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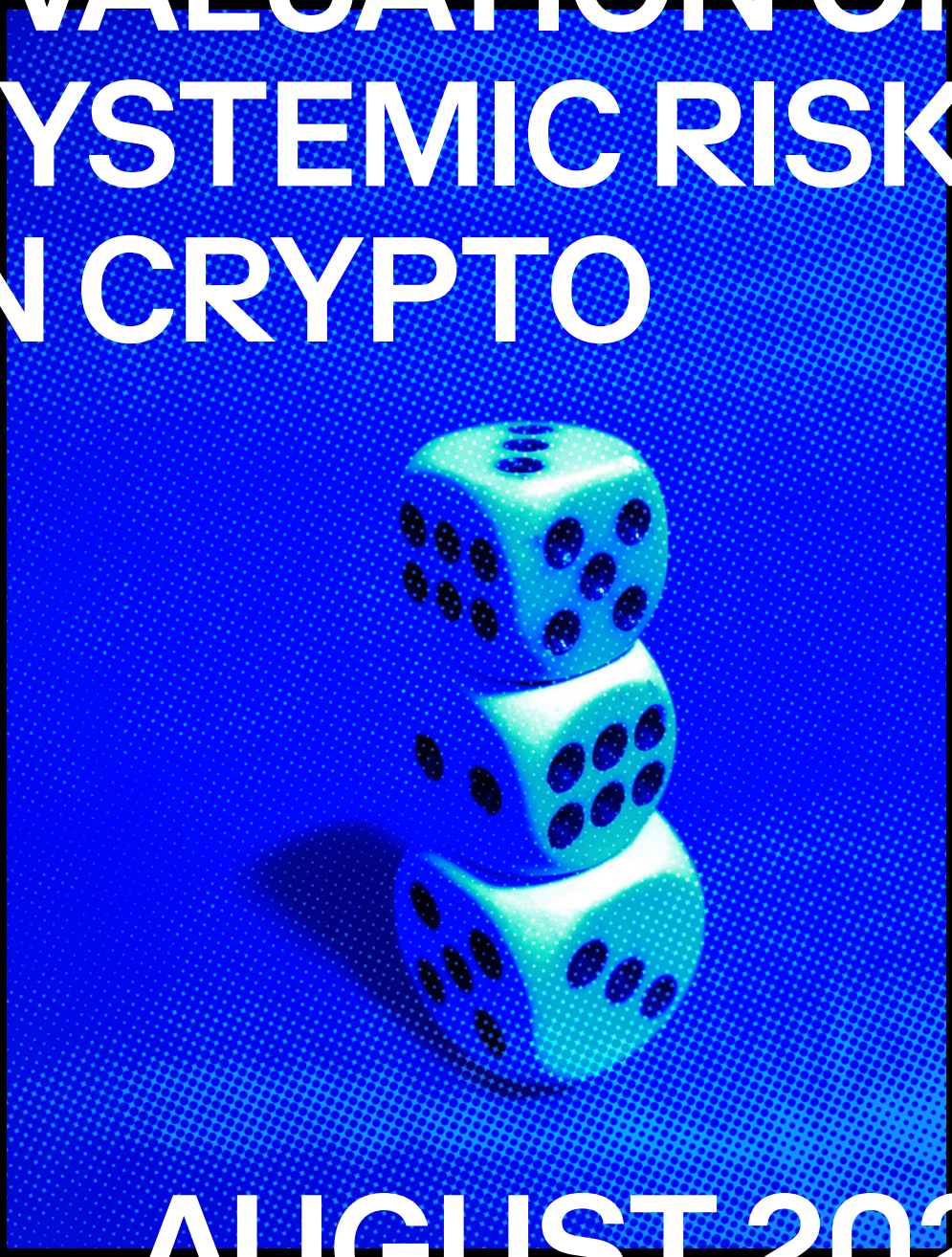
EVALUATION OF SYSTEMIC RISK IN CRYPTO



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Executive Summary

The total market capitalization of all cryptocurrencies is at $1 trillion as of August 2022, after peaking in November 2021 at $3 trillion. While the size of the crypto market is large, it still represents a small fraction of the global financial system, whereas global bank assets alone stand at over $180 trillion. In fact, U.S. Treasury Secretary Janet Yellen acknowledged that even at $3 trillion, crypto does not yet present a systemic risk. But as crypto becomes more integrated with traditional finance, questions about financial stability and systemic risk have already emerged. Looking ahead, it is important that policymakers and regulators understand not only the unique risks and challenges coming from the rise of the cryptoeconomy, but also the ways crypto can mitigate some of the risks present in the traditional financial system today.

Systemic risk refers to the risk that a negative shock can propagate through linkages (or interconnectedness) within the system, and lead to the collapse of an entire financial system or market.

Key factors in measuring systemic risk are (1) the size and importance of certain firms and industries in an economy and (2) the interconnectedness or linkages between these firms or industries.

How to limit and contain systemic risk is a central question for policymakers around the world – one of particular importance in the years following the 2008 financial crisis. In the United States, the Financial Stability Oversight Council (FSOC) determines whether entities are systemically important financial institutions (SIFI) by considering factors such as size and leverage. If an entity is designated a SIFI by FSOC, it will be subject to additional regulation, greater capital requirements, stress testing, and other rules.

As the cryptoeconomy continues to grow, the failure of some of the entities or characteristics of the underlying technology may have cascading effects of systemic importance. Cryptocurrencies that run on decentralized networks have points of re-centralization in the web3 technology stack that could propagate economic shocks. For example:

- On proof-of-work blockchains like Bitcoin and Ethereum, miners often work together in "pools" to make the enterprise economically viable. These pools combine resources and split the rewards of successfully mined blocks. The downside is that this tends to result in reliance on a few dominant pools for security of the network that often share the same

software. Furthermore, there are also many applications built on top of blockchains that rely on third-party operators (e.g. cloud services, API providers, ...) to help them connect or run "nodes" on the network, another potential point of centralization.

- Bugs, hacks and exploits, even just a mistake in code, can be very costly when you're dealing in cash-like tokens and immutable transactions. When combined with leverage, the scale of loss from an irreversible transaction can increase quickly.

- Another significant area of vulnerability are "bridges", applications that enable transactions across different blockchains, and "oracles", providers of data feeds from the traditional economy to the cryptoeconomy. Crypto is evolving into a multi-chain ecosystem. Safety and reliability of bridges and oracles across chains will then become a crucial step to enable cross-chain interoperability and to the success of web3.

- There are also several touchpoints with traditional finance – stablecoins, exchanges, and fiat "on-ramps" that enable conversion of traditional currency into cryptocurrency – which could be systemically important one day. Tokenization also promises to bring more real-world assets online where their ownership interests can be traded and settled on blockchains.

- Lending and the use of volatile crypto assets such as NFTs as collateral, is another area of possible future concern.

While crypto does not pose systemic risk concerns today, it is worthwhile to develop tools now that can help identify which parts of the crypto ecosystem can pose a systemic risk in the future. As transactions are public, we can analyze on-chain flows among participants in crypto platforms to identify key central players. An analysis of Bitcoin on-chain flows shows that at the moment, crypto exchange platforms play a very central role in the Bitcoin network. However, the crypto ecosystem is changing quickly with the rapid adoption of self-hosted wallets, layer-2 solutions like lightning network, and web3 applications. The crypto ecosystem of the future will most likely look very different from the crypto exchange platform-centric model we see today. Monitoring the evolution of fund flows in the sector will be critical to our understanding of how parts of the crypto ecosystem can pose a systemic risk in the future.

Equally important, however, is that certain characteristics of crypto make it less susceptible to the systemic risk present in other markets.

Opacity, multiplicity of intermediaries, counterparty risk, and manual processes are risks that the crypto ecosystem mitigates for. For example, traditional financial markets have:

- A heavy reliance on intermediaries to facilitate transactions. These entities thus become quickly systemically important. Decentralization in the cryptoeconomy, however, favors fewer intermediaries, and it also reduces how much trust individual participants need to place in these intermediaries.

- Transactions that are opaque, and investors often do not know where assets are held, whereas crypto transactions are public and auditable by default. The underlying code is typically "open-source" or otherwise made publicly available – a level of transparency not commonly seen in other markets.

- Execution and settlement of transactions that are separate processes, increasing counterparty risk. Blockchains combine the processes.

- Uncertainty around margin calls, whereas smart contracts can automate collateral liquidation, at the expense of reduced flexibility.

In determining the systemic risk of the cryptoeconomy, policymakers and regulators should carefully consider not only the challenges posed by crypto, but also its unique benefits in mitigating certain financial stability risks in ways that the traditional financial system cannot. After all, Bitcoin – the first cryptocurrency – was an innovation that arrived following the 2008 financial crisis. Many view it as a response to the shortcomings of the traditional financial system.

In the first section, we define what systemic risk is, and how it is measured in the traditional financial sector. Then we address whether crypto is systemically important, with an analysis of the Bitcoin network and discussion of the touchpoints between crypto and the traditional financial sector.

SECTION 1

What is Systemic Risk, and Why is it Important?

1.1

Definition and Example of Systemic Risk

Systemic risk can be defined as the risk that an event can trigger a cascade of other events leading to a significant decline of an industry, or even the entire economy. In contrast to the risk associated with the investment in a specific asset, such as a stock, a bond or a token, systemic risk cannot be diversified away.

One of the most prominent examples of how systemic risk can play out is embodied by the Great Recession. Most believe that in 2007-2008, the sudden collapse of the housing market ultimately led to a drastic contraction in the global economy because of the resulting ripple effects. A post-mortem of what caused the financial crisis pointed to many different culprits, from lax mortgage lending standards, to conflicts in credit rating agencies, weak due diligence by institutional investors, and misaligned incentives in shadow banking.

It may be tempting to simply keep markets separated as that would prevent shocks from propagating. However, this would come at a significant efficiency cost as market segmentation would limit the allocation of capital to its most productive uses. The benefit of a more interconnected economy is that it is more resilient, as firms do not depend on a single relationship or link. On the other hand, larger institutions operating in multiple markets can become natural points of failure. As regulators seek to strike a balance between efficiency and risk, the solution is not necessarily to prevent the formation of large institutions, but to ensure that these institutions manage risks accordingly.

1.2

Measuring Systemic Risk

Systemic risk is related by the size and importance of certain firms and industries in an economy and the interconnectedness or linkages between them. To carefully estimate the systemic risk of each entity in the economy, a model of interconnectedness and dependency among economic agents should be developed. If we consider the economy as a network, then we can plot where firms and industries are located in such a network depending on their relationships with each other. Firms that are centrally located in the network are more important for shock propagation because they are directly connected with many entities, and also because often they indirectly act as brokers between other nodes.

Owing to its size and role in the economy, the financial sector is the primary source of systemic risk and most frameworks to measure and limit systemic risk focus on financial services. Because financial institutions depend on each other in a variety of ways, from lending relationships to counterparty risk, reinsurance, and derivatives, building a model that maps out the interconnectedness of financial institutions is very complex. As a result, most

regulatory bodies use a series of indicators to determine the systemic risk of a firm or industry, rather than building a model of interconnectedness among entities in the economy. In the United States, the Financial Stability Oversight Council (FSOC) determines whether financial institutions are systemically important considering factors such as size and leverage.[1] Systemically important financial institutions (SIFIs) are subject to additional regulation, greater capital requirements, enhanced scrutiny via rigorous stress tests, and the requirement of a living will to orderly dispose of their assets in case of bankruptcy.

[1] Financial Stability Oversight Council Staff Guidance Methodologies Relating to Stage 1 Thresholds (2015).

1.3 Channels of Systemic Contagion

There are several ways idiosyncratic shocks can create cascade effects and impact the whole economy. We identify three key channels:

1. **Wealth to Consumption:** A direct link between asset prices and the real economy operates through households' portfolios. A drop in stock prices can lead investors to cut back on consumption, which in turns reduces revenues and lowers profitability for firms. This in turn results in lower stock prices, creating a negative feedback loop that can exacerbate economic shocks. Estimates on the marginal propensity to consume from changes in income range between 5% and 15% depending on households' income.[2]

2. **Operational linkages:** A shock in demand or supply can spread across the economy through supplier-customer relationships.[3] For example, as trade relations between China and the United States worsened in 2017, exports to China dropped significantly, with a cascade of effects on many industries. Likewise, the steep losses of the financial sector during the 2008-2009 financial crisis led to a credit crunch for banks' clients.

3. **Financial linkages:** Individual market participants routinely borrow from multiple financial institutions and other market participants, which means that a single borrower's failure might create fragility among its lenders even if the borrower operates in a different industry. Furthermore, leverage allows investors to amplify gains and losses, which, in times of distress, might also transform idiosyncratic shocks into market-wide fragility. Finally, the presence of collateral backing loans among investors and institutions reduces credit risk. However, when forced liquidations occur, fire sale externalities might materialize: borrowers who were not originally at risk, receive margin calls because the value of their collateral has significantly diminished. If they are not able to meet these calls, further liquidations might occur which can impact additional market participants.

[2] Fisher, Johnson, Smeeding, and Thompson (2020). Estimating the marginal propensity to consume using the distributions of income, consumption, and wealth. Journal of Macroeconomics vol 65. Di Maggio, Marco, Amir Kermani, and Kaveh Majlesi. "Stock market returns and consumption." The Journal of Finance 75, no. 6 (2020): 3175-3219.

[3] Carvalho, Vasco M., Makoto Nirei, Yukiko U. Saito, and Alireza Tahbaz-Salehi. "Supply chain disruptions: Evidence from the great east japan earthquake." The Quarterly Journal of Economics 136, no. 2 (2021): 1255-1321. Barrot, Jean-Noël, and Julien Sauvagnat. "Input specificity and the propagation of idiosyncratic shocks in production networks." The Quarterly Journal of Economics 131, no. 3 (2016): 1543-1592.

SECTION 2

Reviewing Systemic Risk Factors in Crypto

Over the last decade, cryptocurrencies have risen in popularity, gaining adoption both as an investment vehicle, as well as for other use cases such as payment, gaming, virtual credentialing, trading, and borrowing/lending. The market value of all digital assets peaked at almost $3 trillion in November 2021, and it is around $1 trillion as of August 2022. The creation and growth of an alternative financial system on blockchain rails has prompted questions and concerns about the systemic risk of the cryptocurrency ecosystem.

A common measure of systemic risk in traditional financial markets is firm and industry size. For example, in 2022, the total assets held in U.S. banks is worth almost $23 trillion;[4] The real estate market, which caused the 2008-2009 financial crisis, is valued at $43 trillion; The market cap of all U.S. public companies is over $43 trillion. To gauge the extent to which crypto can cause systemic contagion, it is important to compare the size of the crypto industry relative to the traditional financial markets.

[4] https://fred.stlouisfed.org/series/TLAACBW027SBOG.

Figure 1: Comparison of Size Metrics of Traditional Finance vs Crypto

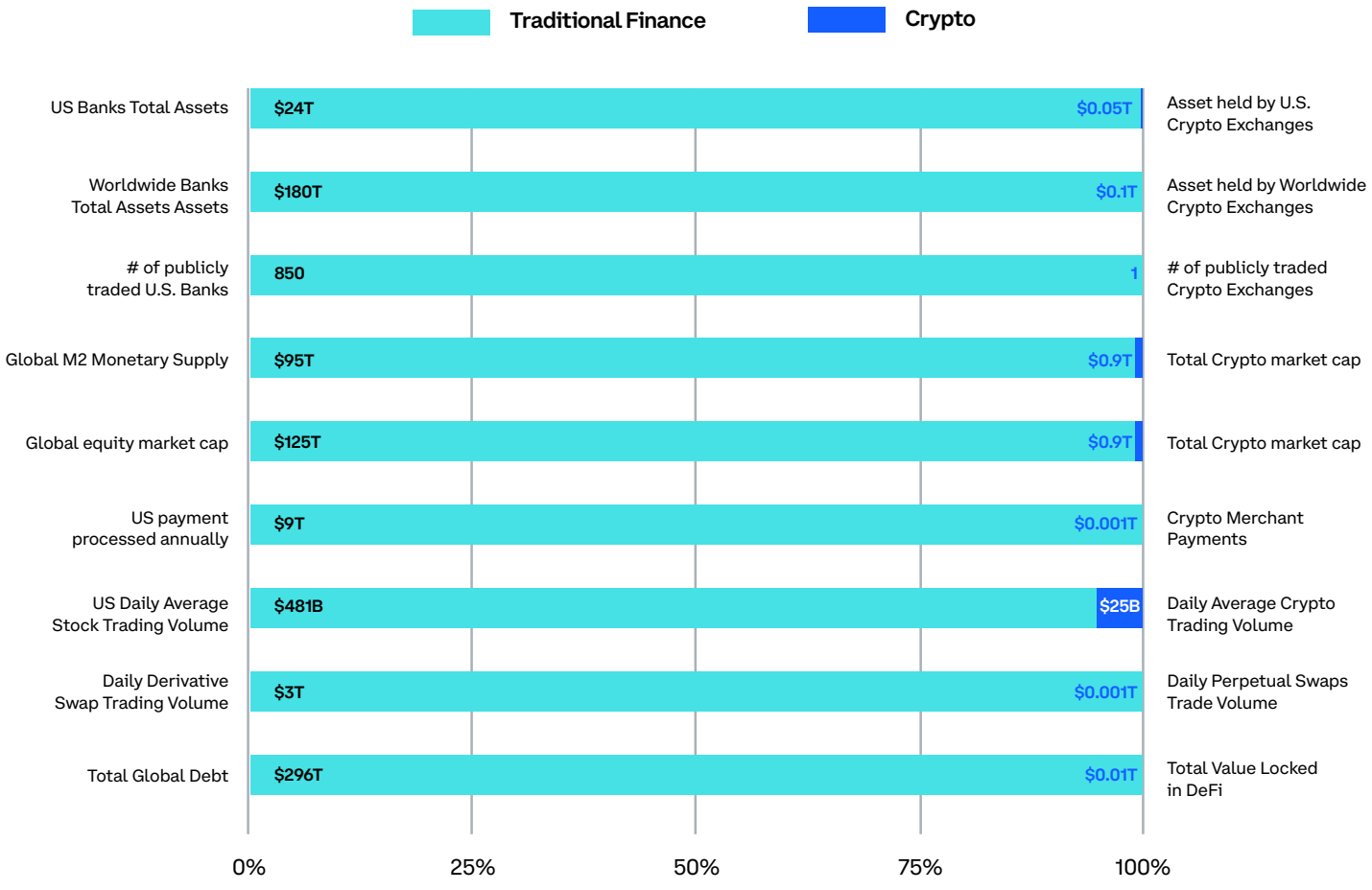


Figure 1 compares the traditional financial market, both from the United States and from a global perspective, with the crypto market across multiple dimensions.

The crypto economy is several orders of magnitude smaller than the traditional financial sector by all metrics.

This highlights both the growth potential of crypto, and also the fact that at its current size, and also in the short to medium term future, crypto does not and will not achieve a size big enough to cause economic contagion, even in the case of a crypto crash. In fact, the latest crypto downturn, with total market capitalization declining from $3T to under $1T in six months, did not cause widespread contagion in the real economy. If anything, there appears to be more evidence that macroeconomic conditions affect crypto prices, not vice-versa.

[5] A recent Coinbase article showed that two-thirds of the recent drop in crypto prices can be attributed to worsening macro-economic conditions.

If anything, there appears to be more evidence that macroeconomic conditions affect crypto prices, not vice-versa.[5]

Making a precise assessment of the threshold at which crypto can become systemically important is complicated. However, we can draw some inferences by looking at the metrics used in the traditional financial sector: FSOC uses a threshold of $250B in total assets to designate whether financial institutions are systemically important. Since the total assets in the banking sector is around $24T, a good rule of thumb is that a company is systemically important if it accounts for at least 1% of economic transactions in the system.

Today, cryptocurrencies' market capitalization captures for the most part the growth of the sector in the future, as the actual amount of real economic transactions is still limited. Thus the crypto ecosystem is still several orders of magnitude smaller than what would be needed to trigger systemic risk concerns, as pointed out in Figure 1. However, if and when traditional assets (like equity, bonds, money market mutual funds, consumer loans and mortgages) become tokenized, the crypto sector might become big and interconnected enough to warrant concerns about systemic risk.

A three-step process can be used to assess the potential areas of systemic risk:

1. Identify the characteristics that make crypto better suited to absorb economic shocks than the traditional financial system.

2. Review critical nodes whose failure can spread within the crypto industry, and cause major disruption to the well-functioning of crypto markets.

3. Study the touchpoints between the crypto and the traditional financial sector.

2.1 Crypto as a Shock Absorber

The traditional financial system is predicated on the existence of intermediaries that connect agents in the economy (e.g., banks, brokers, exchanges). Because of economies of scale, these intermediaries tend to become very large. As a result, a shock to these central institutions can have severe repercussions to the rest of the economy. Furthermore, transactions in the traditional financial system are opaque, and during times of crisis or uncertainty, it is hard to know which institutions are financially solid, and which are affected by the crisis.

By contrast, the main tenets of cryptocurrencies are decentralization, transparency, and interoperability. These features make the crypto ecosystem less susceptible to systemic risk than other markets.

- Blockchains do not require a central party to validate transactions, thus disintermediating economic exchanges among members of the network. The lack of a central intermediary also makes the network more resilient to shocks.

- The transparency and open-source nature of contracts and transactions reduces the uncertainty related to the financial soundness of entities on chain. During the 2008 financial crisis, investors did not know which financial institutions had toxic assets on their balance sheets, and that led to the freeze of commercial paper markets and the breaking of the buck of some money market mutual funds. In crypto, the exposure of each node is known, thus uncertainty over the creditworthiness of the entities in the network can be reduced.

- Finally, blockchain technology enables instant execution and settlement, and thus it does not require a chain of counterparties that take on the settlement risk.

2.2 Areas of Contagion in Crypto

While cryptocurrencies are designed with decentralization in mind, several parts of the crypto ecosystem play an important role for the well functioning of the cryptoeconomy and might pose broad risk:

- **Smart contract risk on "Layer 1" chains:** One of the most devastating incidents that could occur is the exploitation of bugs in the core code of popular blockchains like bitcoin and ethereum. While the risk is probably very low, since the code is open-source and both have been around for many years, errors in code could expose the network to a severe hack or failure, which might or might not be moderated by governance actions.

- **Bridges:** A bridge is used to trade assets across two different blockchain networks. Currently, the way to connect blockchains is through centralized bridges that take custody of the cryptocurrency (e.g. ETH) on one side of the bridge, and create a synthetic crypto (e.g. wrapped ETH) on the other side of the bridge. Synthetic cryptocurrencies are then used extensively in DeFi protocols like decentralized exchanges and borrowing/lending platforms. These bridges have been compromised in the past (e.g. the Feb 2022 Wormhole attack that stole $320m), and the failure of a major bridge could have a cascading effect across all crypto finance products offered on chain.

- **Custody:** Many crypto holders rely on third parties (e.g. centralized exchanges, third-party custodians) to store their crypto, especially when trading. The failure of a large custodian could have significant repercussions across the ecosystem. Similarly, stablecoin issuers act as custodians of fiat currency, and issue stablecoin in exchange. Failure of a major stablecoin to either safely custody deposits, or regulate coin issuance could lead to similar contagion dynamics.

- **On-chain DeFi lending:** Savers deposit crypto assets in blockchain liquidity pools, and borrowers take out a loan from the pool by pledging collateral. The borrowing-lending process is governed by a smart contract, and all transactions are transparently logged on blockchains, and visible to anyone. Crypto markets rely less on credit than traditional markets, because of the overcollateralized nature of the vast majority of the loans, thus reducing the potential for contagion. Deposit interest rates on these platforms are relatively low, between 0.5% and 3%, comparable or slightly higher to what is offered by traditional banks. However, when the collateral value decreases significantly in a short period of time, cascading liquidation could result in more severe price fluctuations.

- **Off-chain crypto lending:** In the United States, deposits in the banking system are insured by the FDIC, while crypto deposits in off-chain crypto lending are not. The yield offered to depositors by these lenders is substantial, up to 10%, to compensate for the extra risk. How crypto lenders deploy deposits is off-chain, with private arrangements not disclosed to the public. Unlike in on-chain DeFi lending, there is little to no way for depositors to assess the riskiness of the loans extended by crypto lenders. In these cases, the blockchain gives a false sense of transparency, because most of these transactions occur in an over-the-counter manner and are not recorded on the chain. This results in the build- up of fragility that is not easily monitored by other market participants. The case of 3AC, Celsius, and Voyager are the most recent and prominent examples of the perils of off-chain risky transactions, where investors cannot correctly assess counterparty risk because they are not aware of the real exposures of the companies they deal with. Finally, collateral deposited by the borrowers can be used by the lending platforms to borrow elsewhere and so could potentially generate a fragile chain of financial linkages across investors. This phenomenon resembles the chain of rehypothecation that preceded the 2008 financial crisis. of off-chain risky transactions, where investors cannot correctly assess counterparty risk because they are not aware of the real exposures of the companies they deal with. Finally, collateral deposited by the borrowers can be used by the lending platforms to borrow elsewhere and so could potentially generate a fragile chain of financial linkages across investors. This phenomenon resembles the chain of rehypothecation that preceded the 2008 financial crisis.

2.3 Central Entities in the Bitcoin Network

In the traditional financial system, institutions are classified as systemically important based on size and leverage, because mapping relationships among institutions is highly complex and confidential. One of the main features of the crypto ecosystem is that it is decentralized, interoperable, and transparent. It is thus possible to map out the relationship among crypto addresses and wallets to assess which entities have a critical central role in the ecosystem.

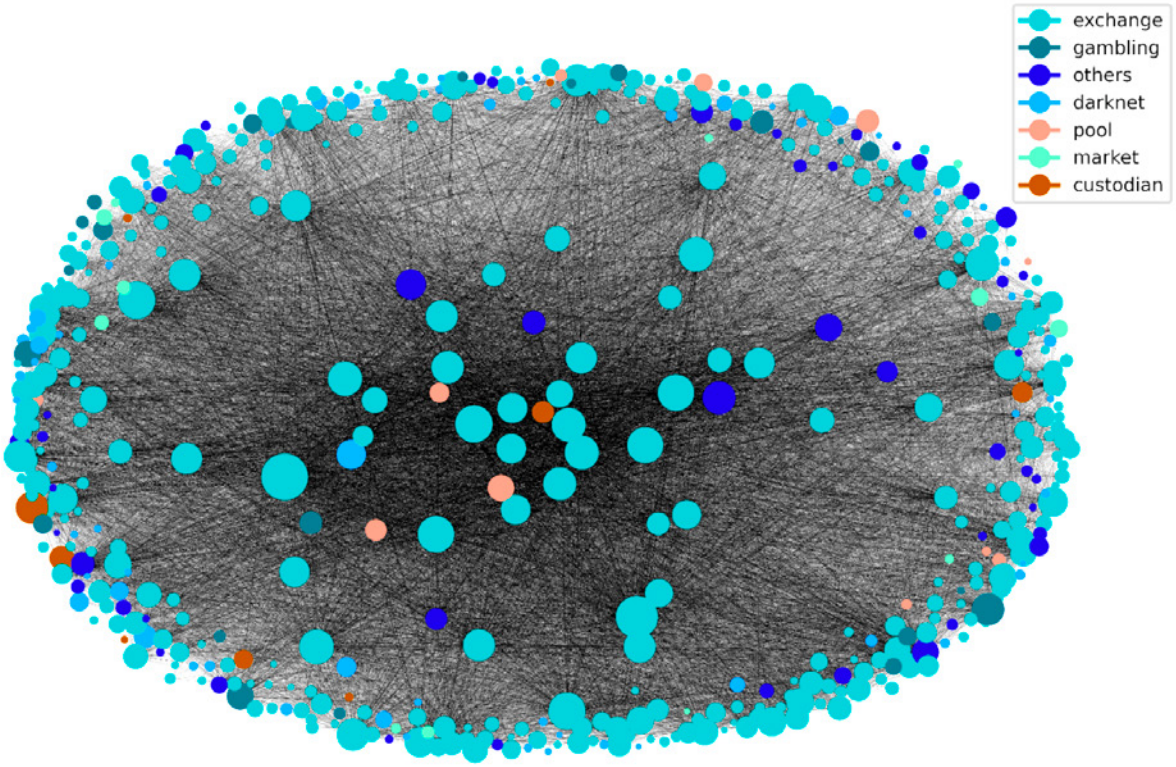
Each transaction in crypto has a sender (one or more input addresses) and one or more receivers (output addresses). Even though addresses are pseudonymous, we can cluster addresses into wallets with simple heuristics like common spending (linking input addresses used in the same transaction), one-time change (return output address), and off-chain information. Furthermore, many crypto companies disclose their public addresses, thus many wallets can be associated with a specific identity. Using this information, we can map flows of crypto funds among all known entities in the crypto ecosystem. Finally, known entities are classified in categories such as exchange, custodian, and miners.

We begin with studying the Bitcoin network, using data from Coinbase Tracer from January 2020 until the end of July 2022. There are 3.1 billion input-output address pairs engaging in transactions during the sample period. Nineteen percent of these address pairs are between 904 wallets for which we know the identity of both the sender and the receiver. 51% of these wallets are crypto exchanges, followed by dark net markets (12%).

Figure 2 shows the network of flows among the largest 500 nodes. The network has a typical hub-and-spoke topology, with a core of entities in the center, and a periphery of less important nodes.

Figure 2: Graph of the Bitcoin network using a spring-layout

Each node is a known wallet, and the width of each edge represents the number of transactions between a pair of nodes.



According to contagion models, nodes in the center of the network are the most susceptible for possible diffusion of economic shocks.

If and when crypto becomes systemically important, central nodes will be the candidates to become shock absorbers, rather than shock transmitters.

Disclosure, regulation, living will, and redundancy are ways to build a robust and resilient ecosystem. We measure node centrality using standard network tools: Betweenness, Eigenvalue, and Closeness.[6] These measures capture how central a node is in a network, with slightly different approaches: Betweenness counts how often a node is "in-between" other nodes; Closeness estimates

[6] See Wasserman and Faust (1994) "Social Network Analysis - Methods and Applications" for a review of these measures.

how close a node is to all other nodes; and Eigenvector measures the "influence" of a node by looking at how well connected its neighboring nodes are. Figure 3 shows that exchanges are the most common central nodes in the Bitcoin network, as they represent between 83 and 86 of the most central 100 nodes in the network.

Figure 3: Top 100 most central nodes in the Bitcoin network.

Betweenness		Closeness		Eigenvector	
exchange	83	exchange	85	exchange	86
others	7	others	6	others	6
gambling	3	gambling	3	gambling	3
pool	3	pool	3	pool	3
darknet	2	custodian	2	darknet	1
custodian	2	darknet	1	custodian	1

Network analysis can be an important tool to identify systemic risk in the crypto ecosystem. This preliminary analysis indicates that at the moment, exchanges are a central component of the Bitcoin network. However, important developments are occurring in the way crypto is held and used, from the rapid adoption of self-hosted wallets to layer-2 solutions like lightning network, and decentralized applications and web3. The crypto ecosystem of the future will most likely look very different from what it is today. One of the core tenets of crypto is its decentralization, and in the future the crypto-ecosystem could be very decentralized, making it intrinsically resilient to systemic risk propagation.

2.4 Touchpoints with Traditional Finance

Even though the crypto ecosystem is still too small to pose a systemic risk, it is important to assess which areas of the crypto ecosystem directly interact with the traditional financial system, as these connections might naturally lead to an increase in contagion risk in the future.

One natural touchpoint between these markets are stablecoins. To some degree, stablecoins perform a similar maturity transformation function as that performed by banks and money market funds: they accept deposits in fiat in exchange for a digital representation of those deposits in the form of tokens, and invest them in low- risk assets. A big difference between banks and stablecoin issuer is that banks invest in much riskier and longer term assets (mortgages, consumer loans, corporate loans) than stablecoin issuers, which usually invest in short term treasuries. The systemic risk profile of well-regulated stablecoin issuers is thus limited. If and when traditional financial institutions become stablecoin issuers, this might create a direct link between the banking sector and the crypto market. A shock to the crypto market could spread to the broader economy through its adverse effects on the banks' balance sheet.

A second area where both markets overlap is in the investor base, especially as larger institutions have entered the crypto markets the last couple of years. If crypto becomes a widely adopted alternative asset class, it is likely to see investors reacting more prominently to swings in crypto valuations.

Lending is another touchpoint between traditional finance and the crypto economy. Off-chain crypto lenders take crypto from savers, and invest in both on-chain and off-chain projects. Volatility in crypto prices might create a maturity and credit mismatch.

Finally, tokenization of real assets is also likely to reinforce the connections between the real economy and crypto markets. If ownership interests of real-world assets start to trade and settle on blockchains, the lines between crypto and traditional markets will start to blur. For example, one might imagine fluctuations in real estate prices to have a significant impact on crypto markets if those real estate assets are tokenized and held by crypto investors. It is worth pointing out that the integration of crypto markets in traditional finance is auspicable even if it might make the economy more sensitive to crypto fluctuations. What might be needed is closer oversight of the linkages that naturally will be formed.

Conclusions

As crypto becomes more integrated with traditional finance, questions about whether it poses a systemic risk have emerged. While the size of the crypto market makes it too small to be a systemic risk, in this paper, we:

- Outline the characteristics that make crypto better suited to absorb economic shocks than the traditional financial system,
- Review which critical nodes whose failure can spread within the crypto industry, and
- Identify the touchpoints between the crypto ecosystem and the traditional financial sector to assess the financial system's ability to absorb possible shocks to the crypto market.

On an ongoing basis, we will continue to monitor the evolution of fund flows in the sector to understand which parts of the crypto ecosystem can pose a systemic risk in the future.