption is conditional on satisfying appropriate know-your-customer verification requirements and other relevant safeguards.

centralized financial intermediaries to custody reserve assets and to mint and burn reserve assets with market participants.

Our focus on Tokenized cash stablecoins stems from their direct interface with the financial system at large and their rapidly growing market share. Moreover, legislative efforts such as the Lummis-Gillibrand bill and policy proposals, such as the National Trust Bank (NTB) approach (T. Jackson & Pennacchi, 2021), are also increasingly focused on requiring stablecoins to hold high quality liquid asset reserves, highlighting the importance of studying their use cases and macro prudential risks. Stablecoins within this category include USD Coin (USDC), Binance USD (BUSD), and Paxos Dollar (USDP), among others. While Tether (USDT) is also reserved with fiat assets, their underlying credit qualities and liquidity vary.

Another category of stablecoins that posses qualities similar to cash are tokenized deposits. The current versions of tokenized deposit such as JPM Coin, issued by JP Morgan, and Avit by Custodia Bank, have largely been confined in the experimental phase. As the name suggests, tokenized deposits are deposit liabilities backed by bank asset holdings varying in quality, maturity, and liquidity. Since deposits support fractional-reserve banking, it cannot be generally considered as one-to-one backed by liquid, hiqh-quality cash holdings. Interoperability could be a challenge since banks vary greatly in their market, credit, and operational risk exposures. A single issuer approach, in which each depository institution issues its own token, can lead to a proliferation of deposit tokens and formation of secondary markets for the exchange of these tokens similar to brokered deposits. A networked issuer approach, in which multiple depository institutions are able to issue the same token, could set false equivalence in the pricing of risks.

The next category includes stablecoins overcollateralized with crypto assets. While fiat-backed stablecoins are issued by entities that need to hold licenses and rely on financial institutions to custody assets, cryptocurrency-backed coins such as Dai and Fei can be constructed and managed in a decentralized way and can be minted by anyone with sufficient collateral in other cryptocurrencies such as Bitcoin and Ether. Such assets can exhibit significant price fluctuations, and abrubpt declines in liquidity, running the risks of leading to undercollateralized smart contracts, where the stablecoin may no longer be fully backed.

The algorithmic, self-referencing, stablecoins, are not backed by external assets and rely on their own equity to deliver some degree of stability. They typically regulate coin supply through two sets of coins: the stablecoin and an investment coin (also called "seigniorage" or "dual" coin) targeted at absorbing market volatility. Their stabilization mechanism inflates the outstanding supply of stablecoins in exchange for investment coins when prices are above par, and deflates it when they are below par. Specifically, when the price is below par, the algorithm issues more investment coins and uses the proceeds to purchase stablecoins and remove them from circulation, therefore raising the price. The investment coin functions as equity, bearing the risk of dilution when coins trade below par, but enjoying additional returns in periods of growth, where its supply declines to enable the minting of additional stablecoins.

Algorithmic stablecoins, by virtue of their use of smart contracts and their lack of external links to external assets (fiat or cryptocurrency), do not require an intermediary and can be truly decentralized. However, as observed in the case of the collapse of the Terra stablecoin (USDT), such arrangements are prone to self-fulfilling crises in which pessimistic market participants running on the reserve can trigger a death spiral. If investors no longer believe the investment coin has value, the algorithm dilute its owners to the point that they are unable to support the peg. Hence, their solvency predominantly depends on the public's confidence in the coin (Catalini and de Gortari (2021)).

Table 1: Types of stablecoins

Type	**Description**	**Examples**
Tokenized cash	Tokens fully-reserved with cash & cash equivalent instruments (e.g. T-bills and other level 1 HQLA with less than 90 days of maturity)	USD Coin (USDC), Binance USD (BUSD), Paxos Dollar (USDP).
Tokenized deposits	Tokens representing fractional-reserved bank deposits	JPM Coin, Avit
Other fiat-asset backed	Tokens reserved with fiat assets of varying credit qualities and liquidity.	Tether (USDT)
Crypto-(over)collateralized	Reserves are over collateralized with crypto asset and/or tokenized fiat assets that do not self-reference to the stablecoin in supply determination.	Dai, Fei
Algorithmic/self-referencing	Stablecoins that are fully or partially backed by a second more volatile reference coin. The supply of the reference coin is pragmatically determined based on the primary coin.	Terra, Iron, Basis, FRAX

3 Background and data description

The usage and holdings of tokenized cash and stablecoin have been debated by industry advocates and policymakers with varying references ranging from "digital currency" to "poker chips". Few attempts to document the usage and holding patterns quantitatively have been made in prior work. The section provides a summary of data on stablecoins with a focus on tokenized cash.

Among the five major stablecoins in circulation at the beginning of 2022, two can be categorized as tokenized cash in their reserve holdings – the USD Coin (USDC) issued by Circle and Binance USD (BUSD) issued by the Binance exchange. Tether (USDT), which has been the largest stablecoin by market cap, is purportedly fiat asset-backed, though with less liquid asset holdings. Figure 1 shows the evolution of market caps for major stablecoins since 2020. As can be seen in the figure, Terra (UST), an algorithmic stablecoin, collapsed in mid-2022, from a market cap of almost $20 billion to zero in days. This event also led to a sizable increase in the market cap of the largest cash token, USDC, and a decline in the market cap of the non-cash token stablecoin, USDT. We discuss this event more in-depth in Section 5.

This paper primarily focuses on the large cash token, USDC, and its holdings on the Ethereum chain. As of August 2022, USDC has approximately $53 billion of outstanding market cap, with around $43 billion secured through the Ethereum chain and associated layer-two and side chains. The rest of the balances are distributed primarily across Solana ($4.1 billion), Tron ($3.4 billion), and Avalanche ($1.1 billion). We obtain granular wallet balance data of USDC through a mapping of Ethereum wallet addresses and public on-chain data. The wallet address labels are derived from several public sources including smart contract code, Etherscan, as well as internal account mappings[5].

[5]Circle did not disclose the identity behind individual account addresses and only shared broad categories of address mapping for this research.

To examine the usage of tokenized cash, we break down the balances of its holders by broad wallet categories and more detailed types. Figure 2 shows the historical breakdown by broad wallet categories. As of July 31, 2022, around 54% ($24.5 billion) of USDC balances on Ethereum are held in Externally Owned Accounts (EOAs), which include individual-owned wallets as well as custodied wallets (excluding exchanges) that are used by both institutions and individuals. Around 38% ($17.4 billion) are locked into smart contracts that support programmability of payment and finance as well as the web3 ecosystem. Less than 8% ($ 3.6 billion) are held in exchanges. The vast majority of growth in the holdings of USDC on Ethereum has been associated with an increase in both Externally Owned Accounts (EOAs) and smart contracts in the sample period from January 2021 to August 2022.

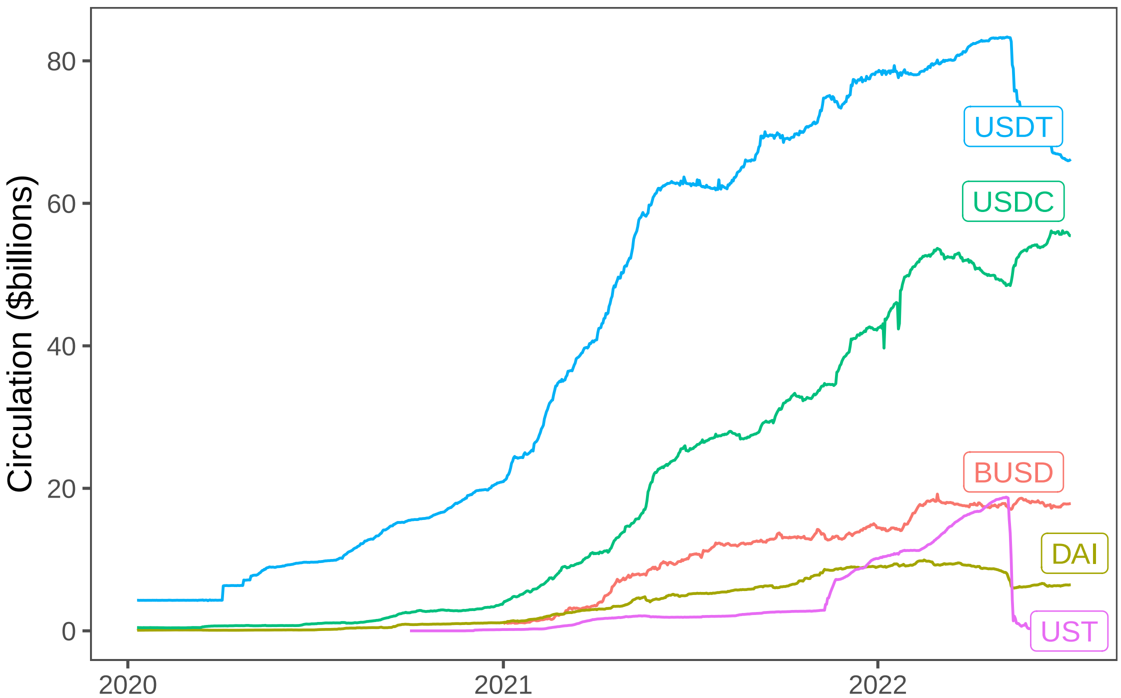
We provide a further snapshot breakdown of different wallet types in Figure 3. EOAs, which include individual wallets and wallets affiliated with unknown entities that cannot be further categorized into different types, constitute around half of the balances of USDC on Ethereum. Bridges to Layer 2 chains, side chains, as well as other blockchains, account for around 13% of balances[6]. The third largest category of holding balances resides in stablecoin liquidity pools that facilitate the conversion of tokenized cash against other stablecoins programmatically through smart contracts to ensure interoperability. As we'll discuss in Section 5, Bridges and Stablecoin liquidity pools saw the largest decline in balances during the Terra collapse, possibly indicating spillover effects.

As holdings via EOAs represent a large fraction of tokenized cash balances and identification of EOAs cannot be easily identified, we perform an additional breakdown of wallet sizes for EOAs that are not in other categories in Table 2. Out of a total of around 2 million wallets observed on Ethereum-compatible chains, around 75% (or 1.5 million) wallets hold less than $100 in value. The majority of balances by value are held in wallets with a size greater than $1 million. A small handful of wallets holding large balances (e.g. 5 wallets

[6]Bridges connect one blockchain to another and facilitate transactions across chains typically through locking up of tokens in smart contracts on one chain and issuing same amount of tokens on another chain. Layer 2 and side chains are scaling solutions that enhance the performance and throughput of Layer 1 blockchain by building additional blockchain infrastructure that is secured by the layer 1 chain.

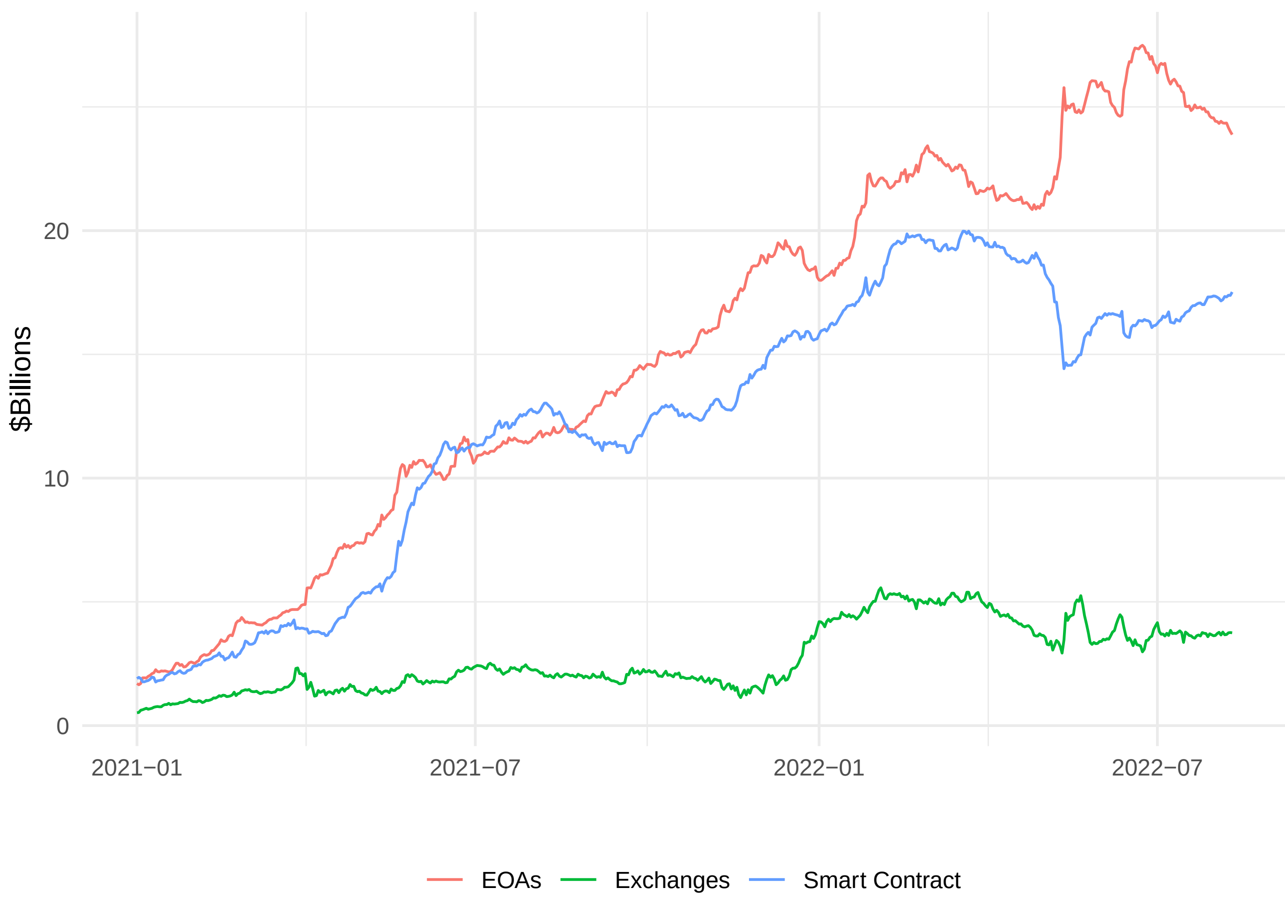
holding balances greater than $100mm) might be tied to unidentified custody providers. We also observe a strong inverse pattern between wallet size and activeness in transactions as measured by the median days since the last transaction.

Figure 1: Major stablecoin market caps



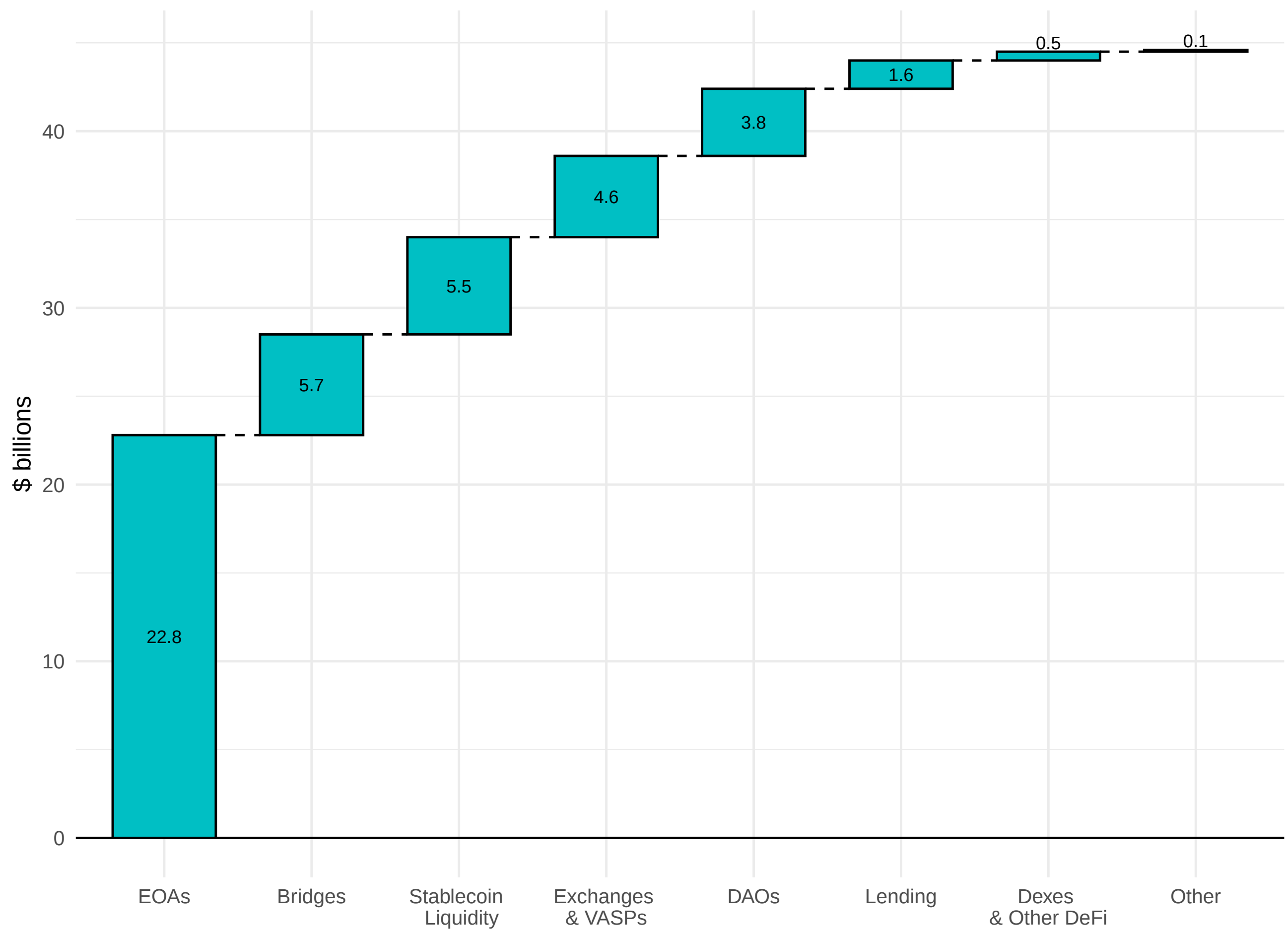
Notes: This figure presents the market cap of the five major stablecoins.

Figure 2: USDC balance by wallet type



Notes: This figure presents USDC balances on Ethereum by broad wallet types.

Figure 3: USDC balance by wallet category



Notes: This figure presents USDC balances on Ethereum by the category of wallets as of July 31, 2022

Table 2: Size distribution of wallets

Wallet Size $	Wallets	Total Balance ($mm)	Median days since last txn
<100	1,501,300	22.0	252
100-10k	488,345	524.8	103
10k-100k	63,872	2,086.3	31
100k-1m	19,673	5,557.3	32
1m-10m	3,196	8,290.4	31
10m-100m	276	5,894.6	18
>100m	5	736.7	1

Notes: This tables shows the distribution of wallet sizes excluding smart contracts, exchanges, and VASPs on Ethereum Virtual Machine compatible chains (Ethereum, Polygon, Arbitrum, Optimism, Avalanche).

4 Liquidity and run risk

The potential systemic risk that stems from a "run" on stablecoins is highlighted as a top policy issue that regulators aim to address [7]. In particular, a rapid loss in confidence in a fiat asset-backed stablecoin could results in a fire sale of reserve assets, possibly causing contagion to the broader financial system and threatening financial stability. Assessing such run risk requires examining both the risk profile of the asset reserves for stablecoins as well as the dynamics of the liabilities that are tied to the broader on-chain eco-system and use cases.

4.1 Inflows and Outflows

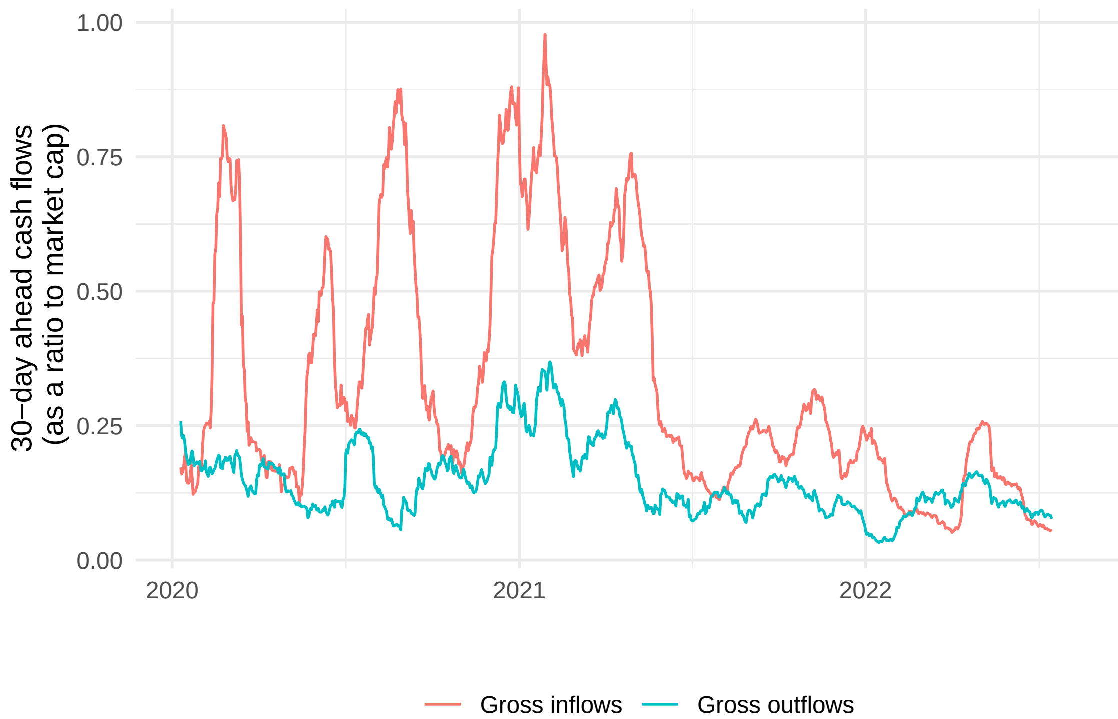
To understand tokenized cash run risks and redemption behaviors we start by exploring historical inflow and outflow patterns that indicate the demand for tokenized cash and the need of issuers to meet issuance and redemption requests. This exercise focuses on the gross as well as the net flows, which is typically not possible with banks and money market funds as

[7] See *President's Working Group on Financial Markets: Report on stablecoins* (2021) and *Executive order on ensuring responsible development of digital assets* (2022).

gross flows are rarely disclosed. The blockchain data allows us to decompose the fund flows, and additionally, the labeling of wallet addresses from this data set allows us to dissect types of wallets that experiences changes in balances. Figure 4 shows the observed 30-day ahead gross inflows and outflows of USDC as a fraction of market capitalization outstanding. To do so, the cash flow rates are calculated in a forward-looking manner, where we calculate daily customer-specific gross inflow or outflow, which is then summed across and accumulated over 30-day rolling windows.

During the majority of the sample period, gross inflows surpassed outflows, reflecting the growth in the demand for tokenized cash. Gross outflows are also remarkably consistent, with the interquartile range confined between 12.8% and 17.9% and a maximum of 36.9% reached during a period when gross inflows were approximately three times that of outflows. In future work we intend to decompose the drivers of inflows and outflows of inflows and outflows to better understand its interaction with the ecosystem.

Figure 4: Outflows and Inflows



Notes: This figure shows the 30-day ahead gross cash outflows and inflows of USDC as a fraction of market capitalization outstanding. The cash flow rates are calculated in a forward-looking manner. At any given date, the plotted values correspond to gross outflow and inflow rates observed over the following 30 days. Intra-day minting and burning by the same customer are netted to calculate daily customer-specific gross inflow or outflow, which is then summed across and accumulated over 30-day rolling windows.

4.2 Asset price relations

We also study whether the demand for tokenized cash is correlated with crypto asset prices. Table 3 presents regression of daily log change in total tokenized cash in circulation, as well as the holding compositions by wallet type, on daily log return of Ethereum. Overall, there appears to be statistically insignificant relationship between the overall demand for tokenized cash and crypto asset price movement. Rather, there appears to be some degree of balancing of cash token holdings among Exchanges & VASPS, EOAs, and Smart Contracts correlating with Ethereum price movements. Cash token balances locked in smart contracts

Table 3: Relationship between tokenized cash holdings and Ethereum price

	$\Delta \log Total$	$\Delta \log Exchanges$	$\Delta \log EOAs$	$\Delta \log SmartContract$
$\Delta \log p$	-0.00588	-0.104	-0.0638	0.0875
	[-0.54]	[-1.67]	[-3.09]	[4.44]
N	586	586	586	586
R2	0.001	0.010	0.043	0.067

Notes: This table presents regressions of daily log change in USDC balances held in wallets of different types on daily log return of Ethereum. T-stats are presented in brackets based on Newey-West standard errors with lag selection by Newey and West (1994). The sample period is from January 1, 2020 to August 10, 2022.

tend to increase as Eth appreciates with flows out of EOAs' holdings, and to a lesser degree, Exchange holdings. For each one standard deviation increase in Eth price (5.3% increase), smart contract holdings of cash token increase by around half a percentage point. This reshuffling between different wallet types depending on risk conditions in the market insulates the token issuer from cyclical redemption demands. Hence there is little relation between overall circulation and crypto returns.

4.3 Liquidity ratio

Banking regulatory frameworks recognize the need to consider both sides of the balance sheet and therefore have built requirements and guidelines such as the Basel III Liquidity Coverage Ratio (LCR) to safeguard against liquidity-induced runs. This ratio balances the quality of assets held in reserves with potential risks of cash outflows. Though there is no exact mapping of the Basel LCR calculation to stablecoin reserves, we apply similar principles, with varying degrees of conservatism in our assumptions, to calculate liquidity ratios for stablecoins.

The Basel LCR ratio, which is required to be over 100% for banks, is typically calculated as a ratio of High Quality Liquid Asset (HQLA) to Total net cash outflow over the next 30 days:

$$\frac{\text{Stock of HQLA}}{\text{Total net cash outflows over the next 30 calendar days}} \geq 100\%, \tag{1}$$

$$\text{Net cash outflows} = \text{cash outflows} - min(\text{cash inflows}, 0.75 * \text{cash outflows}) \tag{2}$$

The amount of HQLAs in the numerator reflects the quality and liquidity of assets and the denominator reflects the assumed runoff risk of liability items. Despite the nomenclature "cash flows", the total net cash flow calculation in LCR is based on a snapshot of the balance sheet and assumed run-off rates for different types of liabilities (e.g. varying from 3% for stable retail deposits to 40% for non-operational deposits) rather than an estimate of expected inflows and outflows. Additionally, the Basel definition of inflows only captures contractual account receivables that are expected to occur.

The numerator is more easily translatable. As discussed in Section 2, tokenized cash by construct is backed by the safest and most liquid assets, mostly level 1 HQLA. As an example, USDC reserves are composed of around 80% T-bills and 20% cash held in bank accounts. The cash deposits that are held in banking accounts would unlikely qualify as HQLA since they are deposits that are fractionally reserved by banks and held as loans and other assets. The T-bill holdings would likely qualify as HQLA without a discount as it is the safest type of asset available.

The denominator is more difficult to map to the Basel LCR standard as the holders of cash tokens represent a mix of retail and businesses based on the breakdown of wallet types and sizes presented in Section 3. Moreover, they may differ in several important ways from the overall population. They may be more sophisticated, as they participate in the fastly evolving Crypto ecosystem, or alternatively, they may have higher rates of risk tolerance, thereby posing different run rate risks.

Rather than constructing our definition of what type of wallets would qualify as retail vs business, operational vs non-operational, and apply the traditional Basel III run risks, we apply multiple approaches. Table 4 summarizes our assumptions and calculated liquidity ratios. The three approaches are discussed below:

- Basel III applies a 3% run-off risk for insured deposits (stable), and 10% run-off risk for non-insured ones. If we apply conservatively a 40% run rate to all tokenized cash liabilities assuming all token holders are classified as non-operational deposits under Basel III LCR guideline, we find a liquidity ratio of 196%[8].

- Even though Basel III does not rely on historically observed net outflows, observed behavior for cash tokens is nonetheless useful as a benchmark. Previous studies on bank runs have also compared observed vs assumed net outflows[9]. We rely on the worst observed 30-day run-rate, calculated in accordance to Equation 2 applied as the run-off rate. Based on this approach we find that the liquidity ratio amounts for 850%.

- Finally, we assume an extreme run-off rate in which no inflow is expected and as well as assuming worst gross outflows based on historical observation. This is a conservative approach since entities have significant inflows that offset outflows over the course of 30 days. Under these assumptions we find a liquidity ration of 212%.

Under these approaches, we find significant variation in liquidity ratios, far exceeding the typical LCR for the eight U.S. GSIBS that averaged around 118% in Q2 2022[10]. Nevertheless, it is important to caveat the calculation and highlight that the nature of tokenized cash holders may be significantly different from the population. In future work we intend to explore in greater detail and empirically tokenized cash holders' run-off risks based on their characteristics.

[8]The liquidity ratio is calculated as $42.47 billion of HQLAs divided by 40% run rate on $54.29 billion of circulation as presented in Table 4.

[9]See, for instance, Martin et al. (2018)

[10]LCR for GSIBs, provided in parentheses, are based on Q2 public disclosures from Citigroup (115%), JP Morgan (110%), Bank of America (118%), Bank of New York Mellon(111%), Goldman Sachs (125%),Morgan Stanley(128%), State Street (106%), Wells Fargo(121%).

Table 4: Liquidity ratios

Assumption	**Run rate**	**Liquidity ratio**
Non-operational deposit run rate under Basel LCR	-40.0%	196%
Observed 30-day worst run rate with inflows capped at 75% of outflows	-9.2%	850%
Observed 30-day worst run rate with 0% inflow	-36.9%	212%
U.S. GSIBs' LCR average 2022Q2		118%

Notes: This table presents the liquid ratio of USDC calculated under different assumptions of run rates. The calculation is based on the reserve as of August 5, 2022 but is broadly reflective of the general reserve mix of 80% T-bill and 20% cash deposits. The total circulation of USDC was $54.29 billion and the amount of HQLA consisting of T-bills was $42.47 billion. The denominator is calculated as the run rate multiplied by the amount in circulation. Liquidity ratio is calculated as a ratio of HQLA to outflow according to Equation 1. The last row provides the LCR of the eight U.S. GSIBs based on their 2022Q2 public disclosures as a comparison.

4.4 Comparison with money market funds

In many policy discussions around stablecoins, parallels are drawn on stablecoins and money market funds (MMFs) with respect to the potential systemic risk[11]. This comparison is over-generalized for several reasons.

Money market funds, like stablecoins, have distinct categories reflecting the diverse asset holdings of funds. Treasury money market funds (TMMF), which hold T-bills and Treasury repo contracts, most closely resemble tokenized cash in their liquidity and risk exposure. In contrast, prime money market funds (PMMF), which hold predominantly commercial papers, and tax-exempt MMFs, which hold municipal debt, hold assets that are more illiquid and higher risk. In fact, PMMFs have had two episodes of "runs" that resulted in market interventions by the Federal Reserve in the past two decades – once during the 2008 financial crisis and again during the March 2020 market turmoil. Stablecoins that hold riskier assets such as commercial papers are more closely mapped to PMMFs, and face greater risk to "break the buck" during market distress (Catalini and de Gortari (2021))

[11] See, for instance, *Oversight of the Treasury Department's and Federal Reserve's Pandemic Response* (2021) and Gensler (2022)

These categorical differences are also directly measurable in terms of liquidity risk. Under the current MMF regulatory framework, MMFs are required to hold more than 10% of their portfolio as Daily Liquid Asset (DLA), defined as cash and direct obligation of the U.S. government. Tokenized cash, by definition, has 100% of its asset held as DLA, the same level as TMMFs. In contrast, institutional PMMFs have an average DLA of 51.1% and retail PMMFs have an average DLA of 38.6% as of July 2022[12].

Additionally, the liability outflows of MMFs also vary greatly depending on the type of asset holdings, with TMMFs generally experiencing inflows and PMMFs experiencing outflows during periods of market stress(“Experiences of US Money Market Funds During the COVID-19 Crisis”, 2020). Similarly, tokenized cash and fiat asset-backed non-cash stablecoins bear resemblance to TMMFs and PMMFs in their holdings respectively.

Lastly, money market funds and tokenized cash serve fundamentally different use cases. Money market funds serve as short-term investments and qualify as securities under the Howey test. In contrast, tokenized cash is non-interest rate bearing and it provides utility value as a means of enabling instant payment on distributed ledgers.

5 Event study: Terra collapse

Which stablecoins are held by users during different market conditions are telling of revealed preferences for the distinct characteristics of different tokens. In this section, we examine the behavior of tokenized cash among other stablecoins around the collapse of Terra/Luna, an algorithmic stablecoin that suffered from a run. The risk of contagion from a stablecoin run has often been raised as a concern by policymakers. This historical analysis offers an important real-world stress test.

We first examine the aggregate market caps of major stablecoins around the Terra collapse before delving into the behavior of wallet balances in tokenized cash. Figure 5 shows the market caps of major stablecoins around the time of Terra’s collapse. Correspondingly,

[12] Securities and Exchange Commission N-MFP filings

Table 5 shows the change in market caps for major stablecoins during the one-month period following the collapse of Terra. As the exhibits show, Terra (UST) lost over 99% of its market cap (around $18.6 billion) during the one-month period following its initial depeg. The loss in confidence in stablecoins likely led to a spillover of a run from Terra to Tether during this period. Tether (USDT), which at the time was backed by a sizable portfolio of commercial papers of unknown quality and origin, suffered an outflow of around $11 billion (13% of its market cap before UST's collapse). The crypto overcollateralized stablecoin, Dai, also suffered a sizable outflow of around 19% of its market cap. In contrast, the two stablecoins that had seen net inflows during this period were both cash tokens, USD Coin (USDC) and Binance USD (BUSD), with respective inflows of $5.3 billion and $750 million.

While the net increase in tokenized cash during this event indicates qualities of safe assets, the gross inflows and outflows provide a richer description of the change in liabilities as the behavior of users is often highly heterogeneous. Figure 6 shows that the highest daily net minting of USDC during this period was around $1.05 billion on May 13, five days after Terra's initial collapse. This net inflow is composed of around $2.2 billion of inflow and $1.1 billion of outflow. Moreover, more than half of the gross outflow (or around $650mm) was offset by intraday inflows by the same accounts, possibly indicating intraday liquidity value and convertibility with fiat cash.

Large simultaneous gross inflows and outflows have also been observed historically in bank runs. For instance, Martin et al. (2018) describes the differences in inflow and outflow dynamics for insured versus non-insured deposit accounts at a distressed bank. Tokenized cash differs in that the accounts minting and burning tokens are often not the same as wallets that end up holding the tokenized cash. This is because the issuer of tokenized cash only services institutional accounts that then distribute the cash tokens to the broader ecosystem.

We examine the changes in tokenized cash balances on Ethereum by wallet type in Table 6. The largest decline in wallet balances occurred in bridges that linked the Ethereum chain to other chains, such as the Terra chain. Stablecoin liquidity pools that were deployed in smart contracts also observed a modest decline in tokenized cash balance during this period. The decline in these two categories of wallets possibly reflects a direct spillover of risk from the collapse of Terra. Other wallet categories mostly saw an increase in cash token balances.

Table 5: Change in Stablecoin market caps around Terra's collapse

Stablecoin	$ Billions	Percent change
BUSD	0.75	4.2
DAI	-1.52	-19.0
USDC	5.32	10.9
USDT	-10.90	-13.0
UST	-18.55	-99.1

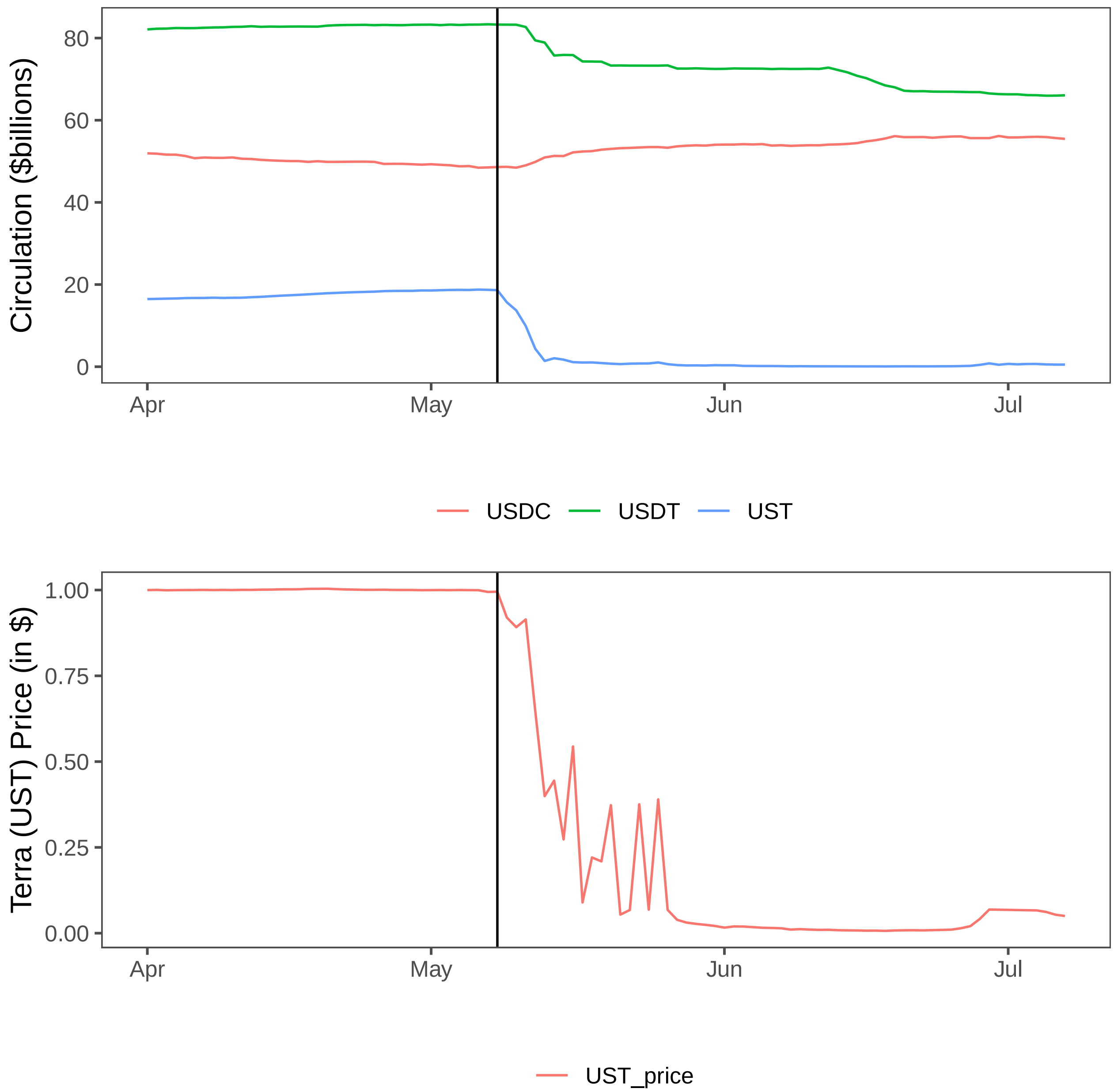
Notes: This table shows the change in the market capitalization of major stablecoins from May 7, 2022 to June 7, 2022.

Table 6: Change in tokenized cash balances by wallet type around Terra's collapse

Category	$Billion	Percent
Bridges	-1.43	-19.6
DAOs	0.63	23.9
Dexes & Other DeFi	-0.21	-11.1
EOAs	3.60	18.9
Exchanges & VASPs	0.67	16.2
Lending	0.17	8.3
Other	0.04	5.1
Stablecoin Liquidity	-0.52	-10.8

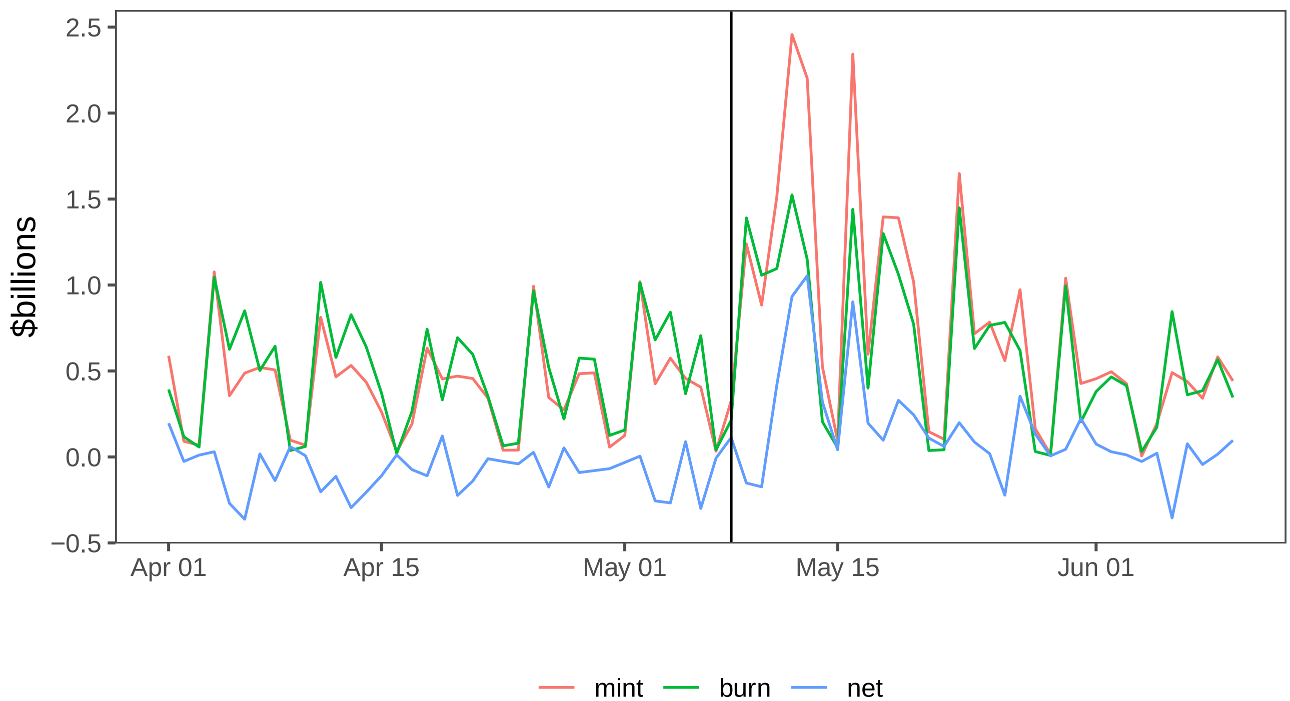
Notes: This table shows the change in the balances of USDC wallets on Ethereum from May 7, 2022 to June 7, 2022.

Figure 5: Stablecoin market caps around Terra's collapse



Notes: This figure shows the evolution of stablecoin market caps around the Terra collapse. The vertical line indicates May 8, 2022.

Figure 6: Inflows and outflows around Terra depeg event



Notes: This figure shows gross mints and burns of USDC around the time of Terra's collapse. The vertical line indicates May 8, 2022.

6 Implications on Treasury market, safe asset collaterals, and lending

Beyond liquidity and run risk, the growth of tokenized cash affects the financial system through two additional channels. First, as tokenized cash are fully reserved with safe assets, the demand for safe asset can affect the availability of collaterals for other institutions. Second, the inflows into tokenized cash might compete with bank deposits that could support credit intermediation. We discuss and contextualize these two channels through quantitative comparisons.

6.1 Safe asset demand

The circulation of all stablecoins, including tokenized cash, remain small relative to the overall amount of safe assets and holdings by other structures. As a comparison, all of stablecoins' market caps combined are around \$150 billion as of August 2022, relative to around to \$4 trillion of holdings by Government Money Market Funds, of which Treasury Money Market Funds account for around \$1.2 trillion[13].

A comparison against history is also helpful to bound the potential impact of stablecoins if they were continue to grow. One example of a large Treasury bill demand shock was the 2016 MMF reform that transformed around \$1 trillion of Prime MMFs to Treasury MMFs over a relatively short period of time. This large increase in short-term Treasury demand caused little deterioration in money market conditions and wholesales funding. The primary response was a cutback in arbitrage positions that the banks were holding using funding from prime MMFs (Anderson et al., 2019). With this historical benchmark in mind, tokenized cash could likely grow by around ten times the current level without likelihood of materially increasing the scarcity of safe asset assets.

[13]Form N-MFP Data, period ending July 2022

The variability of demand for the T-bill market is also likely muted because of cash buffers that tokenized cash issuers hold at depository institutions. For instance, USDC has around 20% of its reserves as deposit holdings spread across a number of depository institutions. Under the typically observed single digit run rates described in Section 4, rapid liquidation of T-bills would unlikely be necessary. The draws from depository institutions are also spread across multiple banks.

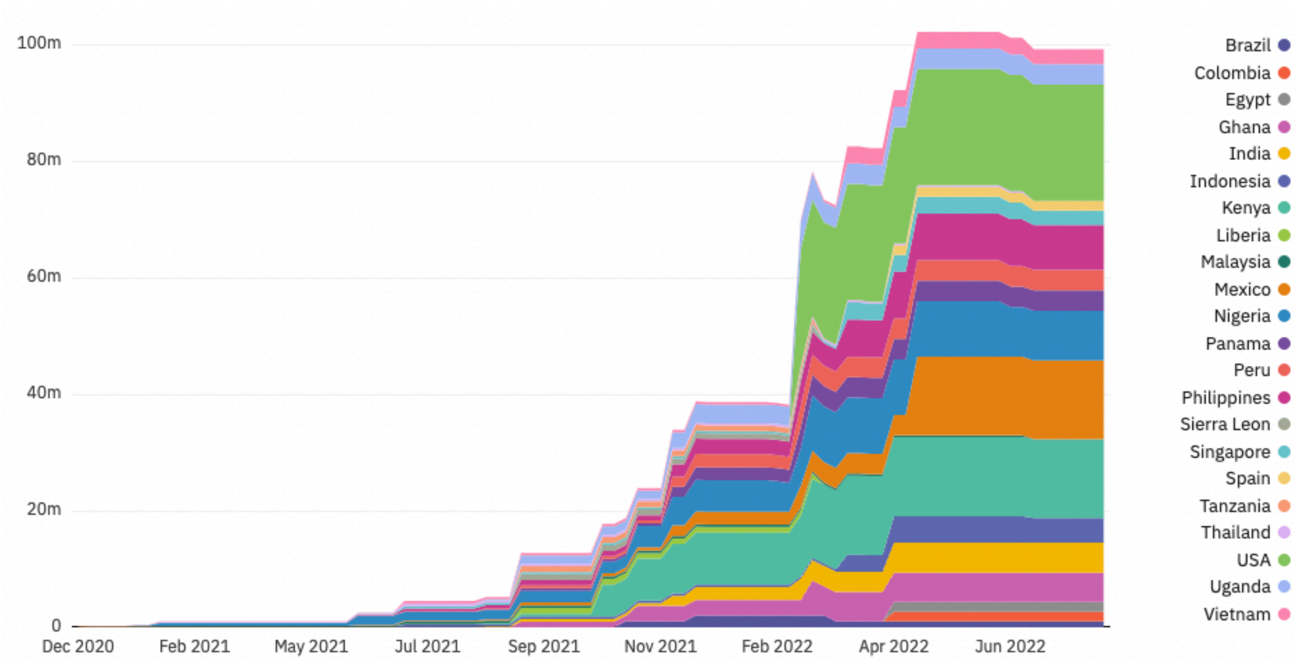
6.2 Deposit competition

The second concern associated with stablecoins locking up liquidity is that the stablecoins might compete away bank deposits, and this could lead to disintermediation of credit and lending to consumers and businesses. This concern is not new. The introduction of checkable money market funds had raised similar discussions on deposit outflows in the past(Hubbard, 1983; White, 1984). There are several reasons why this channel might not pose less risks relative to traditional forms of "narrow" deposits or "narrow" banks.

- On-chain credit lending, not by the stablecoin issuer, but opt-in by stablecoin users through a platform approach can be expand credit in an inclusive manner. Protocol based lending with attestations of business identities has already seen rapid growth, especially in serving firms that lack credit access. For example, Figure 7 shows the growth of on-chain lending in one of the credit protocols that lend out tokenized cash. The diverse geographic distribution across emerging markets showcase the fact that on-chain lending market places can bring more inclusitivity in credit creation.
- Tokenized cash are unlikely to grow without demonstrated long-term utility value for both payments and on-chain credit intermediation given opportunity costs for users to hold a non-interest bearing asset.
- Deposit competition a la Drechsler, Savov, and Schnabl (2017) translates into tighter monetary rate policy transmission, which might be an desirable outcome. Additionally,

competition for retail deposits would raise the interest rate paid to consumers, which could have a crowd-in effect for overall amount of deposits as physical cash in circulation are drawn into the banking system.

Figure 7: On-chain protocol based lending



Notes: This figure shows on-chain lending using tokenized cash (USDC) based on the protocol Goldfinch.

Structured model estimates show that deposit competition with even the safest type of tokenized cash, central bank digital currencies, are unlikely to cause large deposit flow out of banks (Chiu, Davoodalhosseini, Hua Jiang, & Zhu, 2019; Whited, Wu, & Xiao, 2022). This channel of deposit competition also relates to policy debates that occurred throughout the last century on narrow banking frameworks that were proposed to reduce moral hazard in banking with public sector insurance and bailouts. To note, narrow deposits and narrow "banks" in this context refers to institutions that hold safe assets, such as T-bills, without fractionalized reserves (Pennacchi, 2012). A recent revisit of the earlier narrow banking plan, often known as the Chicago Plan, by Benes and Kumhof (2012) shows that the separation between monetary and credit functions of banks would reduce business cycle fluctuations, eliminate bank runs, and increase output by around 10%.

7 Conclusion

This paper is one of the first attempts to apply quantitative data to study the systemic run risks of tokenized cash, a form of stablecoin fully collateralized with high quality, liquid, short-term assets. Using historical data, we calculate a LCR-equivalent measure of liquidity and find that the largest cash token has a liquidity ratio that is at least double that of a typical bank. We find that the overall circulation of tokenized cash is largely insulated from digital asset price movements as well as negative risk spillover from the collapse of Terra, though subcategories of wallets had sizable re-balancing of tokenized cash holdings from smart contracts, particularly cross-chain bridges and stablecoin liquidity pools, to private wallets. We also contextualize the holdings of T-bills by tokenized cash issuers relative to Treasury money market funds and historical episodes of demand shocks in safe asset collaterals. Overall, we find that tokenized cash has ample room to grow before reaching a size that could plausibly affect overall safe collateral demand and credit creation.

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