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The Financial Stability Implications of Digital Assets[1]

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Abstract

The value of assets in the digital ecosystem has grown rapidly, amid periods of high volatility. Does the digital financial system create new potential challenges to financial stability? This paper explores this question using the Federal Reserve's framework for analyzing vulnerabilities in the traditional financial system. The digital asset ecosystem has recently proven itself highly fragile. However adverse digital asset markets shocks have had limited spillovers to the traditional financial system. Currently, the digital asset ecosystem does not provide significant financial services outside the ecosystem, and it exhibits limited interconnections with the traditional financial system. The paper describes emerging vulnerabilities that could present risks to financial stability in the future if the digital asset ecosystem becomes more systemic, including: run risks among large stablecoins, valuation pressures in crypto-assets, fragilities of DeFi platforms, growing interconnectedness, and a general lack of regulation.

Keywords: Digital assets, stablecoins, DeFi, financial stability, financial vulnerabilities, systemic risk.

JEL classification: E42, G01, G13.

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1 Introduction

The digital asset ecosystem grew rapidly until early 2022, and notwithstanding recent volatility advocates continue to expect the system to resume its rapid growth.[2] As the digital asset ecosystem grows, becomes more interconnected with the traditional financial system, and mimics products and structures of traditional finance, it creates new potential challenges to financial stability. The digital asset ecosystem replicates many of the same types of market failures and vulnerabilities that arise in traditional finance—generally without regulatory safeguards—while also introducing new risks.

This paper describes risks associated with digital assets using the Federal Reserve's framework for analyzing vulnerabilities in the traditional financial system, which distinguishes between vulnerabilities and shocks. Financial vulnerabilities are a collection of factors that may amplify financial shocks. Vulnerabilities tend to build up over time, and policies can be designed to lessen them, making the system more resilient and thus more likely to be able to continue to function effectively in the face of shocks. For our analysis we define the digital asset ecosystem as including coins designed to maintain a stable value, crypto-assets without such a peg, centralized lenders and exchanges, and decentralized finance (DeFi) protocols, among other things.

Activities within the ecosystem involve **liquidity and maturity transformation** without access to a liquidity backstop, which exposes the system to the possibility that investors will run to withdraw funds quickly in adverse situations, possibly inducing fire sales of assets to meet those redemptions.

Taking leveraged positions to speculate on changes in the price of digital assets is common. Few limits exist on **leverage** or collateral rehypothecation. Leverage increases the risk that actors in the digital asset ecosystem will not have the ability to absorb even modest losses when hit by adverse shocks and will be forced to cut back lending, sell assets, or even shut down.

Crypto **valuations** have risen and fallen rapidly, are in many cases volatile relative to valuations of traditional assets, and have, at times, exhibited high correlations with valuations in traditional financial assets.[3] These strong correlations and rapid fluctuations in asset values create vulnerabilities when combined with leverage and liquidity transformation practices of lending platforms, DeFi protocols, and centralized exchanges.

Several features of the digital asset ecosystem introduce **novel vulnerabilities** to its stability. Where transaction execution is automated, it reduces the response time for interventions that could prevent fire sales or other destabilizations.[4] At the same time, decentralized governance of certain platforms can hinder rapid action to mitigate stress or create regulatory challenges. Automation may also exacerbate operational vulnerabilities.

Public blockchains, crypto-assets, stablecoin issuers, DeFi protocols, and centralized exchanges are **interconnected**, with no limits on concentrated exposures. Shocks in one area can spill over quickly to

[2] The value of all digital assets is currently approximately $900 billion. See CoinMarketCap (2022), "Total Cryptocurrency Market Cap," chart (accessed July 1, 2022).
[3] Filippo Ferroni (2022), "How Interconnected Are Cryptocurrencies and What Does This Mean for Risk Measurement?" Chicago Fed Letter 466 (Chicago: Federal Reserve Bank of Chicago, March).
[4] Hillary J. Allen (2022), "DeFi: Shadow Banking 2.0?" working paper (Rochester, NY: SSRN, February 18).

others. Digital assets' **interlinkages with the traditional financial system** are limited at present but may grow, increasing the potential for spillovers to the traditional financial system.

The lack of a strong and cohesive **regulatory framework** for digital assets amplifies these vulnerabilities. Many parts of the digital asset ecosystem are designed to avoid regulation. Digital assets do not fit neatly into existing regulatory frameworks. In addition, controlling influence is often obscured (e.g., in DeFi) or dispersed (e.g., blockchain validators).[5] When digital asset companies are registered as legal entities, they are often domiciled in non-G20 countries. Establishing regulation for the digital asset space would be further complicated by novel activities and arrangements operating without legal entities, such as Decentralized Autonomous Organizations (DAOs) and smart contracts.

The digital asset ecosystem has recently proven itself highly fragile. In the context of a changing macroeconomic environment, high-profile projects have failed, and key institutions have found themselves facing liquidity issues and insolvency. However, these adverse shocks have not created negative feedback loops in the traditional financial system, as the digital asset ecosystem does not provide significant financial services outside the ecosystem and its interconnections with the traditional financial system are limited. However, we identify emerging vulnerabilities that could present risks to financial stability in the presence of stronger interlinkages between digital and traditional financial institutions and in the event of future growth of the digital asset ecosystem:

- Run risk in stablecoins, where issuers may dispose of reserve assets quickly to meet redemptions, potentially disrupting traditional financial markets;
- Valuation pressures and risk appetite in crypto-asset markets;
- Fragilities of decentralized and centralized platforms, including leverage and maturity and liquidity transformation, and novel risks such as greater automaticity in DeFi; and
- Interconnectedness across these vulnerabilities and a general lack of regulation in the ecosystem

Section 2 provides an introduction to the components of the digital asset ecosystem. The sections following describe financial stability vulnerabilities associated with stablecoins (Section 3), crypto-assets (Section 4), DeFi (Section 5), lending platforms (Section 6), centralized exchanges (Section 7), and interconnectedness (Section 8). Section 9 discusses regulatory gaps. Section 10 concludes with our assessment of the financial stability implications of digital assets. A case study of the TerraUSD collapse in May 2022 and its repercussions in digital and traditional markets is described in Box 1.

2 A Quick Review of the Digital Asset Ecosystem

Digital assets operate as part of a complex and interconnected digital ecosystem, as shown in Figure 1. The foundation of the ecosystem is the blockchain, a type of distributed ledger where transactions are recorded and participants transact with other participants and decentralized applications. Bitcoin and Ethereum are the two largest blockchain networks. Bitcoin was the first blockchain, designed as the ledger for a payment system but lacking full programmability. Ethereum introduced the concept of a programmable blockchain with smart contracts, which are essential to DeFi (discussed later).

[5] Sirio Aramonte, Wenqian Huang and Andreas Schrimpf (2021), "DeFi risks and the decentralisation illusion", Bank for International Settlements Quarterly Review (27), December.

[Crypto-assets](#) are created and transferred on a blockchain, and most blockchains have a "native" crypto-asset. Bitcoin and Ether, the native assets of the Bitcoin and Ethereum blockchains, respectively, are the crypto-assets with the highest market capitalization. These top native crypto-assets have garnered attention and large market capitalizations and have experienced extreme volatility. Ether and Bitcoin (or "wrapped" synthetic Bitcoin) are commonly used as collateral in digital financial transactions.

Figure 1: The Digital Asset Ecosystem

Application Layer Apps and websites	**Websites and Apps**	**Wallets**	**Centralized Exchanges** On- and off-ramp between fiat and crypto
Smart Contract Layer	**Decentralized exchanges**	**Lending Protocols**	**Other DeFi Applications** *e.g.,* Derivatives, Asset allocation
Asset Layer "tokens" or "coins"	**Native cryptocurrencies** *e.g.,* BTC, Eth	**Stablecoins**	**Other digital-assets** *e.g.,* Governance tokens, NFTs
Settlement Layer	**Blockchains** *e.g.,* Bitcoin, Ethereum, Solana, Terra		

Note: Adapted from the IOSCO Decentralized Finance Working Group Report and Toolkit, *March 2022 and Fabian Schär, "Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets," Federal Reserve Bank of St. Louis Review, Second Quarter 2021, pp. 153-74.*

Stablecoins (SCs) intend to provide a stable-value reference asset within the digital asset ecosystem to facilitate trading, lending, or borrowing of crypto-assets while allowing users to avoid moving in and out of fiat. SCs are essential to transacting across crypto-assets in DeFi. Importantly, SCs of this type—which are common in the digital ecosystem—are not used to facilitate wholesale or retail payments across the real economy. SCs are not widely used as a means of payment at present.

DeFi facilitates the automation of financial activities such as lending, savings, payments, and trading through smart contract code, purportedly eliminating the need for financial intermediaries and centralized institutions. The most prevalent use-cases in DeFi are trading and lending. In the trading space, popular decentralized exchanges such as Curve and Uniswap offer users the opportunity to exchange one asset for another without the involvement of a third party, quoting traders an algorithmically determined asset price. In the lending space, depositors receive yield on digital assets, and pseudonymous borrowers take overcollateralized digital asset loans from protocols like Aave and Compound. **Applications** provide convenient interfaces for accessing assets and smart contracts.

Centralized crypto exchanges serve as the primary means of converting fiat currency to crypto-assets and otherwise provide a range of services akin to those provided by traditional financial intermediaries.

Most crypto-asset trading volume involves centralized exchanges, which hold central limit order books off the blockchain. **Digital wallets** allow users to hold and interact with their digital assets.

3 Stablecoins

SCs are digital assets that aim to maintain a stable value relative to a reference asset—typically the U.S. dollar. Currently there exist different SC designs, as we describe in the next subsection. The least stable designs have already experienced destabilizing runs, like the collapse of TerraUSD in May 2022 (see Box 1). But even the less fragile designs of larger SCs appear subject to runs.

If a sizable share of holders rushed to sell or redeem a large SC like Tether (USDT) or US Dollar Coin (USDC), it could not only create instability in the digital asset ecosystem, but also disrupt certain markets in the traditional financial system, as SC issuers would have to dispose of their reserve assets quickly to meet redemptions. These disruptions would likely be more severe in the case of SCs with less liquid reserve assets, like corporate bonds and commercial paper. Moreover, SCs underpin the crypto ecosystem, and their demise could cause spillovers within that ecosystem, amplified by vulnerabilities from leverage, liquidity transformation, and interconnectedness in the crypto financial system. Nonetheless, financial stability risks from SCs and the amplification mechanisms of such risks through vulnerabilities in the crypto ecosystem are hard to gauge, as information is poor and regulation and supervision are weak.

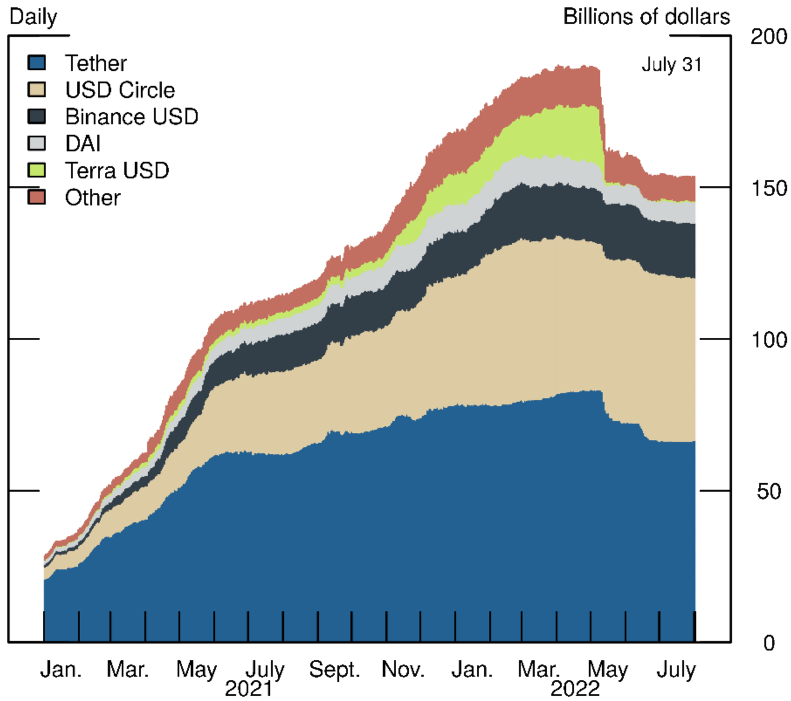
3.1 Overview

SCs experienced rapid growth in 2020 and 2021, with the five major SCs growing more than fourfold in both years (Figure 2). By contrast, year-to-date as of July 31, the market capitalization of the same five SCs has been flat, reflecting the collapse of TerraUSD and the associated decline of other SCs that wiped out the growth in the first four months of the year. As shown in Figure 2, the largest SC is **Tether**, with a market capitalization of $67 billion, down 20 percent from its peak of $83 billion. The second largest SC is **USDC**, with a market capitalization of $54 billion. They are followed by **Binance USD (BUSD)** and **DAI**, with market capitalizations of $18 billion and $7 billion, respectively. The fifth SC presented in Figure 2 is **TerraUSD (UST)**, which experienced a run that reduced its market capitalization from a peak of more than $18 billion at the end of April to $346 million at the end of July; see Box 1.

The recent growth of SCs has coincided with broader growth of the crypto-asset markets and DeFi. Within the crypto ecosystem, SCs primarily exist to facilitate trade and to enhance the *transferability* of funds across blockchains. These properties are desirable as a medium of exchange in the crypto ecosystem, especially given the relatively large fees involved in going from crypto-assets into traditional assets. Moreover, SCs are the assets most commonly deposited and borrowed in DeFi, most quoted in decentralized exchanges, and most touted as earning yields in excess of bank deposits. DeFi applications essentially operate using SCs.

Proponents of SCs argue for their potential to become a widely used medium of exchange within and outside the digital ecosystem. To achieve widespread use, they must be readily transferrable with a reliable and accurate mechanism for transferring ownership, as highlighted in the Presidential Working

Figure 2: Market Cap of Major Stablecoins



Source: DeFi Llama.

Group report.[6] Outside of the crypto ecosystem, SCs might grow to become a medium of exchange available to the general public, thus spurring more competition in the traditional payment landscape. Whether such competition will translate into a welfare gain is still an open question.[7] For the banked population, the development of a retail real-time payments system (such as FedNow) might achieve the goals that an SC could achieve.[8] The unbanked population could benefit from using SCs. Whether the unbanked can realize these benefits depends on digital wallets becoming accessible without relying on bank accounts and traditional payment systems. In addition, SCs that are quoted in different currencies might lower the costs of cross-border payments for both retail and wholesale transactions. Whether the technology underpinning SC transfers can realize such gains depends on how much it can save on the costs of the current correspondent banking system and Continuous Linked Settlement (CLS).[9]

Detractors of SCs highlight their fragility, as exemplified by the recent collapse of TerraUSD and the previous failure of other SCs like Iron in June 2021.[10] Weakly regulated SCs may be subject to runs and

[6] See President's Working Group on Financial Markets, the Office of the Comptroller of the Currency, and the Federal Deposit Insurance Corporation (2021), *Report on Stablecoins* (Washington: Department of the Treasury, November).
[7] In fact, new payment system providers are already promoting competition in this space.
[8] In particular, real-time payments might benefit agents with binding liquidity constraints but should be irrelevant otherwise, as the timing of settlement does not affect the ability to spend in this case.
[9] For details on frictions to cross-border payments, see Financial Stability Board (2020), *Enhancing Cross-Border Payments: Stage 1 Report to the G20* (Washington: FSB, April).
[10] Austin Adams and Markus Ibert (2022), "Runs on Algorithmic Stablecoins: Evidence from Iron, Titan, and Steel," FEDS Notes (Washington: Board of Governors of the Federal Reserve System, June 2).

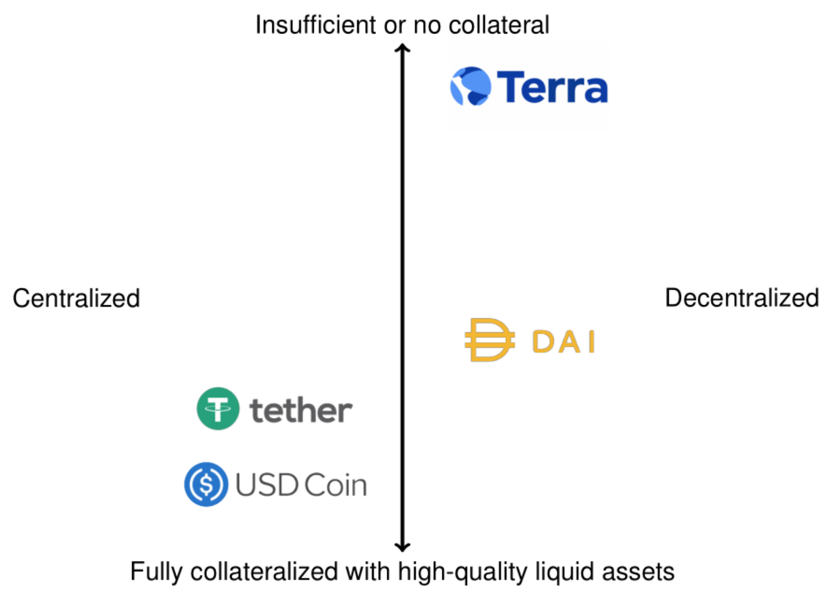
generate negative spillovers across the digital ecosystem and traditional money markets. However, to date, SC use remains largely confined within the crypto ecosystem. An additional consideration introduced by the wide use of SCs may be that bank credit provision would be reduced without a corresponding increase in credit provision through DeFi. The extent to which the wide use of SCs could reduce aggregate credit provision will depend to a large degree on how SCs manage their reserves. If, for instance, SC reserves are used to fund banks through deposits or other money market instruments, credit provision would be less affected.

3.2 Run Risk: Liquidity and Maturity Transformation

SCs are marketed as being stable and pegged to their reference asset, creating the perception that users can redeem them on demand for the reference asset. Yet, in practice, most SC issuers impose redemption restrictions or even reserve the right to withhold redemptions, leaving users that want to liquidate their SCs with only the option to trade them in secondary markets. The perception that SCs can be redeemed on demand is enough for them to create vulnerabilities from liquidity and maturity transformation, as SC reserve assets could be illiquid or have longer maturities.

Different SCs have different designs aimed at maintaining their peg, which can affect their susceptibility to runs. SCs can be partitioned according to two key distinguishing features, as shown in Figure 3: their degree of collateralization, shown on the vertical axis, and their degree of centralization, shown along the horizontal axis.

Figure 3: Stablecoins Key Design Features



Note: Adapted from Mario Gabriele (2021), "Terra: The Moon Also Rises," The Generalist (newsletter), accessed July 1, 2022.

The first key design dimension is the degree of collateralization, the vertical axis. Given the lack of standardization or regulation, SC issuers have been able to use assets of different quality to back SCs. At one extreme, SCs fully backed by central bank reserves are resilient to runs. But holding central bank reserves requires an account at the central bank, which is generally limited to regulated depository institutions. At the other extreme, there are SCs that are backed by low-quality collateral or by no collateral at all, as represented by the vertical axis in Figure 3. Among decentralized SCs, DAI is an algorithmic SC designed to be overcollateralized, while Terra (or TerraUSD for its dollar SC) is an algorithmic SC that was designed with no collateral.[11] Among centralized SCs, USDC is collateralized by higher-grade assets than Tether (based on self-disclosures). In fact, shortly after the TerraUSD collapse, Tether saw redemptions of around $10 billion, while USDC saw a little more than $4 billion of new inflows (Figure 2). This substitution from Tether into USDC illustrates a bigger concern—namely, that resilient SCs can amplify run risks from more fragile ones, as they provide a convenient instrument to run to.

The second key design dimension is their degree of centralization of governance. Some SCs, like Tether, USDC, or BUSD, are issued by a single entity with a centralized governance structure. By contrast, DAI and TerraUSD have decentralized governance structures and are issued and administered using smart contracts. In this case, issuance and redemptions are carried out by a smart contract that follows preset rules that can be modified by a decentralized autonomous organization (DAO). For example, changes in the collateral eligibility for creating or minting DAI tokens are voted on by the governance token holders. Coordination problems at DAOs, given their governance structure, create higher vulnerabilities from decentralized SCs, all else being equal.

It is worth emphasizing that triggers for a run on SCs can arise from different sources. On the one hand, a drop in the price of the collateral assets, or a lack of trust in the custodian of those assets, could trigger a run.[12] On the other hand, the trigger for a run could be a sudden lack of confidence in the SC, which could be self-fulfilling and might be the result of a speculative or short sellers' attack on the SC analogous to those that threaten currency pegs.

A run on an SC can create negative feedback loops via the SC's relationships with DeFi applications and crypto-asset prices. Moreover, because SCs are supposed to be the safest asset in the crypto ecosystem, problems with them pose the greatest systemic risk within crypto. As the SC loses its peg, DeFi platforms that operate using that SC may become stressed. Users withdraw funds from lending platforms and borrowers see their rates increase rapidly. Stress is transmitted to DeFi exchanges, centralized exchanges, and other cryptocurrencies. In the case of the demise of the Terra platform, the collapse of the TerraUSD stablecoin, which had a total market capitalization of about $18 billion by the end of April, was accompanied by a decline of $25 billion of total value locked (TVL) in the Terra blockchain

[11] DAI and Terra employ a set of rules, expressed in software code, that aims to maintain exchange rate stability by dynamically matching the supply of coins with the demand. In the case of DAI, these rules specify that, to create or mint one dollar of DAI, a user needs to deposit more than one dollar of crypto-assets into a vault, and these vaults can be liquidated when the value of the collateral approaches the value of the DAI that was created. This mechanism keeps DAI overcollateralized in the absence of large price swings. In the case of Terra, these rules considered the exchange of Terra for Luna, the native token of the Terra blockchain. In this sense, Luna tokens were akin to the collateral backing the Terra SC.

[12] In essence, SCs are a form of privately produced money, much like bank deposits, which are intrinsically fragile. In fact, bank deposits, before enjoying deposit insurance, experienced frequent runs. Deposit insurance protects depositors up to the legal limit and is granted to depository institutions, which are subject to supervision and regulation and enjoy access to emergency liquidity and Federal Reserve services. Insurance, supervision and regulation, and access to emergency liquidity are the three pillars of public support for deposits to function as money. The President's Working Group report (*supra* note 8) has recommended that SC issuance, and related activities of redemption and maintenance of reserve assets, be carried out by entities that are insured depository institutions.

associated with its DeFi applications, like Anchor and Mirror, with knock-on effects on Terra investors and their counterparties (see Box 1).

In addition, for SC collateralized by traditional financial assets ("off chain"), a run could lead to liquidations and fire sales of the collateral assets. At present, Tether (USDT) is reportedly one of the largest commercial paper holders in the world.[13] A fire sale due to liquidations of commercial paper to address redemptions could have significant financial stability implications.[14]

4 Crypto-assets

Crypto-assets are digital assets that use cryptographic techniques to prove ownership. The crypto-assets with the largest market capitalization, like Bitcoin or Ether, are not designed to maintain a stable value. Some have argued that because these assets do not have associated cash flows, their fundamental value ought to be zero. However, in principle, even in the absence of cash flows, investors might be willing to pay for these assets.[15] First, they could expect that other investors will be willing to pay more for the asset in the future, as in a typical asset bubble. One common narrative is that this valuation motive is stronger for Bitcoin given the scarcity created by its cap on total coin supply and long-lived nature. Second, investors might expect that the assets will generate cash flows in the future, in which case they will be willing to pay for the asset depending on their assessments of the likelihood and the size of these payments. And some investors might view future asset repurchases as akin to future cash flows. Finally, investors might hold these assets if they are needed to perform some activities, like settling transactions on the ledger.

The main financial vulnerability from crypto-assets currently is the buildup of valuation pressures—signaled by prices that are high relative to fundamentals of crypto-assets that are typically associated with increased risk appetite. In fact, periods of elevated asset prices accompanied by risk appetite and followed by large declines in asset prices are common in the short history of Bitcoin and other crypto-assets. Vulnerabilities from valuations are amplified by interconnections and other vulnerabilities within the crypto ecosystem. In particular, crypto-assets are used as collateral in crypto-lending and DeFi and represent the bulk of assets traded in centralized and decentralized exchanges—which facilitate the use of leverage, engage in liquidity transformation, and are unregulated and opaque. As the crypto system grows larger and gets more interconnected with the traditional financial system, vulnerabilities from asset valuations could spill over into traditional financial markets. For example, portfolio effects for hedge funds, crypto-related public companies, and private equity could cause spillovers to other assets as exposures of these institutions to crypto markets continue growing.

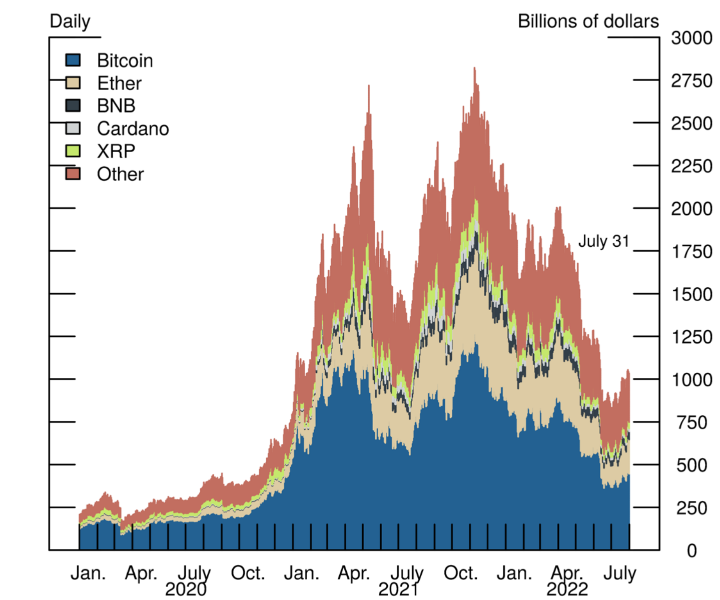
4.1 Overview

Most blockchains have a "native" crypto-asset used to settle transactions on the network (e.g., for transaction fees generated on the Ethereum blockchain, Ether is the only means of payment). Blockchains that allow for richer programming environments are host to a number of non-native crypto-assets such as crypto-asset tokens, SCs, and non-fungible tokens (NFTs).

[13] Siddharth Venkataramakrishnan and Joe Rennison (2021), "Tether's Commercial Paper Disclosure Places It among Global Giants," *Financial Times*, June 10.
[14] During the Terra crash of May 2022, Tether briefly lost its 1:1 peg with the U.S. dollar, but commercial paper markets showed no signs of fire-sale dynamics.
[15] See, for instance, John Cochrane (2017), "Bitcoin and Bubbles," *The Grumpy Economist,* blog, November 30.

The market capitalization of crypto-assets experienced very rapid growth in late 2020 and early 2021, reaching a peak of more than $2.5 trillion for the total market capitalization (this number exclude SCs), as shown in Figure 4. As of July 2022, the largest crypto currency is **Bitcoin (BTC)**, with a market capitalization of $450 billion, down almost 70 percent from its peak of $1,274 billion reached in November 2021. The second-largest crypto currency is **Ether (ETH)**, with a market capitalization of $200 billion. They are followed by **BNB, XRP,** and **Cardano (ADA),** with market capitalizations of $47 billion, $38 billion, and $17 billion, respectively.

Figure 4: Total Market Cap of Crypto-Assets



Source: Coinmetrics.

4.2 Valuation Pressures

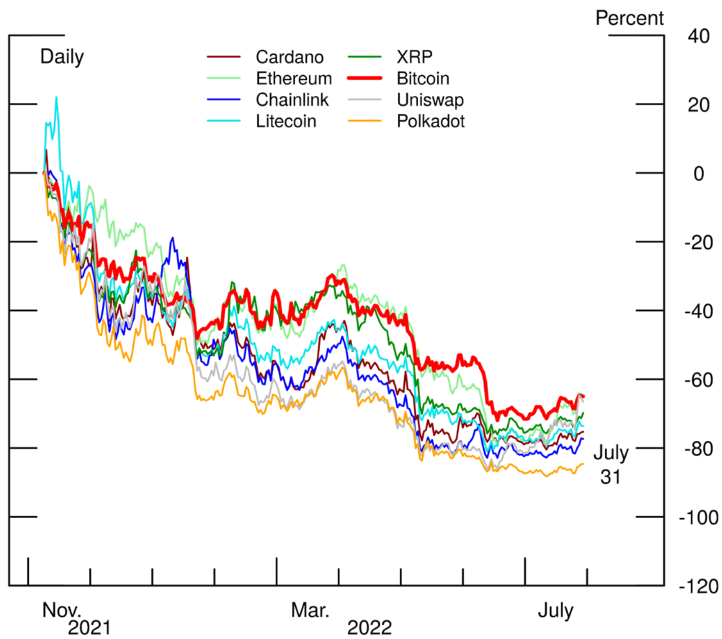
Valuation pressures in crypto-assets are underscored by the recurrent large declines in the price of Bitcoin and other crypto-assets, with Bitcoin having fallen about 70 percent since its peak in November 2021 and having experienced similar declines after its previous peaks in 2017, 2013, and 2011. Without an underlying claim on cash flows, assessing a crypto-asset's fundamental value is a challenge. Further complicating this assessment is the high correlation across crypto-assets and the elevated price volatility. In addition, the purported value of thinly traded assets may not reflect their current value.[16]

Research suggests that most of the variation in the prices of crypto-assets are associated with a common factor, with only a small fraction of price movements associated with the idiosyncratic characteristics of individual digital currencies.[17] In fact, Figure 5 shows that since Bitcoin reached its all-

[16] For example, holders of NFTs have found themselves unable to recoup their initial investments upon selling their tokens and in some instances have taken significant losses. See Christiaan Hetzner (2022), "Death of the NFT? CryptoPunk Bought for $1 Million Sells for $139,000 Just 6 Months Later," *Fortune,* May 9.
[17] See Albert S. Hu, Christine A. Parlour, and Uday Rajan (2019), "Cryptocurrencies: Stylized Facts on a New Investible Instrument," *Financial Management,* vol. 48 (Winter), pp. 1049–68; Yukun Liu and Aleh Tsyvinski (2021), "Risks and Returns of Cryptocurrency," *The Review of Financial Studies*, vol. 34 (June), pp. 2689–727.

time high in November 2021, the prices of major cryptocurrencies have all followed a similar downward trajectory. Over the past few years, the returns on Bitcoin have been strongly correlated with the returns on other cryptocurrencies. High correlation among crypto-assets and low explanatory power of valuation measures suggest a large role for risk appetite in driving the prices of these assets. In addition, many retail traders of crypto-assets exchange information or trading ideas via social media platforms, such as Reddit and Twitter. Information propagation via social media, especially in crypto markets that are lightly regulated, can contribute to price volatility or even market manipulation by coordinating actors across crypto-assets.[18]

Figure 5: Performance of major cryptocurrencies since Bitcoin's all-time high

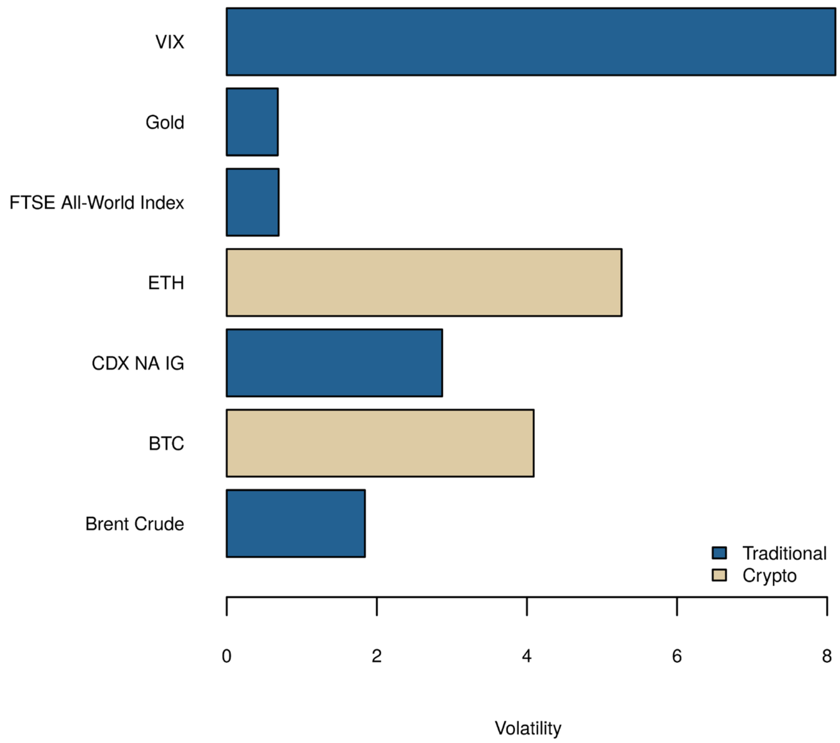


Source: CryptoCompare.

The large price swings of crypto-assets are reflected in high realized volatility for this asset class. Figure 6 compares the volatility of crypto with traditional assets. BTC and ETH display volatilities that are higher than most traditional assets in normal periods, defined as periods where neither the traditional nor the crypto markets experience stress. Moreover, during periods of traditional market stress, crypto-assets can be as volatile as traditional assets, and during periods of crypto stress, these assets are even more volatile than traditional assets.

[18] See, for instance, Raphael Auer, Jon Frost, and Jose María Vidal Pastor (2022), "Miners as Intermediaries: Extractable Value and Market Manipulation in Crypto and DeFi," BIS Bulletin 58 (Basel: Bank for International Settlements, June 16).

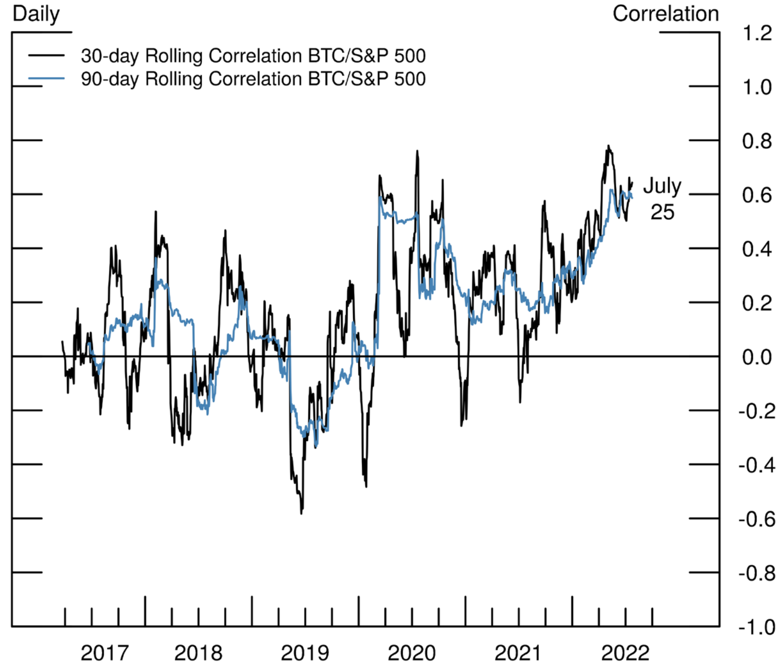
Figure 6: Volatility of Crypto and Traditional Assets in Normal Periods



Note: Normal period spans Feb 1, 2018, to Jan 31, 2020. We thank Christopher Anderson and Sara Saab, who shared with us their crypto-asset market analysis.
Source: Staff elaboration based on Bloomberg and CryptoCompare.

Finally, we compare the correlation of crypto and traditional assets over time. Figure 7 displays the correlation of Bitcoin and the S&P 500 index over moving, rolling windows of 30 and 90 days. The 90-day correlations between these assets started close to zero at the beginning of 2017 but have been much higher lately, displaying higher correlations around the COVID event and in the most recent periods. This pattern is apparent in correlations with other traditional financial assets as well and suggests that crypto-assets are highly susceptible to changes in risk sentiment in traditional financial markets.

Figure 7: Rolling Window Correlations



Source: CryptoCompare and S&P Dow Jones Indices LLC, S&P 500 [SP500], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/SP500.

5 DeFi

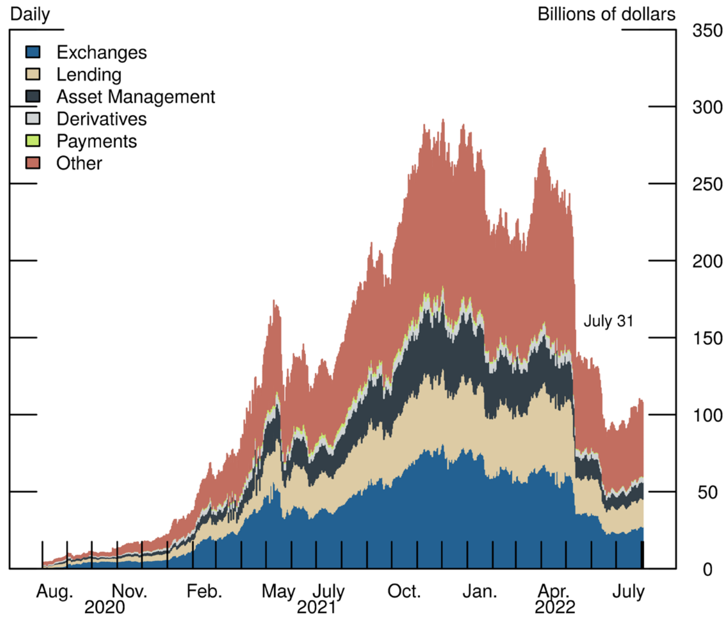
"Decentralized Finance" (DeFi) generally refers to open-source code running on open-access blockchains that aim to provide financial products without traditional financial intermediaries.[19] DeFi facilitates the automation of financial activities through smart contract code. DeFi protocols engage in maturity and liquidity transformation with little or no regulation and without access to a liquidity backstop, offer users leverage to speculate on the value of crypto-assets, and include design features that contribute to volatility in crypto-asset prices. Volatile crypto-assets are used as collateral in DeFi lending and are often rehypothecated in other protocols. DeFi also presents novel risks to financial stability, such as greater automaticity in transactions. While DeFi is also highly interconnected with other aspects of the digital asset ecosystem, its relatively small size and lack of direct connections with traditional financial institutions somewhat mitigate the extent to which DeFi represents a significant financial stability vulnerability in the short run.

5.1 DeFi Overview

DeFi applications experienced explosive growth in 2021 (see Figure 8) as venture-capital-backed DeFi projects proliferated and attracted users with the promise of outsized returns and the potential to gain exposure to rapidly appreciating crypto-assets. This growth drew investment and talent to the space, leading to rapid refinement and evolution of DeFi products and technology. While DeFi aims to create efficiencies and pass them on to users—lowering the cost of transacting, shortening settlement times,

[19] See Board of the International Organization of Securities Commissions (2022), *IOSCO Decentralized Finance Report* (Madrid: IOSCO, March); and Organisation for Economic Co-operation and Development (2022), *Why Decentralised Finance (DeFi) Matters and the Policy Implications* (Paris: OECD).

Figure 8: Total Value Locked by Category



Note: Total Value Locked is the overall value of assets committed to a DeFi protocol. This metric includes governance tokens staked in the protocol, staked tokens where one of the coins in the pair is the governance token, and borrowed coins in lending protocols. Certain tokens are double counted across protocols.
Source: DeFi Llama.

and encouraging competition among service providers—its benefits remain mostly theoretical. In its current form, DeFi presents risk to users of its platforms and is vulnerable to collapse.

5.2 Maturity and Liquidity Transformation

DeFi lending protocols allow depositors to pool assets and earn interest generated from the proceeds of loaning those assets to borrowers. In DeFi lending protocols, depositors receive a "utility token" representing their share of the "liquidity pool" and any accrued interest. Anonymous borrowers generally overcollateralize their loans.[20] Usually, borrowers on DeFi lending protocols pledge crypto-assets as collateral in exchange for loans denominated in SCs, allowing users to access liquidity without selling crypto-assets.[21]

Like banks, DeFi lending protocols facilitate maturity transformation. Loans in DeFi lending protocols typically have indefinite terms and floating rates, and borrowers can repay at any time. Depositors can usually withdraw funds at any time—provided there are sufficient assets in the pool. This maturity mismatch creates a risk that lending protocols mitigate by varying interest rates (on loans and on deposits) to attract deposits and incentivize loan repayment when liquidity is low.[22] When users respond to those incentives, run risks can be mitigated or managed by the software protocol.

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[20] See for example Aave Risk (2021), "Risk Parameters," webpage, accessed May 19, 2021.
[21] More than 90 percent of DeFi lending is denominated in SCs, while 75 percent of the collateral is denominated in volatile crypto-assets. See International Monetary Fund (2022), "The Rapid Growth of Fintech: Vulnerabilities and Challenges for Financial Stability", in *Global Financial Stability Report 2022*, Chapter 3 (Washington: IMF, April), pp. 65–83.
[22] See Aave Risk (2021), "Borrow Interest Rate," webpage, accessed December 2021.

Users of DeFi lending protocols are exposed to liquidity risk. If a particular crypto-asset has been fully loaned out, no depositor may withdraw that crypto-asset from the protocol—and no borrowers can take loans in that crypto-asset—until existing loans are repaid or new deposits are added to the pool. If depositing is unattractive and borrowers are unable or unwilling to repay their loans, depositors would be reliant on liquidation of collateral for depositors to recover their assets (see Section 5.4).[23] As with open-ended mutual fund redemptions, these dynamics could create run risk.

5.3 Leverage

The relative ease with which users can obtain leverage on DeFi platforms contributes to vulnerabilities within the broader crypto ecosystem. A relatively simple way to obtain leverage in DeFi involves a user posting collateral using a crypto-asset (like Ether) in a DeFi lending platform (like Maker) to obtain a loan denominated in an SC (like DAI). Borrowers often use these loans to buy crypto-assets while retaining exposure to the underlying collateral, increasing overall exposure to more volatile crypto-assets (and building up wrong-way risk). Crypto-assets purchased with borrowed funds may be posted as collateral for another SC loan, creating leverage. Excessive leverage increases the risk that actors in the system will not have the ability to absorb even modest losses when hit by adverse shocks.

Collateral Rehypothecation: Rather than loan collateral remaining with a protocol until the loan is repaid or liquidated, the platform can, and many do, rehypothecate the collateral on a different platform (either as collateral for an additional loan or as liquidity in a liquidity pool) or stake the collateral to earn rewards (like Terra's Anchor protocol). The ability to generate leverage and yield through rehypothecation is limited only by the crypto-assets that different DeFi protocols accept. As in the traditional financial system, rehypothecation creates a collateral chain and introduces additional vulnerabilities, as liquidation of the underlying collateral in any protocol could cause a cascading pattern of selling as users unwind positions across different platforms.

Borrowing against depository receipts: Certain DeFi protocols accept digital depository receipts from other protocols as collateral for loans. For example, users may receive tokens for providing liquidity to decentralized exchanges (DEXs). These liquidity provider tokens from decentralized exchanges can be used as collateral in lending protocols (and borrowed value from lending protocols can then be re-deposited elsewhere). Similarly, depository receipts from lending protocols can be exchanged for crypto-assets in a decentralized exchange. While depositors' assets may be lent to a borrower, a representation of those funds supports other financial activity in the DeFi ecosystem. Again, loan liquidations could result in a cascading pattern of withdrawals and users removing liquidity.

5.4 Valuations and Volatility

Several aspects of DeFi arrangements may contribute to volatility in crypto-asset valuations.

Liquidation mechanisms: On a lending platform, if a borrower's collateral value falls below a required threshold, a third party may buy out the position, "liquidating" it by repaying the loan and seizing equivalent collateral plus a "liquidation bonus."[24] These liquidations can have a persistent effect on

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[23] For example, borrowers may have no intention to repay a loan used to extract higher quality assets in exchange for lower quality collateral (e.g., borrowing stablecoins collateralized by the protocol's own governance token).
[24] For a description of lending protocols and liquidations, see Kaihua Qin, Liyi Zhou, Pablo Gamito, and others (2021), "An Empirical Study of DeFi Liquidations: Incentives, Risks, and Instabilities," arXiv, October 1.

crypto-asset prices, leading to further liquidations.[25] Sophisticated actors often use code to look for undercollateralized loans to liquidate or monitor the "mempool" of pending transactions to front run or force liquidations by creating artificial price volatility.[26] These dynamics can result in unexpected losses to less sophisticated users, and technical uncertainty and panic could exacerbate periods of stress.

Blockchain congestion: The smooth operation of DeFi relies on blockchains to process transactions promptly. During periods of high trading volumes, limits on blockchain processing speeds can result in delays in transactions processing, front-running by blockchain validators, and outsized price moves. Congestion on blockchains can result in additional liquidations, as borrowers seeking to recollateralize their positions may be delayed.

Bridges: Greater interoperability through "bridges," which allow tokens designed to be used on one blockchain to be deployed on another, expands access to new protocols and assets[27] but can also become a transmission channel for stress. For example, users might address a loss of liquidity on one blockchain by transferring funds from another, leading to cascading contagion over multiple networks. Bridges have also proved a key source of technical weakness as the targets of many successful cyber-attacks.

5.5 Novel Risks

Automaticity without circuit breakers: Smart contracts, a key feature of DeFi, automatically execute transactions according to prespecified conditions. By design, the code governing smart contracts cannot be amended, transactions cannot be paused, and parties to the smart contract have no recourse in case of an error or exploit. Reliance on smart contracts heightens the risk of contagion in the DeFi ecosystem. Where transaction execution is automated, the response time for interventions that could prevent fire sales is compressed. The absence of circuit breakers and price bands heighten the risk of a flash crash.[28]

Oracle risk: DeFi protocols require price information for the different varieties of collateral they accept (e.g., to determine when a loan is undercollateralized). Oracles are the channel through which a protocol accesses off-chain data or data from other chains. When oracles are manipulated, smart contracts act on false information, which can lead to cascading liquidations (e.g., if an oracle reflects inaccurate high asset prices and positions are assessed as undercollateralized as a result).

Decentralized decision making: The extent to which governance of DeFi protocols is decentralized is often unclear and varies across protocols. Decentralized decision making may preclude rapid action to mitigate stress, as has been demonstrated by events in the digital ecosystem.

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[25] See preliminary research by Alfred Lehar and Christine A. Parlour (2022), "Systemic Fragility in Decentralized Markets," working paper (Hong Kong: Hong Kong Baptist University, June 13).

[26] Liquidators continuously monitor DeFi markets to identify and seize liquidation opportunities. Liquidations are costly for borrowers, as they usually pay a liquidation fee and a liquidation bonus and are forced to sell their collateral. Hence, to avoid liquidation, borrowers must monitor markets to ensure their positions are not in danger of being liquidated and immediately post additional collateral (or pay down the loan) when necessary.

[27] See Dmitriy Berenzon (2021), "Blockchain Bridges: Building Networks of Cryptonetworks," *Medium,* September 8.

[28] See Nick Baker (2022), "How Crypto Exchanges Could Stop Flash Crashes if They Wanted To," *Bloomberg,* October 22.

Flash loans: A flash loan requires no collateral and offers loans with no amount limits as long as the loan is borrowed and repaid within a single transaction. The transaction is automatically cancelled if the borrower cannot repay the loan before the transaction ends. Flash loans are available in numerous DeFi protocols and were originally developed to facilitate arbitrage but are often used to engage in DeFi hacks and exploits, using loaned assets to change protocol governance or drain a protocol of funds.

6 Lending Platforms

6.1 Overview

Crypto lending platforms engage in maturity transformation, attracting crypto-asset deposits from retail customers with high interest rates and using those funds to make loans. In contrast to DeFi lenders, lending platforms extend collateralized crypto-asset loans to retail customers and uncollateralized or partially collateralized loans to crypto-native institutions, and borrowers are generally known, not pseudonymous. Notable operating lending platforms include BlockFi, Nexo, CoinLoan, and, until July 2022, Celsius and Voyager. Platforms' risky bank-like activities— conducted without deposit insurance, access to a government backstop, or prudential requirements that strengthen loss-absorbing capacity— heighten the risk of fire sales and contagion in the ecosystem.

6.2 Vulnerabilities

Of the entities in the crypto-asset ecosystem discussed in this paper, lending platforms are structured most like banks. They suggest that depositors will be able to access the assets in their account on demand and provide credit based on an assessment of borrower quality or collateral value. Unlike banks, however, lending platforms are not subject to prudential supervision and regulation, which ensure adequate resources and strong risk-management practices necessary to support their businesses under stress.

Lending platforms are not subject to capital or risk-management requirements or prudential supervision of their safety and soundness. As such, platforms may maintain little to no loss-absorbing capacity. For example, Celsius, a lending platform, disclosed that it had a 0.1 percent capital ratio before stress forced it to freeze withdrawals and then declare bankruptcy. Without concentration limits, lending platforms may extend large loans to a small number of borrowers, increasing their risk of insolvency in the event of a counterparty default. Thinly capitalized platforms with concentrated exposures may be vulnerable if even one borrower defaults. For example, Voyager Digital made loans to one counterparty (3 Arrows Capital, or 3AC) representing 58 percent of its loan book and more than twice its total capital. 3AC's default eventually contributed to Voyager suspending withdrawals and securing an emergency line of credit, but Voyager ultimately could not remain solvent and declared bankruptcy.

Engaging in risky bank-like activities without liquidity requirements, access to a government backstop, or deposit insurance creates the potential for a run when depositors are exposed to potential losses. As depositors rush to withdraw funds, lending platforms may be forced to sell assets at distressed prices to meet redemptions. These fire-sale dynamics can also create contagion, affecting similarly positioned market participants.

Lending platforms do not only use customer assets to make undercollateralized loans. Celsius' bankruptcy filing, for example, states that the platform was "permitted to use the assets in its sole discretion, including rehypothecating those assets (e.g., using those assets as collateral to take out additional loans)" to generate yield.[29]

When lending platforms use depositors' assets to build leveraged positions, they increase the fragility of the crypto ecosystem. Concentrated leverage could put pressure of the price of crypto-assets, as occurred with staked ether (stETH).[30] As ETH liquidity dried up following the Terra collapse, stETH began to trade at a significant discount to ether, creating liquidation pressures for users that had built leveraged positions in stETH. Greater leverage reduces the potential that platforms can withstand even a small shift in asset prices and heightens the risk that they will face liquidity or solvency crises. Beyond these risks to the ecosystem, lending platforms also contribute to leverage by allowing their users to borrow funds to grow their positions in a certain asset. Margin loans from lending platforms may encourage moderate additional leverage in the system.

7 "Centralized" Crypto Exchanges

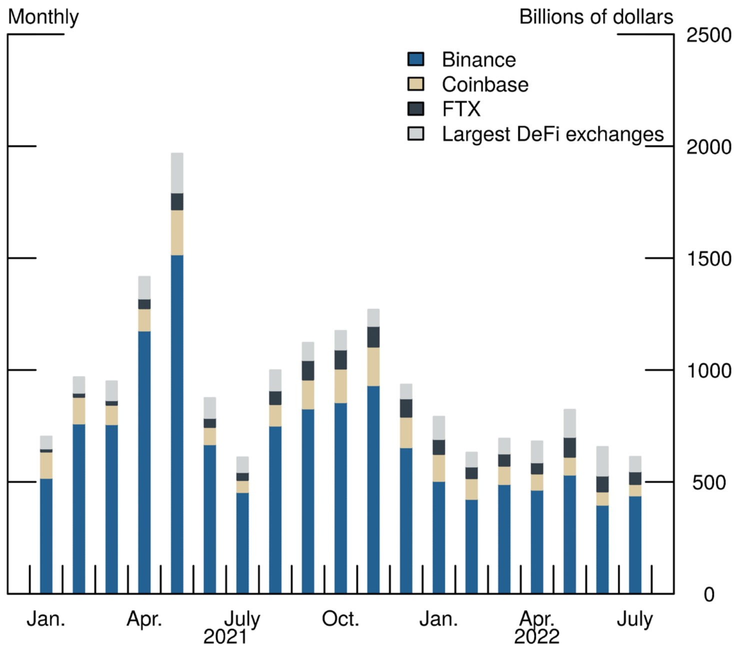
The multiple roles centralized crypto exchanges (CEXs) play in the digital asset ecosystem are opaque, Dargely unregulated, and highly interconnected. In contrast to DeFi exchange platforms (DEXs), which operate on blockchains, centralized exchanges hold central limit order books and operate off-chain. Users generally exchange fiat for crypto-assets using CEXs, making them the key on and off ramps between fiat and digital assets. Yet CEXs go well beyond activities of traditional exchanges within the digital asset ecosystem. Without meaningful oversight or regulatory constraints, CEXs provide a link to traditional markets while also creating deep interconnections and new vulnerabilities in crypto-asset markets.

7.1 Overview

CEXs facilitate the bulk of retail and institutional investor access to crypto-assets, often driving rapid changes in crypto-asset prices upon listing or de-listing.[31] CEXs also offer a range of services including trading execution, custody, margin lending, prime brokerage (for institutions), and writing and listing crypto-derivatives. This paper focuses on **Binance**, **FTX**, and **Coinbase** to illustrate issues with interconnectedness and leverage. These exchanges have daily trading volumes of $12 billion, $2.1 billion, and $1.6 billion, respectively (Figure 9).[32]

[29] See United States Bankruptcy Court Southern District of New York (2022), "Declaration of Alex Mashinsky, Chief Executive Officer of Celsius Network LLC, in Support of Chapter 11 Petitions and First Day Motions," p. 16, July 13.
[30] stETH is a token that represents Ether locked on the Ether 2.0 blockchain, allowing its holder to transact freely while earning staking rewards until Ether 2.0 goes live. See Edmund Kua, Tharm Lertviwatkul, Daniel Khoo, Wayne Lau, Niklas Polk, Yong Li Khoo, Xin Yi Lim, and Sandra Leow (2022), "On-Chain Forensics: Demystifying stETH's 'De-peg'," *Nansen*, June 29.
[31] See Roberto Talamas (2021), "Analyzing the Crypto Exchange Pump Phenomenon," *Messari,* March 31.
[32] These volumes compare with over $60 billion in equities volumes on the largest traditional exchanges; for more information, see https://www.nasdaqtrader.com/trader.aspx?id=FullVolumeSummary#.

Figure 9: Trading Volume for Selected Exchanges



Source: CryptoCompare.

7.2 Interconnectedness

The importance of centralized exchanges, coupled with their related but often obfuscated engagements, intensifies interconnections within and outside of the digital ecosystem. For example, some CEXs operate venture capital funds that develop crypto projects and invest in crypto-assets; hold ownership interest in major blockchains or SCs; engage in proprietary trading, lending, or selling crypto-assets to other exchanges and platforms; and operate media organizations.

Binance, in addition to being the largest crypto-asset exchange, issues a major SC and crypto-asset, developed a major blockchain, and has invested in other third-party crypto projects (including the failed TerraUSD stablecoin) via its venture capital entity "Binance Labs." Through Binance Labs, Binance has acquired the data aggregator CoinMarketCap and holds minority stakes in rival CEX FTX as well as the news agency Forbes.[33,] Coinbase, via its venture capital subsidiary "Coinbase Ventures," also owns a stake in FTX and is a founding member of the consortium that develops stablecoin standards, including for USDC , which is currently the second largest SC by market capitalization.[34] Sam Bankman-Fried, FTX's owner, owns Alameda Research, a trading firm that trades on FTX, and founded decentralized exchange Serum. FTX bought a U.S. broker-dealer in 2021, and Sam Bankman-Fried acquired a stake in Robinhood.[35] Tether has an affiliated trading exchange, Bitfinex, and there have been reports of close ties to other exchanges and traders.[36]

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[33] Coinmarketcap now ranks Binance as the "best cryptocurrency exchange," and Forbes designated Binance "the best cryptocurrency exchange of June 2022."
[34] See CoinMarketCap (2022), "Top Stablecoin Tokens by Market Capitalization," table, accessed May 15, 2022.
[35] See Gary Silverman (2022), "Crypto Platform FTX Expands into U.S. Equities Market," *Financial Times*, May 19.
[36] See Protos (2021), "Tether Papers: This Is Exactly Who Acquired 70% of All USDT Ever Issued," *Protos,* November 10.

7.3 Leverage

CEXs provide leverage in the crypto ecosystem through their facilitation of margin lending and offering of "leveraged tokens," a type of derivative product that gives consumers leveraged exposure to the underlying asset.[37] CEXs offer derivatives and often allow leverage exceeding 100x. However, the extent of the leverage these exchanges allow in the digital asset ecosystem is opaque, given their off-chain operating model and a lack of oversight and financial disclosures. Similarly, it is not clear how much capital the CEXs hold or how large their trading portfolios and private equity investments are. For example, Binance reportedly took $1.6 billion in losses on Terra, but it is unclear if the losses were due to proprietary trading or holding inventory for market making.[38]

8 Interconnectedness with the Traditional Financial Sector

Shocks to digital assets can propagate due to interconnections within the digital ecosystem, as already highlighted. However, the implications of stress in the crypto ecosystem on financial stability depend crucially on how interconnected it is with the traditional financial sector. In this section we outline many ways in which the digital asset ecosystem and traditional financial system are related.

Traditional brokerage firms: An emerging interconnection between crypto markets and the financial system comes from brokerage firms incorporating access to crypto markets into their product offerings. There are several retail brokerages (including Fidelity and Robinhood) that are beginning to offer access to crypto markets. For example, Fidelity plans to allow Bitcoin holdings in 401k retirement accounts.[39]

Traditional exchanges: Traditional exchanges have begun to list financial products tied to crypto assets. For example, the CME offers both Bitcoin and Ethereum futures.[40] Canadian and Australian regulators have approved Bitcoin ETFs that trade on exchanges in those countries. In addition, certain crypto exchanges (such as FTX) have begun offering access to financial asset markets via "tokenized" stocks.[41]

Banks: Banks are exposed to crypto assets through multiple channels. First, banks may hold deposits from companies offering stablecoins. For example, the assets of the largest U.S.-based stablecoin USDC are held across multiple banks. Small banks may be more susceptible to liquidity issues in the event of a run on a stablecoin.

In addition, several banks hold private equity investments in crypto-asset-related companies on their balance sheets.[42] Standard Chartered, BNY Mellon, Citi, and UBS have each invested more than $250

[37] Leveraged tokens each represent a basket of perpetual contract positions. The price of a leveraged token moves along with price changes in the perpetual contract market, and the leverage level moves up and down accordingly.
[38] See Justina Lee and Max Chafkin (2022), "Can Crypto's Richest Man Stand the Cold?" *Bloomberg,* June 23; and Gian M. Volpicelli (2022), "Can Binance Save Crypto? The CEO is Thinking About It," *Wired,* June 24.
[39] See Rob Wile (2022), "Fidelity Lets Companies Offer Bitcoin in a 401(k), but Financial Advisers Warn It's a Risky Bet," *NBC News,* May 22.
[40] See CME Group's "Bitcoin Futures and Options," and "Ether Futures" webpages.
[41] These stocks are tokens that can be traded on a blockchain and are pegged to individual stocks, just like SCs are usually pegged to the U.S. dollar. FTX's offerings are custodied by FTX Switzerland and include an S&P 500 ETF, Tesla, and Alibaba. See FTX (2022), "Tokenized Stocks," table.
[42] See Blockdata (2022), "Top Banks Investing in Crypto and Blockchain May 2022 Update," research paper, June 27.

million in crypto-asset companies. One firm estimates that the ratio of crypto investment to Tier 1 capital could be as high as 1.5 percent, though these estimates are unverified.[43]

Furthermore, banks and other traditional financial institutions are interacting with platforms and protocols to obtain financing. This adoption may increase interconnections with digital assets. For example, Maker has proposed to tokenize real-world assets and issue loans using these tokens as collateral.[44] Société Générale has obtained a $20 million SC loan using a tokenized bond.[45] JP Morgan has expressed interest in tokenizing U.S. Treasuries and shares of money market funds to use as collateral in DeFi, which could become a transmission channel for stress from crypto-asset markets to the U.S. Treasury market.[46]

Venture capital funds: Venture capital firms invested $9.2 billion in crypto-asset-related firms in Q1 2022.[47] The limited partners in these venture capital funds are usually pension funds, university endowments, nonprofit foundations, and finance companies.

Hedge funds: Many mainstream hedge funds are launching dedicated crypto divisions.[48] Centralized crypto-exchange firm Coinbase has stated that institutional investors (presumably hedge funds) traded $1.14 trillion worth of crypto-assets in 2021.

Public and private companies: A growing number of publicly traded companies have crypto-assets on their balance sheets. Because shares in these companies are held by retail and institutional investors, sudden shocks to crypto-asset prices may affect the balance sheets of traditional financial institutions. The largest publicly traded company with significant exposure to crypto-assets is Coinbase, which was publicly listed in 2021. As of Q1 2022, Coinbase holds more than $200 billion worth of crypto-assets for its custodial, brokerage, and market-making services.[49] Besides Coinbase, public companies such as MicroStrategy have significant holdings of crypto-assets on their balance sheets. MicroStrategy has almost $4 billion worth of Bitcoin holdings, about $205 million of which were purchased with a Bitcoin collateralized loan. Tesla and Square also hold Bitcoin (though Tesla announced on July 20 that it sold 75 percent of the bitcoin it had purchased, adding $936 million to its balance sheet).[50]

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[43] The source for these exposures is Blockdata, a relatively new analytics firm.

[44] See Greg Di Prisco (2021), "A Walkthrough of the 6s Capital Trust Structure," MakerDAO Forum, accessed July 1, 2022.

[45] See Andrew Thurman (2021), "Société Générale Applies for $20M MakerDAO Loan Using Bond Token Collateral," *CoinDesk,* September 30.

[46] See Ian Allison (2022), "JPMorgan Wants to Bring Trillions of Dollars of Tokenized Assets to DeFi," *CoinDesk,* June 11.

[47] See CB Insights (2022), *State of Blockchain Q1'22 Report* (New York: CB Insights, May 11).

[48] See. Gregory Zuckerman (2022), "Mainstream Hedge Funds Pour Billions of Dollars Into Crypto," *Wall Street Journal,* March 9.

[49] See Coinbase (2022), *Shareholder Letter* (San Francisco: Coinbase, March).

[50] See Robert Wall (2022), "Tesla Sells 75% of Its Bitcoin Purchases," *Wall Street Journal*, July 20.

Private companies, while creating a smaller risk to the financial system, have exposed retail investors to risk. For example, Stablegains and Celsius have acted as feeder funds to the Terra ecosystem, leading to large losses among some retail investors.[51]

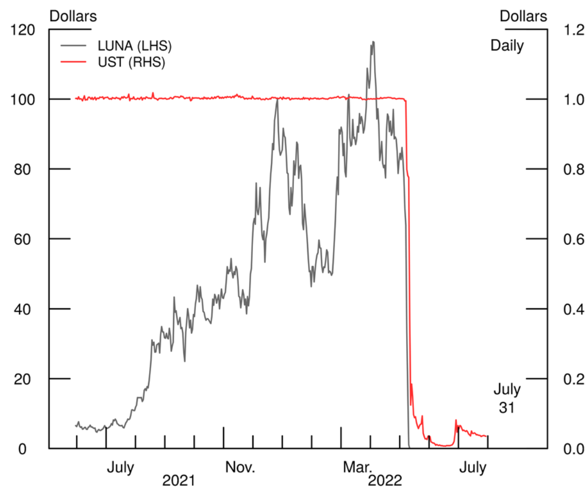
[51] See Vincent Woo (2022), "People Didn't Know They Were Investing All Their Money in Terra. When the Cryptocurrency Collapsed, They Lost Everything—and Say a Y Combinator-Backed Startup Is to Blame," *Insider,* June 9.

Box 1: The Terra Collapse—A Case Study in Interconnectedness[52]

TerraUSD was an algorithmic stablecoin designed to maintain a 1:1 peg to the U.S. dollar despite not maintaining a reserve of assets to back issued coins. In early May, TerraUSD was the third-largest stablecoin, with a total market value equivalent to $18 billion. While TerraUSD was able to be used on more than 100 DeFi platforms on the Terra blockchain, most of the activity on the Terra network was on a single DeFi peer-to-peer lending application, Anchor, which offered deposit yields of close to 20 percent. To maintain its peg, TerraUSD used an arbitrage relationship with Terra's native crypto-asset, Luna. Luna is an unbacked crypto-asset with a free-floating market value and at its peak in April 2022 was trading for over $116, with a total market value of around $40 billion.

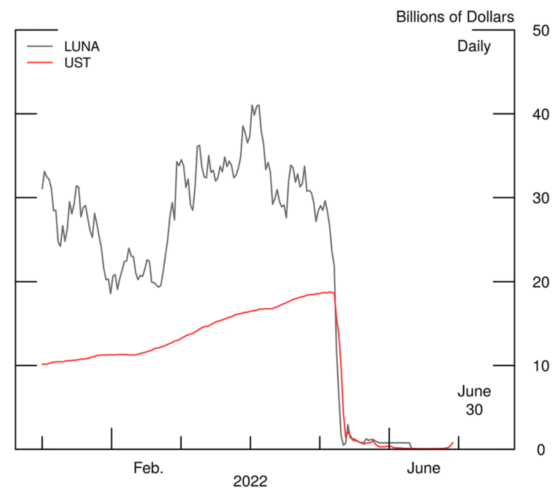
TerraUSD's market value, Luna's price, and the total value locked (TVL) on Anchor grew rapidly from early 2021 through May 2022. However, the entire Terra ecosystem collapsed in less than a week. On May 8 and 9, TerraUSD liquidity dried up across multiple DeFi protocols and crypto exchanges, causing the price of TerraUSD to decline below $0.70. In response, there was a rush to redeem TerraUSD in exchange for newly issued Luna, driving the price of both down rapidly, resulting in a loss of about $60 billion of value that week, as seen in Figures 10 and 11.

Figure 10: Luna and TerraUSD Price



Source: CoinGecko.

Figure 11: Luna and TerraUSD Market Cap



Source: CoinGecko.

Terra's collapse contributed to stress throughout the crypto ecosystem. In the immediate aftermath, Tether briefly traded for as low as $0.94 before returning to $1.00. Crypto hedge fund Three Arrows Capital (3AC), which at its peak reportedly had over $18 billion in assets under management,[53] was heavily invested in Terra/Luna[54] and has been ordered to begin liquidations and has filed for bankruptcy under Chapter 15[55] Voyager Digital, a publicly traded crypto exchange and lender with about $6 billion in assets and about $250 million in total equity as of March 31, claims that 3AC defaulted on a loan worth about $660 million.[56] Similarly, Celsius, another crypto lender that invested in Terra has filed for Chapter 11 bankruptcy protection.[57,58]

In other interconnections, Terra's founder reportedly sold $2.4 billion worth of Bitcoin trying to maintain TerraUSD's peg before its eventual collapse.[59] Additionally, Terra users rapidly withdrew crypto-assets from the Terra blockchain, particularly staked Ether used as loan collateral on the Anchor protocol. These events led to direct pressure on the prices of major crypto-assets. The rapid decline in crypto-asset prices (e.g., Bitcoin's price declined by about 60 percent between April and June) has led to margin calls, selloffs, and liquidations. While Terra's collapse has had a limited effect on traditional financial markets, it illustrates the fragility and interconnectedness of the crypto ecosystem.

9 Regulatory Challenges

Digital assets do not fit neatly into the U.S. regulatory framework, and opacity, extraterritoriality, and new legal structures create further challenges. Limited or no regulation of key entities contribute to fragilities in the digital asset ecosystem.

9.1 Risk from Outside the Regulatory Perimeter

Oversight, comprehensive disclosures, and capital and liquidity requirements, where appropriate, could improve the resilience of entities within the digital asset ecosystem. For example, centralized crypto-entities that act as counterparties to retail users in the digital asset ecosystem are generally not subject to capital, liquidity, or comprehensive disclosure requirements. Where a platform's counterparty risk, leverage, and loss-absorbing capacity are unclear, the exchange's users could be incentivized to withdraw assets at the first sign of stress.

In the traditional financial system, activities like maturity and liquidity transformation and margin financing are housed within financial institutions subject to oversight and regulatory requirements. SCs, in particular those collateralized by off-chain assets, engage in the same type of maturity and liquidity transformation as banks or money market funds but without the same safeguards or regulations.

The Executive Order on Ensuring Responsible Development of Digital Assets has directed the U.S. regulatory agencies to further explore the issue, stating that the United States should ensure that safeguards are in place and promote the responsible development of digital assets to protect consumers, investors, and businesses.[60] Lawmakers may in the future see fit to expand the regulatory perimeter to include digital assets.

This objective may be complicated by resistance to regulation by some in the digital asset ecosystem. Attempts at building sanctions-compliant crypto products have prompted backlash from parts of the crypto community, and migration to less compliant products.[61] While in most cases some entity has

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[52] Data in this box are from Coinmarketcap. Accessed June 30, 2022.

[53] See Will Canny (2022), "FSInsight Accuses Three Arrows Capital of Running a 'Madoff-Style Ponzi Scheme'," *CoinDesk,* June 28.

[54] See Alex Hern and Dan Milmo (2022), "Three Arrows Capital to become Latest Casualty of Crypto Crash," *Guardian,* June 29.

[55] See Hamza Shaban (2022), "Three Arrows Capital Falls into Liquidation after Crypto Crash," *Washington Post,* June 29.

[56] See Yueqi Yang (2022), "Voyager (VOYG) Reveals $660 Million Exposure to Three Arrows Capital (3AC)," *Bloomberg,* June 22.

[57] See Kate Rooney and Paige Tortorelli (2022), "Embattled crypto lender Celsius files for bankruptcy protection," CNBC.com, July 13.

[58] Market participants have suggested that Celsius had exposure to Terra, although Celsius has denied this claim. See Ryan Browne and Arjun Kharpal (2022), "Crypto Lender Celsius Pauses Withdrawals; Bitcoin Slides," *CNBC,* June 13.

[59] See Christiaan Hetzner (2022), "Luna Foundation Guard Has Now Dumped $2.4 Billion from Its Bitcoin Reserves in Failed Attempt to Defend TerraUSD Peg," *Yahoo!,* May 16.

[60] See Executive Office of the President (2022), "Ensuring Responsible Development of Digital Assets, Executive Order 14067," *Federal Register,* vol. 87 (March), pp. 14143–52.

[61] Marathon, a mining company, introduced software in May 2021 that filtered transactions to be compliant with U.S. Treasury sanctions. While its compliance effort was successful, the company quickly abandoned it in response

control or at least significant influence over a blockchain, asset, or protocol, it is often challenging to identify who has responsibility for addressing risks to users.

Where crypto companies exist as legal entities, they are often domiciled in jurisdictions with a focus on privacy over transparency. Bringing entities in the digital asset ecosystem within the U.S. regulatory perimeter could require identifying their linkages with organizations that are under the purview of U.S. regulators or indirectly targeting their activities. These linkages could be difficult to establish. For example, virtual private networks, or VPNs, can mask a user's location, making it difficult to establish a U.S. nexus even when counterparties are physically located in the United States. Given the high degree of interconnectedness in the digital asset ecosystem, interagency coordination and information sharing is crucial—domestically and internationally.

9.2 Regulatory Scope and Novel Digital Assets

Another challenge in expanding the regulatory perimeter relates to novel technologies and arrangements that make even indirect regulation challenging. Smart contracts, for example, function as counterparties and intermediaries and interact with digital asset wallets and other smart contracts, yet they are stored and executed as pieces of code. Revisions to smart contracts may not be possible, even if required by statute, rule, or supervisor, because they cannot be amended once in place. As another example, control of DeFi protocols is purportedly exercised through Decentralized Autonomous Organizations (DAOs). Though legal entities associated with the DAO and protocol often exist, they often act at the direction of the DAO and maybe unable to exercise agency. Subjecting these types of entities to regulation and enforcing such regulations may be challenging

9.3 Related Stablecoin Efforts

Several existing SC issuers and entities with SC projects under development have stated ambitions for the SC they create to be used widely by retail users to pay for goods and services, by corporations in the context of supply chain payments, and in the context of international remittances. Payment SCs face many of the same basic risks as traditional payment systems, including credit risk, liquidity risk, operational risk, risks arising from improper or ineffective system governance, and settlement risk. In order to address such risks, the President's Working Group on Financial Markets, the Federal Deposit Insurance Corporation, and the Office of the Comptroller of the Currency issued a report with the following key recommendations:[62]

- **To address risks to SC users and guard against SC runs**, legislation should require SC issuers to be insured depository institutions.
- **To address concerns about payment system risk,** legislation should require custodial wallet providers to be subject to appropriate federal oversight. Congress should also provide the federal supervisor of an SC issuer with the authority to require any entity that performs activities that are critical to the functioning of the SC arrangement to meet appropriate risk-management standards.

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to severe backlash from the crypto community. See Marathon Digital Holdings (2021), "Marathon Digital Holdings to Launch the First North American-Based Bitcoin Mining Pool, Fully Compliant with U.S. Regulations," *GlobeNewswire,* March 30; and Christie Harkin (2021), "Bitcoin Miner Marathon Will No Longer Censor Transactions, CEO Says," *CoinDesk,* May 31.

[62] See President's Working Group on Financial Markets, *supra* note 8.

- **To address additional concerns about systemic risk and concentration of economic power**, legislation should require SC issuers to comply with activity restrictions that limit affiliation with commercial entities. Supervisors should have authority to implement standards to promote interoperability among SCs. In addition, Congress may wish to consider other standards for custodial wallet providers, such as limits on affiliations with commercial entities or on use of users' transaction data.

Congress is considering proposals related to stablecoin issuance.

10 Conclusion

The digital asset ecosystem is prone to the buildup of financial vulnerabilities. This propensity reflects both the lack of a strong supervisory and regulatory framework for financial activities in the digital space and novel risks associated with new technologies that exacerbate these vulnerabilities.[63] Currently, financial stability risks are not extensive because the digital asset ecosystem does not provide significant financial services and its interconnections with the traditional financial system are limited. At present, the potential spillovers from runs on stablecoins that are backed by money market instruments represent the most salient financial stability risk. Should the digital financial system become more interconnected with the traditional system or expand its provision of financial services, financial stability risks could quickly become material.

[63] A lack of compliance with the regulations would reduce their efficacy, a potential concern in the digital space.

Glossary

Algorithmic stablecoin	An algorithmic stablecoin is a stablecoin that intends to maintain its peg without maintaining reserve assets, instead relying on an on-chain algorithm and/or smart contract that manages the supply of tokens in circulation. A common feature is a set relationship to a second crypto-asset token, wherein trading between the stablecoin and second token is intended to provide arbitrageurs profitable opportunities to return the stablecoin to its peg. However, the algorithm fails if both the stablecoin and the crypto-asset token simultaneously drop in price, resulting in what is colloquially called a “death spiral.”
Automated market maker (AMM)	An AMM is a type of decentralized exchange, a DeFi protocol that creates markets for exchanging one crypto-asset for another. Users can create a liquidity pool by adding any two crypto-assets to the protocol. Other users can exchange one crypto-asset for the other at relative prices that are automatically set by the protocol. To avoid needing external price data, AMMs set relative prices using simple rules. For example, Uniswap, the first and largest AMM, uses a constant product formula, $x * y = k$, where trades must not change the product (k) of a pair’s reserve balances (x and y). Trades cost a set fee (0.3 percent on Uniswap), and liquidity providers earn a share of the trading fees for the pool in proportion to their contribution to the total assets in the pool.
Blockchain	A distributed digital ledger of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules.
Bridge	A system that transfers information (including assets, contract calls, proofs, or state information) between two or more blockchains. Components include a monitor of the state on the source chain, a relayer to transmit information from the source chain to the destination chain, and a mechanism for cryptographically signing information sent to the destination chain. Some bridge models include a mechanism for consensus among actors monitoring the source chain before information is transmitted to the destination chain. Bridges are often the channels through which crypto-assets are “wrapped” and deployed on their non-native chain (see “wrapped token” definition below).
Consensus mechanism	A process to achieve agreement within a distributed system on the valid state. Also known as a consensus algorithm, consensus mechanism, consensus method.
Crypto-asset	A digital asset implemented using cryptographic techniques.
Cryptocurrency	A crypto-asset designed to work as a medium of exchange.
DeFi	Decentralized finance generally refers to open-source software programs running on open-access blockchains that aim to provide financial products without traditional financial intermediaries. DeFi applications are an important subset of “dApps.”
dApps	Abbreviation for decentralized applications. Software applications built from smart contracts, often integrated with user interfaces using traditional web technology. Run on peer-to-peer network or blockchain network instead of centralized servers.

Decentralized Autonomous Organization (DAO)	A blockchain-enforced organizational structure that emphasizes community, as compared to centralized, governance. DAOs usually involve mechanisms such as decision making based on votes by "governance token" holders rather than control by management or a board of directors.
Decentralized exchange (DEX)	A DEX is a DeFi protocol that creates markets for exchanging one crypto-asset for another. DEXs are usually classified as either "automated market makers" or decentralized central limit order books.
Decentralized order book exchange	A decentralized order book exchange matches buyers and sellers of crypto-assets. Unlike in the centralized trading platform context, the operator may never have control of the users' crypto-assets and may serve as a "relayer" of information that is necessary for the trade to be executed and settled on the blockchain. Users interested in buying or selling a particular crypto-asset at a certain price ("makers") will communicate that order to the operator, who will in turn publish the order for the use of others who might be interested in matching the order ("takers"). Once there is a match, the taker submits the order to the protocol, which executes a peer-to-peer exchange of the crypto-assets. The operator collects fees from makers and takers for providing this service. In addition, takers typically pay a protocol fee on each trade, a portion of which may go to makers to reward them for providing liquidity.
Digital asset	An electronic representation of value. See Figure 1.
Flash loan	Flash loans involve using DeFi protocols to borrow and repay a loan within a single transaction, which will automatically cancel if the borrower cannot repay the loan before the transaction ends. Typically, the flash loan uses other smart contracts in a trading strategy designed to make a profit, usually involving either liquidation or arbitrage. As long as the strategy can be executed instantaneously and yield sufficient profit to pay back the loan plus interest and any fees, individuals can use the flash loan to gain access to large amounts of capital with no up-front collateral in order to execute the strategy.
Governance token	Usually associated with a Decentralized Autonomous Organization, a governance token act as a decentralized governance body to vote on the direction of a blockchain project or DeFi protocol or for resetting specific parameters (e.g., the level of collateral needed for borrowing in a DeFi protocol).
Liquidity pool	Collection of crypto-assets locked in a smart contract. Liquidity pools eliminate the need for counterparties to a transaction and are an essential part of automated market makers, borrow–lend protocols, yield farming, and other DeFi applications.
Oracle	An oracle connects a smart contract to external data, on or off chain, that may be an input for that smart contract's functionality.
Programmable blockchain	A blockchain that can be programmed to include logic and conditionality. These blockchains can run code stored on the blockchain, facilitating execution of transactions more complex than direct asset transfer, such as financial applications (e.g., lending and trading).

Protocol	The specific combinations of crypto-assets, smart contracts, and user applications that are necessary for a specific DeFi application, including any related functional components like user interfaces, oracles, governance and voting mechanisms, development grants and foundations, and financial assets such as tokens, Treasuries, and funds. Some of those components may be automated, and some may be carried out by individuals and entities.
Pseudonymization	The processing of personal data in such a manner that the personal data can no longer be attributed to a specific data subject without the use of additional information, provided that such additional information is kept separately and is subject to technical and organizational measures to ensure that the personal data are not attributed to an identified or identifiable natural person.
Smart contract	A collection of code and data (sometimes referred to as functions and state) that is deployed using cryptographically signed transactions on the blockchain network. The smart contract is executed by nodes within the blockchain network; all nodes must derive the same results for the execution, and the results of execution are recorded on the blockchain.
Stablecoin (SC)	Digital assets that seek to maintain a constant value relative to some asset, most commonly the U.S. dollar or other major fiat currency (e.g., Tether, USDC)
Staking	Process of locking up crypto-asset holdings in order to obtain rewards or earn interest. A common form of staking is pledging native settlement assets to support validation in proof-of-stake consensus blockchains. In this case, users who stake more coins have a higher likelihood of being chosen to validate transactions on a network and earn a reward—but any malicious validator could lose their stake. In DeFi, users often stake assets to support a protocol, such as by pledging crypto-assets to provide the protocol with additional liquidity or first-loss capital to absorb potential losses. The ease with which users can “un-stake” crypto-assets varies by blockchain and protocol.
Token	A representation of a particular asset that typically relies on a blockchain or other types of distributed ledgers.
Total value locked (TVL)	A common metric of the size of decentralized finance protocols. Broadly, the statistic measures the value of cryptocurrencies or other tokens that have been transferred to the smart contracts underlying a DeFi protocol, but as these protocols differ in design, TVL is not a standardized measure, and reported values for specific protocols can vary substantially—for example, due to differential accounting for certain sorts of double counting (e.g., DeFi protocols that deposit assets into other DeFi protocols).

Wallet	Software used to store and manage asymmetric keys and addresses used for transactions. A wallet may be hosted or unhosted. A “hosted wallet” (or “custodial wallet”) is administered by a third party where (a) the value belongs to the owner of the virtual currency; (b) the value may be stored in a wallet or represented as an entry in the accounts of the host; (c) the owner interacts directly with the host, and not with the payment system; and (d) the host has total independent control over the value (although it is contractually obligated to access the value only on instructions from the owner). An “unhosted wallet” (or “personal wallet”) is software hosted on a person’s computer, phone, or other device that allows the person to store and conduct transactions in crypto-assets and does not require an additional third party to conduct transactions. The value is the property of the owner and is stored in a wallet, while the owner interacts with the payment system directly and has total independent control over the value. A wallet may be hot or cold. A hot wallet is connected to the Internet, and a cold wallet is offline.
“Wrapped” crypto-asset	A representation of a crypto-asset that is not native to a particular blockchain. Users lock the original asset in a bridge smart contract on the asset’s native blockchain, and the bridge mints a new “wrapped crypto-asset” to transact on the other blockchain. Wrapped tokens and bridges between networks allow non-native assets to be used on other blockchains, improving interoperability.