

Global Cryptocurrencies and Digital Assets

Digital Assets Primer: Only the first inning

Primer

Digital asset sector too large to ignore; not just bitcoin, so much more

With a \$2tn+ market value and 200mn+ users, the digital asset universe is too large to ignore. We believe crypto-based digital assets could form an entirely new asset class. Bitcoin is important with a market value of ~\$900bn, but the digital asset ecosystem is so much more: tokens that act like operating systems, decentralized applications (DApps) without middlemen, stablecoins pegged to fiat currencies, central bank digital currencies (CBDCs) to replace national currencies, and non-fungible tokens (NFTs) enabling connections between creators and fans. Venture Capital digital asset/blockchain investments were \$17bn+ in 1H/2021, dwarfing last year's \$5.5bn. This creates a new generation of companies for digital assets trading, offerings and new applications across industries, including finance, supply chain, gaming and social media.

Welcome to the token economy

Bitcoin was designed as money, but is increasingly viewed as "digital gold." Ethereum created a generalized platform powered by smart contracts, enabling the development of hundreds of applications that could transform finance, insurance, legal, real estate and many other industries. Digital assets that enable applications to be built, like the Apple iPhone did with its App Store, are gaining the most value. Our view is that there could be more opportunity than skeptics expect. In the near future, you may use blockchain technology to unlock your phone; buy a stock, house or fraction of a Ferrari; receive a dividend; borrow, loan or save money; or even pay for gas or pizza.

DApps and NFTs: the most innovation

Decentralized Finance (DeFi) is an ecosystem that allows users to utilize financial products and services, such as lending, borrowing, insurance and trading, without relying on a traditional financial institution. DApps may bring financial services to many of the 1.7bn unbanked globally through a simple smartphone app. NFTs are changing the way creators connect with fans and receive compensation (and Gen Y & Z along with a few boomers are snapping them up). NFT sales were \$3bn+ in August, up from \$250mn in all of 2020, led by demand from celebrities, corporations and individuals (Beeple's digital artwork NFT sale at Christie's for \$69mn was a catalyst, for example).

Risk: regulation coming to the Crypto Wild West

Increased adoption of cryptocurrencies, new blockchain-based applications and stablecoins that could be used as money are drawing attention globally. Some governments, such as China's and India's, have banned bitcoin trading. Governments are working to develop policies and, as the SEC said recently, the digital asset industry's future lies "in the public policy framework." CBDCs appear inevitable, but fiat digital assets, such as bitcoin, may be targeted if central banks see risk to the payments system or credit flow disruption. DeFi applications with security-like features may draw SEC attention, likely pressuring near-term usage. Regulatory uncertainty is the largest near-term risk in our view, but regulation may drive increased investor participation over the long term once the "rules of the road" for digital assets are established.

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Refer to important disclosures on page 139 to 140.

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Contents

Executive Summary & Key Conclusions	3
Most exciting new market in years – blockchain technology	11
Bitcoin: where it all begin	16
It ain't just bitcoin	18
FAQs: so many questions, so little time	21
Digital assets: are they money?	37
Why should you care about digital assets?	40
Digital asset adoption in high inflation nations	43
What you need to know about Bitcoin	44
Supply & demand: drivers of price	48
Derivatives driving bitcoin volatility	57
Altcoins: any coin/token other than bitcoin	59
Stablecoins: pegged to another asset	64
Central Bank Digital Currencies (CBDCs)	71
Non-Fungible Tokens (NFTs)	81
Decentralized Finance (DeFi)	88
Appendix I: Distributed Ledger Technology explained	92
Appendix II: Bitcoin & Gold	94
Appendix III: Digital Assets & Mining	98
Appendix IV: Digital Assets & ESG	103
Appendix V: Digital Assets & Energy	114
Appendix VI: Digital Assets & Technical Analysis	119
Appendix VII: Digital Assets & ETFs	128
Appendix VIII: Digital Assets & Storage	132
Appendix IX: Emerging token ecosystem infrastructure	133
Appendix X: Digital Assets & Data Analytics	137
Figures	138
Research Analysts	141



Executive Summary & Key Conclusions

Digital asset ecosystem value surged in 2021

At \$2.1tn, the digital asset ecosystem aggregate market value is now larger than the GDP of Italy or Canada.¹ We expect further value creation as bitcoin is increasingly adopted, alternative coins/tokens enable new applications and a pipeline of Venture Capital-backed private companies reach public markets.

Bullish on long-term prospects

Despite potential regulatory headwinds (maybe tailwinds ultimately), we are bullish on the long-term prospects for the digital asset ecosystem as it enters the mainstream. We anticipate significant growth as digital asset use cases move beyond bitcoin's store of value thesis to an industry characterized by product innovation, regulatory clarity, increased institutional participation and mainstream adoption.

It's difficult to overstate how transformative blockchain technology, digital assets and the thousands of decentralized apps that have yet to be created could potentially be. We expect rapid changes to the current market structure – new use cases will be discovered and others will be discarded.

We are bullish on the digital asset theme for the following reasons:

1. We are only in the first innings of a major change in applications across most industries that will take place over the next 30 years, in our view. Estimates indicate about 221mn users globally as of Jun'21 have traded a cryptocurrency or used a blockchain-based application, up from 66mn at the end of May'20.²
2. Due to technological advances in decentralized software that is native to the internet, a new medium – with distributed ledgers and blockchain at its core – is emerging rapidly. The applications built on this new software architecture appear to be growing more quickly than past technologies. New companies are likely to emerge and poorly positioned companies will exit, creating significant upside potential for some and downside for others.

While we acknowledge concerns about the speculative digital asset trading that takes place currently, we believe it's the underlying blockchain technology driving this speculation that could be revolutionary.

Diverse and thriving

Hundreds of companies are now within the digital asset ecosystem providing infrastructure support, marketplaces and applications (such as decentralized finance, digital identity, supply chain, gaming and social media). Many are just 2 quants in a garage, though Venture Capital funding jumped to \$17bn+ in 1H/2021 from \$5.5bn in all of 2020. Digital asset public companies' aggregated market caps are \$130bn+ (boosted by COIN's listing in 2021; market cap \$54.6bn as of August 31).³

Digital asset-related M&A ytd jumped to \$4.2bn, up from \$940mn in 2020 and \$2.5bn in 2019, indicating a dynamic and maturing industry.⁴ We're still in the early innings and we see the potential for value creation over the next 5 years but, as in prior tech cycles

¹ All ytd data as of the end of August 2021 unless noted otherwise. \$2.1tn market value from CoinMarketCap.com

² Crypto.com's Measuring Global Crypto Users

³ Pitchbook.com

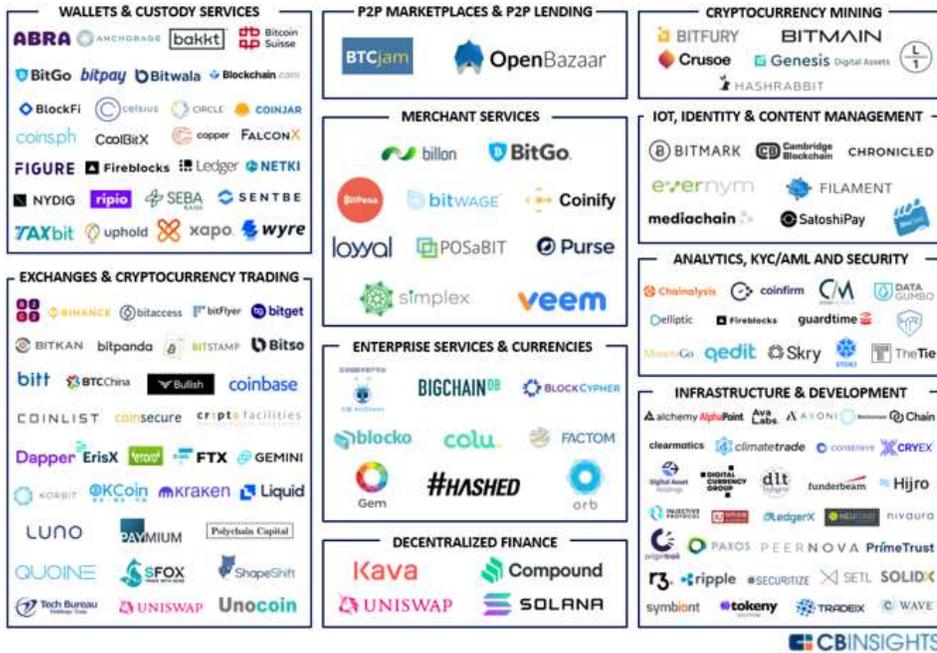
⁴ Pitchbook.com



(PCs, software, internet...), only a handful of well-run, focused companies will likely succeed.

Exhibit 1: Digital asset ecosystem

A quick snapshot of the expansive and developing ecosystem from Wallets & Custody Services to Infrastructure & Development



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Governments & regulators are noticing

Increased adoption, new token-enabled blockchain-based applications and stablecoins that may act like money are drawing attention globally. Some governments, such as China's and India's, have banned bitcoin trading, while they try to figure it out. Others, such as the US, are attempting to bring digital assets into a defined regulatory framework. Digital asset bulls expect strong performance once governments and regulators introduce the rules of the road but, in our view, there's likely to be plenty of volatility along the way.

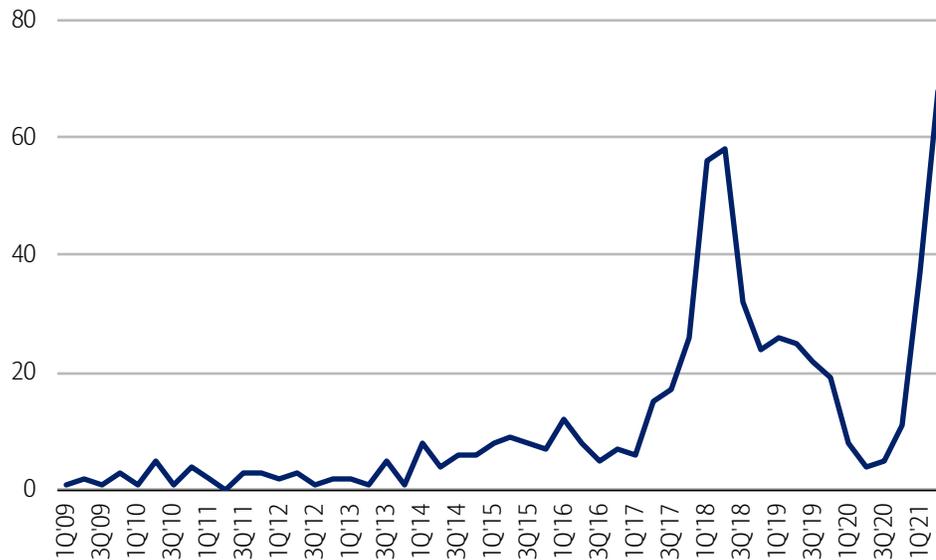
Corp interest growing; earnings call mentions increasing

Recent and increasing regulatory scrutiny as the digital asset ecosystem grows, and more individuals participate, may mean digital assets are a step closer to the end of their Wild West days. If so, corporations may in the future be more willing to consider adding digital assets to their balance sheets for diversification or to participate in the digital asset ecosystem by leveraging blockchain technologies to make their businesses more efficient (Exhibit 2). Partnering with our BofA Predictive Analytics team, we used Natural Language Processing (NLP) to analyze 161,322 earnings call transcripts from 1Q'09 through August 2, 2021, which found corporate interest in digital assets is at an all-time high.



Exhibit 2: Number of US companies that mentioned a digital asset keyword* on an earnings call rose to 147 from 17 a year ago

NLP analysis of earnings call transcripts of the S&P 500; avg 3,174 transcripts reviewed per quarter



Source: FactSet, BofA Global Research

*Keywords include: altcoin, bitcoin, blockchain, crypto, cryptocurrency, decentralized finance, defi, ether, ethereum, NFT, non-fungible-token
Year-over-year calculation period: 1Q'20 – 3Q'20 and 1Q'21 – 3Q'21 through 8/1/21. Note 3Q'21 not shown on chart.

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Holders getting younger; corporates want to keep up

Generational change

Development and adoption of digital assets will likely be led by Gen Y, Millennials and Gen Z. These generations grew up with the internet and expect native internet transactions to be frictionless and digital – without multiple steps and middlemen. Digital asset growth is likely to continue as it enables people to simply and easily transfer value and make payments (PayPal, Venmo and Zelle). It is also real-time and eliminates the middleman (or at least makes the transaction less cumbersome if using a digital asset exchange like Coinbase).

Going mainstream

It's estimated that 14% (21.2mn) of US adults own digital assets and an additional 13% (19.3mn) plan to buy digital assets in 2021. Notably, the average age of these potential buyers is 44 and 53% of the potential buyers are female.⁵

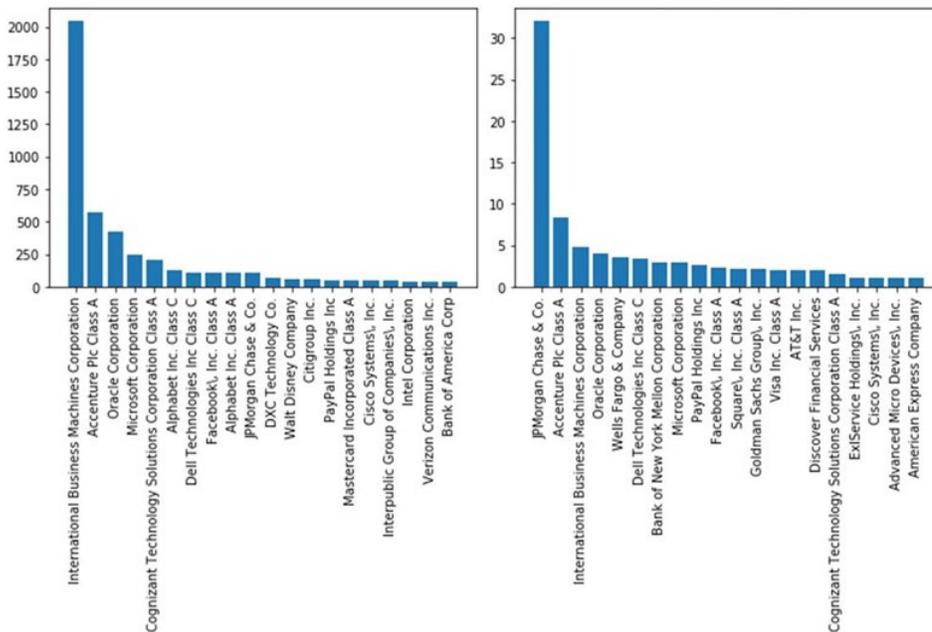
Corporations aren't risking being left behind

Companies aren't taking the risk of ignoring digital assets and applications and are actively exploring this new technology and its use cases. Leading tech companies, banks and others are adjusting their approach (Exhibit 3).

⁵ Gemini's 2021 State of the U.S. Crypto Report

Exhibit 3: Total blockchain-related headcount (LHS) vs Avg blockchain-related job postings per month as of April 2021 (RHS)

Blockchain-related interest skewed to tech and financial companies



Source: Revelio Labs

Revelio Labs is a workforce intelligence company that indexes hundreds of millions of employment documents from online public profiles, resumes, immigration data, and job postings. The ultimate output is a universal workforce dataset that provides detailed information about the employment dynamics of all companies from 2008 to the present. We note the dataset may not fully reflect the entire workforce of all companies analyzed, but provides a good representative sample.

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Bitcoin leading the way

Bitcoin is up over 2x its 2017 high at ~\$47,000, as adoption by individuals increased, corporate managements begin due diligence and regulators work to provide a framework that could bring digital assets into the mainstream. Bitcoin remains the most valuable digital asset at an aggregate value of \$887bn. Value drivers include supply/demand dynamics, scarcity (only 21mn coins total; ~19mn already mined) and potential ETF approval timing.⁶

But it’s not just bitcoin; value of altcoins is rising

Coins other than bitcoin are known as alternative coins or altcoins. There are now 11,500+ altcoins (or tokens), although many do not have a clear use case. Digital assets that enable a platform to be built, like the Apple iPhone did for applications, are gaining the most value; the top 3: ether (365% ytd to \$403bn value), cardano (142% ytd to \$89bn value) and binance coin (1142% ytd to \$78bn value).⁷ Applications built on these blockchains that are gaining the most momentum are Decentralized Finance, Digital Identity and Supply Chain tracking. Key value drivers are increases in developers’ building applications on these tokens and user adoption of the applications – tokens without this engagement are not likely to survive except as novelties.

Individual interest in Alternate Coins is rising as our Twitter analysis (Exhibit 4) and Reddit analysis (Exhibit 5) indicate.

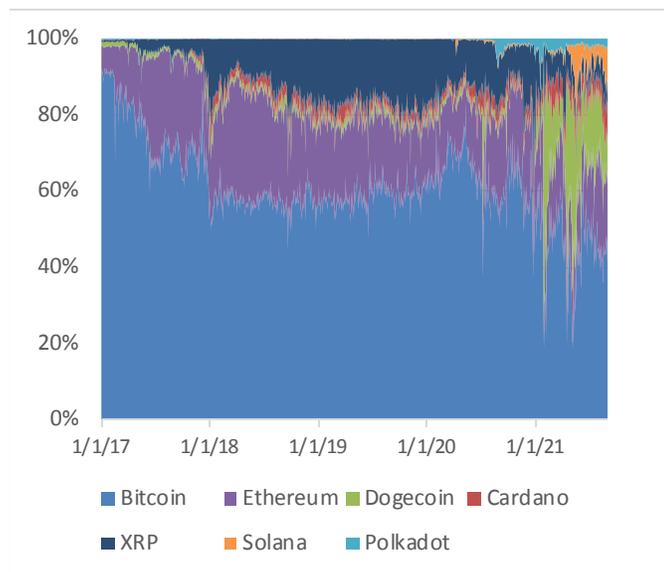
⁶ CryptoCompare.com

⁷ CoinMarketCap.com



Exhibit 4: Twitter digital asset mentions

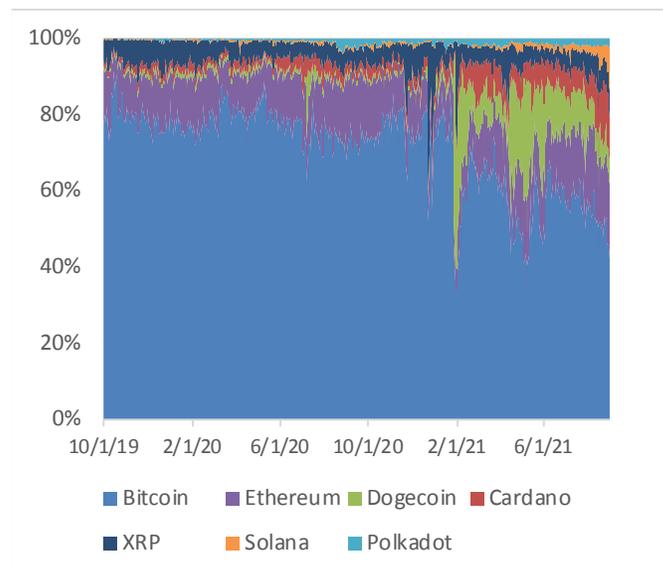
Twitter mentions of bitcoin fell to 44% of all mentions ytd through August across the 7 coins listed from 63% in 2020



Source: ListenFirst, BofA Global Research
 Data: 1/1/17 – 8/31/21. Note that searches for mentions also included tickers, i.e., BTC.
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Exhibit 5: Reddit digital asset mentions

Altcoins mentions increasing across both Twitter and Reddit with Reddit mentions of dogecoin jumping 3032% in Jan'21 m/m



Source: ListenFirst, BofA Global Research
 Data: 10/1/19 – 8/31/21
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Digital assets & ESG – plans to shift to greener energy

Mining digital assets uses a lot of resources. Many digital assets plan to shift to less energy-intensive forms of mining (Proof of Stake vs Proof of Work – see our detailed explanation in FAQs: so many questions, so little time and Appendix III: Digital Assets & Mining) and to move to greener/renewable energy. For example, the current process of creating bitcoin consumes ~91 terawatt-hours of electricity annually, up 10x in the past 5 years. This represents ~0.5% of global electricity consumption, which causes critics who believe that Bitcoin adds no value to argue that using as much electricity as Finland or the state of Washington is wasteful.⁸ Bitcoin supporters counter that the energy use will get better and is worth the consumption for the future value it will provide against the devaluation of fiat currencies. Supporters also point out that homes in the US use ~1,375 terawatt-hours of electricity annually and that Christmas lights in the US use ~6.6 terawatt-hours of electricity annually – more than the annual electricity consumption of El Salvador or Ethiopia.⁹

Stablecoins critical for digital asset applications, but bring risk

Stablecoins (tokens pegged to a fiat currency such as the US dollar and backed by fiat currencies/assets) established a firm foothold in the digital asset ecosystem this year, with the top 6 by market value rising to \$115bn and 1H/2021 transaction volume of \$2.8tn+.¹⁰ Stablecoins are designed to eliminate volatility and act as a store of value and a medium of exchange (act as money) (see our detailed explanation in Stablecoins: pegged to another asset). We view stablecoins as a waiting zone between fiat currencies and digital currencies, which could further accelerate adoption of the latter. The top 3 by market value are tether, USD coin and binance USD.

Facebook’s proposed Diem stablecoin, broader stablecoin acceptance and a lack of transparency around stablecoins’ reserves’ composition have drawn regulatory scrutiny. Some stablecoins aren’t backed 1:1 with US dollars and, instead, partially use reserves

⁸ The New York Times
⁹ Natural Resources Defense Council (NRDC), Center for Global Development
¹⁰ CoinMarketCap.com, Messari



such as commercial paper and/or corporate debt to provide extra yield to the stablecoin creator, which creates the risk of forced liquidation if market conditions become illiquid or if there's a broader market correction. In response, the leading stablecoins have issued public statements that their reserves are composed of dollars or Treasury Bonds, but increased regulatory scrutiny is likely.

Central Bank Digital Currencies (CBDCs) – when, not if

Inspired by digital assets and stablecoins, Central Bank Digital Currency activity increased significantly in 2021 in an effort to create the next evolution of money – Cash 2.0. Central banks from countries that represent over 90% of global GDP are reported to be exploring CBDCs.¹¹ Three of the world's major currencies – the dollar, euro and renminbi – are actively moving to the introduction of a CBDC. China's e-Renminbi is in the lead with a potential 2022 launch coincident with the Beijing Winter Olympics.

Governments and regulators globally have stepped up efforts to limit usage of digital assets, as adoption and use have increased. Some of the key issues that governments and regulators appear to be focused on revolve around AML/KYC, mitigating potential bank runs, taxation and liability. A central bank-issued/managed CBDC would address these issues, while maintaining central bank monetary policy control.

Non-fungible tokens (NFTs) – a surprise for all

The rise of NFTs caught even old-time digital asset players by surprise (even OGs). NFT sales increased to \$3bn+ in August 2021 (although the market has cooled a bit since), up from \$250mn in 2020 driven by corporate, celebrity and individual demand.¹² NFTs are unique digital files created on the blockchain (immutable, transparent record) that usually contain data that point to an online version of art or a physical asset and usually confer ownership or certain rights. NFTs can be used instead of deeds, titles or anything currently needed to demonstrate ownership – and all without a middleman charging a fee.

Collectors view the current generation of NFTs as the firsts of a new digital art form. The NFT wave was kick-started earlier this year by Beeple's digital artwork NFT sale at Christie's for \$69mn (3rd highest auction price for a living artist). Yes, the image could be copied, but the blockchain establishes the true ownership (provenance) and any associated rights.

NFTs are evolving with AI and smart contracts being added to the code. With an embedded smart contract, the NFT can act as a perpetual royalty stream for the original creator; every time the NFT is sold, a percentage of the sale price can be sent back to the creator.

Recent NFT sales (with strong demand) of CryptoPunks (CryptoPunk #3100 sold for \$7.6mn on March 11 and is now on sale for \$111.2mn) or of simple images like a black background with a few words of text make us concerned that there are heightened risks in this segment that need to be fully understood before NFTs can achieve true adoption.¹³

Decentralized finance/applications & regulatory trends

Tokens such as ether, cardano, solana and others with blockchains that can do more than securely record payments (Bitcoin's strength) can execute automated programs (smart contracts) such as making a payment after an event. This is Decentralized Finance (DeFi) where smart contracts automate manual processes of traditional finance, such as loans without a middleman (trusted intermediary). DeFi applications are a fast-growth segment of the digital asset ecosystem with Total Value Locked (measure of token value

¹¹ Atlantic Council

¹² Dune Analytics (<https://dune.xyz/rchen8/opensea>), NonFungible.com

¹³ Larvalabs.com



used for decentralized finance applications) increasing to \$90bn in August 2021 from \$17bn in August 2020.¹⁴

DeFi is an area that regulators are reviewing because applications may be viewed as securities once they provide traditional financial services as per SEC Chair Gary Gensler's recent comments. The SEC is investigating DeFi applications and companies to determine if and how they should bring them into the current regulatory framework. We are optimistic about the long-term growth of this segment as it matures and regulatory uncertainty is clarified.

Market structure maturing

Digital asset market structure matured with bitcoin futures volume reaching \$1.7tn (+304% y/y) and ether futures volume reaching \$953bn (+471% y/y) in August.¹⁵ Institutional users and platform assets increased by 67% and 589%, respectively, on Coinbase in 2020¹⁶

Illicit activity concerns

Digital assets have a mixed reputation not least due to high-profile ransomware cases and their underlying foundation of anonymity. What we think is underappreciated is that the blockchain is permissionless and transparent, enabling on-chain analytics to track digital asset fund flows through multiple wallets and provide law enforcement with the ability to track criminals and other bad actors, as was done with the recent Colonial Pipeline ransomware event. Illicit digital asset transactions dropped to under 1% of total transactions in 2020 from over 2% in 2019 (and over 35% in 2012).¹⁷

Risks: what could go wrong?

We summarize the key risks that could slow the adoption of blockchain technology and the digital assets that we discuss in our report. We categorize these key risks as technology/adoption risk – the risk that characteristics of blockchain technology prevent broad adoption or development of use cases – and legal/regulation risk – the risk that pending legal and regulatory frameworks prevent the development of use cases – as described below and discussed in detail throughout our report

¹⁴ *Defipulse.com*

¹⁵ *TheBlockCrypto.com*

¹⁶ *Coinbase Form S-1*

¹⁷ *Elliptic's Financial Crime Typologies in Cryptoassets*



Exhibit 6: Risks for digital assets and applications

Key risks that could slow the adoption of blockchain technology

Technology	Technology/Adoption Risk	Legal/Regulation Risk
Cryptocurrencies/Tokens	<p>Energy consumption Risk of potential adopters avoiding coins/tokens because of their perceived environmental impact</p>	<p>Environmental risk Risk of regulatory action to reduce the environmental impact of PoW mining</p>
	<p>Too big, too fast Risk that grand ideas to transform or remake industries don't pan out, causing potential adopters to cast doubt on the digital asset ecosystem</p>	<p>Regulatory risk Risk of the SEC implementing onerous regulations or preventing the formation of crypto ETFs</p> <p>Governmental risk Risk of countries banning crypto trading (China and India already have in some capacity)</p>
Non-Fungible Tokens (NFTs)	<p>Awareness Risk that investors may have limited understanding of what they're purchasing or may be buying into the hype phase, causing current and potential adopters to avoid in the future</p>	<p>Legal risk NFTs and legal frameworks that involve assets other than images, such as physical assets or the IP for digital art/collectibles, are still developing</p>
	<p>Underlying tech Risk that software bugs cause smart contracts to fail, leading to lack of confidence in the underlying technology</p>	
Decentralized Finance (DeFi)	<p>Consumer protection Risk that hacks, fraud and rug pulls (developers abandoning failing projects) involving current adopters with limited recourse will cause both current and potential adopters to revert to traditional financial institutions</p>	<p>Regulatory risk Risk of greater disclosure, AML/KYC and reserve requirements creating headwinds for DeFi companies or forcing an industry intended to be decentralized into a more centralized form</p>
Stablecoins	<p>Disclosure Risk that limited disclosure requirements about reserves could lead current and potential adopters of stablecoins to avoid them</p>	<p>Regulatory risk Risk of impending regulations requiring 1:1 currency reserves, reducing the usefulness of stablecoins, or imposing a ban due to the perceived risk of losing monetary policy control</p>
	<p>Too big to fail Risk that stablecoins pegged to fiat currencies could fail, creating a liquidity shock and leading current and potential adopters to cast doubt on the stability of the digital asset ecosystem</p>	
Central Bank Digital Currencies (CBDCs)	<p>Privacy Risk that potential adopters perceive the loss of privacy as a reason to avoid</p>	<p>Regulatory risk Risks that issuance is delayed due to concerns around AML/KYC (anti money laundering / know your customer), that benefits of a smoother payments system could be offset by creating competition with bank deposits, or that financial stability could decrease given the potential for bank runs</p>
	<p>Underlying tech Risk that underlying blockchain technology will not scale effectively</p>	

Source: BofA Global Research

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Most exciting new market in years – blockchain technology

We are just getting started

“I think the transformation we’re living through right now could be every bit as big as the internet in the 1990s” – Gary Gensler, SEC Chair 2021 on digital assets and fintech

For deep dives on digital asset mining, ESG, energy, technical analysis methodology, ETF methodology, storage and token infrastructure, please see our detailed appendices.

Our Primer focuses on what may be one of the most exciting new markets in years – digital assets and the companies that are leveraging them to create applications that are faster, frictionless and do not require trusted 3rd parties. For us, digital assets are not about payments per se. They’re about a new computing paradigm – a programmable computer that is accessible everywhere and to anyone and owned by millions of people globally. The digital asset ecosystem’s market value is \$2tn+, led by bitcoin at ~\$900bn and ether at ~\$400bn. There are 200mn+ crypto users globally and ~\$125bn in transaction volume daily.¹⁸

Despite rapid growth and market values on par with some of the largest public companies in the world, we believe the digital asset ecosystem is only getting started. There’s no way for us to fully cover the complexities of the quickly evolving blockchain-based ecosystem (yes, it’s more than just Bitcoin), but we are beginning the long journey of covering what we believe to be the next generation of technology – blockchain-based digital assets and applications.

Along with our Primer and in conjunction with our Equity Analysts, we publish our Primer Miner, highlighting companies exposed to the digital asset ecosystem.

Digital assets/blockchain are software – eating the world

Let’s start with the most basic foundation: digital assets/blockchain are software. And software is eating the world (Marc Andreessen). Software is the foundation of Netflix, Uber, Airbnb and others that are upending traditional industries.

Digital assets represent an architectural shift in how technology works – it is a move to distributed consensus. Anyone in a network can establish a process (application or project) that provides consistency and trust. This is a trend that has barely started - money is the easiest application and the bitcoin use case started here.

But digital assets are much more than a form of money

Supporters believe digital assets are a new monetary system that liberate us from central banks and government oversight, while skeptics criticize them as a danger to economic stability and to governments’ ability to tax and prevent illicit activity. But digital assets are much more than a form of money; the next wave of digital assets is likely Decentralized Finance (DeFi) code that builds internet-native contracts, loans, insurance, titles to real world assets, unique digital goods (known as non-fungible tokens or NFTs), online corporate structures (such as digital autonomous organizations or DAOs) and on and on – this is likely to be a major trend for the next 20 years.

Digital assets’ promise is decentralization

Digital assets also fundamentally change the user and stakeholder’s incentive structure. Up to now, online meant a company website or portal or an open source software code project like Linux that had no money attached to it. With digital assets, you can create thousands of incentive systems for collaborative work online without a real-world

¹⁸ CoinMarketCap.com, Crypto.com’s Measuring Global Crypto Users



company even needing to exist. Digital assets' promise is decentralization – imagine a social network where the more you use it, the more of it you own. Early forms are starting now and will likely mature within 5-10 years. Digital asset applications provide decentralization for applications across every industry, which we're likely to see over the next 30 years.

Most innovation appears as “solutions looking for a problem”

We remember similar thoughts and concerns as internet adoption started to take off in the 90s (yes, we were there). Our view is that most innovation leaps initially appear to be “solutions looking for a problem” (see examples below). Moreover, disruptive innovation that doesn't produce naysayers is likely not that disruptive or innovative. Some of our favorite quotes follow:

- **Telephones:** “What use could this company make of an electrical toy?” – William Orton, President of Western Union 1876, when offered the opportunity to buy the patent for the telephone
- **Computers:** “I think there is a world market for maybe 5 computers” – Thomas Watson, President of IBM 1943
- **e-Book Readers:** “It doesn't matter how good or bad the product is, the fact is that people don't read anymore” – Steve Jobs, CEO of Apple 2008, in response to the release of Amazon's Kindle
- **Video Streaming:** “Neither RedBox nor Netflix are even on the radar screen in terms of competition” – Jim Keyes, Blockbuster CEO 2008
- **Mobile Gaming:** These mobile games are “candidly disposable from a consumer viewpoint” – Reggie Fils-Aimé, President of Nintendo 2011
- **Smartwatches:** “An Apple Watch is an interesting toy, but not a revolution” – Nick Hayek, Swatch executive 2015
- **Connected Cars/Tesla:** “An iPhone belongs in your pocket, not on the road” – Oliver Blume, Porsche CEO 2016

Challenges that need a solution

Our current financial infrastructure was not created for the minimized friction our global economy needs as the form of money changes to digital. Today, our financial infrastructure is centralized (difficult to move accounts), limits access (1.7bn unbanked), is inefficient (cross-border, settlement), lacks interoperability (proprietary applications) and lacks transparency (silos).¹⁹

Intersection of technology, finance and public policy

The blockchain-based digital asset ecosystem is based on principles that differentiate it from today's technology and should provide services that are cheaper, faster, more secure and personalized (the promise and the challenges):

- **Permissionless:** the blockchain is open and transparent – everyone can see it and be assured of a transaction's validity.
- **Open-Access:** easy to create new applications and smart contracts with verifiable open-source code; software works across a peer-to-peer virtual machine, unlike today's software that runs a centralized PC or set of servers owned by a single entity.

¹⁹ The World Bank's The Global Findex Database 2017



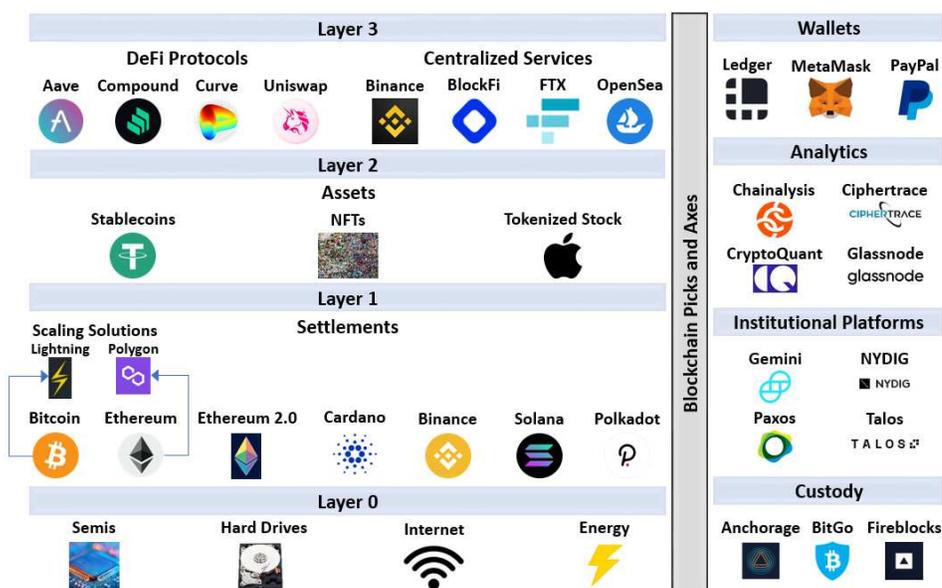
- **Global:** anyone with a computer / smartphone anywhere can participate.
- **Composable:** new applications easily and immediately interoperate with any other applications that already exist.
- **Transparent:** anyone can see the code and transactions sent.
- **Decentralized:** digital assets such as bitcoin and digital asset-based applications across finance, supply chain and identity have no central authority (government or company). A group of developers creates the code/application and users are responsible for its evolution, but this structure makes it difficult for regulators to find accountability.
- **Trustless:** no third-party intermediaries; it's all code, so no need to trust an institution or the person on the other side of a transaction. The challenge is potential software code bugs with limited recourse.

What is the digital asset technology stack?

Here's a simplified graphic of the blockchain layers (Exhibit 7) – keep in mind that the industry is in such early innings that there is overlap across the layers and even the layers are changing.

Exhibit 7: Digital asset technology stack

Layers 0 through 3 and blockchain picks and axes



Source: BofA Global Research
Companies and tokens listed above are for illustrative purposes and are not an investment recommendation

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In 1991, the World Wide Web (WWW) was launched when a new standard enabled developers to create web pages with just a few lines of code and to surf the internet with links instead of using command line interfaces. Web1 (AOL and Prodigy) was a centralized and permissioned network. However, a decade of Web / HTML maturity resulted in user-friendly websites that moved us beyond the early internet days of online billboards. Web2 was born. The digital asset ecosystem starts with cryptocurrencies, which are known as coins/tokens. Tokens are to the future Web3 what websites were to Web1.

Another way to think of digital assets is as building blocks. As developers scale these building blocks, they act more like operating systems. Once these operating systems (networks) are mature (smart-contract enabled), applications can be built on top of them

for multiple use cases across finance, consumer, supply chain, identity and more. The difference from prior technology cycles is that the operating systems (scaled blockchain networks) are not owned by a specific company. Blockchain networks are decentralized, so we are currently seeing valuation increases at the token (building block) level and the infrastructure around them.

Decentralization and tokenization are not that far off

Tokenization is comparable to the early days of the internet. It's easy to create a blockchain and crypto coin with open-source software or to create a token with a few lines of code. But more mature tokens with strong developer support, such as ether, cardano, solana and others, are moving tokens up the technology stack, making it simpler for developers to create new applications on top of an existing blockchain, mainly by updating the token protocols to enable smart contracts and increased scalability. Hundreds of companies are forming to leverage blockchain networks with applications across finance, supply chain, identity, e-commerce, data storage, social media and more. Just as there was an explosion of simple to complex websites in the 90s that eventually transformed how we shop and interact, in the not too distant future we could see the decentralization and tokenization of many aspects of finance.

Blockchain-supported apps threaten mature industries

Cryptocurrencies were the first applications of blockchain technology, bringing peer-to-peer payments that enabled the participation of many people without access to traditional banking services. In 2015, smart contracts (automated transactions) were introduced by the Ethereum blockchain network. Decentralized applications (DApps) were built on top of smart contracts, providing interoperability between blockchain networks. Over the last 2 years, we have seen the next generation of applications: Decentralized Finance (DeFi) further expands access to financial services, including savings, lending, derivatives, asset management and insurance products.

All of these applications pose a threat to mature industries that fear a loss of market share (or margins). Many companies with the greatest risk of disruption are proactively exploring how they can enter the digital asset ecosystem, leverage its technology and boost/diversify assets.

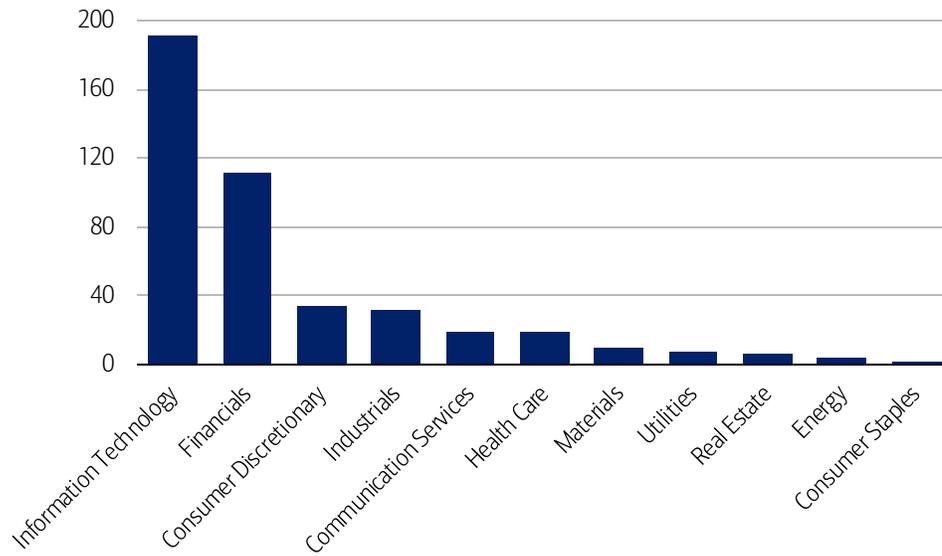
Tech and Financials companies lead in “digital asset” interest

Partnering with our BofA Predictive Analytics team, we used NLP to analyze 161,322 earnings call transcripts from 1Q'09 through August 2, 2021. Our analysis shows a renewed and significant increase in interest in the space since the beginning of the year with Tech and Financials companies leading the pack (Exhibit 8).



Exhibit 8: Sector breakdown of US companies that mentioned a digital asset keyword* on an earnings call skewed to Tech and Financials

NLP analysis of 48,117 earnings call transcripts since 1Q'18; avg 3,208 transcripts reviewed per quarter



Source: FactSet, BofA Global Research

*Keywords include: altcoin, bitcoin, blockchain, crypto, cryptocurrency, decentralized finance, defi, ether, ethereum, NFT, non-fungible-token
Data: 1Q'18 – 8/2/20. Note that the number of transcripts analyzed vary by sector.

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Risk and opportunity: regulation could speed up mainstream adoption

The popularity of digital assets has not gone unnoticed by governments and regulators. Facebook's 2019 proposal of Libra, a stablecoin backed by various currencies, to let its 2bn+ users make inexpensive payments, was likely an important catalyst, prompting regulators to take notice.

- Central Bank Digital Currencies appear to be inevitable (but the road there will likely be long and complex) to ensure payments system control and will likely act to limit private competition.
- Regulation will likely speed up mainstream adoption of digital assets from today's believers to broader public participation. It seems likely that regulators globally may step in for increased oversight. For now, more speculative digital assets or those viewed as stores of value are complementary and not competitive with regular money. Despite increased volatility as regulatory frameworks appear, clearer rules for digital assets and their applications may accelerate adoption.

Bitcoin: where it all begin

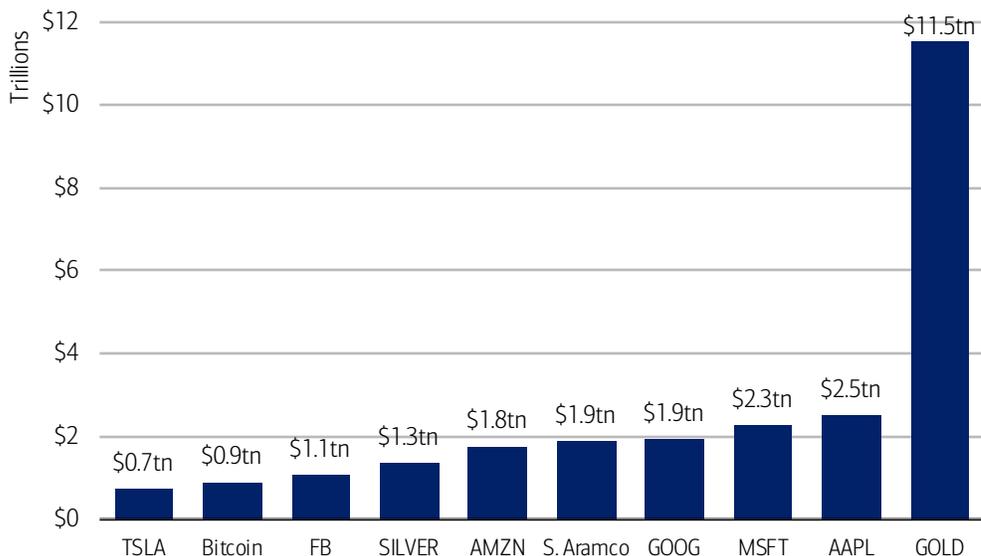
Bitcoin: The first 50 bitcoin were mined on January 3, 2009, the first bitcoin transaction occurred on January 12, 2009 and the first commercial bitcoin transaction occurred on May 22, 2010. The first commercial transaction was 10,000 bitcoin for two Papa John’s pizzas, which amounts to \$236mn *per pizza*, using bitcoin prices at the end of August. Since then, the digital asset market has reached \$2.1tn in value with \$100bn+ in daily transaction and trading volume.²⁰ Bitcoin has become one of the largest assets by market value in the world (Exhibit 9) and its value continues to appreciate ytd (Exhibit 10).

Bitcoin’s ~19mn coins (there will only be 21mn) aggregate value is ~\$900bn

Although bitcoin’s promise was to become a form of payment, it is increasingly viewed as a store of value, mainly due to scalability issues (transaction validation times are long and not inexpensive, although the Lightning Network may mitigate some of these issues). Current bitcoin price dynamics appear to be driven by supply/demand and increased Institutional interest that may accelerate as regulatory rules become clearer and investor protections are implemented.

Exhibit 9: Bitcoin is the 9th largest asset in the world by market value – larger than Tesla but smaller than Facebook

Bitcoin market value vs largest assets by market cap (\$tn)



Source: Bloomberg, BofA Global Research
Data as of 8/31/2021

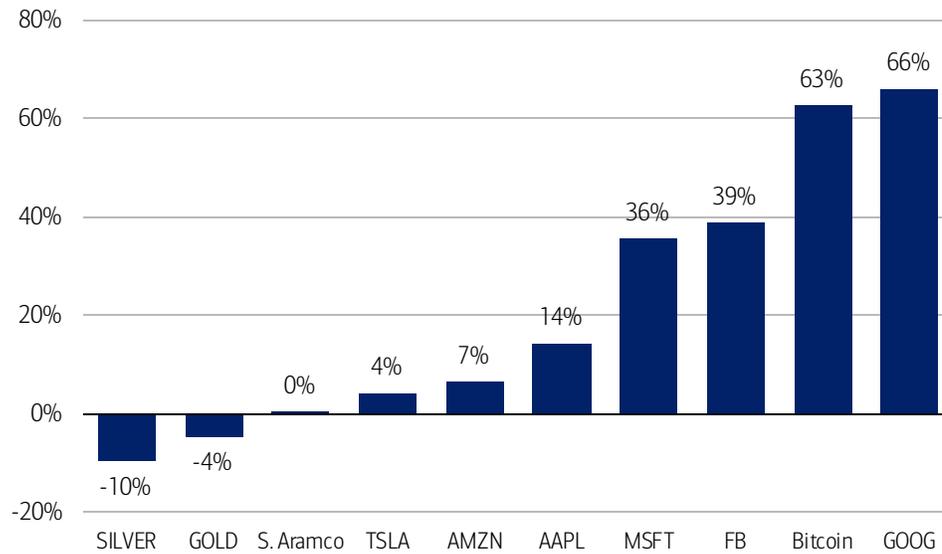
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²⁰ CoinMarketCap.com



Exhibit 10: Bitcoin is the 2nd best performing asset (+63%) relative to the 10 largest assets by market value and is significantly outperforming gold (-4%) and silver performance (-10%)

Price appreciation ytd of the 10 largest assets by market cap



Source: Bloomberg, BofA Global Research
 Data as of 8/31/2021. Silver performance represented by silver spot price (US\$) per troy ounce. Gold performance represented by gold spot price (US\$) per troy ounce.

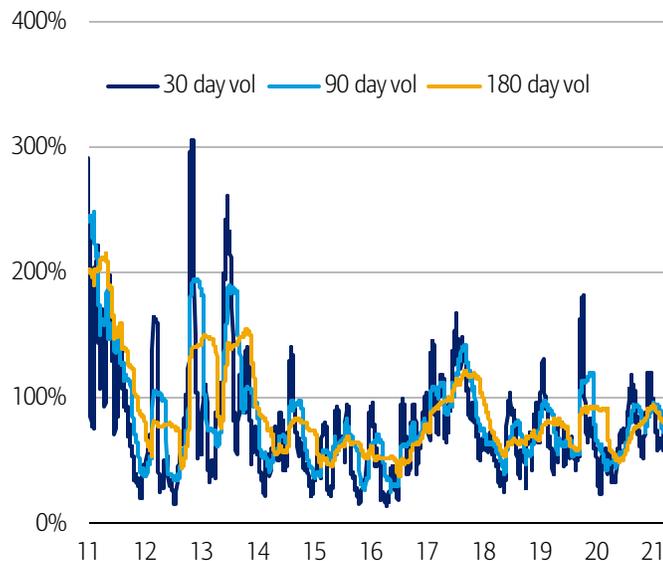
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Volatility declining with increased adoption/ownership

Bitcoin’s volatility is still high at nearly 70% annualized volatility; however, it is showing signs of maturing from when it breached 300% in 2013. While bitcoin’s volatility remains high, especially compared with SPX or Gold, investors can utilize traditional portfolio allocation approaches to adjust their position sizing by inversely weighting volatility; higher volatility assets would receive a lower portfolio allocation.

Exhibit 11: BTCUSD volatility still high relative to other assets but has come down relative to earlier years as the market matures

Rolling annualized volatilities

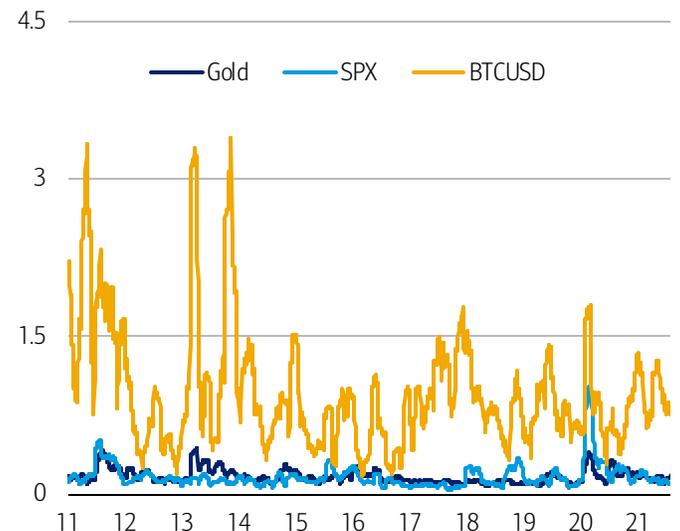


Source: CryptoCompare, BofA Global Research

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Exhibit 12: BTCUSD volatility remains elevated versus other assets but investors can down weight portfolio allocations to BTCUSD by inversely weighting by volatility (i.e. volatility adjustment)

Rolling annualized volatilities



Source: CryptoCompare, BofA Global Research

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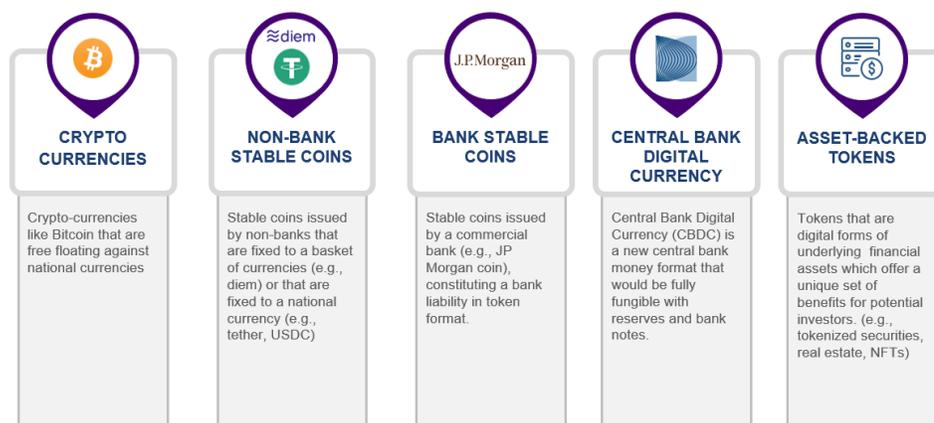


It ain't just bitcoin

With over 11,500 tokens, it's no surprise that many find it difficult to differentiate between them.²¹ We think that coins/tokens that develop a platform are likely to be of greatest interest. We would watch platform development milestones, developer engagement to build applications and user growth to help determine value.

Exhibit 13: Digital assets have emerged with distinct purposes that continue to evolve

5 types of digital assets with descriptions – from cryptos to asset-backed tokens



Source: Accenture

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Ether (ETH): second most valuable & traded after bitcoin

Proposed in 2013 and released in 2015 as a blockchain that enables decentralized applications vs Bitcoin's blockchain and vision of a currency replacement. Ethereum enables DApps through the ability to host smart contracts (automated functions) that can replace the manual processes done in traditional finance, especially in lending, insurance and exchanges. Ethereum is in the middle of a major update to Ethereum 2.0, targeted for 2022, that should significantly increase its functionality and scalability while reducing environmental issues (no more "mining" as it shifts to proof of stake from proof of work).

Fans of Ethereum liken it to a platform like the iPhone enabling applications (projects) or as Digital Oil vs Bitcoin as Digital Gold. By running decentralized applications (DApps) on the Ethereum infrastructure platform, developers are able to leverage a network of computers that combine into a single and powerful decentralized supercomputer (virtual machine). Use cases range across smart contracts, NFTs, stablecoins, DeFi and ICOs (initial coin offerings).

After bitcoin and ether, other tokens (Exhibit 14) such as cardano, solana and binance coin are jockeying for developers to build projects (applications) with the promise of better features, lower costs and faster transaction rates.

We will provide deep dives into the top tokens by market value in follow-up reports as each has fundamental development roadmaps, on-chain developer engagement analytics and user adoption that may be used to determine increasing or diminishing platform value.

²¹ CoinMarketCap.com



Exhibit 14: Top 10 tokens by market value

Solana and dogecoin have both appreciated over 5,000% ytd

Name	Ticker	Price	Market Value (\$bn)	YTD
Bitcoin	BTC	\$47,166.69	\$887	63%
Ether	ETH	\$3,433.73	\$403	365%
Cardano	ADA	\$2.77	\$89	1427%
Binance Coin	BNB	\$464.42	\$78	1142%
XRP	XRP	\$1.19	\$55	441%
Dogecoin	DOGE	\$0.28	\$37	5848%
Solana	SOL	\$108.48	\$32	7084%
Polkadot	DOT	\$31.47	\$31	239%
Uniswap	UNI	\$29.42	\$18	469%
Terra	LUNA	\$31.56	\$13	4737%

Source: CoinMarketCap.com

Data as of 8/31/2021. Excludes stablecoins.

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The rise of decentralized applications (Web3)

The Ethereum blockchain added smart contracts, which are business rules that execute automatically if certain events occur. The benefit of these decentralized applications is that they replace centralized firms, like traditional banks or social media/e-commerce platforms, with decentralized organizations. These decentralized organizations have users with a personal stake who are rewarded with incentives for using the application usually in the form of a token. DeFi Applications, Stablecoins and NFTs are all examples of projects that can be built on smart contract-enabled blockchains.

Decentralized Finance (DeFi): Most applications of smart contracts are in the segment enabling market makers, algorithmic stablecoins, yield farming, lending, insurance and more. Future iterations of DeFi protocols will likely include more automation features, including AI-managed derivative products, AI-mitigated risk management solutions and user scoring. A measure of growth in this market is the amount of tokens (usually ether) committed to smart contracts known as Total Value Locked (TVL). TVL at the end of August 2021 was \$90bn, up from \$17bn in August 2020.²²

NFTs (unique digital tokens): The Non-Fungible Token (NFT) market is one of the fastest growing, reaching \$3bn+ sales in August with over 200k participants. This is the fastest growth area for token applications as total sales for 1H/2021 were \$2.5bn, up from only \$14mn in 1H/2020.²³ NFTs are mainly built on the Ethereum network with success providing a tailwind to ether's market value (+365% ytd). NFTs empower both creators and collectors – new opportunities for musicians, artists and other creators to connect with fans. New smart contract features even enable a royalty stream back to the original creator every time an NFT changes hands. Christie's sale of Beeple's Digital Art NFT for \$69mn in March was a catalyst for the market.

Stablecoins (tokens backed/pegged to an asset like the US dollar): These tokens have seen a significant jump in adoption across DeFi applications as traders are able to reduce exposure to digital asset volatility without converting digital assets back to a fiat currency (and paying significant transaction costs). Other use cases include cross-border payments and remittances where, for example, an overseas worker may send \$200 a month back home to Asia, but also incur a ~\$10 fee each time (a stablecoin transferred wallet to wallet is relatively free). Regulators are rightly concerned about this new form of money, especially as many stablecoins lack transparency into the underlying reserves (dollars or dollar-equivalents), potentially creating liquidity and capital risks, as well as structural risks to the digital asset ecosystem.

²² Defipulse.com

²³ Dune Analytics (<https://dune.xyz/rchen8/opensea>), DappRadar

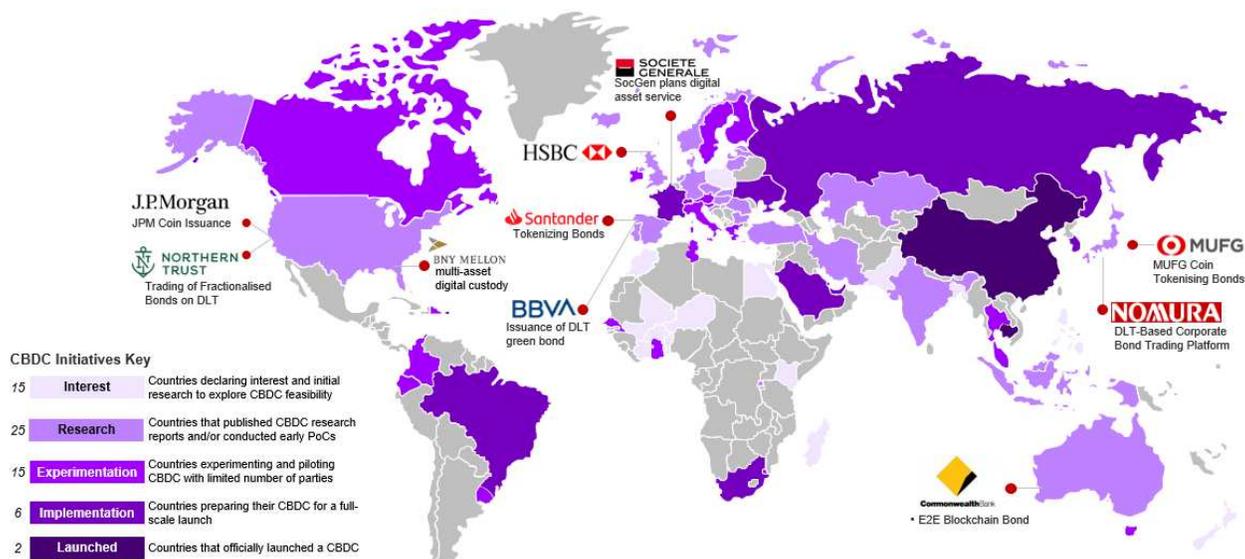


Central Bank Digital Currencies (CBDCs): A digital form of cash (fiat currency issued by central banks) is an inevitable move for central banks as the world shifts to cashless payments. A sense of urgency is also emerging as private company sponsored stablecoins gain adoption, potentially impacting central banks’ ability to implement monetary policy. CBDCs would also make transactions faster and less susceptible to counterfeiting, as well as cheaper than printing and minting paper and metal currency. Digital money is also able to be tracked across wallets and potentially bring unbanked lower-income people around the world into the financial system. There are many good reasons to shift to digital currency, but the details will take time to work out as central and commercial banks accelerate CBDC and digital asset initiatives (Exhibit 15).

- China has started large-scale trials of the e-yuan with the potential for broader rollout next year.
- The European Central Bank (ECB) starts its investigation phase of a digital euro in October. The ECB intends to make its decision on whether to create a digital euro once the investigation phase, which will last for ~2 years, is completed. The ECB will test and create possible solutions with the help of banks and other companies that will provide technology and services.
- The US is likely in investigation mode (although nothing formal has been announced) with Fed Chair Powell saying America would prefer to “get it right than to be first.”

Exhibit 15: Central and commercial banks across the world have significantly increased CBDC and digital asset initiatives

Global CBDC and digital asset initiatives map



Source: Accenture
As of August 2021



FAQs: so many questions, so little time

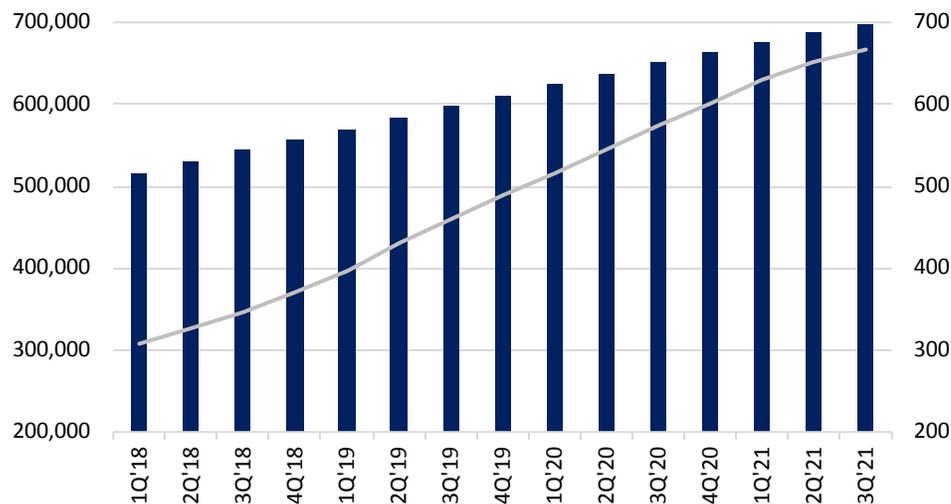
Here you'll find all the questions you ever wanted to ask in one place:

Q: What is blockchain technology?

A: Blockchain technology sounds complicated – and is – but at its core it is really quite simple. A blockchain is a public (permissionless) or private (permissioned) network that immutably records blocks of transactions in sequential order, which creates a chain of blocks, each building on top of the last. The blockchain protocol is a set of rules that allows for trustless peer-to-peer (P2P) transactions to be verified, processed and confirmed by adding these transactions to a distributed ledger (database) that rewards those who provide network security. Imagine a dollar bill in NYC: the dollar bill could sit in your wallet or it could be used as payment 50 times in one day. In the case where it is never used, it sits on the blockchain, unmoved and in the possession of the last person who acquired it. In the case where it is used 50 times, it moves along the chain each time a transaction occurs with the blockchain's network of participants keeping track of who owned it and when. From inception through August 31, Bitcoin's blockchain had 698,471 blocks containing 666.9mn bitcoin transactions that were verified, processed and confirmed on the blockchain (Exhibit 16).

Exhibit 16: Bitcoin's blockchain includes ~700,000 blocks containing ~667mn transactions

Bitcoin blockchain's block height (LHS, bars) and transaction count (RHS, line, in mns)



Source: CryptoCompare, BofA Global Research

Block Height and Transaction Count data reflects end of period numbers. 3Q21 data through 8/31/21.

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Q: Who controls the blockchain? What are forks?

A: No central authority owns or controls the blockchain, but stakeholders – nodes, developers and network participants – can implement changes to the protocol (set of rules) when they identify a security risk or the potential for new functionality. Hard forks occur when changes are made to a blockchain's protocol and result in two blockchains, each with its own unique currency. The two blockchains resulting from a hard fork are the original blockchain, which remains unchanged, and a new blockchain, which uses an updated version of the original blockchain's protocol. Soft forks occur when changes are made to a blockchain's protocol, but result in only one blockchain, albeit one with an updated protocol. In the past, soft forks have resulted in Segregated Witness (SegWit) and hard forks have resulted in the creation of Bitcoin Cash, Bitcoin Gold, Bitcoin SV and Litecoin, among others.



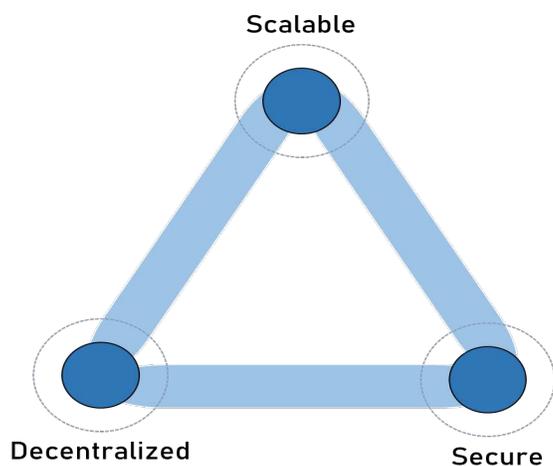
Q: What is the blockchain trilemma?

A: The blockchain trilemma (aka scaling trilemma) refers to the trade-off between scalability, security and decentralization. In other words, an application that requires a large number of secure transactions must give up some aspects of decentralization. (Exhibit 17).

- **Scalability** refers to a blockchain protocol's ability to scale with future expected growth. Scalability is key for blockchain ecosystems to surpass existing legacy systems. In simplistic terms, it is where a blockchain can process a transaction on more than one node (i.e. computer laptop).
- **Decentralization** is one of the core ethos of blockchain technology and refers to when no significant amount of trust is placed with a centralized actor. In the pure sense, decentralization means that if a set of nodes within a network cannot be run with a simple consumer laptop, then it is not truly decentralized. Note that some protocols, such as Solana, opt for optimizing speed on the fastest computers over decentralization.
- **Security** refers to when a large percentage of the existing network nodes can resist a potential attack. Attacks occur when more than 50% of the network nodes are under control of a single group (51% attack). In this scenario, the consensus of the network is not sufficiently distributed and a hypothetical single group of attackers could manipulate the data to their financial benefit. As an example, Bitcoin Gold, suffered a 51% attack, which resulted in hackers stealing digital assets worth \$18mn at the time.

Exhibit 17: Blockchain trilemma refers to the feature trade-off

Trade-offs between decentralization, scalability and security



Source: BofA Global Research

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Q: What are the potential solutions to the blockchain trilemma?

A: The landscape is evolving quickly with competing protocols attempting to solve the blockchain trilemma, but with mixed success. The solutions can be categorized either at the Layer 1 or Layer 2 level. Think of layer 1 as the base level blockchain protocols, such as Bitcoin and Ethereum, with layer 2 operating on top of the blockchain protocols as applications.

For adoption, scalability (more transactions faster) is key. Two potential solutions at Layer 1 are the transition from proof of work (PoW) to proof of stake (PoS), exemplified by Ethereum 2.0, and sharding. Sharding is a database concept that allows data on a main database to be split into distributed databases in an efficient manner. Breaking a



blockchain into shards increases the scalability of the network (Ethereum 2.0 will deploy this technology).

For Layer 2 solutions, there are a range of options emerging. The most popular one for Bitcoin is the Lightning Network, which is built on top of the blockchain. However, the Lightning Network sacrifices decentralization in exchange for increased scalability, exemplifying the blockchain trilemma.

Q: What are hot and cold wallets?

A: Digital asset wallets are similar to the ones you keep in your pockets, but with some key differences. There are two main types of digital asset wallet – hot storage wallets and cold storage wallets. Unlike the wallet stuffed with cash, a digital asset wallet doesn't actually hold a user's digital assets. Rather, a digital asset wallet allows users to make transactions using their digital assets, which are digitally stored on the blockchain.

There are 3 types of hot wallet, all of which are permanently connected to the internet, and 1 type of cold wallet, which only connects to the internet when transactions occur. Hot wallets include desktop, mobile and online wallets and cold wallets, also known as hardware wallets, are physical devices that look like USB drives and connect to a user's computer. There are tradeoffs between convenience and security for both wallet types.

Online/Web digital asset wallets provide the highest level of convenience when transacting, but the lowest level of security. These wallets store users' private keys in the cloud and are constantly connected to the internet, allowing users to access their digital assets from any device connected to the internet, but they also increase users' exposure to a hack. Online/Web wallets are best suited for users who trade regularly or own a small amount of digital assets because purchasing a cold wallet could be more expensive than the digital assets it holds. We note that digital asset owners, specifically institutional investors with large digital asset holdings, will likely want to store the majority of their digital assets in cold wallets.

Desktop and mobile wallets provide ease-of-use when transacting, but are less secure than cold wallets because of internet connectivity. A desktop/mobile wallet is software downloaded directly to your device that stores a user's private key on a hard drive (HDD) or a solid-state drive (SSD). This ease of use provides convenience, but also opens the user to the risk of losing control of their private key if their device is hacked, which is why users should ensure that their desktop/mobile wallet offers multi-factor authentication. Another drawback is that these types of wallet can require several hundred gigabytes of space. These wallets, specifically mobile wallets that provide QR codes, are commonly preferred by users who make frequent or face-to-face digital asset transactions.

Cold wallets provide the highest level of security, but at the expense of ease of use when transacting. A cold wallet is hardware that stores a user's private key offline, but allows the user to transact online using digital assets. The downside of these wallets is that it takes longer to transact with the digital assets held in the user's cold wallet. Cold wallets are also more expensive than hot wallets, which are usually free, and are sometimes only compatible with larger coins. However, if users hold digital assets worth more than \$100–200, the small cost of safely securing their digital assets is negligible.

Q: What are public and private keys?

A: Digital asset wallets consist of a private key, a public key and an address. A digital asset wallet allows users to make transactions using their digital assets, which are digitally stored on the blockchain. A user's private key authenticates them as the owner of the digital asset held on the blockchain and a user's public key is derived from the private key and acts as a signature that the blockchain (nodes) uses to verify the user's private key without actually revealing it publicly. Both private and public keys are linked to a user's digital asset wallet's address, which is like a bank account.



Digital asset ownership is determined by whoever possesses a wallet's private key: in other words, not your key, not your coin.

Q: What is digital asset mining and why does it use so much energy?

A: The Bitcoin blockchain, along with the majority of digital asset blockchains, uses a Proof of Work (PoW) consensus mechanism. Miners expend energy to process and confirm blocks of transactions in exchange for block rewards and transaction fees. But what's the puzzle that miners need to solve? First of all, we think the term "puzzle" is somewhat of a misnomer because it implies that skill or strategy is involved. The puzzle is really more like a lottery with a high barrier to entry. Miners compete against one another to solve a computationally-intensive problem, which requires trial-and-error and utilizes a 256-bit Secure Hashing Algorithm, also known as SHA-256, which takes a data input and compresses it into a unique 64 character output. Exhibit 18 shows an example of the output generated from two unique messages:

Exhibit 18: Cryptographic hash function

SHA-256 bit Secure Hashing Algorithm – changing 1 character produces an entirely different hash value

Message	Message hash value
Bitcoin 101	d27026240a739f642bb4c918605fd202c5d826afe75a90ebe317a170ce6bda65
Bitcoin 102	b67ebffc39d1e54a9d5b0834af67a798ff847845227944bc333f52a62ee5e8c5

Source: BofA Global Research

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Before we continue, it's important to understand that changing the last character from "1" to "2" in the messages above creates a completely different output and that the hashing function is a repeatable one-way function. Miners select pending, but verified, transactions from a waiting room called a memory pool, or mempool, to include in their block and then perform the SHA-256 hashing function, which uses data from the previous block called the root hash and the hash of the data from the pending transactions. There is also a variable called a nonce (number only used once), which is what miners attempt to solve and where the computationally intensive problem comes into play. Miners generate nonces continuously until the resulting hash is less than a target value. The process of guessing a nonce that will produce a hash less than the target value is the "work" in "Proof of Work." Once the nonce is discovered, the puzzle is solved and a miner adds the block of transactions to the blockchain, which are then confirmed.

We note that bitcoin mining isn't generating large emissions for nothing; the "work" in Proof of Work refers to the energy consumption and, therefore, cost associated with mining. Bitcoin is considered the most secure blockchain, but the tradeoff to being the most secure is the work and inherent cost involved to mine blocks of transactions, as well as scalability issues.

Q: Can I still mine bitcoin from my bedroom?

A: The short answer is you can, but the likelihood of receiving a block reward is low. HIVE Blockchain Technology, a digital asset mining company, generates ~\$600,000 a day from block rewards, which is equal to 12.5 bitcoin.²⁴ Excluding rewards in the form of transaction fees, this indicates that they are the first to produce a block hash below the target value only about twice a day. Bit Digital, a digital asset mining company, has 32,500 mining rigs, which each cost about \$12k, totaling \$390mn in equipment.²⁵ The probability of you receiving a block reward, even with a top of the line ASIC (Application-Specific Integrated Circuit) mining device in your room, is exceptionally low. The digital asset mining industry has matured to high barriers to entry via capex (cost of ASIC mining device) and high variable costs from the cost of utilities (Exhibit 19).

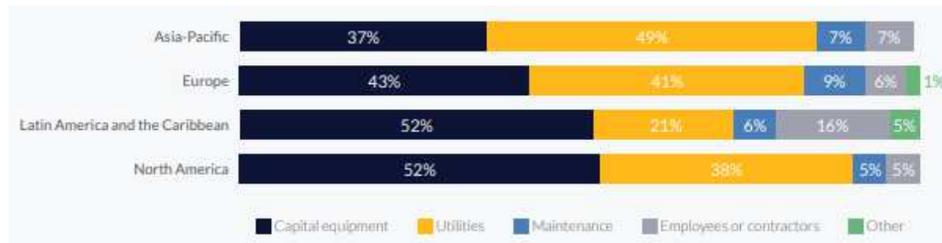
²⁴ [Hiveblockchain.com](https://hiveblockchain.com)

²⁵ [Bit-digital.com](https://bit-digital.com)



Exhibit 19: Over 50% of North and Latin American miners' cost goes to capital equipment, which underscores the high barriers to entry of the digital asset mining industry

Miners' cost breakdown by region



Source: 3rd Global Cryptoasset Benchmarking Study (2020), University of Cambridge
Data: March 2020 – May 2020

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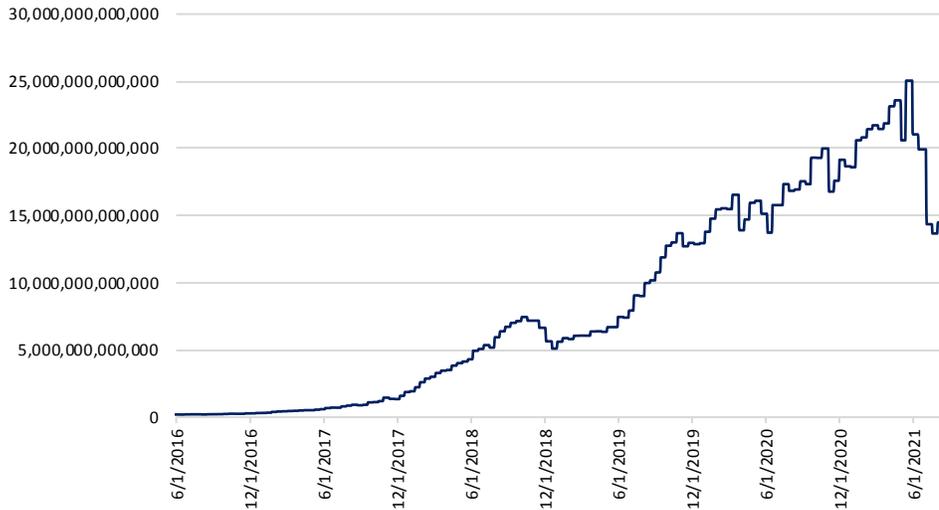
The digital asset mining industry has evolved continuously since the first bitcoin was mined in 2009. Increased competition for block rewards has driven innovation and the adoption of new hardware with greater processing power. Consequently, mining difficulty, which measures how challenging it is for a miner to find a hash below the target value, has increased over time to maintain an average time of 10 minutes for blocks to be added to the blockchain (Exhibit 20). For the first two years of bitcoin's existence, mining devices that used CPUs (central processing units) were sufficient to compete for block rewards and to confirm transactions. It may be hard to imagine that a simple desktop computer was once sufficient to compete for block rewards, but this was before bitcoin's price increased exponentially and digital asset mining became a large and lucrative industry.

Mining devices that used GPUs (graphics processing units), which can be programmed to compute mathematical functions more efficiently, were introduced in 2010 as mining competition increased. Shortly after, mining devices that used FPGAs (field programmable gate arrays) were introduced, which further improved efficiency. Around 2013, mining devices that used ASICs (application-specific integrated circuits) were introduced, which had 130nm chips and were designed specifically for mining, unlike more general-use CPUs, GPUs and FPGAs. It's estimated that recently introduced ASIC mining devices, which have 7nm chips, can compute mathematical functions at a rate 100bn times faster than the CPU used to mine the first block in 2009.²⁶

²⁶ CoinDesk Research

Exhibit 20: The ASICs revolution – rapid innovation has led to mining devices with higher computing power needs

Bitcoin mining difficulty overtime



Source: CryptoCompare, BofA Global Research

Bitcoin mining difficulty measures how difficult it is for a miner to find a hash below the target value and automatically readjusts about every 2 weeks based on the time it took to add a block to the blockchain over the last 2016 blocks. Calculating mining difficulty is beyond the scope of our report.

Data: 6/1/16 – 8/31/21

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Exhibit 21: Not your bedroom

Mining has transitioned to industrial-scale operations with high barriers to entry



Source: <https://www.investopedia.com/tech/are-large-mining-pools-bad-cryptocurrencies/>

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Q: Why don't supercomputers dominate the mining market?

A: Believe it or not, you would be better off mining bitcoin with the machine shown below to the left than with the supercomputer shown below to the right (Exhibit 23). ASIC mining devices are optimized to efficiently compute the SHA-256 hash function; that's the only thing that the mining ASIC can do. Supercomputers, which are a large number of CPUs running at one time, specialize in processing large amounts of data and are generally used for computationally-intensive exercises. Supercomputers are for general-purpose use and, therefore, inferior for digital asset mining relative to

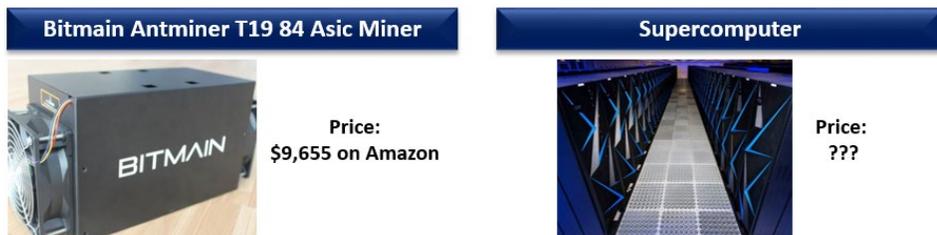


specialized-purpose ASIC devices. If you don't believe that something you can buy on Amazon could possibly be superior to a supercomputer in any way, you can ask the numerous people who have tried it, including the Harvard student who used his school's supercomputer to mine Dogecoin.²⁷

Even if a supercomputer were theoretically superior to an ASIC mining device, the Bitcoin protocol adjusts the difficulty of the computation problem that miners attempt to solve approximately every two weeks so that it takes an average of 10 minutes for a miner to confirm a block of transactions and add it to the blockchain. Also, the energy cost to run a supercomputer would likely be greater than any block reward received.

Exhibit 22: ASIC Miner vs Supercomputer

An ASIC miner is the more profitable (and cheaper) choice for mining



Source: CoinDesk, U.S. Department of Energy

Note that image shown above is not the Bitmain Antminer T19 84 model

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Q: What is proof of work (PoW) and proof of stake (PoS)?

A: PoW is the first consensus algorithm method in a blockchain network. It is a way to determine who is permitted to publish blocks to a blockchain. Each miner competes to find a number, which is used to solve the cryptographic puzzle and generate a required hash (best understood as a mathematical equation that has to be solved).

The proof is easy for any node in the network to verify, but extremely computationally intensive as it requires miners to guess a complex answer by brute force using computing power. After finding the number, the successful miner is permitted to announce a new block, while being rewarded with newly created bitcoins. In addition, the Bitcoin blockchain has a target rate of block production of one every 10 minutes.

An alternative consensus algorithm, PoS, has emerged more recently with the key advantage of reduced computational requirements that translate into significantly less energy use. PoS is a method that allows network participants to reach consensus according to their ownership stake in the network. In other words, the more coins participants hold, the more power they have in the network. For example, if a network participant staked 10 coins in a 100-coin network, the participant would have a 10% probability of receiving the transaction fee (reward). Most importantly, without a complex cryptographic puzzle to solve, the energy consumption of blockchains that use a PoS consensus mechanism is significantly lower than those using a PoW.

Q: What is staking?

A: Staking is a method of investing within the digital asset ecosystem that allows users to independently or collectively commit their digital assets to a blockchain network, earning passive income in return, as well as actively contributing to the sustainability of the network. Blockchains will likely replace PoW consensus mechanisms with PoS consensus mechanisms over time. Notably, the Ethereum network's upgrade to Ethereum 2.0 includes a transition from PoW to PoS.

²⁷ <https://www.thecrimson.com/article/2014/2/20/harvard-odyssey-dogecoin/>

Q: How does proof of work mining score from an ESG perspective?

A: It depends on your perspective regarding digital assets' monetary and social value. We'll use bitcoin as a reference, given that it's the largest digital asset that runs on a blockchain using a proof of work consensus algorithm. If Bitcoin were a country, it would be ranked 35th in the world for electricity consumption. Finland and Belgium consume less electricity annually than Bitcoin consumes via mining. That's a lot of energy and reason for concern if you believe that Bitcoin has no value. However, Bitcoin's electricity consumption is insignificant relative to large, industrialized countries like China and the US. Its electricity consumption annually is about 1.4% of China's and 2.4% of the US's. The Bitcoin network – a global network with over 100mn users – uses less than 0.1% of the world's energy consumption.

Bitcoin supporters counter that the energy consumption is worth the increased financial inclusion, democratization of finance and as a store of value as fiat currencies are devalued. Supporters also point out that 76% of digital asset miners used a form of renewable energy in 2020. Renewable energy accounted for 39% of energy consumed for PoW mining and is expected to increase as mining pools relocate from China to the United States.²⁸

Exhibit 23: Bitcoin's power consumption relative to countries and companies

Bitcoin's electricity consumption is larger than Finland's, but insignificant relative to consumption in China and the US

Name	Population (mn)	Annual Electricity Consumption (TWh)
China	1,446.2	6,543
United States	333.4	3,844
All of the world's data centers	-	205
State of New York	19.3	161
Bitcoin network	-	91
Finland	5.5	84
Belgium	11.6	82
Bangladesh	166.7	71
Google	-	12
Facebook	-	5
Walt Disney World Resort	-	1

Source: Cambridge Centre for Alternative Finance, Science Mag, New York ISO, Forbes, Facebook, Reedy Creek Improvement District, Worldometer
As of August 31, 2021

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Exhibit 24: Digital asset mining energy sources by region

Renewable energy accounted for 39% of energy consumed for PoW mining

Energy Source	Asia-Pacific	Europe	Latin America and the Caribbean	North America
Hydroelectric	65%	60%	67%	61%
Natural gas	38%	33%	17%	44%
Coal	65%	2%	0%	28%
Wind	23%	7%	0%	22%
Oil	12%	7%	33%	22%
Nuclear	12%	7%	0%	22%
Solar	12%	13%	17%	17%
Geothermal	8%	0%	0%	6%

Source: University of Cambridge
As of Sept 2020

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²⁸ University of Cambridge's 3rd Global Cryptoasset Benchmarking Study



Q: What's the difference between crypto coins and tokens? Are cryptocurrencies really currencies?

A: Cryptocurrency is a broad term that encompasses coins and tokens. Coins, like bitcoin and ether, have their own native blockchain, which securely stores ownership data and permits for coins to be transferred and used to reward miners who maintain the network by processing transactions and adding them to the blockchain. Tokens are built on an existing blockchain, but the main difference between a crypto coin and token is the potential for the latter to have additional functionality. Unlike coins, which are issued through their native blockchains and can mainly be used to transfer value, tokens are issued through ICOs (Initial Coin Offerings). Think of a stock's IPO, but instead of receiving ownership of a company, you receive a token that can be used to transfer value, the rights to a real-world or digital asset and the rights to access a platform or vote on governance proposals, among other functions. For example, there are asset tokens, governance tokens, non-fungible tokens, platform tokens, security tokens, transactional tokens and utility tokens to name a few.

We think the term "cryptocurrency" is misleading because there aren't any tokens that are actual currencies. At least not yet. We're not saying that cryptocurrencies will never become currencies, but there are currently none that encompass the properties of money, making the term a misnomer. We also think the term "crypto coin" is misleading because "coin" implies "money," but we use coin and token to differentiate between the two.

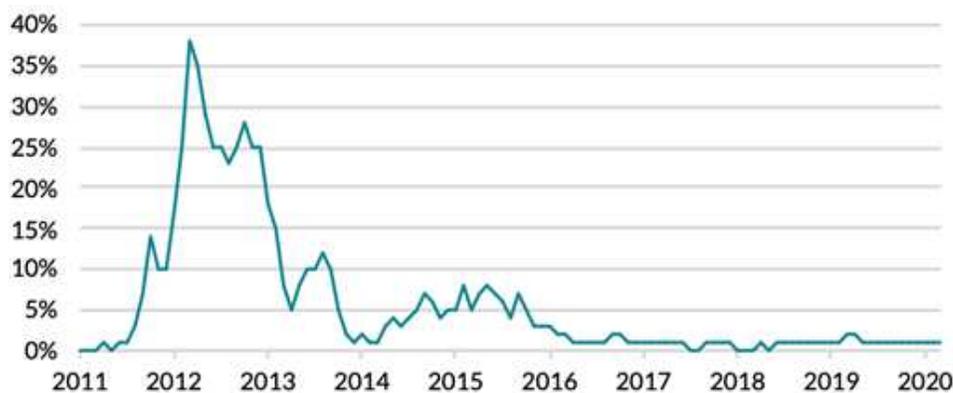
Q: Aren't digital assets just for illicit activities?

A: No. Illicit activity using digital assets likely represented less than 1% of digital asset transactions last year, down from 2.1% in 2019 (Exhibit 25). The transparency provided by the blockchain actually provides a more efficient way to track transactions and discover bad actors. For comparison, the United Nations Office on Drugs and Crime estimates that 2-5% of global GDP is connected to illicit activity. Illicit activity does happen though; major digital asset thefts, hacks and frauds reached \$681mn through July 2021 (Exhibit 26).

One potential reason for the percentage decline is the rise in exchange trading volume. Coinbase launched in 2012, around the time that illicit transactions began to fall, and had 6.1mn retail users in Q1'21 who made at least one trade.²⁹ Even if illicit activity remained constant, the increase in total transactions would skew the proportion of bitcoin transactions linked to criminality lower.

Exhibit 25: Bitcoin transactions linked to illegal activities fell to ~1% in 2020

Proportion of all bitcoin transactions linked to criminality



Source: Elliptic

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²⁹ Coinbase SEC filings



Exhibit 26: Digital asset fraud dips as DeFi hacks continue to grow

Digital asset transactions for illicit purposes continue to decrease



Source: CipherTrace Cryptocurrency Intelligence

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Q: What is Bitcoin? What happens after all 21mn bitcoin enter circulation?

A: Bitcoin was created by an unidentified programmer, known as Satoshi Nakamoto, who released his Bitcoin proposal to the internet in 2008. The first bitcoin transaction was in 2009. For many, digital assets are synonymous with bitcoin. At ~\$900bn of aggregate value and bitcoin bulls expecting a single coin to grow in value to \$500,000, or even \$1mn, within 10 years from the current ~\$47,000, it's certainly worth paying attention.³⁰

Bitcoin is the world's first completely decentralized, trustless and permissionless digital currency. What does this mean?

- **Decentralized:** There is no Central Bank or other intermediary with the ability to alter the supply or make discretionary decisions regarding the underlying blockchain protocol (the rules). The responsibility of maintaining and securing the network falls on the network's participants, but no one participant has more power than another. The network is global, so no government or other authority can control, alter or shut it down. The decentralization of the network is also what makes it a peer-to-peer network. When you transact with bitcoin, you are sending your bitcoin directly to another network participant without an intermediary. In contrast, when you make a payment by writing a check or using a credit card, you are involving banks and credit cards to process the transaction.
- **Trustless:** The nature of a decentralized blockchain network is that it's trustless; you don't need to trust, or even know, other network participants for the network to function properly. Our current monetary system requires us to trust banks, credit card companies and the Fed to maintain the system. We note that the need for trust is not completely eliminated from a blockchain network. Rather, it is spread across participants on the network, which incentivizes good behavior and, therefore, trust. What do you need to trust? In order for a monetary system to function, participants transferring value must actually own what's being transferred (the transaction is valid) and the transfer of value can't be revoked after it's sent (the transaction is irrevocable).
- **Permissionless:** Anyone can join the Bitcoin network. This might not seem like a big deal, but 1.7bn people in the world don't have a bank account and many more don't have a credit card. Some of these people have access to a bank account or credit card but don't want either. However, many don't have the funds to open bank account or the credit history to qualify for a credit card. In contrast, you can join the

³⁰ CoinMarketCap.com as of 8/31/21

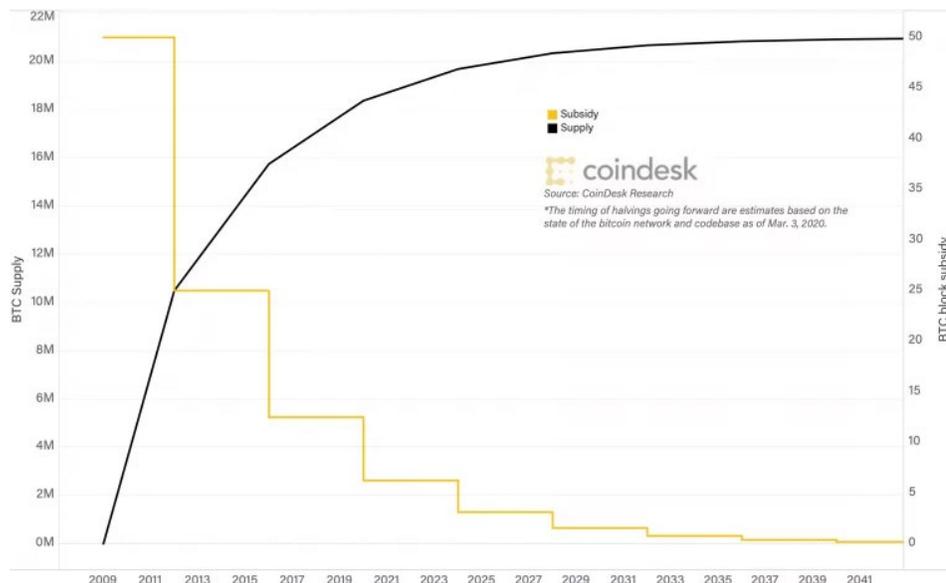
Bitcoin network to transact with other network participants, even if you have no money and/or you can join the Bitcoin network as a node or miner validate, process and confirm transactions and potentially earn rewards for maintaining and securing the network.

The Bitcoin protocol stipulates that the total supply of bitcoin will never exceed 21mn. To date, 90% of bitcoin have entered circulation. It's estimated that the final bitcoin will be issued in 2140 (Exhibit 27). In addition to being bought, sold and sometimes used as a medium of exchange, bitcoin are used to reward miners who expend computing power to confirm verified transactions and then immutably record them on the distributed public ledger. So how will miners be rewarded for their work when there are no more bitcoin left to be issued? Well, miners also receive transaction fees as an incentive from users who want the confirmation of their pending transaction to be prioritized and included in the next block added to the blockchain.

A block of transactions cannot exceed more than 1MB in size, which creates network congestion when there are many pending transactions. Miners prefer to fill their blocks with smaller transactions because they're easier to verify and take up less space in the block, but transaction fees incentivize them to include transactions with the largest fee to size ratio. Transaction fees are currently a small part of miners' total block reward, but as the supply of bitcoin left to be mined decreases, transaction fees will likely replace newly issued bitcoin as the miners' reward for maintaining the blockchain. However, there is debate around whether transaction fees will efficiently replace block rewards.³¹

Exhibit 27: Bitcoin supply and block subsidy by year

Block rewards (yellow line) approach zero as supply (black line) approaches its 21 mn cap



Source: CoinDesk Research

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Q: Is Bitcoin an inflation hedge like gold?

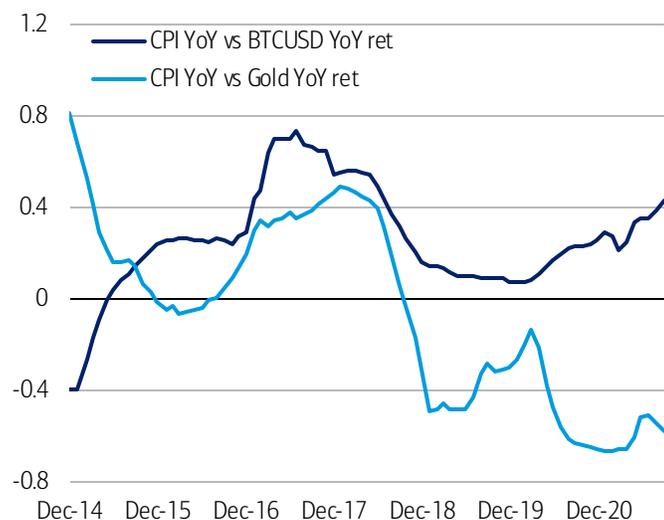
A: A common argument is that Bitcoin and Gold are hedges against inflation. We do see some evidence that Bitcoin is more correlated with CPI y/y than Gold the last 5.5 years, but more history is needed over longer interest rate cycles. When looking at core inflation (CPI y/y ex-Food and Energy), correlations do not exhibit a consistent pattern.

³¹ https://www.cs.princeton.edu/~arvindh/publications/mining_CCS.pdf



Exhibit 28: Some evidence Bitcoin correlates with CPI y/y over Gold, but more history and over longer cycles are needed

Rolling 36 month correlations

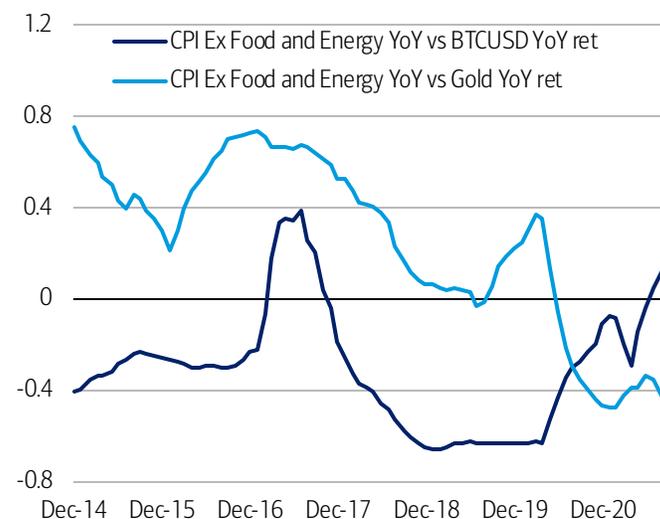


Source: CryptoCompare, Bloomberg, BofA Global Research

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Exhibit 29: Not clear once Food and Energy are stripped away

Rolling 36 month correlations



Source: CryptoCompare, Bloomberg, BofA Global Research

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Q: What is Ethereum? What is gas?

A: Ethereum is the 2nd largest blockchain network and its native digital asset is ether (ETH). Ethereum's blockchain is differentiated from Bitcoin by the capability of running computer programs called smart contracts. The transition to Ethereum 2.0, a proposed improvement on the Ethereum blockchain, began in December 2020 and is scheduled to be released in 2022. The transition to 2.0 will shift the protocol to proof of stake from proof of work, reducing environmental concerns, and improve scalability, significantly increasing transactions per second. Estimates indicate that transactions per second could increase from ~15 to ~100,000.³²

Gas refers to the fee required to execute a transaction or smart contract on the Ethereum blockchain and is a measure of the amount of computational effort needed to execute the operation. Gas fees are set by miners, paid in ether, denoted in gwei (equal to 0.000000001 ETH) and intended to compensate miners for the energy required to validate and process transactions.

Q: What is a stablecoin?

A: Stablecoins are digital assets pegged to another asset such as a fiat currency (like the US dollar), a commodity (like gold), other digital assets or a combination of assets with the goal of maintaining a stable value. Digital asset holders and traders use stablecoins to reduce exposure to more volatile digital assets, lock in gains from trading, transfer funds between exchanges or between exchanges and wallets and as a safe haven if expecting a downturn or during a pullback. For example, as bitcoin fell ~11% on September 7th and ~6% on April 18th, many stablecoins traded at premiums to their \$1 pegs as bitcoin holders rotated out of bitcoin and into stablecoins.³³

Constantly converting digital assets to fiat currencies or transferring fiat currencies to exchanges via ACH or wire transfers is expensive and slow, but transferring funds between wallets and digital asset exchanges via stablecoins is inexpensive and fast. Some exchanges don't have bank relationships needed to offer fiat currency deposits or withdrawals, but can and do accept stablecoins, such as tether, the largest stablecoin by market value (Exhibit 30). Stablecoins can be used to make purchases and money

³² Standard Chartered's Ethereum investor guide³³ CoinMarketCap.com

transfers, such as remittances, faster and less expensive by using blockchain technology, instead of the traditional payments infrastructure.

Stablecoins may also help push adoption of digital assets as a medium of exchange, given digital asset holders likely would prefer not to use a volatile digital asset to buy a coffee if they expect the \$5 of digital assets spent today could potentially be worth \$10 next week.

Exhibit 30: Top stablecoins by market value

Tether is the largest stablecoin by market value

Coin	Ticker	Symbol	Price Range	Market Value (\$bn)
Tether	USDT		\$1.00	\$65.53
USD Coin	USDC		\$0.9998 - \$1.00	\$27.41
Binance USD	BUSD		\$0.9998 - \$1.00	\$12.25
Dai	DAI		\$1.00	\$6.14
TerraUSD	UST		\$0.9975 - \$1.00	\$2.40
TrueUSD	TUSD		\$0.9998 - \$1.00	\$1.40

Source: CoinMarketCap.com

Chart includes coins with +\$1bn market value. Price Range includes the low and high price on 8/31/21. Market value as of August 31, 2021.

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Q: What is the stablecoin market size and potential?

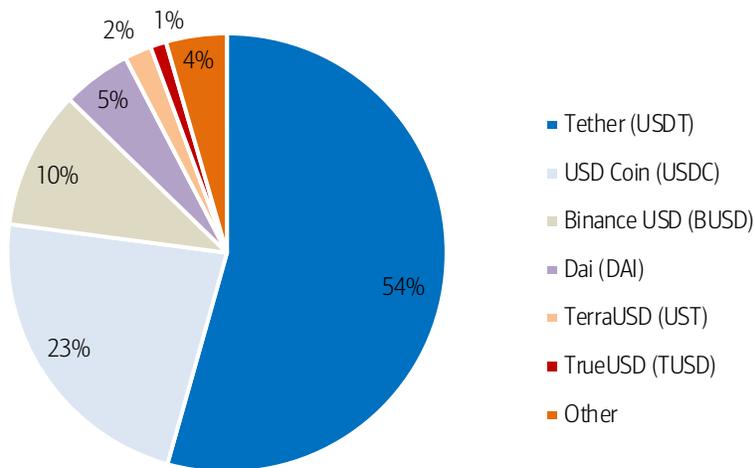
A: The current market value for all stablecoins – there are over 200 – is ~\$120bn with projections reaching as high as \$1tn by 2025, driven largely by the growth in DeFi apps (DApps)³⁴. The three largest coins – tether (\$66bn), USD coin (\$27bn) and binance coin (\$12bn) – comprise 87% of the total stablecoin market value (Exhibit 31). You may be wondering how stablecoin companies will get their hands on over 5% of the M1 money stock for collateral if the stablecoin market value were to reach \$1tn and the implications of that much cash being taken out of the economy. But remember, not all stablecoins require 1:1 reserves and some aren't pegged to fiat currencies at all.

There are likely more stablecoins to come, especially ones that run on private (permissioned) blockchain networks. Facebook led a consortium that made waves with plans for a stablecoin that was first to be called Libra, then Diem, but the idea has lost momentum in the face of regulatory opposition. J.P. Morgan built a payments network leveraging blockchain technology to facilitate instantaneous and cross-border transfers between institutional clients and introduced a stablecoin called JPM Coin, redeemable for US dollars on a 1:1 basis. JPM Coin is a private coin only available to institutional clients and not available to the public, unlike the stablecoins in the table above.

³⁴ Matthew Gould via Business Insider

Exhibit 31: The stablecoin market is highly concentrated

The top three stablecoins by market value have 87% market share



Source: CoinMarketCap.com

Coins shown have market values +\$1bn. Data as of 8/31/2021

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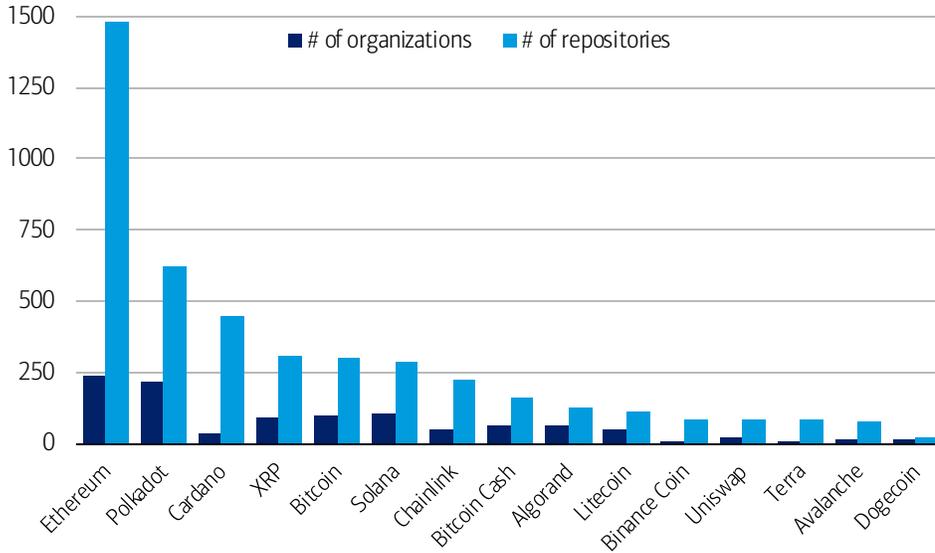
Q: How can you determine if a crypto coin or token is overvalued or undervalued?

A: The short answer is that you can't. Tokens can be priced, but they can't be valued because there's no intrinsic value. However, there are ways to evaluate a token's demand, which would likely affect its price. We look at a token's functionality, adoption and development (Exhibit 32 & Exhibit 33). In general, a token needs at least 2 of the 3 for demand to build (and potentially create market value). For example, a token that has a great use case (functionality), but low adoption and a limited number of developers working on it, probably won't be the next big thing. A token that has increasing adoption, but no clear use case and only a handful of developers working on it, is probably trading on hype. A token that has a large number of developers working on it, but no clear use case and low adoption seems unlikely because no developer would want to work on a project that has limited use or to receive the coin as compensation.



Exhibit 32: There are more projects on Ethereum than on Polkadot, Cardano and XRP combined

Blockchain repositories/projects on the top 15 cryptos by market value

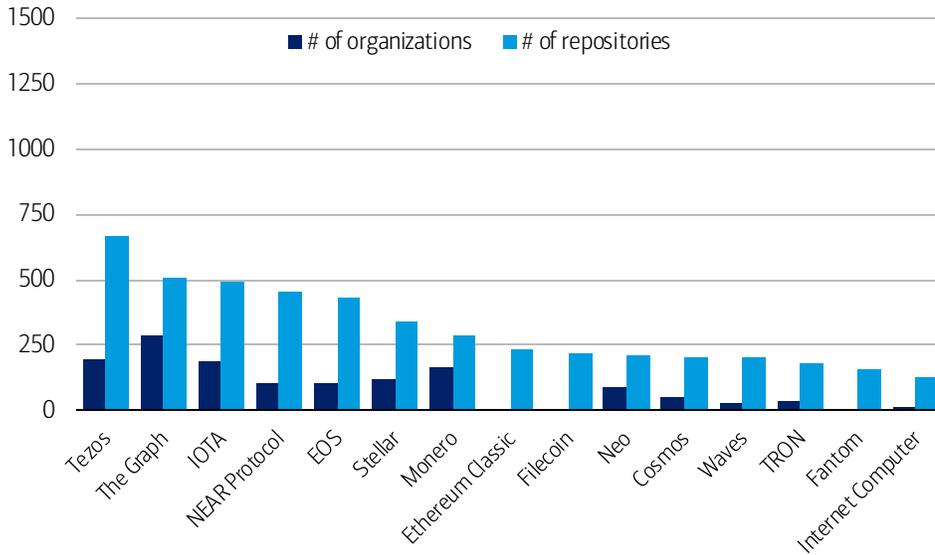


Source: Electric Capital
Data as of 9/13/21. Excludes stablecoins.

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Exhibit 33: Tokens outside of the top 15 by market value have received significant developer interest

Blockchain repositories/projects on tokens outside of the top 15 by market value



Source: Electric Capital
Data as of 9/13/21. Excludes stablecoins.

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Q: What are NFTs?

A: An NFT is a non-fungible token – that means it’s unique. For example, bitcoins are fungible – one coin is the same as any other – while a one-of-a-kind trading card is unique. The technical definition of an NFT is a blockchain-stored certificate of authenticity for *unique* digital or physical assets. The transaction and ownership information are verified through decentralization, recorded within the blockchain and seen as tamper-proof (immutable).



Specifically, the digital artwork file itself is not the NFT and is not stored via the blockchain. Only the proof of ownership information is stored. Currently, since the most widely used application of NFT is ownership of digital files, such as digital art work, the word NFT is used in conjunction with digital artworks. Although most NFT applications are associated with digital artwork so far, they can be used to authenticate physical assets as well. For example, at the end of 2019, Nike explored authenticating physical, collectible shoes with digital NFTs.

The majority of NFTs are built within the Ethereum blockchain network, which is likely at least partly responsible for ether's recent price appreciation (Exhibit 34). This is not a necessary requirement. There are multiple lesser-known digital asset standards, such as EOS and NEO, that also support NFT transactions, but Ethereum currently dominates the NFT market. Note that the Bitcoin blockchain does not support NFTs.

Exhibit 34: Top 20 NFT projects have seen \$7.2bn in total trading volume

Ethereum is the most widely used blockchain network for NFTs

Project	Network	Total Trading Volume All-Time (\$mn)
Axie Infinity	ETH	1920
CryptoPunks	ETH	1250
NBA Top Shot	FLOW	678
Art Blocks	ETH	659
Bored Ape Yacht Club	ETH	453
Inertial Moment	ETH	400
Mutant Ape Yacht Club	ETH	230
Loot	ETH	225
Meebits	ETH	209
Rarible	ETH	150
PUNKS Comic	ETH	139
ON1 Force	ETH	129
VeeFriends	ETH	115
Parallel Alpha	ETH	113
Pudgy Penguins	ETH	110
Zed Run	ETH/Polygon	90
Bored Ape Kennel Club	ETH	82
Cool Cats	ETH	80
Curio Cards	ETH	80
Foundation	ETH	76

Source: DappRadar

NFT collections are ranked by USD trading volume since project inception as of 9/8/21

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Digital assets: are they money?

What's money and what's the problem with it?

Let's talk about money. Money is generally defined as a medium of exchange, a store of value and a unit of account. The dollar is an excellent medium of exchange (generally accepted globally) and unit of account. As a store of value, it's mixed with \$1 in 2020 equal to the purchasing power of \$26.14 in 1913.³⁵ Hence the use of gold and other commodities when inflation concerns rise.

Also, this definition of money is only today's. Historically, money started as barter, transitioned to commodities with value, then to representative money and finally to today's fiat currency, which only has value because a government says it does. Digital assets have "no intrinsic value", but neither does fiat currency, such as the dollar – a decent reason for Central Bank reluctance and skepticism.

Cash (a physical token) is great because it's private and simple. You and the person you pay/give are the only ones that know the transaction took place. The transaction can't be undone without returning the cash and you can't spend the same cash twice.

Cash is actually a permissionless, decentralized peer-to-peer technology. If someone gives you a \$5 bill, you've completed a settled transaction without any intermediaries. But for online transactions, it was always necessary to use an intermediary until digital assets, such as bitcoin, enabled the transfer of ownership of a coin (or a fraction of a coin) with multiple ledgers updated for each transaction to provide confirmation.

The problem with cash is you can't use it online – enter today's digital money (pre-digital assets). Digital money requires a 3rd party to keep track of account balances. You and your counterparty have to open accounts with a 3rd party like PayPal or a bank and you can transfer money with the 3rd party, which changes your and your counterparty's account balances. Digital money is transferred by increasing and decreasing balances in accounts held by a trusted intermediary.

Exhibit 35: Money: from barter to banknotes and now digital

A brief history of money from barter to bitcoin



Source: BofA Global Research

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Are digital assets money? That's the wrong question

Cryptocurrencies are the first digital assets created for the internet. They are the first digital assets of value that can be transferred over the internet without a 3rd party.

Cryptocurrencies are tools that implement functionality by charging for blockchain usage and/or rewarding participants who contribute to the protocol and keep it running. Using a cryptocurrency as money for payments is only a specific application.

Enter bitcoin – no longer need an intermediary

Bitcoin is the most popular digital asset with an aggregate market value of ~\$900bn.³⁶ It is the world's first completely decentralized, open-source and peer-to-peer digital currency. It scores well as a store of value (especially as a speculative investment), average as a medium of exchange and poorly as a unit of account (limited merchant acceptance and high volatility).

³⁵ Bureau of Labor Statistics, Morris County Library of Historic Prices

³⁶ CoinMarketCap.com as of 8/31/21

Before bitcoin, an online transaction always required a 3rd party trusted intermediary like PayPal or Visa. 3rd party intermediaries keep a ledger of account holder balances. When Alkesh sends Andrew \$100 over the internet, PayPal deducts the amount from Alkesh's account and adds it to Andrew's account. Without a trusted intermediary like PayPal keeping the ledger updated, digital money could be spent twice since no one would be keeping track (double-spending). Bitcoin is revolutionary because it solves the "double spending" problem, but without the need for a 3rd party intermediary.

Institutional adoption – trading volumes are accelerating

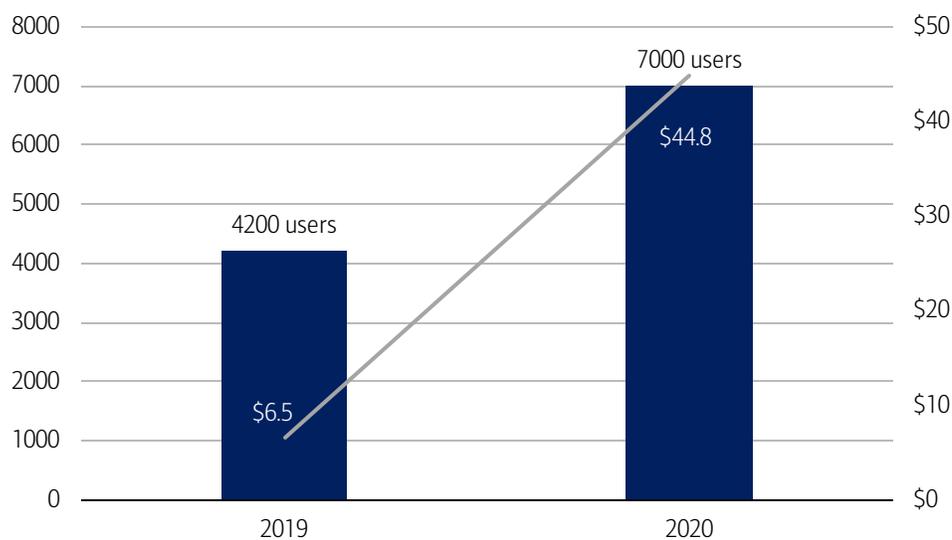
It's still early innings for institutional digital asset adoption, but data provided by Coinbase suggests that institutional adoption and trading volumes are accelerating in absolute terms and relative to retail adoption. Coinbase had approximately 4% market share of crypto trading volume on exchanges ytd through July 28th, but we view institutional trends on the platform as representative of the broader industry, given that sophisticated institutional investors frequently spread large trades across multiple exchanges in an attempt to access liquidity and reduce slippage costs.

- Institutional users on Coinbase increased by 67% from the end of 2019 to the end of 2020 as retail users increased by 34% over the same period.³⁷
- Institutional platform assets increased by 589% from the end of 2019 to the end of 2020 as retail platform assets decreased by 46% over the same period (Exhibit 36).
- Institutional users represented less than 1% of all Coinbase users at the end of 2020, but held 50% of platform assets and contributed to 64% of platform trading volume (Exhibit 37).

The fact that institutional users represent less than 1% of Coinbase users, but hold half of platform assets and contribute to more than half of platform trading volume, exemplifies the potential increase in future digital asset demand. There are currently 7,000 global institutional users on Coinbase consisting of Hedge Funds, Financial Institutions and Corporations.³⁸

Exhibit 36: Coinbase: Institutional users (LHS) and platform assets (RHS, \$bn)

Institutional users and platform assets on Coinbase increased by 67% and 589% in 2020, respectively



Source: Coinbase Form S-1

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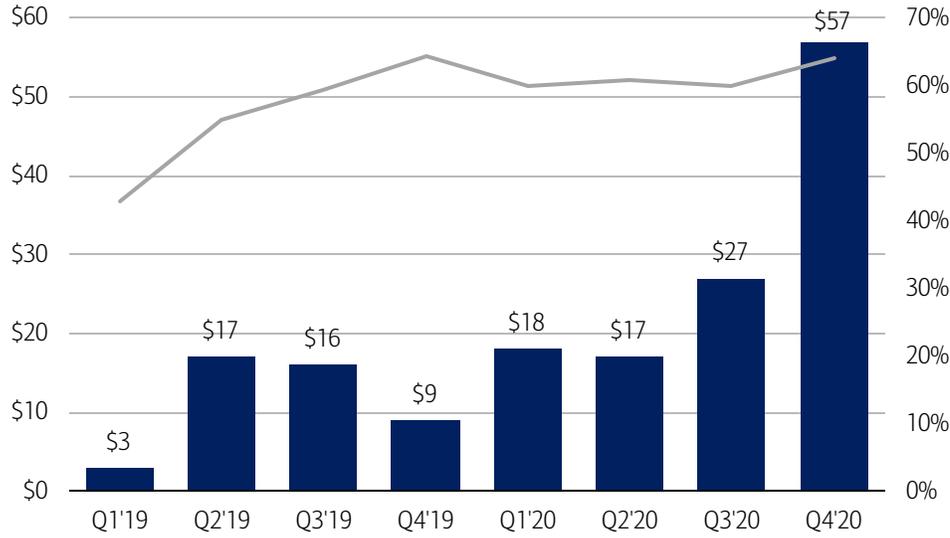
³⁷ Coinbase SEC filings

³⁸ Coinbase SEC filings



Exhibit 37: Coinbase: Institutional transaction volume (LHS, \$bn) vs share of total platform transaction volume (RHS, %)

Institutional users held 50% of platform assets and contributed to 64% of platform trading volume at the end of 2020, but represented less than 1% of all Coinbase users



Source: Coinbase Form S-1

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We also note that large trades, which we define as trades of \$1mn or more, have significantly increased, indicating growth in institutional digital asset adoption (Exhibit 38).

Exhibit 38: Crypto trading volume by size of trade (\$bn)

Large trades of \$1mn or more have increased significantly



Source: Chainalysis

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Why should you care about digital assets?

Digital assets as the next big disruptor

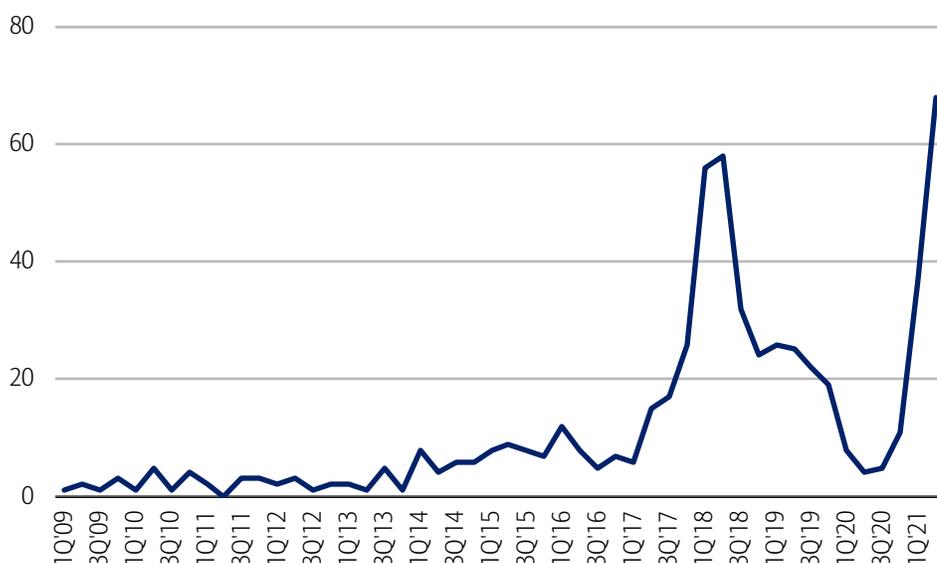
The digital asset ecosystem has the potential to disrupt both established and emerging industries. Our view is that you can't afford not to care. The tech bubble of the late 90s resulted in many businesses appearing and disappearing, but it also led to enormous returns for diligent investors who were able to distinguish hype from reality. In the same way, we believe that the digital asset ecosystem may produce significant value creation.

Companies really do care

Even if you don't care about the digital asset ecosystem, corporations certainly do. Along with our BofA Predictive Analytics team, we used NLP to analyze 161,322 earnings call transcripts from 1Q'09 through August 2, 2021 (Exhibit 39). Our analysis shows a renewed and significant increase in interest in the space since the beginning of the year with Tech and Financials companies leading the pack (Exhibit 40).

Exhibit 39: Number of US companies that mentioned a digital asset keyword* on an earnings rose to 147 from 17 a year ago

NLP analysis of earnings call transcripts; avg 3,174 transcripts reviewed per quarter



Source: FactSet, BofA Global Research

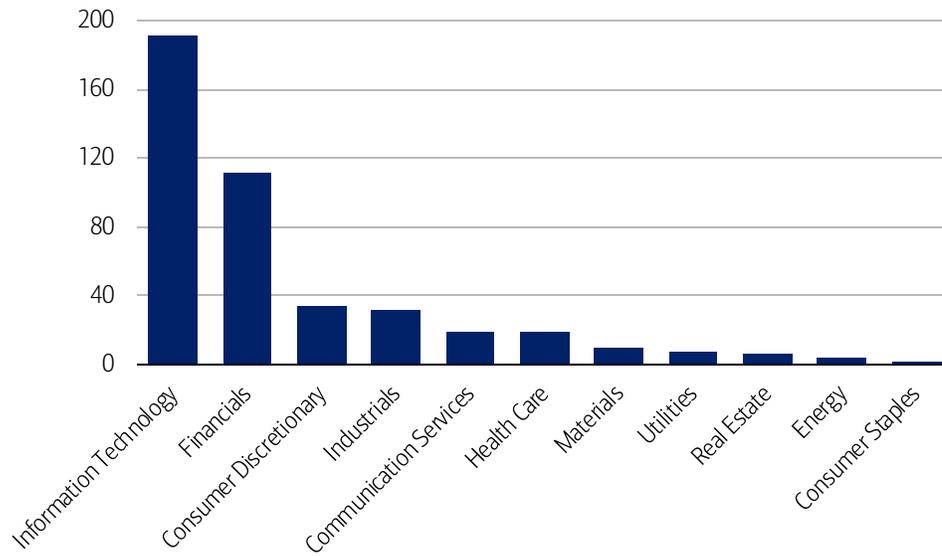
*Keywords include: altcoin, bitcoin, blockchain, crypto, cryptocurrency, decentralized finance, defi, ether, ethereum, NFT, non-fungible-token
Year-over-year calculation period: 1Q'20 – 3Q'20 and 1Q'21 – 3Q'21 through 8/1/21. Note 3Q'21 not shown on chart.

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Exhibit 40: Sector breakdown by sector of US companies that mentioned a digital asset keyword* on an earnings call skewed to Tech and Financials

NLP analysis of earnings call transcripts since 1Q'18; avg 3,208 transcripts reviewed per quarter



Source: FactSet, BofA Global Research

*Keywords include: altcoin, bitcoin, blockchain, crypto, cryptocurrency, decentralized finance, defi, ether, ethereum, NFT, non-fungible-token
Data: 1Q'18 – 8/2/20. Note that the number of transcripts analyzed vary by sector.

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Why should institutional investors care?

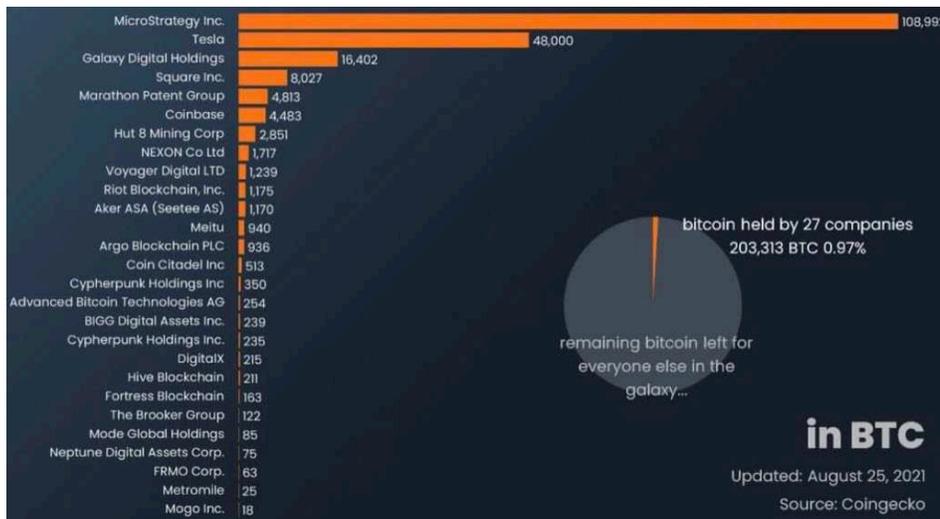
Our view is that the digital asset ecosystem is too big for institutional investors to ignore. This is not a fad.

We understand that investing in digital assets can be daunting, given the need for new types of analysis and new exchanges. We provide an overview of the top 20 tokens by market value later in the report to help you familiarize yourself with these new assets.

Why should corporate managements care?

The digital asset ecosystem has the potential to disrupt mature industries – that includes traditional financial intermediaries and how you manage your balance sheet. At the end of August, 27 public companies held 203,313 bitcoin worth ~\$10bn on their balance sheets, with MicroStrategy accounting for about half of all public-company holdings. Non-digital asset-related firms are already allocating treasury reserves to digital assets, while others are investing to obtain indirect exposure to it.

Exhibit 41: MicroStrategy's bitcoin holdings account for half of all holdings by public companies Public companies with bitcoin exposure



Source: Screenshot from CoinGecko.com

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MicroStrategy (MSTR), an enterprise analytics software and services company with a market cap of ~\$7.1bn, amended its capital allocation strategy/treasury reserve policy in July'20 and adopted bitcoin as its primary treasury reserve asset. At the end of August, Microstrategy held 108,992 bitcoin worth ~\$5.3bn at the time. Moreover, Morgan Stanley purchased a 10.9% stake in MicroStrategy in Dec'20, illustrating the acceptance of digital assets place in the world of traditional finance. MicroStrategy's CEO, Michael J. Saylor, explains the rationale of holding bitcoin on the balance sheet below:

"Our investment in Bitcoin is part of our new capital allocation strategy, which seeks to maximize long-term value for our shareholders. This investment reflects our belief that Bitcoin, as the world's most widely-adopted cryptocurrency, is a dependable store of value and an attractive investment asset with more long-term appreciation potential than holding cash. Since its inception over a decade ago, Bitcoin has emerged as a significant addition to the global financial system, with characteristics that are useful to both individuals and institutions. MicroStrategy has recognized Bitcoin as a legitimate investment asset that can be superior to cash and accordingly has made Bitcoin the principal holding in its treasury reserve strategy. MicroStrategy spent months deliberating to determine our capital allocation strategy. Our decision to invest in Bitcoin at this time was driven in part by a confluence of macro factors affecting the economic and business landscape that we believe is creating long-term risks for our corporate treasury program — risks that should be addressed proactively. Those macro factors include, among other things, the economic and public health crisis precipitated by COVID-19, unprecedented government financial stimulus measures including quantitative easing adopted around the world, and global political and economic uncertainty. We believe that, together, these and other factors may well have a significant depreciating effect on the long-term real value of fiat currencies and many other conventional asset types, including many of the assets traditionally held as part of corporate treasury operations."

Tesla (TSLA), with a market cap of ~\$713.2bn, has flip-flopped on allowing EV purchases with bitcoin, but held 48,000 bitcoin worth ~\$2.4bn. Square (SQ), with a market cap of ~\$123.2bn held 8,027 bitcoin on its balance sheet worth ~\$393mn. We expect companies to continue adopting bitcoin as a treasury reserve asset to provide a store of value, diversification and appreciation.



Not ready to allocate significant portion of treasury reserves to digital assets?

Here's another idea

Today, cash kept in a savings account yields 0.06% on average with higher yields for cash equivalents. If a large institution had \$30bn in cash and cash equivalents on its balance sheet at the end of 2020 and these assets yield 0.5% on average, the large institution would generate about \$150mn over the year. With yield farming, you can stake coins in exchange for significantly higher yields (~2%) on Curve Finance's Automated Market Making (AMM) platform. The large institution could convert some of the low-yielding cash sitting in a savings account to stablecoins like USDT, USDC or DAI, which are pegged to USD, and become a Liquidity Provider (LP) by supplying coins to a liquidity pool.

If a large institution took 10% of its cash and cash equivalents and received a 2% yield instead of a 0.5% yield, it would generate an incremental \$45mn over the year, increasing total yield by 30%.

Digital asset adoption in high inflation nations

Digital assets more stable than some fiat currencies

We provide a conservative estimate of potential digital asset adopters by looking at countries with the highest inflation rates relative to the population with smartphones and bank accounts (Exhibit 42). All that is needed to buy digital assets is a smartphone. Populations in countries with high inflation could begin to transfer volatile fiat currencies into more stable digital assets. We note that the population with bank accounts data is from 2017 and the chart below includes only the 10 countries with the highest inflation rates, excluding those with populations under 1mn. Assuming the unbanked population has decreased over the last 3+ years, and noting that our analysis includes only 10 countries, we believe the number of potential digital asset adopters is likely significantly higher than the 94mn shown below, making the number of potential digital asset adopters a conservative estimate.

Exhibit 42: Potential digital asset adopters from EM/Developing Economies

94.4mn – a conservative estimate of potential digital asset adopters

Country	Inflation Rate (% , 2020)	Population (mn, 2020)	Smartphone Users (mn, 2020)	Population Banked (% , 2017)	Potential Digital Asset Adopters (mn)
Venezuela	2,355.10	28	16.6*	73	12.2
Zimbabwe	557.2	15.2	5.4	55	3
Sudan	163.3	44.3	13.9	15**	2.1
Lebanon	88.2	6.8	4.4	45	2
Argentina	42	45.4	34.8	49	17
South Sudan	38	13.8	NA	9	NA
Iran	36.5	84.1	58.2	94	54.7
Yemen	26.2	32.5	NA	6**	NA
Haiti	22.9	11.4	2.5	33	0.8
Angola	22.3	31	9.3	29**	2.7
					94.4

Source: IMF, Statista, World Bank

*2019 estimates

**2014 estimates

Note: Excludes countries with population under 1mn

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What you need to know about Bitcoin

What is a Bitcoin?

In 2008, a paper was published by an unidentified programmer known as Satoshi Nakamoto proposing the creation of a cash-like electronic payment system that would remove the middlemen in the financial system, such as governments, banks and credit-card networks. Bitcoin is the world's first completely decentralized, open-source and peer-to-peer digital currency, meaning there is no Central Bank with the ability to alter the supply and that holders can transact without a third party intermediary.

We view bitcoin as a long-term store of value, although it can't be valued. However, although bitcoin cannot be intrinsically valued, it can be priced and traded.

Exhibit 43: Bitcoin pricing vs valuing

Bitcoin cannot be intrinsically valued

	Price	Value
<i>Underlying philosophy</i>	The price is the only real number that you can act on. No one knows what the value of an asset is and estimating it is of little use.	Every asset has a fair or true value. You can estimate that value, albeit with error, and price has to converge on value (eventually).
<i>The process</i>	You try to guess which direction the price will move in the next period(s) and trade ahead of the movement. You have to be right more often than wrong about direction and to exit before the winds shift.	You try to estimate the value of an asset, and if it is under(over) value, you buy (sell) the asset. You have to be right about value (for the most part) and the market price has to move to that value.
<i>Key drivers</i>	Price is determined by demand & supply, which in turn are affected by mood and momentum.	Value is determined by cash flows, growth and risk.
<i>Information effect</i>	Incremental information (news, stories, speculation) that shifts the mood will move the price, even if it has no real consequences for long term value.	Only information that alter cash flows, growth and risk in a material way can affect value.
<i>Tools of the game</i>	(1) Technical indicators (2) Price Charts (3) Investor Psychology	(1) Ratio analysis (2) DCF Valuation (3) Accounting Research
<i>Time horizon</i>	Can be very short term (minutes) to mildly short term (weeks, months).	Long term
<i>Key skill</i>	Be able to gauge market mood/momentum shifts earlier than the rest of the market.	Be able to "value" assets, given uncertainty.
<i>Key personality traits</i>	(1) Market amnesia (2) Quick Acting (3) Gambling Instincts	(1) Faith in "value" (2) Faith in markets (3) Patience (4) Immunity from peer pressure
<i>Biggest Danger(s)</i>	Momentum shifts can occur quickly, wiping out months of profits in a few hours.	The price may not converge on value, even if your value is "right".
<i>Added bonus</i>	Capacity to move prices (with lots of money and lots of followers).	Can provide the catalyst that can move price to value.
<i>Delusional Participant</i>	A trader who thinks he is trading based on value.	A value investor who thinks he can reason with markets.

Source: <http://aswathdamodaran.blogspot.com/2017/10/the-bitcoin-boom-asset-currency.html>

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Bitcoin in your portfolio

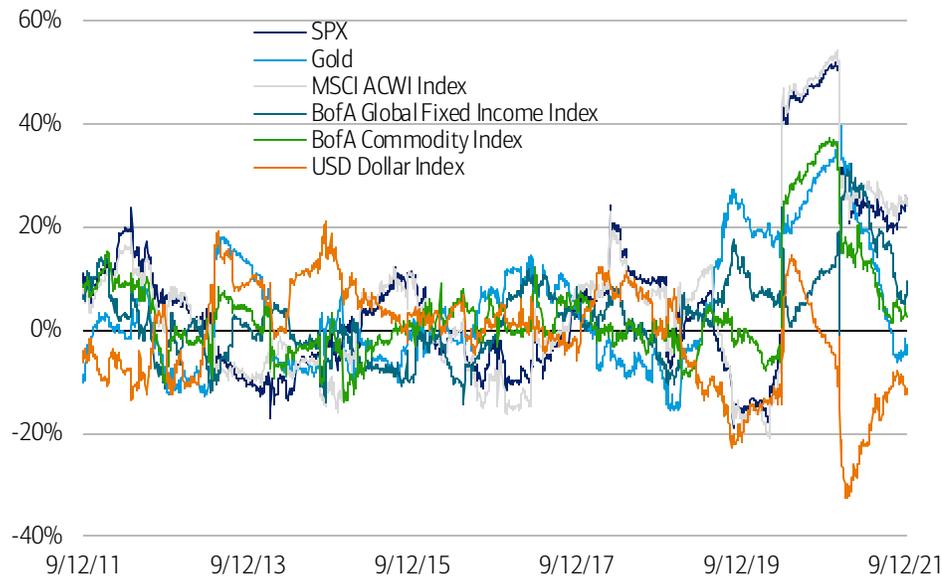
Bitcoin's aggregate market value has increased by 304% to ~\$887bn over the last 12 months ending August 31st, 2021.³⁹ It is gradually establishing itself as a store of value due to low correlations with other assets (Exhibit 44). Hedge funds, endowments and corporates have increased allocations, providing a tailwind and likely leading to diminished volatility as adoption increases.

³⁹ CoinMarketCap.com



Exhibit 44: Correlations between bitcoin and other assets spiked during Covid, but have decreased significantly since then with the exception of equities

Rolling 180 day correlations



Source: CryptoCompare, Bloomberg, BofA Global Research

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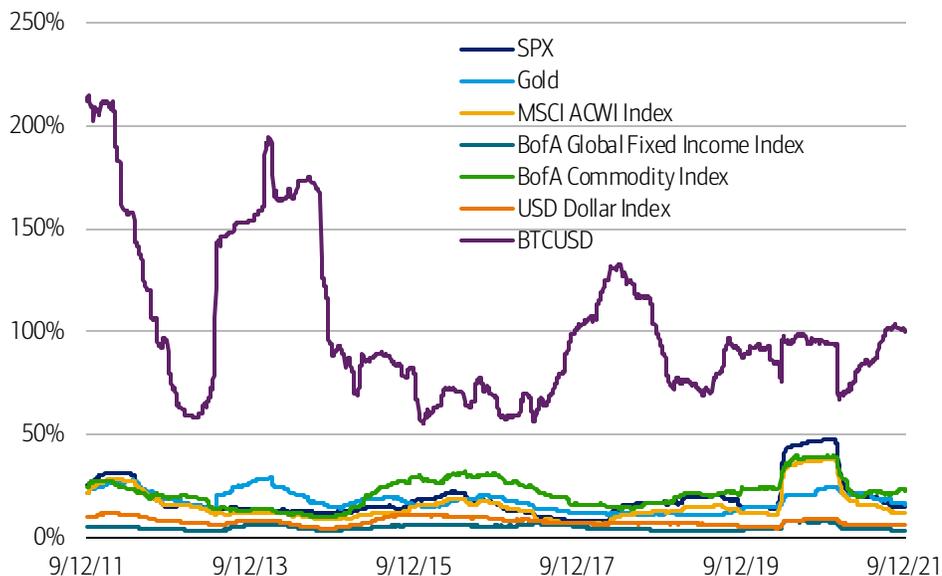
Is bitcoin digital gold?

Is bitcoin a store of value and on par with gold? This is an important question for investors considering an allocation to digital assets. We find that although bitcoin's historical volatility is higher than traditional asset classes (Exhibit 45), it has shown signs of stabilizing. How else do we measure if bitcoin is a store of value or if it's becoming one? We look at correlations between bitcoin prices and traditional measures of inflation, as well as the number of digital asset investors who are HODLers, which is digital asset slang for long-term holders or those who "Hold On for Dear Life." More than 50% of bitcoin in circulation haven't been used in a transaction in the last 12 months as of the end of July, indicating that holders – or HODLers in this case – are increasingly viewing bitcoin as a long-term investment, which would likely lead to decreasing volatility.⁴⁰

⁴⁰ Bitcoin.org

Exhibit 45: Bitcoin’s volatility has decreased and stabilized over time

Rolling 180 day volatility



Source: CryptoCompare, Bloomberg, BofA Global Research

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We think bitcoin is more similar to gold in that it can be viewed as a potential store of value, especially when markets lose faith in fiat currencies. Bitcoin and gold share many similar properties: limited supply, price driven by supply and demand and must be extracted/mined. Bitcoin and gold are also both viewed as stores of value, which allows us to use a Total Addressable Market (TAM) approach to model the price of one bitcoin assuming various market capture scenarios (Exhibit 46 & Exhibit 47). Note that this analysis does not assume bitcoin replaces gold as a store of value, but rather creates a store of value market in addition to the gold market. Whether there is demand for a store of value market in addition to the gold market remains to be seen, but readers should remember that gold is not the only store of value. Art, offshore assets, real estate and other commodities exemplify additional store of value markets.

Exhibit 46: Scenario Analysis: Bitcoin price by total addressable market (TAM)

Assumes supply of bitcoin at 21mn

% Gold Market Captured	Price
1%	\$5,823
2%	\$11,646
5%	\$29,115
10%	\$58,230
20%	\$116,459
25%	\$145,574
50%	\$291,149
100%	\$582,297

Source: BofA Global Research, World Gold Council, CryptoCompare, Bloomberg

Assumes the market value of gold above ground is \$12.2tn. Gold prices and above-ground stock as of 12/31/20.

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Exhibit 47: Scenario Analysis: Bitcoin price by total addressable market (TAM)

Assumes supply of bitcoin at 18,802,887

% Gold Market Captured	Price
1%	\$6,503
2%	\$13,007
5%	\$32,517
10%	\$65,034
20%	\$130,068
25%	\$162,585
50%	\$325,169
100%	\$650,338

Source: BofA Global Research, World Gold Council, CryptoCompare, Bloomberg

Assumes the market value of gold above ground is \$12.2tn. Gold prices and above-ground stock as of 12/31/20. Bitcoin supply was 18,802,887 as of 8/31/21.

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Supply & demand: drivers of price

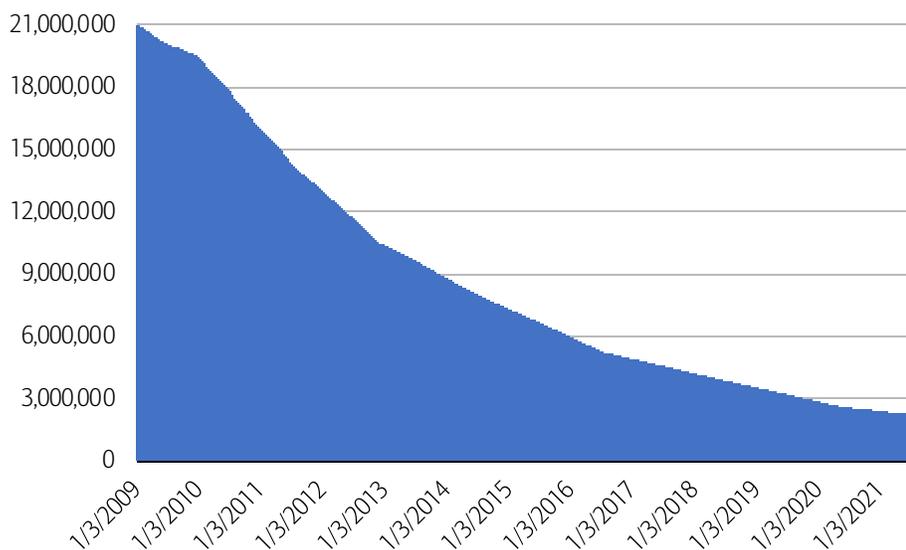
Bitcoin prices may appreciate due to scarcity, illiquidity and growing demand.

Supply is capped

The Bitcoin protocol limits the supply of bitcoin available to be mined at 21mn and puts forth an adjusting, but rules-based issuance schedule. The fixed supply of bitcoin – estimates put 2140 as the year when the last bitcoin will be mined – contributes to upward pressure on prices. As of August 31st, 18.8mn bitcoin of the available 21mn have been mined, meaning that 90% of the total bitcoin supply is “above ground” and only 10% is left to enter the total supply (Exhibit 48). However, there’s a difference between the number of bitcoin mined and the circulating supply. A significant number of bitcoin have been mined, but are essentially removed from circulation because the owner lost the private key. Approximately 20% of all bitcoin mined are permanently lost, according to estimates.⁴¹ Although unfortunate for those who forgot their private keys, bitcoin lost either in the past or in the future reduces the supply and, therefore, increases the price.

Exhibit 48: Bitcoin remaining supply as it approaches its 21 mn cap

The final bitcoin is estimated to be mined in 2140



Source: CryptoCompare
Data as of 8/31/21

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Demand is a major driver of bitcoin prices

Capped supply, coupled with accelerating adoption, will likely put upward pressure on bitcoin prices over the medium and long term. The main drivers of adoption are institutional investment; decreasing barriers to entry, mainly for retail investors; and growing acceptance of bitcoin as a store of value and inflation hedge in Developed Economies and Developing Economies, respectively.

⁴¹ <https://www.nytimes.com/2021/01/13/business/tens-of-billions-worth-of-bitcoin-have-been-locked-by-people-who-forgot-their-key.html>

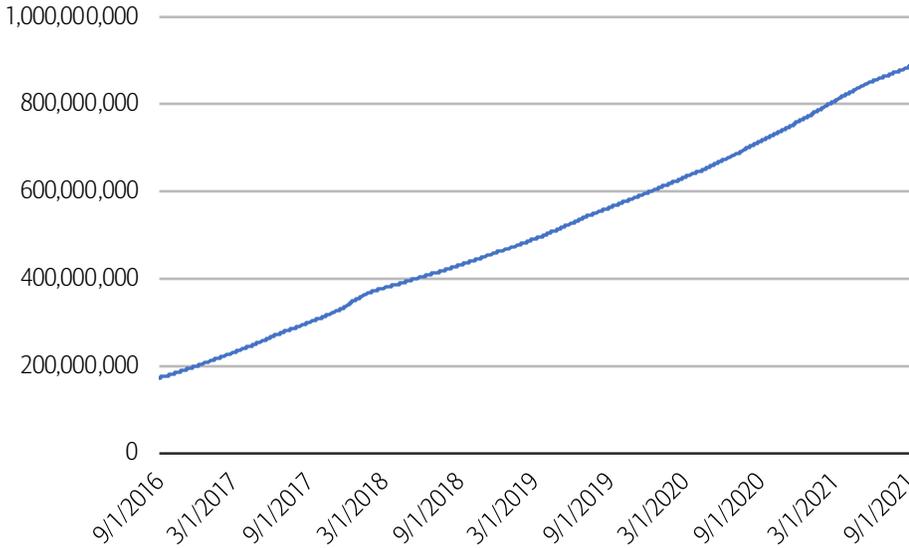


Adoption and holding period are increasing

The number of unique bitcoin addresses that have executed at least one transaction continues to increase as participants enter the ecosystem (Exhibit 49). The rate of newly created bitcoin addresses has decelerated since the bitcoin price appreciation from Nov'20 through Apr'21, but the rate of active bitcoin addresses has decelerated faster, indicating that bitcoin investors are increasingly holding bitcoin for extended periods (Exhibit 50).

Exhibit 49: Bitcoin unique addresses all time

Unique bitcoin addresses that have executed at least one transaction continue to increase



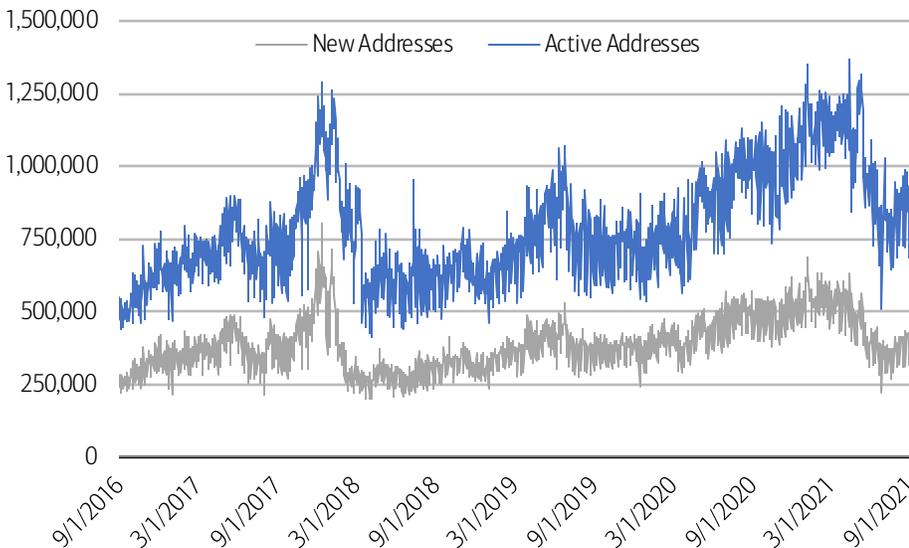
Source: CryptoCompare

Data: 6/1/16 – 8/31/21. Bitcoin unique addresses all time measures the sum of addresses that executed at least one transaction since inception

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Exhibit 50: Bitcoin new address vs active addresses

Active addresses have decelerated faster than new addresses, indicating that bitcoin investors are holding bitcoin for extended periods of time



Source: CryptoCompare

Data: 6/1/16 – 8/31/21. New addresses measures the number of addresses that were created during a given day and active addresses measures the number of addresses that executed at least one transaction during a given day.

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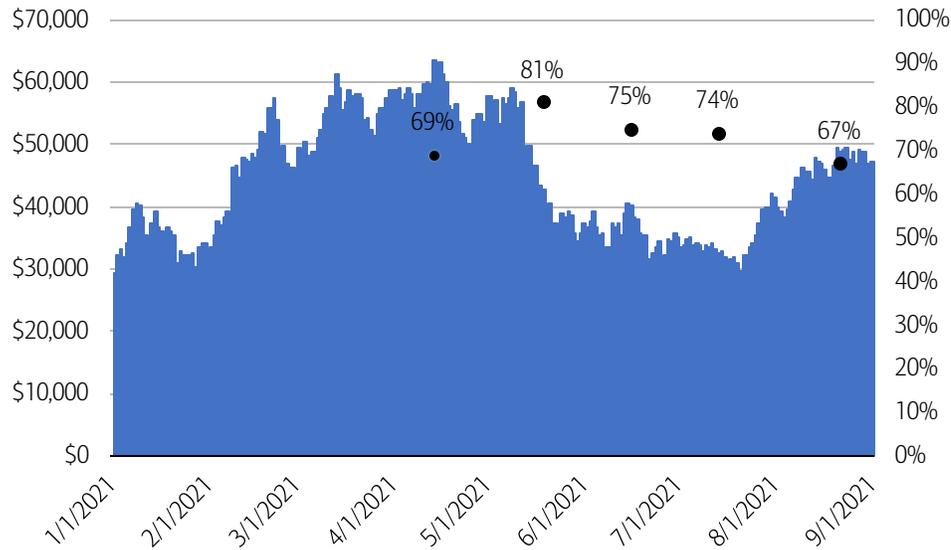


Institution consensus is that bitcoin is a bubble

Looking at Exhibit 51, we see that institutional investors largely view bitcoin as a bubble. However, we note that May's response followed bitcoin's significant price appreciation and that responses in June, July and August indicate that views of bitcoin as a bubble have fallen slightly, even as bitcoin prices rose. We expect volatility to continue to decrease as adoption increases and the market matures.

Exhibit 51: Bitcoin price (LHS) vs "Is Bitcoin a Bubble" responses (RHS)

Surveyed institutional investors largely view bitcoin as a bubble



Source: BofA Global Fund Manager Survey, CryptoCompare
Data: 1/1/21 – 8/31/21

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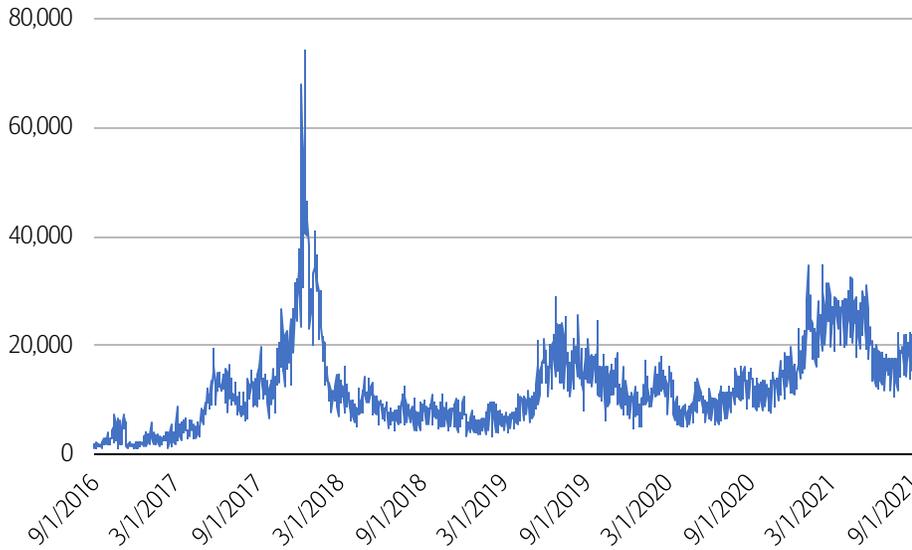
Transactions: large holders transitioning to HODLers

Looking at on-chain data, we find that large bitcoin transactions of \$100k or more have increased by 106% y/y through August 31st (Exhibit 52). Large bitcoin transactions of \$1mn or more rose from 30% of all transactions in 2020 to over 65% of all transactions ytd through July, likely driven by investors accumulating bitcoin rather than selling, according to Glassnode. We believe the acceleration in large bitcoin transactions indicates the entrance of institutional investors into the digital asset market and that these investors are holding long term instead of trading.



Exhibit 52: Bitcoin large transaction count per day

Bitcoin transactions of \$100k+ have increased by 106% y/y as of August 31st



Source: CryptoCompare

Data: 9/1/16 – 8/31/21. Bitcoin large transactions measures the number of on-chain transactions per day with values greater than \$100k

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...But there are significant risks to holding bitcoin

Bitcoin is the first and most secure digital asset – which isn't insignificant – but other digital assets have other real-world functionality, mainly faster or instant transactions. Ethereum is the platform for Finance 2.0 and Coinbase reported that ether trading surpassed bitcoin in their most recent earnings call. Altcoins, like utility tokens also have legitimate uses. Although we expect bitcoin to remain the largest digital assets by market value and the de facto store of value in the digital asset space given the security of its blockchain, it's worth considering if bitcoin's dominant position in the space could be overtaken by ether or other altcoins in the years to come.

Lightning Network (LN)

Bitcoin's protocol limits the number of transactions that can be processed per 10 minute intervals by design. Enter the Lightning Network.

Quick take – enabling digital assets to enter the mainstream?

The Lightning Network is a concept outlined in a whitepaper published by Joseph Poon and Thaddeus Dryja in 2015, which promises to deliver instantly processed transactions, low or no transaction fees and the ability to process millions of transactions per second – a jump from Bitcoin's 7 transactions per second. The LN is a layer 2 payment protocol, or routing network, that enables off-chain transactions via payment channels and using smart contracts. The LN was intended originally for Bitcoin, but has expanded to support altcoins. The main objective of the LN is to solve Bitcoin's "scalability problem," which limits its use as a medium of exchange and overall adoption and has become one of its main drawbacks.

Bitcoin processes 7 transactions per second on average, but Visa processes 24,000 transactions per second on average.⁴² Bitcoin's scalability problem is the reason that some developers branched out via hard forks to start their own digital assets. The LN addresses Bitcoin's scalability problem by essentially posing the question: Do we need to record every transaction on the blockchain exactly when it occurs? The LN launched its beta version in March 2018, but a production version has yet to be released. However, several companies have released implementations of the LN, and others have released LN wallets, most of which are beta versions. There's been significant adoption to date, but it's still early innings. Advocates claim the LN will revolutionize Bitcoin, allowing digital assets to enter the mainstream and be used as a medium of exchange.

What's Bitcoin's scalability problem?

The Bitcoin blockchain protocol limits the size of blocks added to the blockchain to 1MB – a new block is added to the blockchain every 10 minutes on average – which results in a limit on the number of transactions that can be processed in a given period. In reality, blocks are usually a bit larger than 1MB, but that's a discussion for another time. Network congestion can occur when many transactions are pending, resulting in longer settlement times and higher miner (transaction) fees (Exhibit 55).

Network congestion wasn't much of an issue in Bitcoin's early days, but there are now over 100mn bitcoin users globally and adoption is expanding.⁴³ Blocks rarely include more than 2,500 transactions, but we'll use this number (Exhibit 53). Assuming 2,500 transactions per block and one block added to the blockchain every 10 mins, that's 360,000 transactions processed a day. If you think that's a lot of processed transactions, Visa processes 150mn transactions a day.⁴⁴ Transaction confirmation times have fallen since July, but consider the implications if you needed to wait 10 minutes for a cashier to say the payment went through every time you bought a coffee (Exhibit 54).

The Bitcoin blockchain can improve its scalability by increasing the permitted block size or by decreasing the average time it takes for a block to be added to the blockchain, which would require a decrease in mining difficulty. However, doing either one of these two actions to improve scalability would decrease the blockchain's security, which we view as the main advantage of bitcoin and its blockchain over altcoins and their blockchains. We note that increasing block size limits or decreasing mining difficulty to reach transactions per second on par with Visa's would be problematic in theory and likely impossible in reality.

⁴² Visa.com

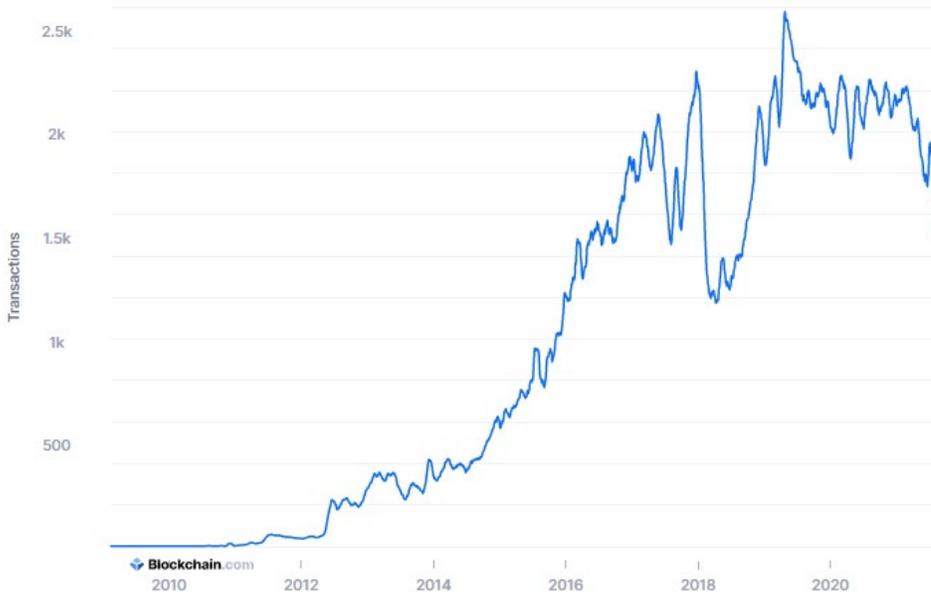
⁴³ Crypto.com's *Measuring Global Crypto Users*

⁴⁴ Visa.com



Exhibit 53: Transactions per block have increased significantly over time

Number of bitcoin transactions per block (30-day moving avg)

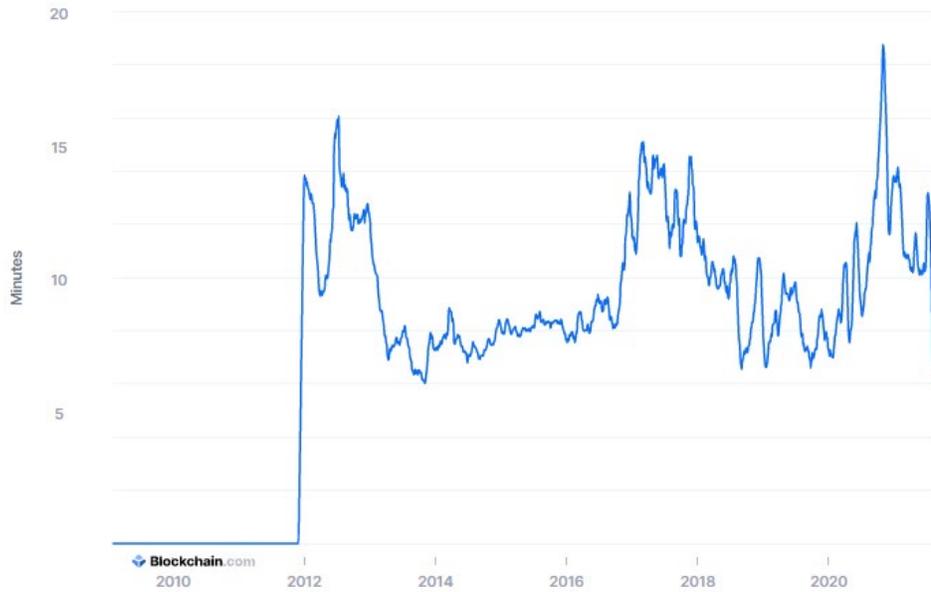


Source: blockchain.com

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Exhibit 54: But, periods of network congestion are still problematic...

Median confirmation time for a bitcoin transaction (30-day moving avg)



Source: blockchain.com

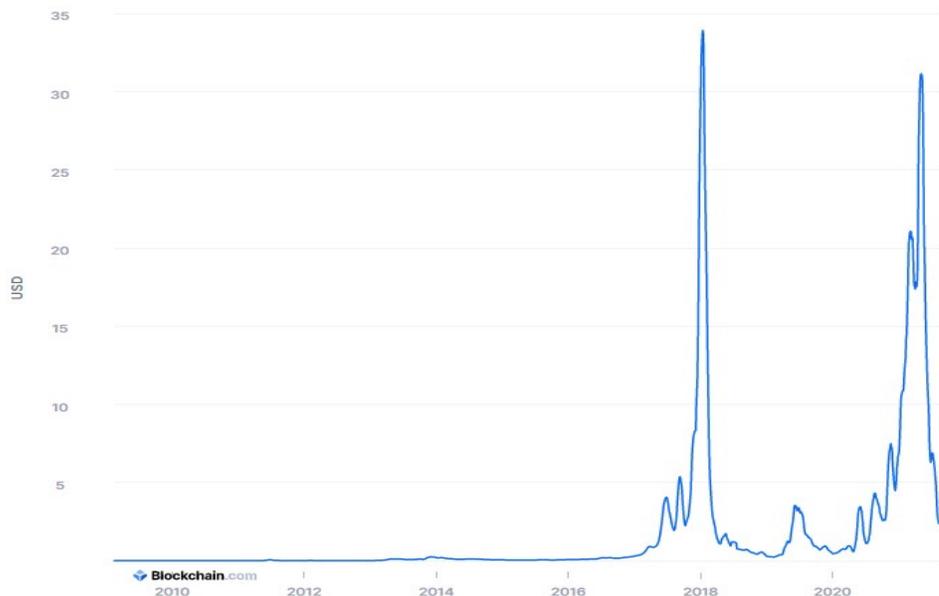
Median confirmation time excludes transactions without miner fees

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Exhibit 55: And transaction fees needed to prioritize a transaction remain volatile and can reach levels making micropayments untenable

Fees per bitcoin transaction in USD (30-day moving avg)



Source: blockchain.com

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How does the Lightning Network address Bitcoin's scalability problem?

If block sizes can't be significantly increased and the time it takes for a block to be added to the blockchain can't be significantly decreased, what other options are there?

If you want to transfer bitcoin to someone, you can access your digital asset wallet and enter in the recipient's wallet address, and...wait. The transaction could be added to the blockchain and, therefore, confirmed in seconds, or it could take 10 to 20 minutes, or longer. But, if you're planning on sending small amounts of bitcoin (micropayments), or don't want to pay a transaction fee to prioritize your payment, you could be waiting awhile for a miner to include your transaction in a block. The LN attempts to create efficiencies by only broadcasting opening and closing transaction to the blockchain. Any intermediary transactions between two parties after the initial transaction are aggregated and reflected in a closing transaction. Here's a simplified example:

Let's say you live with a roommate and you're constantly charging each other small amounts of money that you both agreed to pay in digital assets. Instead of constantly waiting for a transaction to be confirmed, and maybe paying transaction fees that are high relative to the amount of money you're sending, the roommates can open a payments channel on Monday with a funding transaction using a multisignature (multisig) wallet, which is a wallet that two or more people can access with their own private keys and that requires all, or some, signatures to approve a transaction. For the LN, a 2-of-2 multisig wallet is used. After the funding transaction, the roommates credit and debit each other's balances during the week (called off-chain commitment transactions) and then settle what they owe on Friday. When a closing transaction is initiated, the final balance is broadcast to the blockchain and the channel is closed. The beauty is that only the first and last transactions were broadcast to the blockchain and none of the small payments throughout the week were broadcast to the blockchain. Even better, they were settled instantly and with no transaction fee. This could be replicated by millions of people without creating network congestion.



Drawbacks of LN

A main concern currently is that the LN and implementations of the LN are still being tested, which raises the risk that software could contain bugs. Another drawback is that problems can arise if trying to send large payments through the LN with a routing transaction. You can only receive an amount of bitcoin equal to the amount used to open your payment channel via a funding transaction. Similarly, you can't send more bitcoin through a channel than the receiver used in their funding transaction to open their payment channel. The implications are that if you attempt to send a large amount of bitcoin to someone with whom you do not have an open payment channel, and this transactions needs to be routed through several other payment channels to reach the destination, each payment channel needs to have been opened with a funding transaction equal to or larger than the amount being routed through – not simple and still in test phase.



Derivatives driving bitcoin volatility

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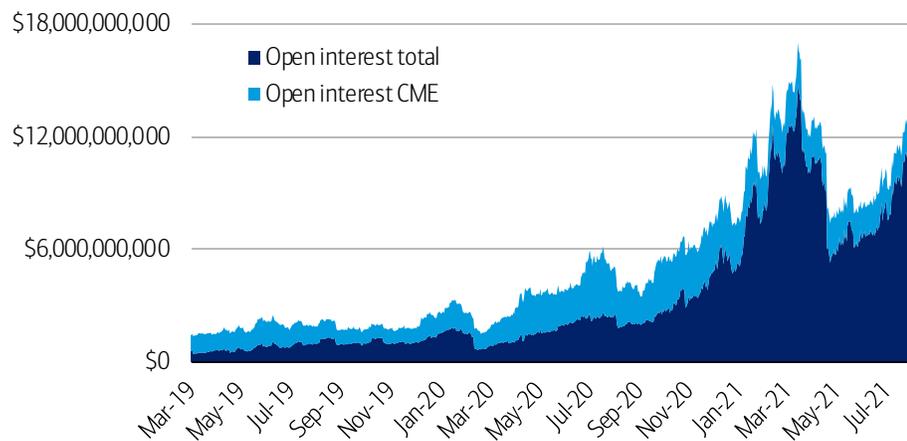
Andrew Moss

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At the start of 2021, the majority of leverage came from outside the US, given the limited ability of US investors to buy digital asset derivatives products ex-CME (Exhibit 57). The availability of leverage has fundamentally changed the price discovery process for bitcoin as long liquidations result in short-term negative price impacts, whereas short liquidations result in short-term positive price impacts (Exhibit 58). The landscape may change even further if the US market expands past the CME, though regulatory clarity is needed.

Exhibit 57: Most of bitcoin's leverage comes from outside of the US

CME futures do not contribute significantly to total open interest



Source: CryptoQuant, Bloomberg, BofA Global Research

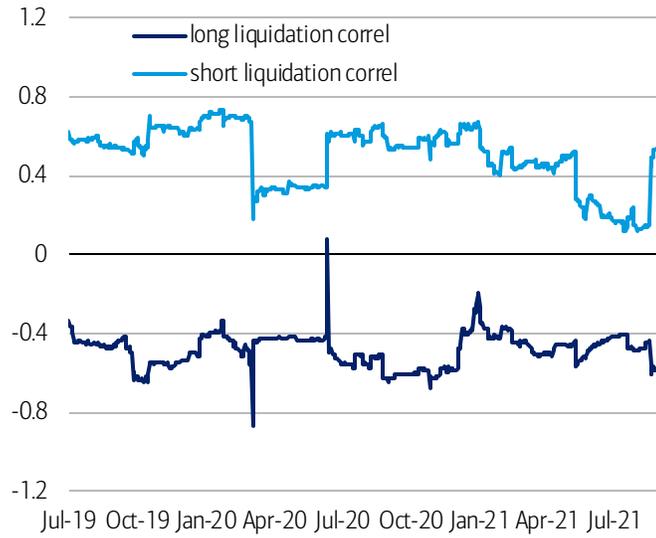
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The price discovery process is not instantaneous (Exhibit 59). It evolves throughout the course of a 24-hour period.



Exhibit 58: Evidence of daily bitcoin price impacts when liquidations occur

Rolling 100 day correlations on long and short liquidations with bitcoin returns

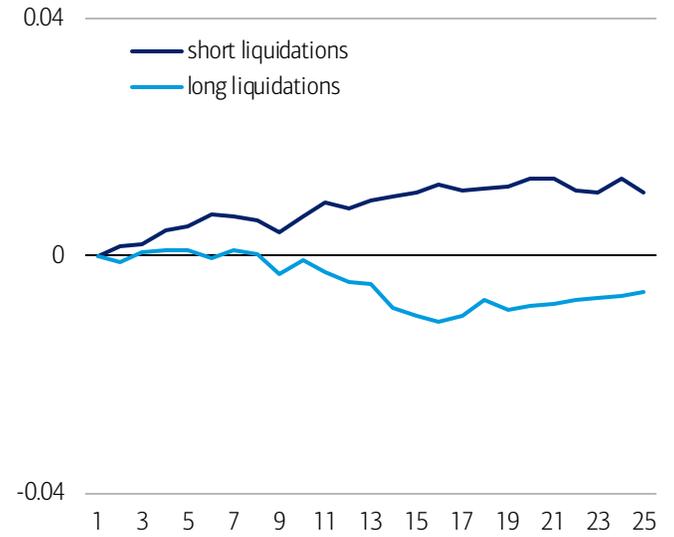


Source: CryptoQuant, BofA Global Research

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Exhibit 59: Zooming in per hour shows impact not instantaneous

Cumulative bitcoin returns when either short or long liquidations breach 8 standard deviations



Source: CryptoQuant, BofA Global Research

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Altcoins: any coin/token other than bitcoin

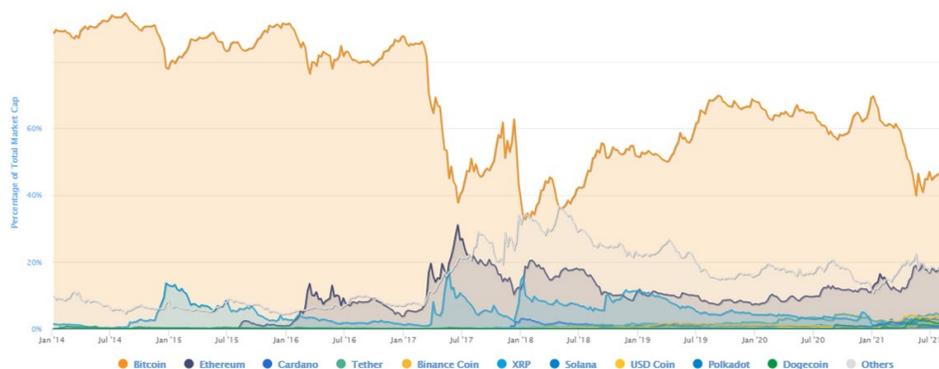
Altcoins, or alternative coins, include any cryptocurrency or token other than bitcoin. You've probably heard of bitcoin and ether and maybe several others, but there are actually over 11,500 altcoins in circulation.⁴⁵ Some were created to improve upon the protocol of a different coin by adding new functionality and some don't appear to have any purpose. For example, Bitcoin Cash (BCH) was created following a Bitcoin hard fork, with the most significant difference between the two being Bitcoin Cash's ability to accommodate block sizes of 32MB (Bitcoin can accommodate block sizes up to 1MB), which improves scalability by allowing for more transactions to be processed in a given period of time.⁴⁶

A concern highlighted by SEC Chair Gary Gensler is that some coins have what appears to be the same sponsor and promoter, potentially creating the risk of "pump and dump" schemes.

As the digital asset economy expands, the market share of altcoins has expanded significantly, capturing bitcoin market share. Bitcoin's market value accounted for ~97% of the crypto market value in November 2013, but had fallen to under 45% in August 2021 – a positive as coins for new use cases are created (Exhibit 60). In fact, there are now ~100 coins valued at over \$1bn, which we view as a sign of an expanding ecosystem.⁴⁷

Exhibit 60: Tokens by percentage of total market value

Bitcoin's dominance has fallen close to all-time lows as altcoin market values have risen



Source: CoinMarketCap.com

Data: 1/1/14 – 8/31/21

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We view the number of repositories, or projects, on a blockchain as an indication of developer interest and future demand for the blockchain's native digital asset (Exhibit 61 & Exhibit 62). See "Q: How can you determine if a crypto coin or token is overvalued or undervalued?" for additional analysis. There are more Ethereum projects currently being worked on than there are for Polkadot, Cardano and XRP combined. We define projects as the total number of blockchain-based code repositories. The total number of projects per blockchain provides a measure to gauge network effects. Put simply, a large or growing number of people involved in developing a network tends to inspire future developers to join because they can benefit from those already in the network.

⁴⁵ CoinMarketCap.com

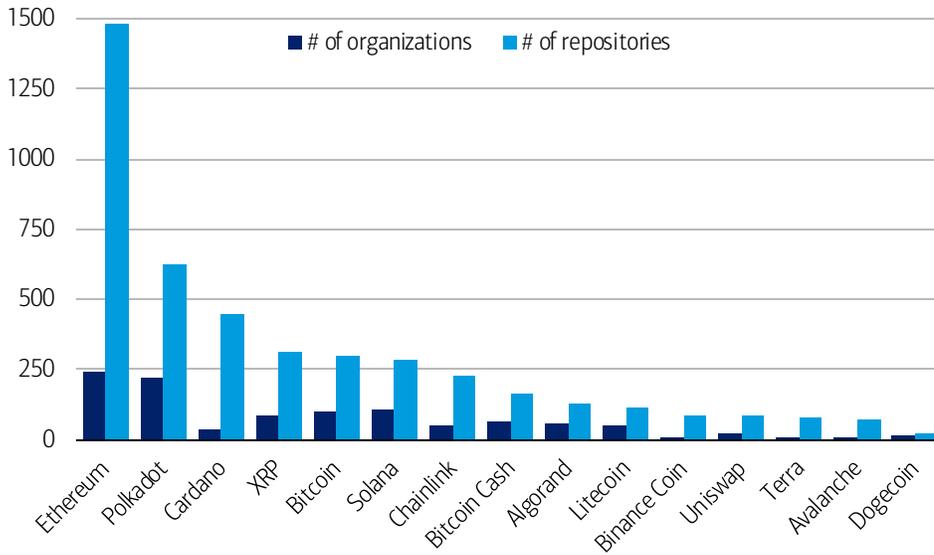
⁴⁶ Bitcoincash.org

⁴⁷ CoinMarketCap.com



Exhibit 61: There are more projects on Ethereum than on Polkadot, Cardano and XRP combined

Blockchain repositories/projects on the top 15 cryptos by market value

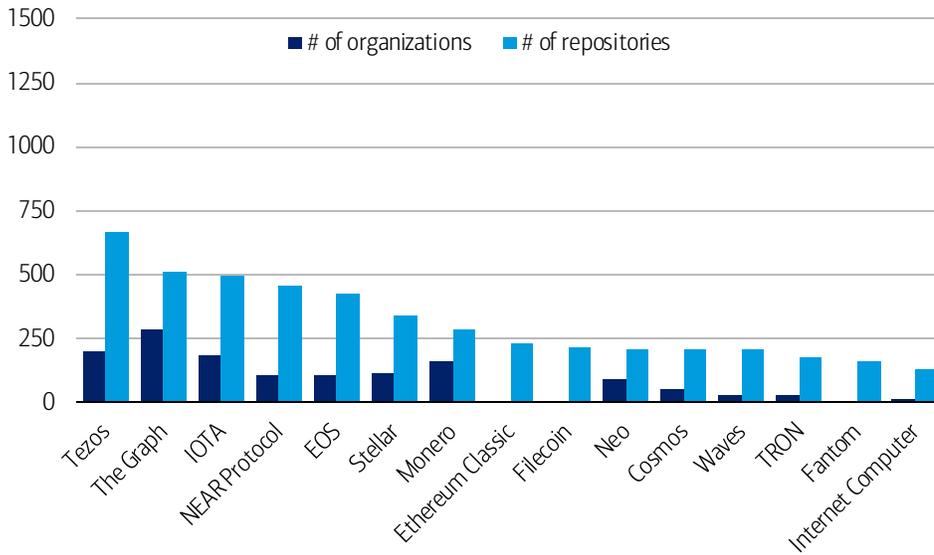


Source: Electric Capital
Data as of 9/13/21. Excludes stablecoins.

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Exhibit 62: Tokens outside of the top 15 by market value have received significant developer interest

Blockchain repositories/projects on tokens outside of the top 15 by market value



Source: Electric Capital
Data as of 9/13/21. Excludes stablecoins.

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Exhibit 63: Altcoin market values and use cases

Altcoin use cases are broad

Coin	Ticker	Symbol	Market Value	Description
Aave	AAVE		\$5.2bn	Aave's native utility token provides holders with discounted platform fees and allows them to stake their coins and vote on governance proposals. AAVE runs on the Ethereum blockchain (PoW).
Aspen Coin	ASPD		\$20.7mn	Asset-backed security token, issued through a Security Token Offering (STO), provides holders with indirect ownership of the St. Regis Aspen Resort, which is owned by Aspen Digital and managed by ER-RE, a subsidiary of Elevated Returns. ASPD was issued on the Ethereum blockchain, but migrated to the Tezos blockchain (PoS).
Binance Coin	BNB		\$78.1bn	Binance's native utility token provides holders with discounted trading fees and more. BNB was issued on the Ethereum blockchain, but migrated to the Binance Chain blockchain (PoS).
Bitcoin Cash	BCH		\$12.0bn	Created following a Bitcoin hard fork, BCH improves scalability by accommodating block sizes larger than Bitcoin's 1MB block size limit. BCH runs on the Bitcoin Cash blockchain (PoW).
Cardano	ADA		\$89.1bn	Cardano's native utility token provides holders with the ability to store/transfer value, stake their coins and vote on governance proposals. ADA runs on the Cardano blockchain (PoS).
Chainlink	LINK		\$12.0bn	Chainlink's native utility token provides external data providers, also known as nodes or oracles, with payment for accurate off-chain data. LINK runs on the Ethereum blockchain (PoW).
Crypto.com Coin	CRO		\$3.9bn	Crypto.com's native utility token provides holders with the ability to store and stake CRO, make payments to vendors and receive cashback rewards with the Crypto.com Pay app. CRO runs on the Ethereum blockchain (PoW).
Dash	DASH		\$2.3bn	Created following a Litecoin hard fork (which was itself the result of a Bitcoin hard fork), DASH provides instantly settled payments for daily transactions and increased anonymity. DASH runs on Dash's two-tier/hybrid blockchain, which introduced masternodes (PoW and Proof of Service (PoSe)).
Dogecoin	DOGE		\$36.5bn	Created following a Luckycoin hard fork (which followed a Litecoin hard fork, which followed a Bitcoin hard fork), DOGE provides holders with the ability to store/transfer value and differentiates itself with fast transaction and low fees, which makes it ideal for micropayments/tipping. Unlike Bitcoin, blocks are mined every minute instead of every 10 minutes, supply is not capped (there are over 130bn coins in circulation with ~14.4mn issued every day), ASIC devices are incompatible with mining and protocol updates are limited. DOGE runs on Dogecoin's blockchain (PoW).
EOS	EOS		\$4.8bn	EOSIO's native utility token allows holders to use network resources, build/run DApps, vote for block producers and vote on governance proposals. EOS runs on the EOSIO blockchain, which has annual supply caps, but no total supply cap (delegated Proof of Stake (DPoS)).
Ether	ETH		\$402.9bn	The second largest cryptocurrency by market value, ETH provides holders with the ability to store/transfer value and pay gas fees and has no supply cap. ETH runs on the Ethereum blockchain (PoW) with plans of an upgrade to Ethereum 2.0 (PoS).
Ethereum Classic	ETC		\$8.3bn	Created following an Ethereum hard fork resulting from a disagreement about how to respond to a hack (actually, ETH was created and ETC maintained the original Ethereum protocol), ETC provides holders with the ability to store/transfer value and pay gas fees and, unlike ETH, has a supply cap. ETC runs on the Ethereum Classic blockchain (PoW).
Filecoin	FIL		\$7.7bn	Filecoin's native utility token allows holders to store data in a cloud-based and decentralized storage network (DSN) by paying for unused hard drive space. FIL runs on Filecoin's blockchain (Proof of Replication (PoRep) and Proof of Spacetime (PoSt)).
FTX Token	FTT		\$4.6bn	FTX Exchange's native utility token can be used as collateral for derivatives trades and staking and allows holders to receive

Exhibit 63: Altcoin market values and use cases

Altcoin use cases are broad

Coin	Ticker	Symbol	Market Value	Description
Internet Computer	ICP		\$9.9bn	discounted trading fees, a fraction of exchange fees and airdrop rewards. FTT runs on the Ethereum blockchain (PoW). Internet Computer's native utility token allows holders to pay for access to the network and to receive rewards for operating nodes/data centers and for voting on governance proposals. ICP runs on the Internet Computer blockchain (PoS), which aims to decentralize the public internet.
Klaytn	KLAY		\$3.9bn	Klaytn's native utility token allows holders to pay transaction fees when creating or executing smart contracts within its ecosystem of DApps, which supports the issuance and exchange of digital assets, and rewards DApp developers. KLAY runs on Klaytn's blockchain, which combines features of public and private blockchains.
Litecoin	LTC		\$11.5bn	Created following a Bitcoin hard fork, and sometimes referred to as the "digital silver to Bitcoin's digital gold," LTC improves scalability and usability as a medium of exchange by providing faster transaction confirmations and negligible transaction fees. LTC runs on the Litecoin blockchain (PoW).
Monero	XMR		\$5.1bn	Created following a Bytecoin hard fork, XMR is a privacy coin that increases the anonymity of users and transactions, but also increases concerns about illicit use. XMR runs on Monero's blockchain (PoW).
PancakeSwap	CAKE		\$5.0bn	PancakeSwap's native governance token provides rewards to liquidity providers who deposit tokens into a liquidity pool via smart contracts and allows holders to pay the entrance fee for a lottery held every 6 hours. CAKE runs on the Binance Smart Chain blockchain (PoS).
Polkadot	DOT		\$31.1bn	Polkadot's native utility token allows holders to transfer value across blockchains in exchange for everything from data to tokens, vote on governance proposals and stake tokens. DOT runs on the Polkadot blockchain, which enables cross-chain interoperability by connecting public and private blockchains (PoS).
Polygon	MATIC		\$8.7bn	Polygon is a Layer 2 scaling solution for the Ethereum network that also enables DApp creation. Polygon's native token, MATIC, allows holders to pay sidechain transaction fees, stake their tokens and vote on governance proposals. MATIC has a total supply cap and runs on the Ethereum blockchain (PoW).
Solana	SOL		\$31.6bn	Solana enables DApp creation and provides DeFi solutions while maintaining low transaction fees and high scalability due to its hybrid consensus mechanism. Solana's native token, SOL, allows holders to store/transfer value and pay for transactions. SOL has a total supply cap and runs on the Solana blockchain (Proof History (PoH) and PoS).
Stellar	XLM		\$8.0bn	Stellar provides a payments solution with low and flat transaction fees, enabling cross-border payments/remittance by partnering with institutions. Stellar's native token, XLM, allows holders to store/transfer value on the network. XLM has a total supply cap and runs on the Stellar blockchain (Stellar Consensus Protocol (SCP)).
Theta	THETA		\$6.7bn	Theta is a decentralized video streaming network that provides participants with the ability to share bandwidth. Theta's native token, THETA, allows holders to vote on governance proposals and stake their tokens. THETA has a total supply cap and runs on the Theta blockchain (PoS).
Tron	TRX		\$6.4bn	Tron provides a content sharing and entertainment platform that allows for file sharing and content creation, as well as DApp creation. Tron's native token, TRX, allows holders to pay for services. TRX has a total supply cap and runs of the Tron blockchain (DPoS).
Uniswap	UNI		\$18.0bn	Uniswap is a decentralized exchange (DEX) that facilitates automated market making (AMM). Uniswap's native token, UNI, allows holders to store/transfer value and vote on governance proposals. UNI runs on the Ethereum blockchain (PoW).



Exhibit 63: Altcoin market values and use cases

Altcoin use cases are broad

Coin	Ticker	Symbol	Market Value	Description
VeChain	VET		\$7.9bn	VeChain is a supply chain management platform that enhances transparency/traceability and provides buyers with the ability to evaluate the authenticity of products. VET, one of VeChain's two native tokens, allows holders to pay for transactions. VET has a total supply cap and runs on the VeChainThor blockchain (PoS).
Wrapped Bitcoin	WBTC		\$9.4bn	WBTC is a tokenized version of Bitcoin, the original crypto, that can be used within the Ethereum network. WBTC has a 1:1 ratio with bitcoin and runs on the Ethereum blockchain (PoW).
XRP	XRP		\$55.3bn	XRP Ledger's native token allows holders to store and transfer value on its global payments network and enables real-time settlement with low transaction fees. Financial institutions use XRP to facilitate currency conversions. Supply is capped at 100 billion tokens, which have already been created, the majority of which are owned by Ripple, a private fintech company. XRP runs on the XRPL Ledger, which requires transactions to be verified by at least 80% of the network's validator nodes.

Source: BofA Global Research, CoinMarketCap.com
Market values as of 8/31/21. ASPD market value as of 9/29/21.

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Stablecoins: pegged to another asset

There are 200+ stablecoins today priced at an aggregate market value of \$120bn with projections of \$1tn by 2025, driven by the growth of Decentralized Applications (DApps), especially in Finance (DeFi).

What's a stablecoin and what's its use?

Stablecoins are digital assets pegged to another asset class such as a fiat currency (like the US dollar), a commodity (like gold), other digital assets or a combination of assets with the goal of maintaining a stable value. Digital asset holders and traders use stablecoins to reduce exposure to more volatile digital assets in digital asset accounts, lock in gains from trading, transfer funds between exchanges or between exchanges and wallets and as a safe haven when expecting a downturn or during a pullback. An example is as bitcoin fell ~8% on April 18th, many stablecoins traded at premiums to their \$1 pegs as bitcoin holders rotated out of bitcoin and into stablecoins. Constantly converting digital assets to fiat currencies or transferring fiat currencies to exchanges via ACH or wire transfers is expensive and slow, but transferring funds between wallets and digital asset exchanges via stablecoins is inexpensive and fast. Some exchanges don't have bank relationships needed to offer fiat currency deposits or withdrawals, but can and do accept stablecoins, such as tether, the largest stablecoin by market value (Exhibit 71). Stablecoins can be used to make purchases and money transfers, such as remittances, faster and less expensive by using blockchain technology, instead of the traditional payments infrastructure.

Stablecoins may also help push adoption of digital assets as a medium of exchange, given digital asset holders likely would prefer not to use a volatile digital asset to buy a coffee if they expect that the \$5 of digital assets spent today could potentially be worth \$10 next week.

Exhibit 64: Top stablecoins by market value

Tether is the largest stablecoin by market value

Coin	Ticker	Symbol	Price Range	Market Value (\$bn)
Tether	USDT		\$1.00	\$65.53
USD Coin	USDC		\$0.9998 - \$1.00	\$27.41
Binance USD	BUSD		\$0.9998 - \$1.00	\$12.25
Dai	DAI		\$1.00	\$6.14
TerraUSD	UST		\$0.9975 - \$1.00	\$2.40
TrueUSD	TUSD		\$0.9998 - \$1.00	\$1.40

Source: CoinMarketCap.com

Chart includes coins with +\$1bn market value. Price Range includes the low and high price on 8/31/21.

As of August 31, 2021

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Stablecoin market size and potential

The current market value for all stablecoins – there are over 200 – is ~\$120bn with projections reaching as high as \$1tn by 2025, driven largely by the growth in DeFi apps (DApps).⁴⁸ The three largest coins – tether (\$66bn), USD coin (\$27bn) and binance coin (\$12bn) – comprise 87% of the total stablecoin market value (Exhibit 65). You may be wondering how stablecoin companies will get their hands on over 5% of the M1 money stock for collateral if the stablecoin market value were to reach \$1tn and the implications of that much cash being taken out of the economy. But remember, not all stablecoins require 1:1 reserves and some aren't pegged to fiat currencies at all.

There are likely more stablecoins to come, especially ones that run on private (permissioned) blockchain networks. Facebook led a consortium that made waves with

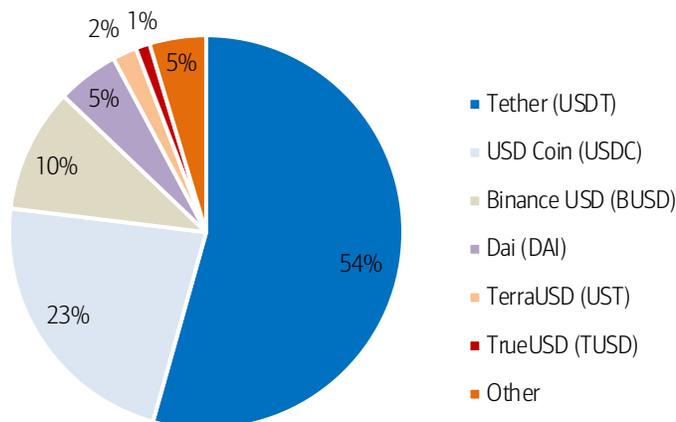
⁴⁸ CoinMarketCap.com, Matthew Gould via Business Insider



plans for a stablecoin that was first to be called Libra, then Diem, but the idea has lost momentum in the face of regulatory opposition. J.P. Morgan built a payments network leveraging blockchain technology to facilitate instantaneous and cross-border transfers between institutional clients and introduced a stablecoin called JPM Coin, redeemable for US dollars on a 1:1 basis. JPM Coin is a private coin only available to institutional clients and not available to the public, unlike the stablecoins in the table above.

Exhibit 65: The stablecoin market is highly concentrated

The top three stablecoins by market value have 87% market share



Source: CoinMarketCap.com
Coins shown have market values \$1bn+

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How do stablecoins remain stable?

Fiat-backed stablecoins

- Stablecoins backed by fiat currencies provide holders with a coin pegged to the price of a fiat currency, usually USD, but also EUR, GBP, AUD and others. Fiat-backed stablecoins are not always perfectly stable, but they experience volatility similar to traditional currencies, which have price swings that are generally far smaller than those of bitcoin. Stablecoin issuers collateralize the value of their tokens by holding liquid assets. The most popular stablecoin, tether, traded at \$1.0005 as of August 31st and is designed to always trade for about \$1 (Exhibit 66). Tether is the 5th largest of all tokens by market value and sees the largest daily trading volume (+\$84bn) of any digital asset.⁴⁹ Tether (the company) issues new tokens and maintains full collateralization by depositing an equal amount of USD-based liquid assets into its reserves for each coin it issues. When a holder wants to exchange tether (the coin) for USD, Tether (the company) withdraws the required amount of USD from its reserves, sends it to the holder's bank account and burns a proportional number of coins in circulation.

Commodity-backed stablecoins

- Stablecoins backed by commodities provide holders with a digital asset pegged to the price of precious metals, oil and real estate. Commodity-backed stablecoins sometimes provide holders with a physical asset as well, but without the associated storage costs. They also provide the opportunity to buy fractional amounts of a commodity, such as physical gold, which can be easily transferred. Tether Gold, a stablecoin that tracks the price of one fine troy ounce of gold and is linked to a unique gold bar via a barcode, can be traded or redeemed in physical form in

⁴⁹ CoinMarketCap.com

Switzerland. The gold bars are securely held in vaults in Switzerland and the custodian pays for insurance on behalf of the holders. TG Commodities Limited, the issuer, creates new tokens and maintains full collateralization by purchasing gold from Switzerland gold dealers and depositing it into secured vaults. Prices of physical assets like gold or oil are volatile, which can lead to unstable prices for stablecoins pegged to them even if they are effectively pegged (Exhibit 67).

Digital asset-backed stablecoins

- Stablecoins backed by digital assets, like ether or a pool of digital assets, provide holders with a digital asset pegged to, but not collateralized with, a fiat currency. Digital asset-backed stablecoins use smart contracts and do not maintain a 1:1 ratio of stablecoins to reserves. Instead, they are overcollateralized to maintain price stability. For example, you may deposit \$15 worth of ether, but receive \$10 worth of stablecoins; in the event ether's price falls by 10%, the value of the stablecoin would remain fully collateralized. For other stablecoins, a pool of coins is used as collateral to decrease the risk of undercollateralization if one coin were to fall sharply in value. Digital asset-backed stablecoins are frequently used by DeFi applications. These applications are usually built on top of the Ethereum blockchain and use stablecoins for several functions, such as yield farming/staking.
- Dai is a stablecoin created by MakerDao, a decentralized autonomous organization, and is pegged to the price of the dollar, but backed by coins like ether, among others (Exhibit 68). Holders deposit digital assets as collateral and borrow against it to receive newly issued Dai. If at any point, the collateral deposited falls below the value of the Dai held, the collateral is liquidated. If the value of the collateral deposited appreciates, Dai holders can borrow additional Dai. Collateral is held until the corresponding Dai is returned, along with a variable-rate stability fee used to alter demand, and consequently burned. Dai is further collateralized by MKR, MakerDao's native governance token, which would be liquidated if Dai's price were to crash. Dai maintains decentralization; there's no private company that makes subjective decisions and all transactions are done on-chain using smart contracts, unlike fiat or commodity-backed stablecoins, which require individuals to purchase reserves in the public market.

Are stablecoins actually stable?

Stablecoins occasionally become unpegged when excessive volatility in the broader digital asset market pushes holders to rotate out of more volatile digital assets and into stablecoins, driving up demand and causing stablecoins to trade at a premium to the dollar. Others, like Fei, became unpegged and traded at a discount to the dollar almost immediately after launch in April because of a bug in the protocol that made it impossible to sell, but the bug was fixed and it has traded around \$1 since June (Exhibit 69).



Exhibit 66: Tether/USD Price has hovered around \$1

Tether traded at premium on April 18 as bitcoin prices fell ~8%, illustrating its use as a safe-haven asset



Source: CoinMarketCap.com
Data: 1/1/21 – 8/31/21

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Exhibit 67: Tether Gold/USD Price (LHS) vs XAU/USD Price (RHS)

Tether Gold's price has consistently mirrored gold's spot price

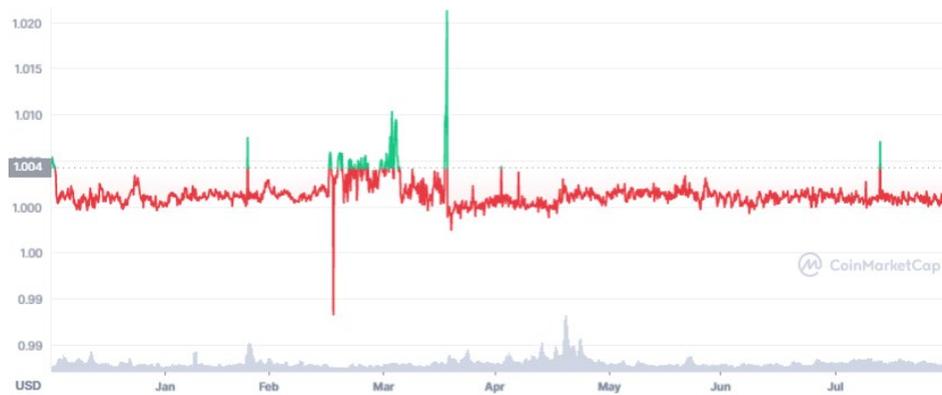


Source: CoinMarketCap.com, Bloomberg
Data: 1/1/21 – 8/31/21

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Exhibit 68: Dai/USD Price

Dai traded at premium on April 18 as bitcoin prices fell ~7.5%, illustrating its use as a safe-haven asset



Source: CoinMarketCap.com
Data: 1/1/21 – 8/31/21

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Exhibit 69: Fei/USD Price

Fei traded at a discount after launching, but has since stabilized around \$1



Source: CoinMarketCap.com

Data: 1/1/21 – 8/31/21

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How do stablecoin companies make money?

The short answer is: interest and fees. Companies that issue fiat-backed stablecoins make money by investing the cash that users deposit into various short-term government and other securities to earn interest. With billions invested, interest can add up. For commodity-backed digital assets like tether gold, user deposits are converted into actual gold, leaving no cash to be invested. Instead, users pay a fee at the time of purchase and redemption. For digital asset-backed stablecoins, like Dai, the company makes money from stability fees, which are variable-rate interest fees on the amount of Dai borrowed against the deposited collateral.

What are stablecoins' risks to consumers?

It depends on the stablecoin type. Collateralized stablecoins run the risk of fraud if the reserves used as collateral are fictional or not invested in liquid assets. Those tied to digital assets like ether could crash if ether does. And like any asset, digital or tangible, there is the risk of secondary-market manipulation that could skew coin values and threaten to break an underlying peg. Lastly, regulators could decide that stablecoins are securities and must be registered in jurisdictions like the US or the European Union, or be excluded from those markets (such as China's tether ban).

Important to do due diligence on reserves/composition

Fiat-back stablecoins are fully collateralized, but not always by the dollar. Tether, with a \$66bn market value, claimed that its tokens were backed 1:1 by US dollars, securities and commercial paper, but rules for reserve transparency are still evolving. Bitfinex, the digital asset exchange that operates Tether, agreed in February to pay \$18.5mn to settle a suit brought by New York State Attorney General Letitia James, charging that it hid the loss of commingled client and corporate funds and lied about reserves. "Tether's claims that its virtual currency was fully backed by US dollars at all times was a lie," James said. Her investigation led to the revelation that tether was only 74% backed by cash and short-term securities at one point.

Since the settlement, Tether has attempted to improve its credibility.

As part of New York State settlement, Tether agreed to provide quarterly reports for two years on the reserves backing tether. So far, Tether has published two reports.

- In March, Tether published an assurance report, showing only 2.9% of reserves were held in cash. They provided no insight to assess the riskiness of the commercial paper held, which represented 49% of all reserves at the time (Exhibit 70).

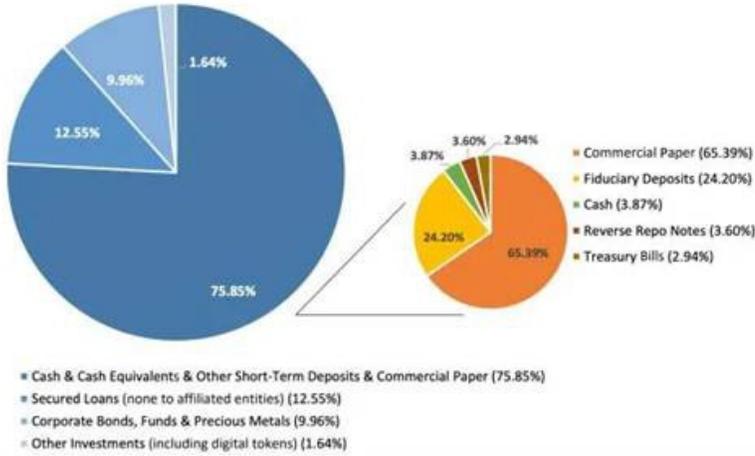


Exhibit 70: 49% of tether reserves are backed by unspecified commercial paper

Cash represents 3% of reserves



Reserves Breakdown at March 31, 2021



Source: Tether via CoinDesk

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- In August, Tether published another assurance report and tweeted “Tether has always been fully backed and the assurance opinion made available today confirms it once again, and puts Tether ahead of the industry on transparency.” It’s unclear whether this statement is demonstrably false, but it is clear that Tether has never acknowledged any wrongdoing and that they are not leaders of the industry on transparency. See Exhibit 70 for the assurance report. We also note that Tether hired Moore Cayman, an accounting firm with 10 employees listed on its website.

Exhibit 71: Tether's consolidated reserves report still provides little insight into its commercial paper, which represents 49% of its reserves

Consolidated Reserves Report as of June 30, 2021

- **Asset Breakdown:** At the reporting date, the breakdown of the minimum consolidated total assets is as follows:

Cash & Cash Equivalents & Other Short-Term Deposits & Commercial Paper:	
Commercial Paper and Certificates of Deposit ²	\$30,807,654,349
Cash & Bank Deposits ³	\$6,282,756,692
Reverse Repo Notes ⁴	\$1,000,662,458
Treasury Bills ⁵	\$15,279,528,705
Subtotal	\$53,370,602,204
Secured Loans (none to affiliated entities)	\$2,517,140,390
Corporate Bonds, Funds & Precious Metals	\$4,830,821,277
Other Investments (including digital tokens)	\$2,054,626,204
Total	\$62,773,190,075

- **Commercial Paper & Certificates of Deposit:** At the reporting date, the rating⁶ of the commercial paper and certificates of deposit held in the minimum consolidated total assets is as follows:

A-1+	\$149,810,724
A-1	\$14,516,595,696
A-2	\$13,984,034,997
A-3	\$1,697,939,867
Other	\$459,273,065
Total	\$30,807,654,349

At the reporting date, the breakdown of the maturity of the commercial paper and certificates of deposit held in the minimum consolidated total assets is as follows:

0-90 days	\$10,570,890,544
91-180 days	\$6,496,275,937
181-365 days	\$13,740,487,868
Total	\$30,807,654,349

Source: https://tether.to/wp-content/uploads/2021/08/tether_a_ssurance consolidated_reserves_report_2021-06-30.pdf

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It's difficult to determine the liquidity and creditworthiness of tether's reserves or the implications if tether were to fail, but we believe that the digital asset ecosystem could become at risk of collapse if tether failed. Why? To start, AG James banned tether trading in New York and Ethereum's founder, Vitalik Buterin, claimed in a tweet from May 20th "...I don't expect Tether to survive forever; they're certainly flying close to the sun and every time they expand issuance they get closer". With a \$66bn market value and limited regulatory oversight, tether's liquidity and reserves may present a significant risk to the digital asset ecosystem.

What about other stablecoins?

USD Coin (USDC), the second-largest stablecoin has a market value of \$27.4bn and is backed 1:1 by US dollars and Treasuries. It is supported by Circle and Coinbase and its reserves are attested for on a monthly basis by accounting firm Grant Thornton LLP.

TrueUSD, with a market value of \$1.4bn, is another collateralized stablecoin that holds US dollars for 100% of coins issued and is independently audited by an accounting firm. In June, TrueUSD said that Signature Bank will integrate the stablecoin for settlement by commercial clients. Paxos Standard (PAX) and Gemini Dollar (GUSD) are approved and regulated by New York State Department of Financial Services.

Regulation

A recently introduced congressional bill defines digital asset securities (tokens) and gives the Federal Reserve permission to create a central bank digital currency (CBDC). The bill would also provide the government veto power over US stablecoins as they would have to receive approval from the Fed and the SEC. The bill doesn't address applications such as DeFi as they would fall outside of digital assets.



Central Bank Digital Currencies (CBDCs)

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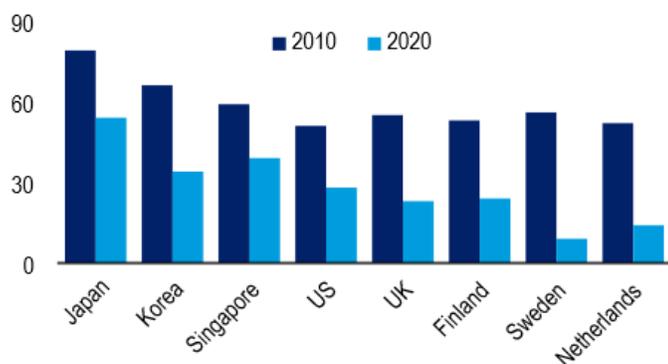
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Quick take – a substitute for cash?

Central banks are exploring the implications of digital currencies and considering Central Bank Digital Currencies (CBDCs) as a substitute for, or even total replacement of, physical cash. Sovereign digital currencies could provide a more effective payment system than cash, an opportunity to increase the legal economy and more efficient cross-border payments and fund transfers. But, they may also introduce risks such as competition with bank deposits, loss of monetary sovereignty by small countries, loss of privacy and more frequent bank runs. Despite the risks, central banks from countries that together represent over 90% of global GDP are exploring CBDCs (Exhibit 75).⁵⁰ Our view is that CBDCs are a natural progression of monetary systems; the use of physical bank notes and coins have been declining around the world (Exhibit 72) and plunged in the US in 2020 (Exhibit 73). The bottom line is that CBDC adoption appears inevitable for three reasons: 1) the risk of central banks losing monetary control to emerging stablecoin adoption; 2) the diminishing role of physical currency; and 3) the private sector adoption of blockchain. Widespread adoption of CBDCs globally appears to be just a matter of time (the devil is in the detail, though).

Exhibit 72: Consumers are using less physical cash

Physical cash usage as % of total consumer transactions has dropped sharply in all advanced countries over the last decade



Source: McKinsey

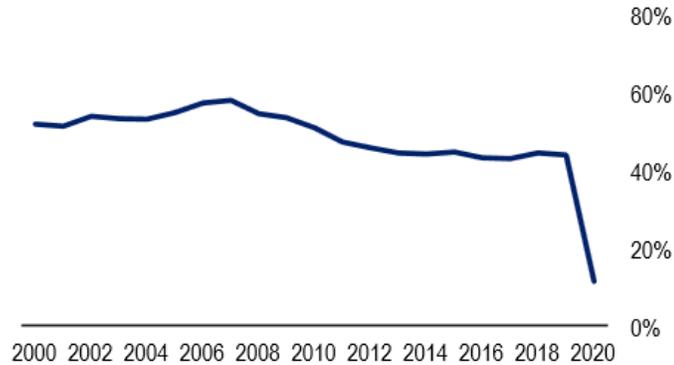
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⁵⁰ Atlantic Council



Exhibit 73: Physical notes & coins are becoming less relevant

Circulated physical notes & coins as % of M1 for the US fell to 11%



Source: The Federal Reserve

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Is CBDC adoption that huge of a leap?

Digital currencies are a way to transfer spending power electronically, rather than physically. While the technology of bookkeeping and transfer is different for a digital currency, we already pay for most transactions electronically in advanced economies, and increasingly so in the rest of the world, when we pay with a credit card or a debit card. Most transactions for the general public – sending and receiving electronic balances in our commercial bank accounts – go through the commercial banking system. The difference is that with credit or debit cards, we still electronically transfer claims to paper money, but with CBDCs, we would directly transfer electronic money, either tokens or account entries. The digital dollars are backed by the central banks and deposit insurance and, therefore, are as sound as a central bank liability.

Wait, what's the difference between CBDCs, stablecoins and cryptocurrencies like bitcoin?

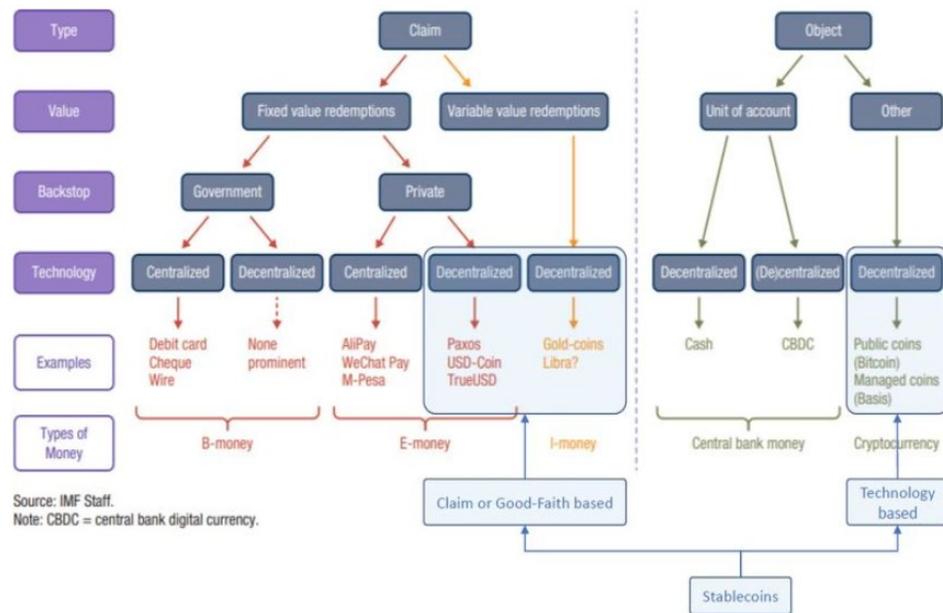
CBDCs and cryptocurrencies are very different in our view and comparisons could be misleading. CBDCs will have a stable value and very low, if any, returns, while the latter will be volatile and potentially appreciate as adoption and use cases increase. The same way that paper bills are a claim to the central bank, and, therefore, an official claim to the government, a CBDC represents exactly the same claim, but electronically – it is just a digital claim instead of paper money. However, most cryptocurrencies do not represent a claim to anything. They have a price just because other people accept them. As such, they fluctuate substantially with demand, unless they are fiat-backed stablecoins.

The Bank for International Settlements (BIS) has argued that "cryptocurrencies are speculative assets rather than money." Stablecoins could in theory qualify as money, but only because they are supposed to represent a stable claim to actual, official money.



Exhibit 74: The IMF money tree

Placing stablecoins into the IMF's money tree



Source: IMF

For details, see "Stablecoins, Digital Currency, and the Future of Money" A. Lipton, A. Sardon, F. Schär, and C. Schüpbach (2020)

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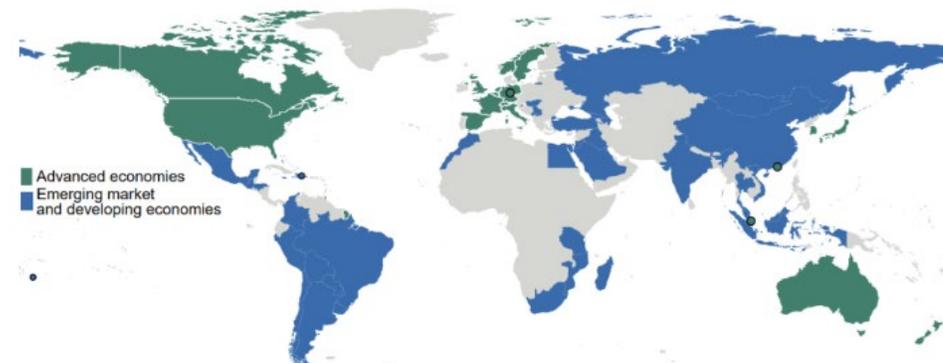
Central banks are doing the work

A number of central banks are exploring the possibility of issuing their own digital currencies with Facebook's Diem and rapid stablecoin adoption and usage adding urgency. Concerns are that a coin used by Facebook's 2bn users or further adoption of fiat-backed stablecoins, could undermine a central bank's ability to manage its own currencies and economies.

- The Bahamas launched the first CBDC called the Sand Dollar in Oct'20.
- Islands in the Eastern Caribbean, including Antigua and Barbuda, Grenada, Saint Kitts and Nevis and Saint Lucia, which share a central bank, launched their own digital currency called Dcash in Mar'21.
- The first major central bank to roll out a CBDC on a large scale is likely to be the People's Bank of China (PBoC), which has begun trials in major cities with a digital yuan, or e-CNY.
- The Fed is working on a digital-currencies report, which Chairman Powell said could be released in Sept'21. Among other things, the report will include a discussion on the risks and benefits of stablecoins, he said.
- The ECB released a report on the digital euro in Oct'20, launched the digital euro project in July'21 and will begin the project's investigation phase in Oct'21, which will last for about 2 years. The whole process [of launching a digital euro]...will in my view take another four years, maybe a little more," said ECB President Christine Lagarde in Mar'21.
- Over 80 countries are exploring the possibility of issuing their own CBDCs, including Brazil, Canada, the European Union, Japan, Marshall Islands, Morocco, Nigeria, S. Africa, S. Korea, Sweden and the UK.

Exhibit 75: Countries exploring CBDCs

Central banks from countries that together represent over 90% of global GDP are exploring CBDCs



Source: totalkrypto.com

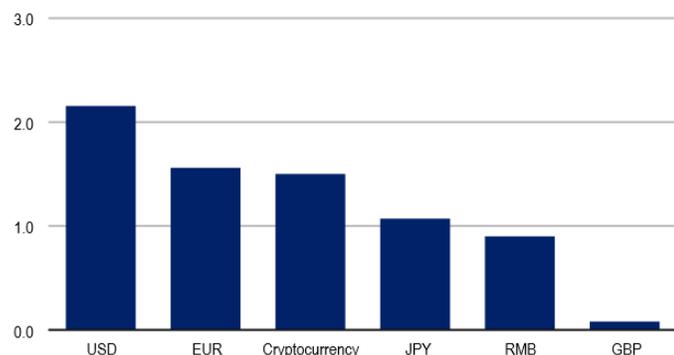
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Are CBDCs a threat to the dollar as a reserve currency?

At this stage, we do not see digital assets as an existential threat to the dollar as a reserve currency, but if the Fed is slow to innovate, some retail payments could shift away from the dollar. The vast majority of payments would continue to flow digitally through the banking system. There is a good reason for the dominant position of the dollar in global markets: the US has the biggest, deepest capital markets, free capital flows and a strong legal system. China's e-CNY could catch on in China and for countries heavily dependent on China, but it is hard to see it competing with the dollar.

Exhibit 76: Total currencies in circulation (\$trns)

USD still dominates currencies in circulation, but digital assets are catching up



Source: Bloomberg, Investopedia, Various Central Bank Websites

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Why are CBDCs inevitable?

Our view is that central banks that do not introduce their own digital currencies could, in some cases, see demand for their currencies fall substantially. For the USD and the EUR in particular, avoiding the digital era could eventually even diminish their global role. In a world in which every central bank offers a digital currency, the FX implications will depend on which one offers the better service and is the most easily available. We outline 3 reasons why CBDC adoption appears increasingly inevitable:

1) Risk of losing monetary control (and revenue)

Central banks that don't introduce their own digital currency could see a gradual loss of monetary control to the private sector if the public slowly adopts a global digital asset or another country's CBDC. The public's demand for digital assets has been undeniably accelerating. Facebook's proposal of a global currency (Diem) has raised concerns in many central banks around the world. In some cases, loss of monetary control could lead to inflation well above current central bank targets. Countries without CBDCs could also end up losing control of their monetary policy to countries with CBDCs. ECB's Panetta



has warned that without CBDCs, central banks would allow large tech companies to gain a dominant market position in the payment system. The fear is that Facebook's Diem, or another private digital currency, could at some point dominate global payments. Moreover, financial activity taking place outside the regulated banking system (nondomestic, internet-based institutions lending in non-national currencies) could create financial stability risks.

CBDCs may make monetary policy more effective in some cases. In particular, this is the case at the zero interest rate bound, which will actually disappear in the presence of interest-bearing CBDC, as central banks could charge a negative interest rate for their digital currencies. Banks have difficulty doing so today, as people can just withdraw their cash, instead of using the money to shop or invest in risky assets with a positive return. However, in a world with CBDCs, negative rates will lead to higher demand for goods and services and more flows into investment, making monetary policy more powerful. Note that this does not apply to non-interest bearing CBDCs.

Besides losing policy control, the government is at risk of losing seigniorage revenue. Seigniorage comes from issuing currency and minting coins at a cost below their nominal face value. In the case of bitcoin, for example, miners earn seigniorage revenue from issuing new money (cost of energy to mine bitcoin vs the significantly higher face value), and not the government treasury or the central bank. Estimates suggest US annual revenue from seigniorage is about \$25bn, or 0.1% of GDP.

2) Diminishing role of physical currency

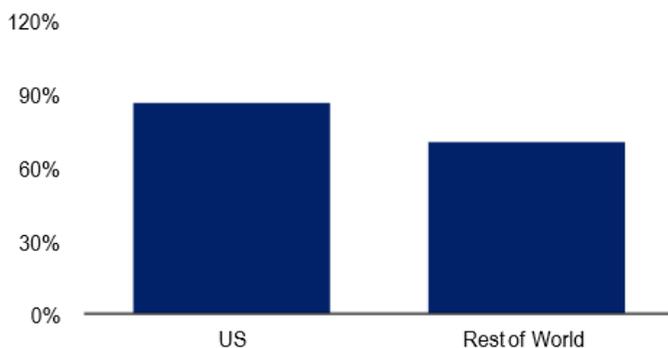
Physical notes and coins in the US as a percentage of total M1 have been declining over the past decade. With unprecedented fiscal stimulus measures implemented in 2020 and little rise in the supply of physical currency, the ratio has seen an even sharper decline, which could also reflect an explosion in reserves. With the rise of smartphones and various digital payment methods over the past decade, consumers are also using less physical cash on a day-to-day basis. The Covid-19 shock in 2020 also accelerated the adoption of a digital business for commercial banks. The bottom line is that physical currency use has been declining around the world for the last decade and central banks will likely look to fill the void with CBDCs or face the risk of being replaced by fiat-backed stablecoins or private stablecoins.

3) Private sector adoption of blockchain

If central banks do not adopt CBDCs, they risk being perceived as falling behind the demands of evolving marketplaces. A recent survey shows 86% of firms in the US and 70% outside the US already have, or are in the process of building, blockchain-oriented teams (Exhibit 77). Respondents also expressed strong belief in the gradual adoption of digital currencies (Exhibit 78).

Exhibit 77: Private sector firms are widely adopting blockchain

86% of US firms already have, or are in the process of building, blockchain teams



Source: Deloitte

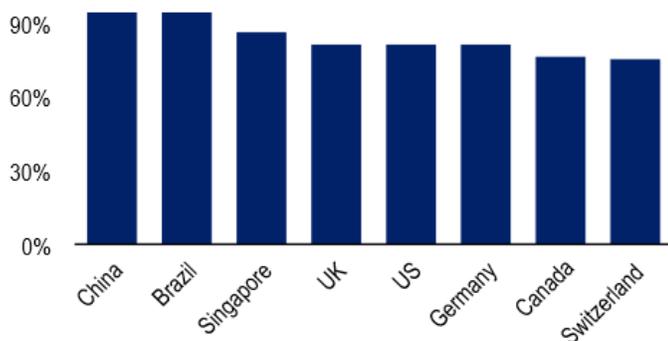
Survey polled 1,488 corporate executives and practitioners globally across 14 countries

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Exhibit 78: Private sector is optimistic on CBDCs

Percent of survey respondents who strongly or somewhat agree that digital assets will be an alternative to or replacement of fiat currencies in the next five to 10 years across regions



Source: Deloitte

Chart shows the percent of respondents who strongly or somewhat agree that digital assets will be an alternative to or replacement of fiat currencies in the next five to 10 years across 1,488 surveyed corporate executives.

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What are the risks to CBDC adoption by central banks?**Competition with bank deposits**

Perhaps the biggest concern is that the benefits of a smoother payments system could be more than offset by the disruption to the flow of credit. CBDCs are in some ways superior to bank accounts as a store of value, particularly during times of crisis. Nothing is safer than an asset backed by the central bank. Even with deposit insurance, bank deposits are not as safe, particularly those that are above the insurance thresholds. Therefore, CBDCs could cause disintermediation of the banks.

Monetary sovereignty of small countries

We are concerned that if CBDCs for major currencies, such as the dollar or Euro, are available internationally, they could erode the monetary sovereignty of smaller countries and, potentially in times of turbulence, facilitate capital flights. This is not an easy matter to fix and would require close coordination among jurisdictions and, very likely, access limits for foreign uses.

Loss of privacy

Another key concern about CBDCs is the potential loss of the privacy and anonymity that the public enjoys with cash today. The ability to balance the need to police the payments system while maintaining privacy is key. Purely anonymous payments are an anathema to central bankers. In fact, a major focus of bank regulation is to prevent money laundering, the financing of terrorism, tax avoidance and underground activities in general. At the same time, central bankers are concerned about an unnecessary invasion of privacy.

However, the level of privacy for a CBDC primarily depends on the design choice of the central bank. In practice, payments using CBDCs can remain anonymous, with a legal framework giving the right to the central bank or the government to trace transactions in case of indications of criminal activity, tax evasion, money laundering, or financing of terrorism.

The public may still be concerned that governments may abuse the power once they have it, although we want to believe that this is not the case in advanced economies. If the public still has such concerns, the demand for such CBDCs could be low, resulting in central banks that address privacy concerns in their legal frameworks receiving the strongest demand for their digital currencies.

More frequent bank runs

CBDCs could make bank runs easier. During a time of stress in the banking system, people could withdraw deposits and put them into CBDC, heightening bank stress and



increasing financial stability risks. However, in such cases, the central bank could introduce temporary limits, either on transfers into central bank accounts and/or deposit withdrawals, which already happens during bank runs.

In the US, the Bank Secrecy Act requires cash withdrawals over \$10,000 to be disclosed to the Office of Foreign Asset Control (OFAC). Business CBDC wallets for the Bahamas Sand Dollar, the first CBDC to be rolled out, are subject to a maximum cap of \$1mn.

Similar measures may also be applied to future CBDCs, preventing them from becoming a large-scale store of value. Having said that, suspending full interchangeability of CBDCs with other forms of money is not ideal and could fragment the payment system. But again, such risks do not apply in the case of indirect CBDC.

What are the benefits to CBDC adoption by central banks?

A more effective payment system than cash

Why carry cash around when you can pay electronically? Why have an actual wallet at all when you can have an electronic wallet? Paper money has a cost to print, circulate and replace, not to mention the risk of it getting lost or stolen. Storing paper money or keeping track of it can also have difficulties. With CBDCs, trips to the ATM can be avoided. Issues with having enough change during cash payments disappear. It will be easy to know exactly how much (electronic) cash you have. It is simply a much easier and cheaper form of payment.

Opportunity to increase legal economy

Use of CBDCs instead of cash could help increase the official economy. Anecdotal evidence suggests that the majority of large cash bills are used by organized crime, which is what forced the ECB to withdraw the €500 bill in 2016. India also withdrew high currency denominations in 2016 to reduce the size of the underground economy. Economist Ken Rogoff has estimated that about a third of US dollar cash in circulation is used for criminal activities and tax evasion. An interesting case study is the limit on cash withdrawals and the introduction of capital controls during the crisis in Greece in 2015, both of which led to a sharp increase in electronic payments and, as a result, a substantial increase in the official economy, in turn increasing efficiency and government revenues. We also note that most countries today do not allow large purchases with cash and most businesses would not accept it either. The BIS has also expressed strong concerns that "cryptocurrencies are in many cases used to facilitate money laundering, ransomware attacks and other financial crimes," which could be avoided with CBDCs.

Cross-border payments and fund transfer

CBDCs could also make cross-border payments and fund transfers considerably cheaper, easier and faster. It is not surprising that the trend is already towards electronic payments to be increasingly replacing cash payments in most countries. The question then is why do we need CBDCs when we are already moving to a world of mostly electronic payments? As the Bank for International Settlements (BIS) has argued, CBDCs offer in digital form the unique advantages of central bank money: settlement finality, liquidity and integrity can contribute to an open, safe and competitive monetary system that supports innovation and serves the public interest.

Another tool in the central bank toolkit?

For now, most central banks are not looking to CBDCs as another tool for monetary policy. As economists like Ken Rogoff have argued, if cash is replaced with digital money, then the central bank will have much more room to move interest rates into negative territory when they want to stimulate the economy. All they need to do is put a negative interest rate on reserves and digital money. They will not have to be concerned about people piling into zero-return cash. At this stage, however, central banks seem loath to open this politically sensitive topic.

Financial inclusion

Introduction of CBDCs would likely further enable financial inclusion for the low-income, unbanked, and rural population which has not yet entered the digital payment era.

CBDCs: a deeper dive

The simplest way to think about CBDCs is that it is digital cash. CBDCs are technologically more advanced than paper money, just as paper money is technologically more advanced than the heavy coins used in ancient Greece. Instead of transferring the ownership of a USD or a EUR bill to buy goods or a services, in the case of CBDCs, you transfer the ownership of the equivalent amount electronically. CBDCs have the full backing of the central bank, although they could be managed by designated private financial institutions, and are a direct liability of the central bank, denominated in the local currency.

In our view, widespread adoption of CBDCs is just a matter of time. The BIS has already given its (qualified) blessing: "CBDCs offer in digital form the unique advantages of central bank money: settlement finality, liquidity and integrity...(and) can contribute to an open, safe and competitive monetary system that supports innovation and serves the public interest." According to the BIS, 56 central banks are either already developing or are considering digital currencies, including all the major central banks covered by BofA. Furthermore, China is already gradually rolling out its e-CNY.

The literature suggests a wide range of benefits from well-designed CBDCs. Cash is costly to make and store, it can be hard to keep track of and it can be stolen or lost. Digital money can be transferred much more quickly, particularly for people without bank accounts. For example, during the pandemic, stimulus payments went out almost instantly to people with bank accounts but very slowly otherwise. As Fed Governor Brainard points out: "Cross-border payments, such as remittances, represent one of the most compelling use cases for digital currencies. The intermediation chains for cross-border payments are notoriously long, complex, costly, and opaque. Digitalization, along with a reduction in the number of intermediaries, holds considerable promise to reduce the cost, opacity, and time required for cross-border payments." She warns however, that CBDCs are only part of the solution: international collaboration on standard setting and protections against illicit activity will be required in order to achieve material improvements in cost, timeliness, and transparency."

Potential approaches to CBDC implementation

Indirect CBDC: mimics the traditional banking transmission mechanism

The indirect CBDC approach mimics the traditional banking transmission mechanism. Commercial banks continue to intermediate between central banks and the public. Instead of depositing cash, the public would deposit CBDCs in a dedicated CBDC account created by commercial banks. This approach is the easiest to implement, but one drawback is that the public remains exposed to the credit default risk of commercial banks for deposits in excess of the FDIC limit. The advantage, however, is that commercial banks do not lose any deposits as a result of the introduction of CBDCs.

Direct CBDC: directly deposit CBDCs into accounts created by central banks

Under the direct CBDC approach, the public would directly deposit CBDCs at virtual accounts created by the central bank, circumventing financial intermediaries such as commercial banks. This approach requires central banks to directly communicate with and owe liability to the public. As we discuss below, CBDC accounts created by central banks could act as competitor to traditional deposit accounts at commercial banks, since the public can choose between the two. However, we believe central banks are unlikely to choose this approach, due to the infrastructure development needs, maintenance costs and staffing for customer service requirements of serving accounts for the whole population.



Hybrid CBDC: central banks back CBDCs, but don't incur infrastructure costs

An alternative model to implement CBDCs is the hybrid CBDC approach. Payment service providers (PSPs) like commercial banks continue to directly face and provide deposit service to the public, but no longer owe direct liability to the public. Central banks would owe direct liability to the public, with the liability passed through PSPs. This approach allows for central banks to directly back the CBDC, but not incur the infrastructure costs associated with managing CBDC accounts for the general public. The BIS backs this approach.

Where do G10 Central Banks stand on CBDCs? How about China and the US?

G10 Central Banks

No G10 central bank has committed yet to launching a retail CBDC which, ultimately, may be a political decision. The G10 central banks may not be equally keen on CBDCs, but they all are monitoring international developments on this closely and the motivation of some has strengthened in recent months.

The Fed's interest has increased, with Chair Powell announcing in May that a report on CBDCs is due soon.

The ECB has published a report and performed experiments, with a follow-up report also due soon and with a plan of action in place.

With no plans to launch a retail CBDC, the BoJ, the BoC, the RBA, the RBNZ and the SNB are less keen on retail CBDCs. But some of them (especially the BoJ and the BoC) want to be well-prepared nonetheless. In fact, the BoJ is currently testing a Proof of Concept. Some (BoJ, SNB, BoC, RBA) have been actively exploring wholesale CBDCs – not the focus of this report.

The BoE remains engaged research-wise, while Norges Bank's motivation is renewed and strengthened. As for the Riksbank, having already completed the first phase of its pilot, it is at least one – big, we would argue – step ahead.

The G10 central banks consider international cooperation important and 7 of them (Fed, ECB, BoJ, BoE, BoC, Riksbank and SNB), along with the BIS, have put forward a framework outlining the foundational principles and core features of CBDCs.

China

China's digital currency pilot program (DC/EP) appears to be leading and pressuring other countries to follow suit. China's digital currency will use a real-time ledger, but it will be centralized and operated by the PBOC, unlike most digital assets that operate on a distributed ledger.

China is ahead with a Central Bank Digital Currency (e-CNY), which raises concerns that the government will track every transaction – both of its citizens and foreign companies in the country. China has seen a decrease in cash usage, partially due to the private payment services of companies such as Alipay and WeChat Pay. The PBOC's plan is to use approved commercial banks and nonbank payment firms to circulate the currency.

US

US Treasury Secretary Janet Yellen and Federal Reserve Chair Jerome Powell are focused on stablecoins. They fear that their very usefulness could create risks for consumers and potentially even for the financial system; Yellen is pushing financial regulators to "act quickly" in drafting stablecoin rules. Furthermore, others like Fed Vice Chair for Supervision Randal Quarles remains skeptical, which he outlined in "Parachute Pants and Central Bank Money." The tone of this piece is basically, "hold on a second, we need to think carefully about this." Quarles worries that the move into CBDC could be driven by "boosterism and the fear of missing out." He points out that "the US payment system is very good, and although it is not perfect, work is already underway to significantly

improve it." This includes speeding up payments, lowering transactions cost and bringing banking services to underserved populations.

Quarles goes on to warn about the risk of unintended consequences. A CBDC could cause a lot of deposits to leave the banking system, particularly in times of stress. The Bank of England paper suggested this might not be a major problem, but Quarles argues it could hurt the availability of credit and the central bank would need to either restrict the size of CBDC accounts or find ways to recycle the funds back into the financial system. Of course, Quarles does not have the final say at the Fed, but he is an example of the skeptical end of the debate.

A final "bit" of unfinished business is that any expansion of the payments system requires updating the plumbing. All of these payment methods have to link seamlessly together with the necessary regulatory controls on basic things like "know your customer," protection against money laundering, cyber security making sure smaller banks are not disadvantaged and so on. Talking to the people who run our own payments platforms, this will be a very complex, challenging process and hence will take some time to play out.

Still, others see stablecoins as the catalyst that will force central banks to dive into the digital coin business themselves, but at this point, there are more questions than answers.

Exhibit 79: G10 Central Banks and retail CBDCs

Not all G10 central banks are equally motivated

	Interest in retail CBDCs	Stage (research/official report/other details)	Motivation (or lack thereof)	Interest-bearing or not?
Fed	Moderate but increasing	Has conducted research/Official report due soon/ technological research and experimentation	Stablecoins; payments/cash; cross-border payments/foreign CBDCs; financial inclusion	
ECB	High	Research/Report Oct20/launched digital euro project in July 2021 /public consultation, experiments	Digitalization/strategic independence; payments/cash; cross-border payments/foreign CBDCs/private payment methods; financial inclusion	
BoJ	Low, but wants to be prepared	Research/Report Oct-20/Testing a Proof of Concept	Payments stability; however, falling cash usage less of a concern relative to elsewhere; cross-border payments/foreign CBDCs	
BoE	High	Research/Main report Mar-20, partial update in Jun-21/Public consultation	Payments/cash; stablecoins; financial inclusion; cross-border payments	
BoC	Low, but wants to be prepared	Research/Report Feb-20	Cash/payments although less of a concern than elsewhere; stablecoins and foreign CBDCs; financial inclusion less of a concern	Non-interest-bearing
RBA	Low	Research/No official report	Not particularly motivated	Baseline is non-interest-bearing
RBNZ	Low	Research/No official report	Payments/cash; cross-border payments; financial inclusion	Baseline is non-interest-bearing
SNB	Low	Research/Federal Council report in Dec-19	Not much concerned about payments/cash; financial inclusion, cryptocurrencies (although things may be different for stablecoins); worried about CBDC risks for monetary policy & financial stability	
Norges Bank	High	Research/Third-phase report Apr-21/experimentation part of the fourth phase	Payments/cash; stablecoins; foreign CBDCs	
Riksbank	High	Research/Several reports/First phase of pilot completed in Apr-21	Payments/cash; stablecoins; cross-border payments	Technical solution compatible with both

Source: BofA Global Research, G10 central bank websites

Note: Degree of interest is BofA Global Research assessment



Non-Fungible Tokens (NFTs)

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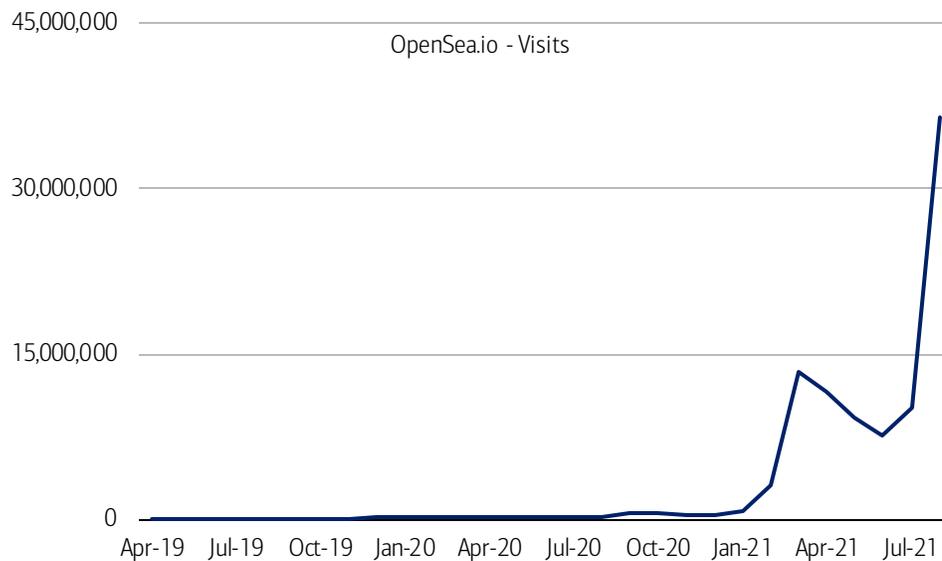
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NFTs are one of the hottest segments of the digital asset ecosystem. Corporates, celebrities and regular individuals are getting involved. We haven't seen government involvement yet – for or against – but it's likely only a matter of time. OpenSea, the largest NFT marketplace, had \$3.4bn of sales in August from 218k registered users across 1.7mn NFTs sold (that's up from \$250mn in August 2020 across all NFT platforms).⁵¹ There are concerns that we may be nearing some form of correction as NFTs enter the “hype phase” of adoption (Exhibit 80) and emerge as a new status symbol (we would still prefer a Lamborghini).

Exhibit 80: OpenSea.io site visits increased 11,859% in Aug'21 y/y

OpenSea is the largest NFT marketplace



Source: Similarweb
Data through 8/31/21

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⁵¹ Dune Analytics (<https://dune.xyz/rchen8/opensea>), NonFungible.com



What is an NFT?

A NFT is a non-fungible token, which means it's unique. For example, bitcoins are fungible – one coin is the same as any other – while a one-of-a-kind trading card is unique. The technical definition of an NFT is a blockchain-stored certificate of authenticity for *unique* digital or physical objects. The transaction and ownership information are verified through decentralization, recorded within the blockchain and seen as tamper-proof (immutable).

Specifically, the digital artwork file itself is not the NFT and is not stored via the blockchain. Only the proof of ownership information is stored. Currently, since the most widely used application of NFT is ownership of digital files, such as digital art work, the word NFT is used in conjunction with digital artworks. But NFTs can also be used to authenticate physical assets. For example, at the end of 2019, Nike explored authenticating physical, collectible shoes with digital NFTs (more detail in the section: NFT as a certificate of authenticity for real-life objects).

At the moment, the vast majority of NFTs are built within the Ethereum blockchain network, likely at least partly responsible for ether's recent price appreciation. This is not a necessary requirement. There are new rising blockchains, such as Cardano and Solana, that also support NFT minting, but Ethereum currently dominates the NFT market (Exhibit 81). Note that the Bitcoin blockchain does not support NFTs.

Exhibit 81: Top 20 NFT projects have seen \$7.2bn in total trading volume

Ethereum is the most widely used blockchain network for NFTs

Project	Network	Total Trading Volume All-Time (\$mn)
Axie Infinity	ETH	1920
CryptoPunks	ETH	1250
NBA Top Shot	FLOW	678
Art Blocks	ETH	659
Bored Ape Yacht Club	ETH	453
Inertial Moment	ETH	400
Mutant Ape Yacht Club	ETH	230
Loot	ETH	225
Meebits	ETH	209
Rarible	ETH	150
PUNKS Comic	ETH	139
ON1 Force	ETH	129
VeeFriends	ETH	115
Parallel Alpha	ETH	113
Pudgy Penguins	ETH	110
Zed Run	ETH/Polygon	90
Bored Ape Kennel Club	ETH	82
Cool Cats	ETH	80
Curio Cards	ETH	80
Foundation	ETH	76

Source: DappRadar

NFT collections are ranked by USD trading volume since project inception as of 9/8/21

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How are NFTs related to cryptocurrencies?

Cryptocurrencies and NFTs are similar given both are built on blockchain networks. The difference is that cryptocurrency is fungible, or interchangeable, unlike NFTs, which are unique. For example, a \$1 bill is interchangeable with any other \$1 bill, but an original painting or a house is unique and can't be swapped for an identical asset.

Ethereum-based NFTs are built with the ERC-721 token standard, which represent a class of unique assets and was introduced in 2017 with the CryptoKitties game, while Ethereum-based cryptocurrencies are built with the ERC-20 token standard and are interchangeable. The difference in the token standard is what allows NFTs to be unique.



Both Ethereum and Ethereum-based NFTs benefit from the decentralized and network-authentication capability of blockchain technology. Conceptually, one can think of ether as the medium of exchange specifically for NFTs. In practice, NFTs built on the Ethereum blockchain are quoted in ETH, and buyers normally pay with ETH.

Main marketplaces for NFT transactions

Investors can currently transact with NFTs via dedicated online platforms or auction houses. OpenSea, Rarible and SuperRare are the three largest online marketplaces for NFT items and they only accept ether as the method of payment. Auction houses like Christie's and Sotheby's also host auctions for the high-profile NFT items and are responsible for some of the most lucrative NFT transactions to date. The auction houses accept a variety of traditional payments, including ether. Recently, NFTs have been in the media when Beeple, the digital artist (real name: Mike Winkelmann) sold an NFT he created called "Everydays: the First 5,000 Days" – a collage of 5000 digital images – for \$69mn at a Christie's online auction in March.

An indicator of NFT interest is the number of new active wallets over a period of time and the percent of those wallets that remained active in the following weeks or months – 60k new wallets interacted with NFTs during the peak hype phase from March through April and 25% of those wallets interacted with NFTs over the next 5 weeks, indicating that a significant number of new users who were attracted to NFTs, have remained active.⁵²

OpenSea, an NFT marketplace, had over \$1bn of NFT on-chain trading volume in a single week at the end of August, according to DappRadar.

We've mentioned different types of tokens throughout our report. See Exhibit 82 for a refresher.

Exhibit 82: Token types

Breakdown of fungible and non-fungible token types

FUNGIBLE TOKENS	NON FUNGIBLE TOKENS	RESTRICTED FUNGIBLE TOKENS	RESTRICTED NON FUNGIBLE TOKENS
<ul style="list-style-type: none"> ▶ In Game Points ▶ Stable Coins ▶ Loyalty Points ▶ System Credits ▶ Cryptocurrencies 	<ul style="list-style-type: none"> ▶ In Game Items ▶ Supply Chain ▶ Real Estate ▶ Identity ▶ Certifications ▶ Collectables 	<ul style="list-style-type: none"> ▶ Securities ▶ Gov't Issued Fiat ▶ Certifications 	<ul style="list-style-type: none"> ▶ Real Estate ▶ Ownership Registries ▶ Regulatory Certifications

Source: An example of asset types provided by Algorand

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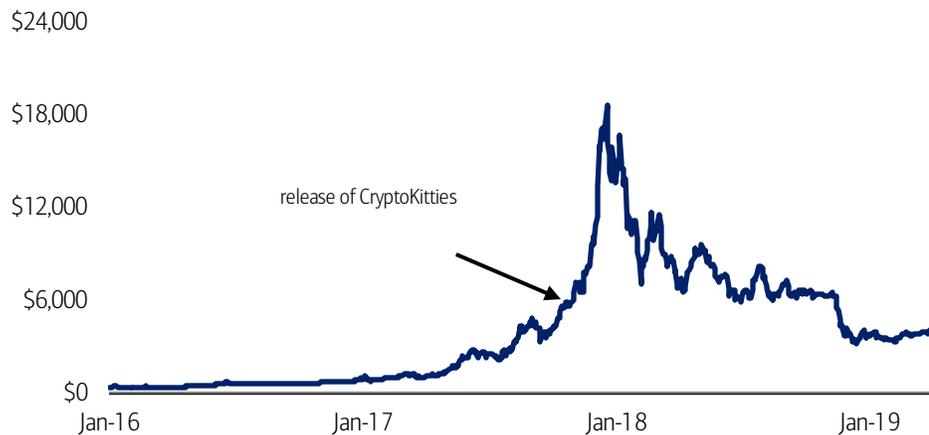
NFT started off as part of a game

The first time NFT received mass mainstream media attention was likely through a blockchain-based game called CryptoKitties (Exhibit 83). The game was built with Ethereum blockchain network, and first introduced in October 2017, amid the 2017 digital asset bull market. The game allows players to adopt, breed, and trade unique digital "cats."

⁵² NonFungible.com

Exhibit 83: CryptoKitties was released amid the digital asset bull market

Bitcoin price from 2016-2019; the last bull run peaked at around \$18,000



Source: Bloomberg, BofA Global Research

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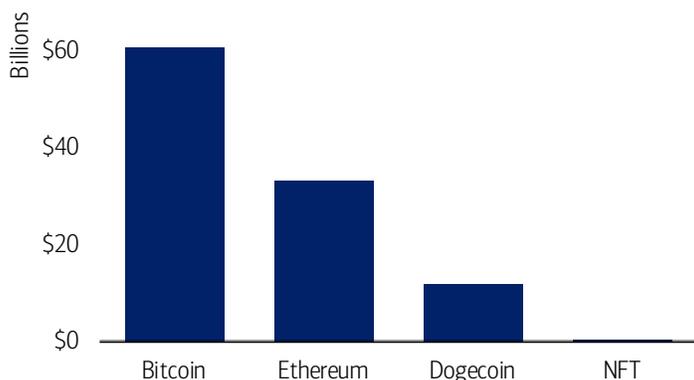
The game quickly gained popularity and the high volume of CryptoKitties transactions caused congestion in the Ethereum network as early as December 2017. By September 2018, a CryptoKitty named “Dragon” was sold for 400 ETH, worth \$172,000 at the time and ~\$1.4mn as of August 31. “Dragon” remained the most expensive NFT until 2021.

NFTs are not out-of-reach

The majority of NFT transactions are currently for collectibles and digital arts; these two categories account for more than 90% of the entire market. It is also worth noting that although the most widely reported NFT transactions are multi-million dollar deals, the average price of an NFT is much lower (Exhibit 85). The top-10 most actively traded NFTs from Nifty Gateway have an average original price of c.\$850, and an average resale price of c.\$1,745. Given the higher average resale value, it is possible that some of the demand is driven by speculation of possible future capital gains, as well as an intrinsic demand for the underlying collectible or artwork due to inherent scarcity.

Exhibit 84: NFTs trading volume is nowhere close to cryptocurrency

Average daily trading volume (\$bn) for April 2021; bitcoin has the highest average daily trading volume at more than \$60bn USD

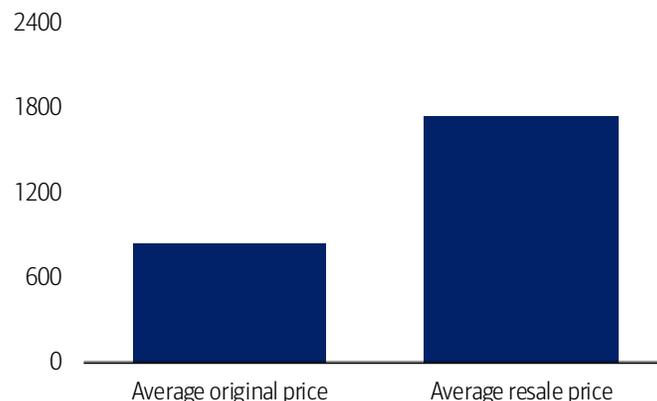


Source: CoinMarketCap.com, BofA Global Research

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Exhibit 85: Most NFTs are still affordable

Average original and resale price of top 10 NFTs from Nifty Gateway; both average original and resale prices are below \$2,000



Source: Nifty Gateway, BofA Global Research

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Secondary market plays a major role for NFTs

The NFT market is also characterized by primary and secondary markets. The primary market consists of the initial sales of NFTs from the creator to the buyer, roughly analogous to the function of an IPO of equity or new construction of housing. The

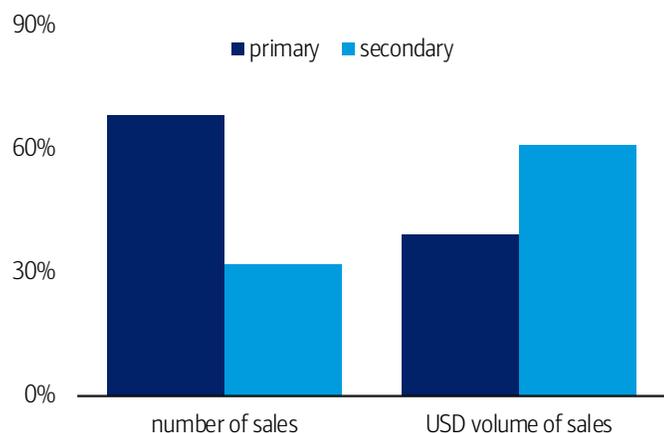


secondary market consists of peer-to-peer trading of NFTs, also like the secondary market for stocks and analogous to used home sales in real estate.

For both NFT art and collectibles, the secondary market has a lower or comparable number of unit sales, but at a higher USD-volume traded, establishing apparent appreciation in the market so far (Exhibit 86 & Exhibit 87). This means that NFTs have risen in value on average, following the initial sale. This may reflect momentum or perhaps the inherent scarcity of unique supply. Moreover, a larger share of the NFT buyers have been holding onto the NFTs after purchasing it, instead of actively trading their tokens.

Exhibit 86: NFT art market has higher value of secondary sales

Primary vs secondary market statistics for NFT art; NFT art primary market has higher number of sales while secondary market has higher USD volume of sales

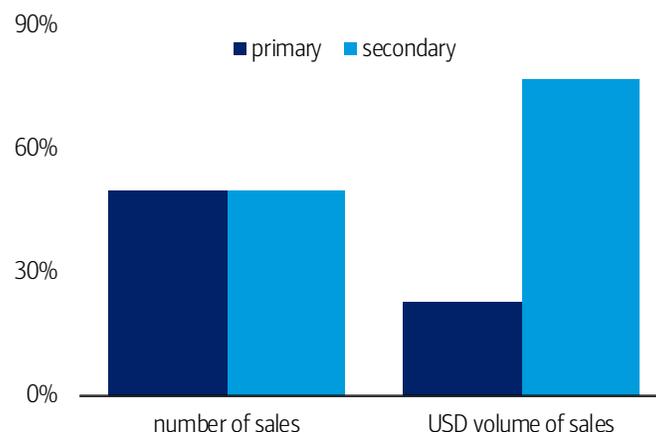


Source: nonfungible.com

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Exhibit 87: NFT collectibles also has more value in secondary market

Primary vs secondary market statistics for NFT collectibles; NFT collectibles has comparable number of sales in primary vs. secondary market, but higher USD volume of sale in secondary market



Source: nonfungible.com

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Regulatory oversight

NFT transactions could have tax implications. In the US, digital assets are currently recognized as a capital asset, not a currency. When an investor buys an NFT by paying ETH, a capital gain or loss is realized for the buyer on the amount of ETH used to pay for the transaction. If the same investor resells the NFT, another capital gain or loss is realized. In the case of Winkelman’s NFT auction, because it is not a resale, profit earned by Winkelman from the auctions is recognized as ordinary income.

Potential benefits of NFT

NFT as a certificate of authenticity for real-life objects

At the end of 2019, Nike was awarded a US patent for the “method of generating cryptographic digital assets for footwear.” The method would allow Nike to manufacture digital footwear in the form of NFTs named “CryptoKick”. Cryptokicks currently only exist virtually and may also be traded virtually. They may be linked to physical Nike footwear in the future. Buyers of physical Nike shoes would be granted NFT Nike shoes at the same time, ensuring proof of ownership of the physical shoes. When the said buyer resells the shoes to someone else, the NFT and the physical shoes would be both passed onto the next owner.

One of the motivations for this initiative by Nike is the need for sneaker authenticity in its large and growing secondary market for collectible sneakers, valued at \$6bn globally in 2019. In many cases, the resale of a pair of sneakers has a higher price than the original sale due to scarcity and anticipated demand. As the resale takes place between individuals, and knock-off sneakers are rampant, proof of authenticity has gained vital importance.



The Nike patent digital footwear initiative could have much wider implications, when the concept is extended to not only shoes but also real-life collectibles and artworks. Sellers with NFT contracts for the physical product they sell would be much more credible. Moreover, as transactions are recorded on the blockchain, sellers also would not be able to dupe prospective buyers by selling the same object twice. Recently, Justin Sun, CEO of TRON, purchased physical artwork by Picasso and Warhol and registered the artwork on the blockchain.

NFT use cases in the media and entertainment industry

There appears to be practical use cases for NFTs in the media and entertainment industry. We expect adoption of NFTs by most studios over time. The foundation of media companies is their IP and content assets, which provides ample source material to create NFTs and could support demand for a marketplace of these new assets when coupled with a loyal and engaged fan base. The market is in early stages and most media organizations have not yet participated in any meaningful way, but all are weighing the opportunity. We see several potential benefits of NFT adoption by creators/owners in the media and entertainment industry: 1) a new way to create a monetization stream for content and existing assets by engaging with the consumer directly; 2) a way to reduce piracy due to blockchain technology's authentication and verification capabilities; and 3) the ability to maintain ongoing (partial) ownership of an asset, even through multiple rounds of resale, thereby deriving continued economic upside as an asset accretes in value over time. Our view is that any meaningful NFT market adoption will reinforce the value and importance of IP and content, but in the near term, we expect it to have a minimal P&L impact.

To date, there have been a number of media-related NFT transactions, including the NBA's launch of Top Shot; Autograph's partnerships with Tom Brady, Tiger Woods and Wayne Gretzky; Kings of Leon becoming the first band to sell a new album NFT; and the sale of *Claude Lanzmann: Spectres of the Shoah*, which was the first Oscar-nominated documentary to be sold as an NFT. As evidenced by these examples, as well as the others listed in Exhibit 88, the potential range of media items that can be sold as NFTs is extensive. However, this marketplace remains in very early innings and will likely take time to evolve as several companies and leagues, such as the NFL, are taking a more cautious approach to the marketplace. (The NFL is not allowing teams to sell NFTs.)

Exhibit 88: Select NFTs in media

NFT sales have ranged from new release albums to NBA highlights, independent film financing to film access

Date	Seller	Description	Value
Oct. 2020	NBA	NBA Top Shot – NFT marketplace for highlight clips and collectibles	\$700mn and ongoing
Feb. 2021	Shawn Mendes	Partnership with Genies to sell digital goods	N/A
Feb. 2021	3LAU	Various digital items incl. a custom song, access to new music, art	\$11.6mn
Feb. 2021	Grimes	Digital art	\$6mn
Mar. 2021	Kings of Leon	New album, perks for live shows and digital art	\$2mn
Mar. 2021	Steve Aoki	New music and art collection	N/A
Mar. 2021	<i>Claude Lanzmann: Spectres of the Shoah</i>	First ever Oscar nominated documentary sold as NFT	N/A
Mar. 2021	Associated Press	Visual depiction of Electoral College map from space using AP election data	\$180k
Apr. 2021	The Weeknd	Collection of new music and limited-edition art	\$2.3mn
Apr. 2021	Trevor Hawkins	<i>Lotawana</i> – financing for film and access to premiere	N/A
May. 2021	Associated Press	Series of 10 NFTs representing iconic photographs	N/A
Jun. 2021	Gannett	First newspaper delivered to the moon – 50 years of space coverage	\$8.2k
Jul. 2021	MLB	Lou Gehrig's "Luckiest Man" speech	N/A
Jul. 2021	South China Morning Post	ARTIFACT litepaper for recording historical accounts and assets	N/A
Aug. 2021	Disney/Marvel	Inaugural series of classic Marvel comic books	\$6.99
Sept. 2021	La Liga / Sorare	Fantasy football cards	N/A
Sept. 2021	iHeartMedia	"Poker Chip" with eligibility for limited edition NFT by Cory Van Lew	N/A

Source: BofA Global Research

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Movie and television studios also have a trove of IP and content that could potentially be sold as NFTs, including iconic movie and TV show scenes. NFTs have also been used to help finance films. Filmmaker Trevor Hawkins created 1k tokens each priced at \$1k, which represented shares of ownership and provided profit participation of his independent film *Lotawana*. In addition to using NFTs to help finance the films, \$100 tokens were also created, which offered access to the movie's online premiere.

NFT as a cost-effective channel to reach customers

As Aston Martin returned to Formula One for the first time in 60 years, it created NFT video clips to capture historic moments from the races in March 2021. Each video clip was sold for \$3,000, and hundreds of these NFTs were bought from the initial sale, most likely by racing fans. The NBA has also been exploring the benefit of NFTs as well. NBA's TopShot is the official site selling digital highlights from the basketball games in the form of NFTs, similar to sports trading cards from the 1990s. It has been popular among basketball fans.

Compared to the cost of creating and distributing physical peripheral product to consumers, the cost of creating and distributing NFT peripheral products is much lower. Moreover, compared to physical products, NFTs cannot be stolen or tampered with, which supports their value from dilution by unauthorized copies. In this aspect, NFTs provide real-life benefits to both corporations and consumers.

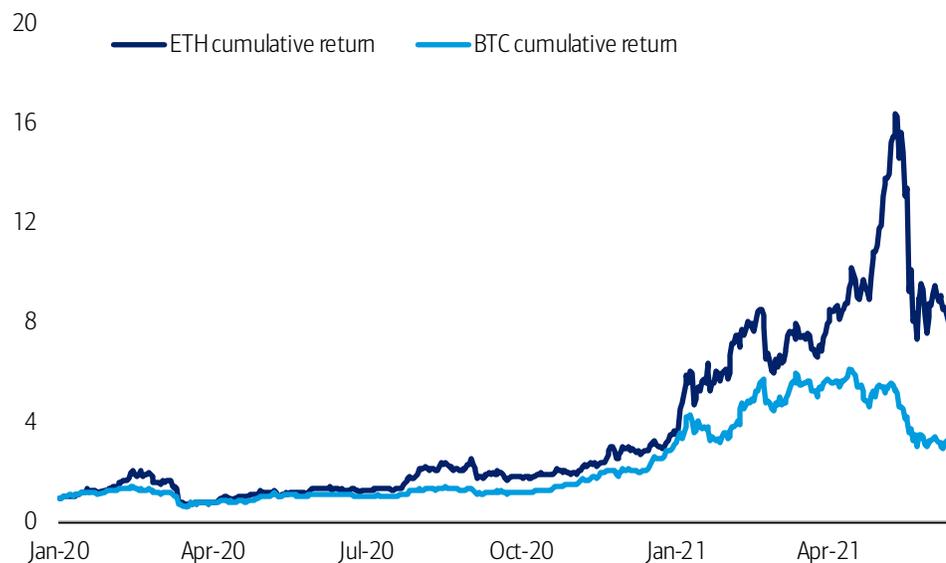
Potential risks

Risk of self-promotion

Since the majority of NFTs are built with the Ethereum blockchain network, their rising popularity has benefitted the valuation of ETH more than bitcoin (Exhibit 89). Part of the recent outsized gains in ETH may be attributable to the marketing promotion of NFTs by ETH investors. (Alternatively, some ETH outperformance in Q1 may have been unrelated to NFTs, e.g. supported by Canada and Germany approving ETFs on ETH and investors anticipating review by US regulators.)

Exhibit 89: NFTs have contributed to the rise in ETH value this year

ETH and BTC cumulative return since 2020; surge in ETH price after March 2021 has led to ETH's cumulative return more than doubling BTC



Source: Bloomberg, BofA Global Research

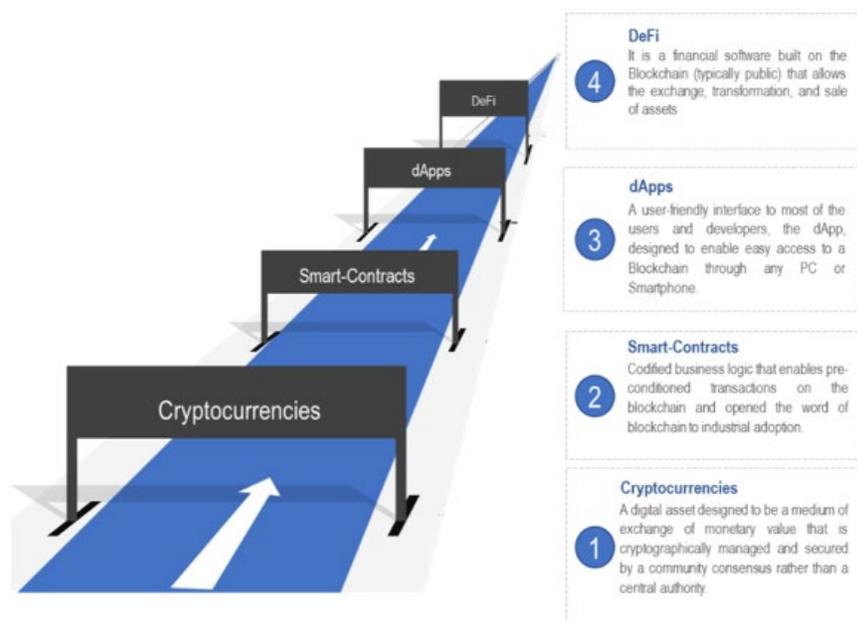
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Decentralized Finance (DeFi)

The Decentralized Finance (DeFi) ecosystem has grown significantly in the last 18 months due to smart contracts enabling the creation of distributed apps (DApps). We see significant value in the intermediate-term for DeFi DApps, with hundreds of companies focused on the space (although many are just 2 people in a garage).

Exhibit 90: Finance 2.0

Where is the digital asset ecosystem headed? From cryptos to DeFi



Source: Bipconsulting.com/insights/defi-the-new-financial-revolution

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Ethereum – enabling Finance 2.0

Ether's price rose 895% in the 12 months ending June 2021 and aggregate trading volume on Coinbase increased to \$1.4tn in 1H/21, up 1,461% y/y, mainly due to increased Decentralized Finance protocols built on the Ethereum blockchain. Ethereum is currently the default blockchain for most Decentralized Applications (DApps).⁵³ Additionally, the Ethereum 2.0 roadmap is finalizing a shift to “proof of stake” vs “proof of work” that should enable ether 2.0 to be a yielding asset.

After Bitcoin, Ethereum was created as the next stage of blockchain technology to enable user-issued assets, stablecoins, prediction markets, decentralized exchanges and more. It introduced general-purpose programmability, allowing blockchain-based contracts that can hold digital assets and transfer them according to pre-defined rules (smart contracts), as well as support non-financial components.

Transition to Ethereum 2.0 is underway with progress toward the Ethereum Improvement Proposal (EIP) 1559. EIP-1559 is a milestone in the roadmap to move the network to a proof of stake consensus mechanism from a proof of work. Under EIP-1559, each transaction will involve burning the gas (transaction) fee, automatically decreasing circulating supply. A significant amount of ether is locked in smart contracts or staked, and due to the new gas burn mechanism, prices for the coin are rising.

The Ethereum blockchain enabled the creation of new digital asset products, like binary futures contracts and tokenized stocks.

⁵³ Coinbase's H1 2021 in Review



Ethereum is facilitating millions of transactions through numerous DeFi services, metaverse games and NFT services built on top of the network. It's estimated that there are now 20mn+ monthly active user accounts using Ethereum.⁵⁴

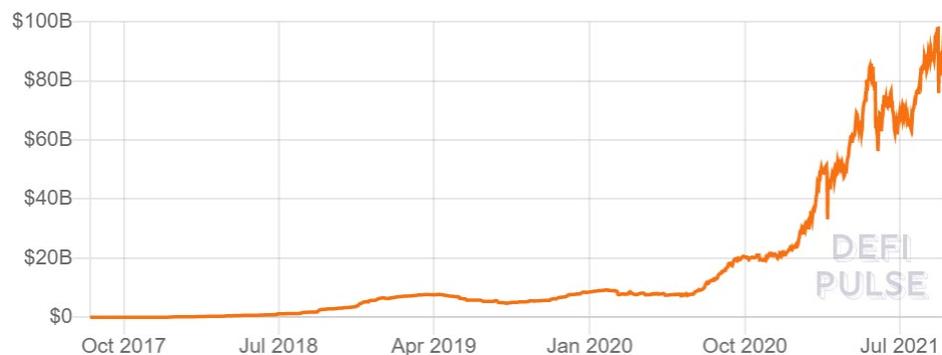
What is Decentralized Finance (DeFi)?

DeFi is an ecosystem that allows users to utilize financial products and services, such as lending, borrowing, insurance and trading, without relying on a traditional financial institution. The goal is to “disintermediate” finance, using software to eliminate the need for trust and middlemen from transactions. These financial services and products are built via DApps and the majority of these applications are being built using Ethereum with other platforms such as Solana, Cardano and Polkadot emerging.

DeFi's promise is to disintermediate traditional centralized financial models, enabling anyone with internet access to participate. The goal is to algorithmically govern instructions between peers, permitting them to buy, sell, lend and borrow more efficiently and economically. DeFi services and applications attempt to replicate existing financial offerings on a new technology rail (blockchains). Our view is that it's unlikely DeFi will replace the traditional financial infrastructure soon, but its application technologies are likely to provide near-term efficiencies and increased transparency to existing firms especially in the areas of tokenization. Growth of DeFi can be tracked through the total value locked (TVL) of USD in contracts. TVL is \$80bn, up from ~\$1bn in March 2020 (Exhibit 91).

Exhibit 91: Total Value Locked in DeFi contracts is \$80bn+

TVL has increased by 277% ytd through 8/31/21



Source: defipulse.com

TVL measures the total balance of ether and ERC-20 tokens held by smart contracts on the Ethereum blockchain.

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Risks

Two significant risks for DeFi are hacks with the potential to lose assets with minimal recourse and projects failing (rug pulls) where developers abandon projects.

Regulatory

The government and regulators rely on centralized financial institutions like banks to provide information, such as AML/KYC, to prevent illicit activities and capital appreciation data for tax purposes. DApps are not built to capture this information, but ultimately DeFi companies will likely need to automate certain procedures to provide this information.

DeFi main categories

We'll cover 9 categories detailing various DeFi ecosystems with a range of financial products and services that are aiming to emulate or augment traditional financial industries, such as banking, insurance, bonds and money markets.⁵⁵

⁵⁴ Simon Kim, CEO at Hashed

⁵⁵ We are inspired by "How to DEFI" by Coingecko

Stablecoins

Stablecoins, backed by “stable” assets such as the US dollar, were created to address digital asset volatility. Stablecoins’ aggregate market value was ~\$120bn at the end of August, up from ~\$30bn at the beginning of January as DeFi adoption has accelerated.⁵⁶ Many DeFi applications require a transfer to a stablecoin from the holder’s digital asset to take advantage of DeFi services. Regulatory oversight is growing for stablecoins to ensure they are backed as advertised. Tether (USDT) an early stablecoin needed to adjust its marketing because its reserves were not backed 1:1 with USD. Decentralized Stablecoins aim to address the trust concern as they operate on decentralized ledgers, are overcollateralized and are governed by a decentralized autonomous organizations (DAOs) such as Maker DAI.

Lending and borrowing

Investors can earn interest on their digital asset holdings (usually at a higher interest rate than at a bank) or borrow against their digital asset holdings by overcollateralizing (but without needing a typical credit score). Service providers include BlockFi, GeminiEarn, Kraken Bank and Compound. Compound is decentralized with borrowing and lending automated – assets are \$18bn+ earning interest.⁵⁷ Risk to lenders earning interest is that their assets are not FDIC insured as they would be at a traditional bank earning interest.

Exchanges

Exchanges such as Coinbase or Binance are centralized; they are both the custodian and intermediary for the digital assets. However, since they are centralized, users’ assets could still be at risk if the exchange gets hacked or they default on other obligations. In response to this centralized risk, decentralized exchanges are popping up with the aim of not taking custody (i.e. Uniswap, Serum and Blockchain.com). Note that the traded assets are currently focused on cryptocurrencies, however, in the long term this framework can extend to other asset classes, such as equities, commodities and rates.

Derivatives

The majority of the digital asset derivatives volume within the US has been taking place on the CME, primarily BTCUSD futures. However, the majority of the derivatives volume is taking place internationally (e.g. FTX or Binance) and some of the places have had a 100 to 1 leverage ratio on a 70 vol asset. The leverage has since come down at some of the derivatives exchanges. Similar to the exchanges section above, there are a new wave of ecosystems emerging that utilize decentralized frameworks.

Fund Management

Some DeFi projects have created decentralized passive income fund management. Part of the rationale is that the costs and the fund allocations are made in a transparent way.

Lottery

Creating a lottery system with a DeFi spin allows the removal of a custodian, but pools the capital while specifying the outcomes within a smart contract. Some lottery ecosystems allow the pooled capital to generate earned interest so that once the winner is paid out, the leftover funds are used to reimburse users who purchased a ticket.

Payments

The current traditional system used for fiat currency settlements is Swift, which was designed over 50 years ago. With some of the latest blockchain technologies, settlements can occur in seconds as opposed to in 2-3 days.

⁵⁶ *Theblockcrypto.com*

⁵⁷ *Compound.finance*



Insurance

While smart contract technology can be used for classic insurance products such as cars, home, health and life, DeFi can insure against losses if other DeFi products get hacked. For example, a smart contract insurance product could deal with rainfall for crop insurance, while detailing payment amounts, contract dates, the index to be measured, thresholds, and agreed payout value. According to Accenture, only 29% of customers trust insurers, so smart contracts could reduce the lack of trust for users and insurers.



Appendix I: Distributed Ledger Technology explained

Distributed Ledger Technology (DLT) and Blockchain – decentralized databases

Blockchain: a distributed database that maintains a growing list of ordered records called blocks:

A blockchain is a distributed database that maintains a growing list of ordered records called blocks. Historically, databases were centralized with the first non-computer database being the filing cabinet, which some of you may be familiar with. The first computer database was built in the 60s as lists with the items unconnected in the database. In the 70s, an IBM scientist introduced the relational database that Oracle brought to market, which became the dominant database through the 90s. The relational database was architected on the assumption that it would always be run on a single machine. Recently, Google Research introduced a distributed database architecture that may be adopted by enterprises.

DLT is decentralized; current database tech is centralized

The key difference between blockchain/distributed ledger technology and evolving database architectures is that blockchain/DLT architectures have no centralized authority. Current database technology (even distributed) are based on a centralized authority managing the data. Blockchain enables a set of peers (across the internet) to work together and create a unified and decentralized network. Blocks (time stamped transactions) are put together into a chain across multiple ledgers (databases) and the order cannot be changed (immutable). What does this really mean? It means that ownership, data, identity, payments, and anything that involves a centralized party, will be the shared responsibility of all network participants to verify, process and confirm.

Blockchain architectures are now increasingly being tested.

Exhibit 92: Centralized vs decentralized ledgers

Network participants share responsibility in a decentralized network

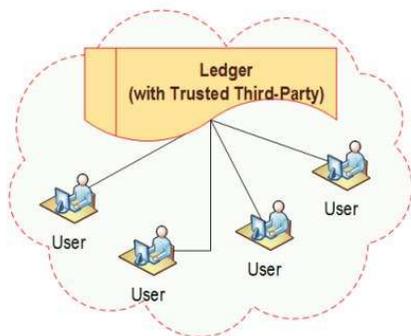


Figure 1. Traditional centralized ledger technology with a trusted third-party.

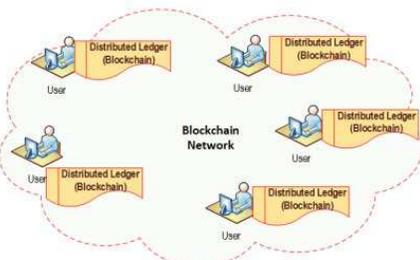


Figure 2. A typical example of Blockchain technology—distributed ledger technology—without a trusted third-party.

Source: Danda B. Rawat, Vijay Chaudhary and Ronald Doku, "Blockchain Technology: Emerging Applications and Use Cases for Secure and Trustworthy Smart Systems," *Journal of Cybersecurity and Privacy*, Vol. 1, No. 1, pp: 4- 18, Nov. 2020.

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What is Distributed Ledger Technology (DLT)?

Distributed ledger technology is a digital network of ledgers for recording transactions and their details in multiple places (nodes) simultaneously.

DLT is the framework that enables blockchain protocols such as Bitcoin, Ethereum, Dogecoin, etc.

For applications, there are two important differences to keep in mind – is the blockchain centralized or decentralized and is the blockchain permissioned or permissionless.

Exhibit 93: What's the difference?

DLT vs blockchain

DLT	Blockchain
A record of consensus maintained and validated by network participants	A type of DLT comprised of immutably recorded data that is validated, processed and confirmed by network participants and stored in blocks
Constructs a ledger and achieves consensus among participants without requiring trust	A type of DLT that constructs a ledger in a decentralized manner that requires consensus among network participants and makes it difficult for malicious participants to attack the network
Records new information in real time and only adds new entries for registered users	Blockchain uses a consensus algorithm, along with cryptographic hash functions, for increased security

Source: BofA Global Research, BI Intelligence, yourtechdiet.com

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Blockchain is the main underlying technology spawning applications across Finance (online payments, digital assets, remittances) and non-financial applications, such as smart contracts, the Internet of Things (IoT), reputation systems/digital identities, security services, wireless network and visualization. The key is that DLT applications eliminate or reduce the function of an intermediary, such as a bank or lawyer.

Distributed Ledger Technology-based networks are decentralized – the networks continue to work even if users (nodes) are added or removed. If failure occurs in parts of the network, the DLT-based network is always on.

Digital asset supporters and enthusiasts start with the mission of creating an open financial system to the world – not just for people in developed countries or who have bank accounts. The most enthusiastic supporters hope to change the world by using blockchain technology to democratize capital (provide banking for the unbanked), eliminate middlemen and re-humanize commerce. To participate in the digital asset financial system, you just need connectivity. If you can get online and access the internet, you can make a financial transaction using this technology.

Why distributed ledger?

- Unique – only one exists; can't be copied or "spent" twice
- Ownership – no question as to who holds it
- Transparent – everyone sees the same; any change is apparent
- Massive value pool at stake



Appendix II: Bitcoin & Gold

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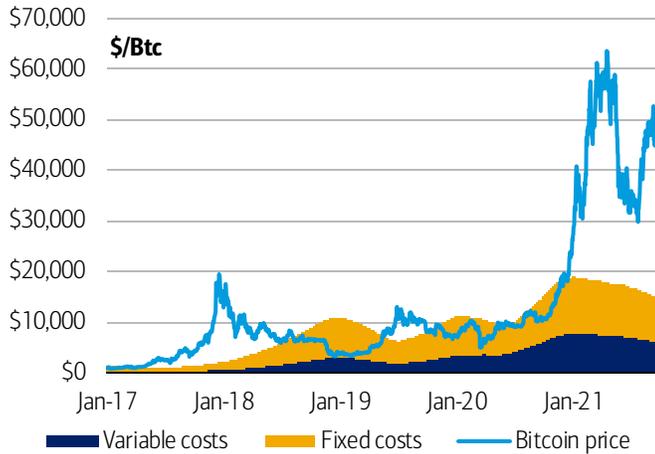
Bitcoin supply is designed to become increasingly constrained

As it is the case in all other commodities, supply and demand drive bitcoin prices. Also, by construction, the cost of bitcoin mining features prominently (Exhibit 94) in price discovery, particularly energy. Yet a key feature of this digital asset that makes it similar to gold is that supply is capped and designed to become increasingly constrained. When Bitcoin was launched in 2009, its supply was set to be maxed out at 21mn coins, and new coins have to be issued (or “mined”) constantly to reward the miners that “clear and settle” transactions on the blockchain. By design, the creators of bitcoin allowed more than 100 years to get to this maximum level of 21mn coins. Mining rewards are halved approximately every 4 years, which has positively impacted prices in recent years by artificially reducing supply growth rates (Exhibit 95). Similarly, commodities like gold that are also viewed as long-term stores of value, typically see limited supply growth of around 1.5% of the existing stock every year and are naturally scarce.



Exhibit 94: Bitcoin cost of supply

Most of the variable costs of bitcoin mining come from energy

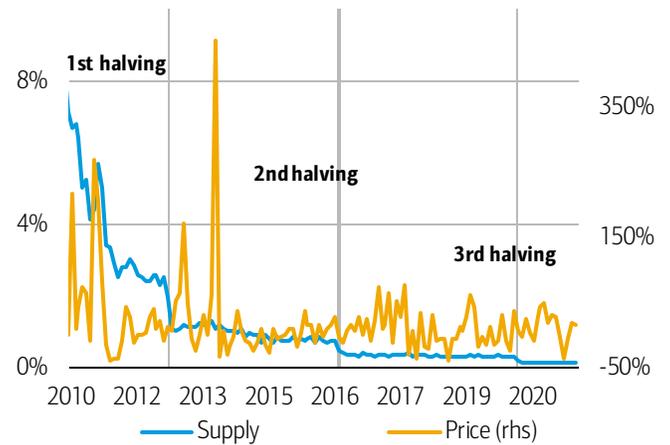


Source: Blockchain.com, ASICMinerValue.com, BofA Global Research estimates
 Notes: Assume 5c/kwh and annual mining hardware upgrades (20% resale value)

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Exhibit 95: Bitcoin supply growth and price changes

Halving events have positively impacted prices historically



Source: CoinMarketCap.com, BofA Global Research
 Bitcoin halving events are designed to take place approximately every 4 years

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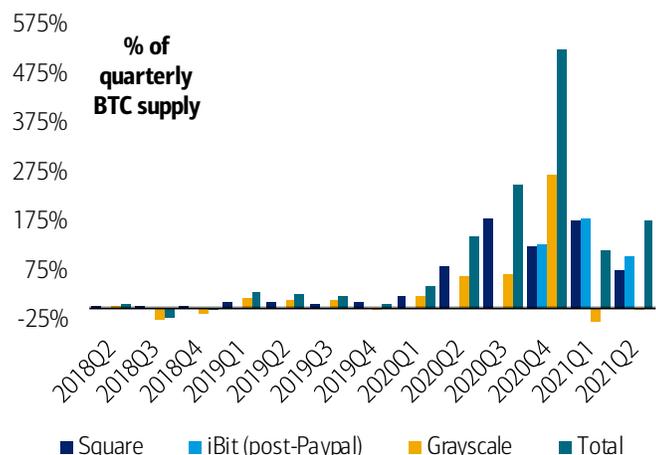
Institutional demand has become more active in the past year

With supply capped by design and supply growth built to halve approximately every 4 years, the various swings in bitcoin demand in recent years have been key to price changes. While there is no easy way to categorize bitcoin demand, we would differentiate between retail and institutional/whale demand for digital assets. For example, institutional announcements in the past year have led to major price increases (Exhibit 96), but also corrections, as a number of household names like Tesla, Square, and PayPal have incorporated (or pulled back from) bitcoin into their businesses, either as a treasury holding or as a means of payment. Partly because institutional flows have been hard to accommodate in such a small market, the price volatility of bitcoin has failed to come down even as prices have risen. Bitcoin's volatility is well above that of FX, gold and silver and its volatility in 2021 has remained in line with historical patterns (Exhibit 97).



Exhibit 96: Quarterly trading volume and change in GBTC and major institutional holdings relative to new bitcoin supply

Institutional demand is overwhelming supply

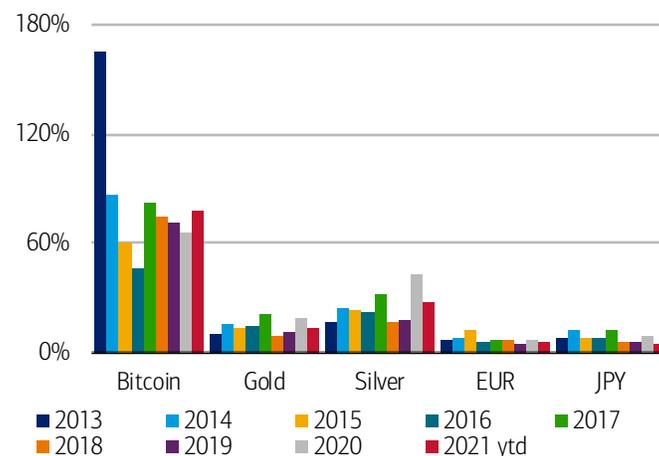


Source: Blockchain.com, nomics.com, The Block, Bloomberg, BofA Global Research estimates. Square and iBit reflect quarterly trading volume, and Grayscale reflects change in holdings based on AUM estimates.

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Exhibit 97: Yearly annualized standard deviations of daily returns

Bitcoin's volatility remains in line with prior years



Source: BofA Global Research, Bloomberg

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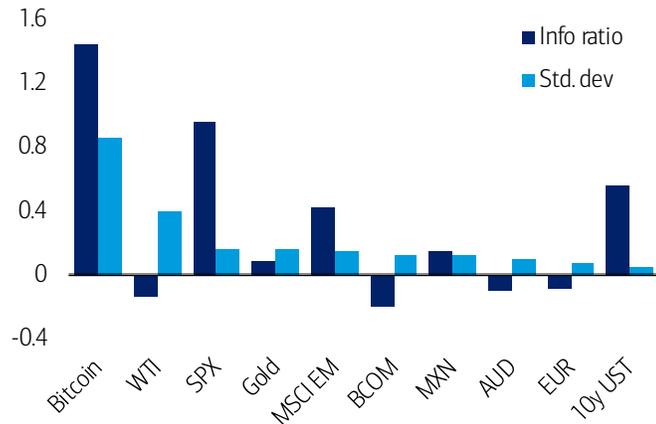
Just like gold, bitcoin is a unique asset with unique features

Bitcoin is a unique asset given its supply mechanics, ownership concentration and historical performance. Also, bitcoin has produced relatively high risk-adjusted returns, despite having one of the highest volatilities in the cross-asset space (Exhibit 98), as the idea of transferring value digitally between two parties without the need of an intermediary has gained traction. But just like bitcoin volatility is multiples of the volatility observed in other commodity markets, we also note that it vastly exceeds that of many Emerging Market FX. For instance, bitcoin is more volatile than currencies with severe capital controls (Exhibit 99), which tend to be EM countries with high inflation. On the positive side, bitcoin liquidity has improved dramatically in recent years. For instance, the notional dollar value of bitcoin trading volume has risen to over 10x that of GLD in the past 2 years. Large transactions are increasingly common in the digital asset space.



Exhibit 98: Bitcoin and cross-asset daily return information ratios and standard deviations over past 10 years

Bitcoin has the highest volatility and risk-adjusted returns relative to the cross-asset landscape

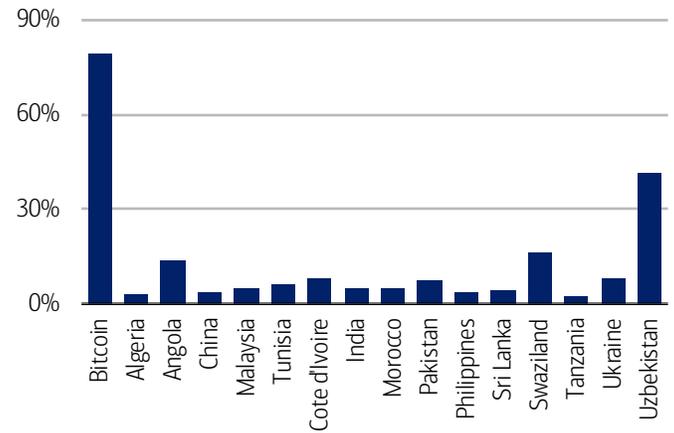


Source: BofA Global Research, Bloomberg

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Exhibit 99: Annualized standard deviation of weekly returns

Bitcoin is more volatile than currencies with significant capital controls



Source: BofA Global Research, Bloomberg

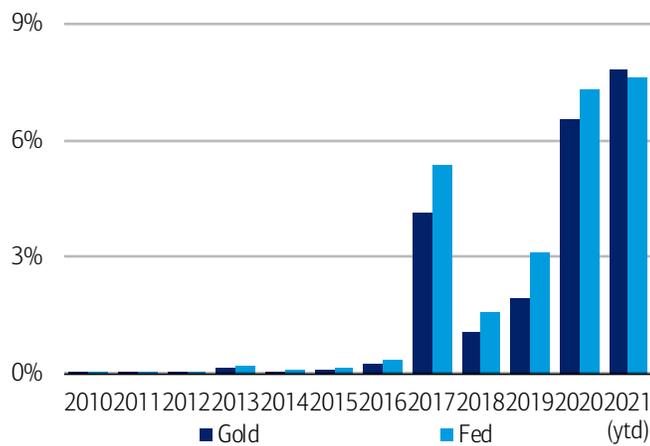
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The market value of Bitcoin has been rising relative to gold

Another way to look at the importance and growth trajectory of bitcoin is to compare it to the size of other major physical and financial assets. In particular, we believe assets like the Fed's balance sheet or the price of gold are relatively good reference points for bitcoin. In that regard, bitcoin's market value is still less than 10% of gold's market cap and the Fed's balance sheet, even after years of steady growth (Exhibit 100). The value of bitcoin is enormous relative to the largest silver ETF (SLV) and the physical stock of silver in vaults (Exhibit 101), underscoring the diminishing importance of silver as a reserve asset and the growing interest in digital assets. After all, one of the reasons bitcoin has value is because over 100 million people use it.

Exhibit 100: Bitcoin market value relative to gold and Fed balance sheet

Bitcoin's market value is still less than 10% of gold's and the Fed's balance sheet

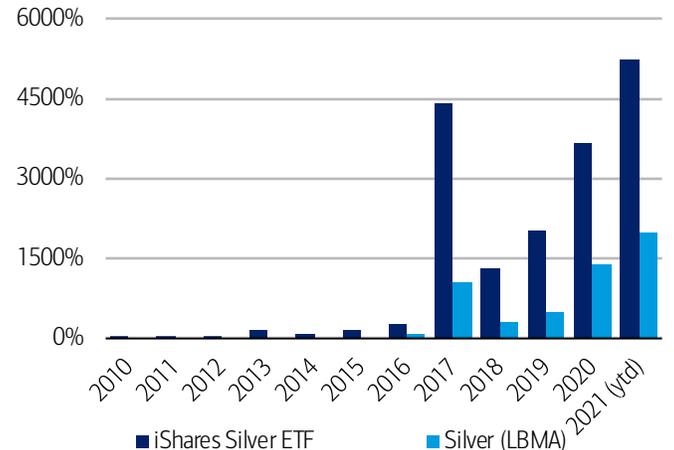


Source: BofA Global Research estimates, Bloomberg

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Exhibit 101: Bitcoin market capitalization relative to SLV ETF and silver at the LBMA

Bitcoin's market value is significantly larger than SLV's market cap and the physical stock of silver in vaults



Source: BofA Global Research estimates, Bloomberg

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Appendix III: Digital Assets & Mining

What is the process of proof of work mining?

Reminder: miners expend energy for the right to confirm transactions (and receive block rewards)

There are two main types of consensus mechanism used by blockchain protocols: proof of work (PoW) and proof of stake (PoS). We'll explain both over the next couple of sections, but the outcomes are ultimately the same: blocks of transactions are validated, processed and confirmed when added to the blockchain.

If we lose you at any point, just remember that miners expend energy for the right to confirm transactions, which are then added to a sequential list of all transactions since the blockchain's inception, in exchange for a reward. This process provides the security necessary to transact with someone anywhere in the world, who you've never met, without any intermediary to ensure the transaction is completed properly.

A Deeper Dive: PoW ultimately allows for trustless peer-to-peer (P2P) transactions

The Bitcoin blockchain, along with a significant number of digital asset blockchains, uses a proof of work (PoW) consensus mechanism, which ultimately allows for trustless peer-to-peer (P2P) transactions. We discuss three main types of nodes: full, light and mining (Exhibit 102). All of these contribute to maintaining the blockchain infrastructure and the integrity of the data stored. A node is any device connected to the blockchain, whether it is a computer, smartphone or hot storage wallet. Full nodes maintain a copy of the entire blockchain since inception, validate individual transactions and blocks of transactions, and update its copy of the blockchain continuously as new blocks are added. Light nodes, usually in the form of hot wallets, help out full nodes by maintaining a data-lite version of the blockchain. The process by which nodes come to agree which transactions are legitimate without a central authority is the "consensus" in "consensus mechanism."

Mining nodes, also known as miners, expend energy in the form of computing power to process and confirm blocks of transactions by adding them to the blockchain in exchange for block rewards (bitcoin), also known as coinbase rewards, and transaction fees (also bitcoin).

Exhibit 102: Node types

Nodes have different responsibilities for maintaining the blockchain

	Proposes new blocks of transactions?	Stores blockchain history since inception?	Validates new transactions?	Stores digital asset wallet balances?
Full nodes	No	Yes	Yes	Yes
Light Nodes	No	No	Yes	Yes
Mining Nodes	Yes	No	No	No

Source: BofA Global Research

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Miners attempt to solve a puzzle, which involves no skill or strategy

But how do miners confirm blocks of transactions after nodes verify them and what's the criteria to receive block rewards and transaction fees? Miners attempt to solve a puzzle, which involves no skill or strategy. Instead, the puzzle utilizes a 256-bit Secure Hashing Algorithm, also known as SHA-256, which takes a data input and compresses it into a unique 64-character output. See Exhibit 103 for an example of the output generated from two messages.



Exhibit 103: Cryptographic hash function

SHA-256 bit Secure Hashing Algorithm – changing 1 character produces an entirely different hash value

Message	Message hash value
Bitcoin 101	d27026240a739f642bb4c918605fd202c5d826afe75a90ebe317a170ce6bda65
Bitcoin 102	b67ebffc39d1e54a9d5b0834af67a798ff847845227944bc333f52a62ee5e8c5

Source: BofA Global Research

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It's important to understand that changing the last character from "1" to "2" in the messages above creates a completely different output and that the hashing function is a repeatable one-way function, meaning that identical inputs will always have the same output. It's easy to compute the output if given the input, but it's impossible to compute the input if given the output. This is what makes it secure. Miners select pending verified transactions from a waiting room called a memory pool, or mempool, to include in their block and then perform the SHA-256 hashing function, which uses data from the previous block called the root hash (which uses data from the previous block and so on until and you reach the genesis block and all blocks are accounted for that were ever processed) and the hash of the data from the pending verified transactions.

There is also a variable called a nonce (number only used once), which is what miners attempt to solve and where the puzzle comes into play. Miners continuously generate nonces through trial-and-error until the resulting hash is less than a target value, which the protocol automatically adjusts to ensure that the average time to find the random nonce that produces a hash less than the target value is ten minutes. The process of guessing a nonce that will produce a hash less than the target value is the "work" in "proof of work."

The beauty of the puzzle is that it's easy for the network to check that the transactions in a miner's proposed block are valid, while at the same time creating a barrier for bad actors to mine a block with invalid transactions because of the required computing power and resulting cost. If a bad actor attempted to alter a previous transaction in a block, the block's hash would change and reverberate up the blockchain so that the resulting root hash would also change. The puzzle that miners solve secures the network by preventing "double-spending," which is the ability for someone to send the same bitcoin to two different wallets, although the implications of double-spending are more problematic than this simple example.

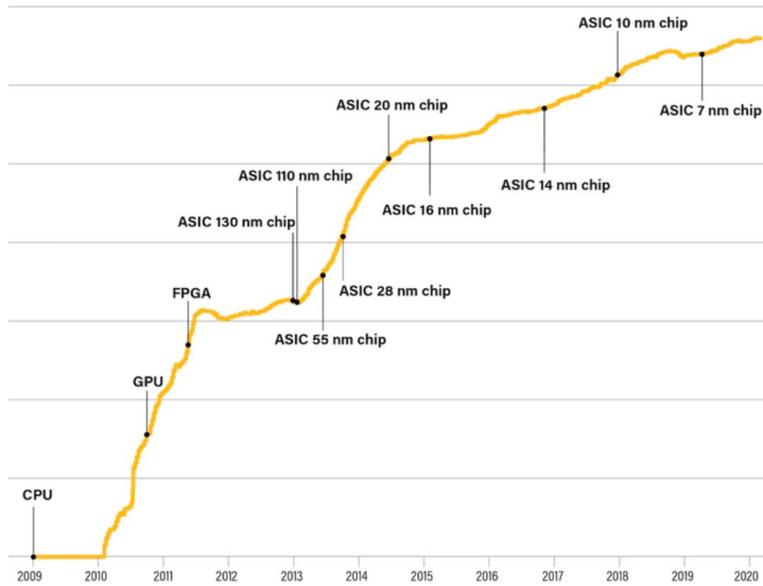
How profitable is PoW mining?

Digital asset mining profitability depends on three main inputs: Bitcoin's price, the network's hashrate and energy costs. The digital asset mining industry has evolved since the first bitcoin was mined in 2009 with innovation driven by bitcoin's market value rise. Competition for block rewards increases as bitcoin prices rise and the block reward becomes more valuable, driving innovation and adoption of new hardware with greater processing power. For the first two years of bitcoin's existence, mining devices that used CPUs (central processing units) were sufficient to compete for block rewards, but digital asset mining has evolved into a large and lucrative business that requires specialized ASIC mining equipment. See Exhibit 104 for a snapshot of how the mining industry has evolved.



Exhibit 104: Bitcoin mining difficulty over time

Introduction of ASIC mining devices has exponentially increased mining difficulty



Source: CoinDesk Research

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Miners frequently form mining pools, which aggregate computing power, to increase the chance of receiving a block reward. Essentially, you would have a better chance of winning the lottery with 10 tickets than with 1 ticket, for example. Bit Digital, a digital asset mining company has 32,500 mining rigs, which each cost about \$12k.⁵⁸ With \$390mn in equipment, it's easy to see why your personal computer can't compete.

Blockchain Efficiency: how is a blockchain that uses a PoW consensus mechanism efficient?

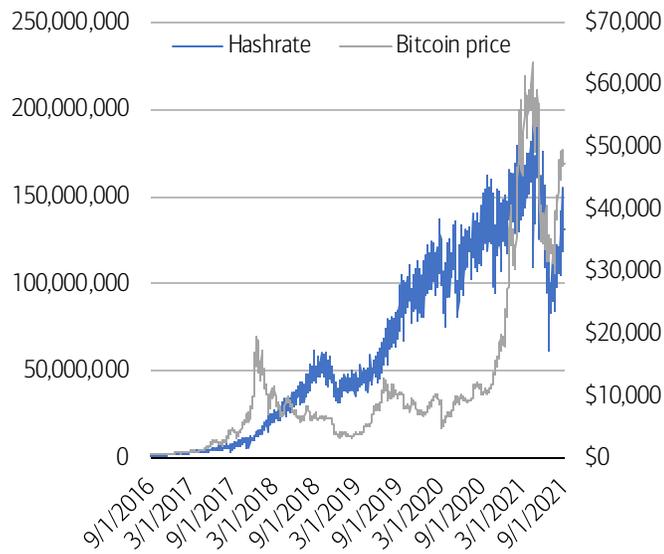
Hashrates – a measure of competition for block rewards – and bitcoin block size – a function of the number and size of transactions included in the block — decreased in July (Exhibit 105, Exhibit 106, Exhibit 107, Exhibit 108) as bitcoin prices fell and as transactions processed remained low on a historical and ytd basis (Exhibit 109 & Exhibit 110). A decrease in bitcoin prices generally leads to a decrease in hashrates and block size because the block reward that miners receive decreases in value as bitcoin prices fall. The decrease in the value of block reward results in miners going offline or attempting to decrease energy costs because the value of block rewards are not high enough to justify the energy input costs. It also can result in smaller block sizes because processing larger blocks requires more energy consumption from miners, which results in higher costs. However, after hashrates (competition) fell, miners were encouraged in August to go back online as bitcoin prices rose, which led to a subsequent increase in hashrates, block size and transaction count, exemplifying the network's efficiency.

⁵⁸ [Bit-digital.com](https://bit-digital.com)



Exhibit 105: Bitcoin blockchain hashrate (LHS) vs bitcoin price (RHS)

A rising block reward value incentivizes miners to participate in the network

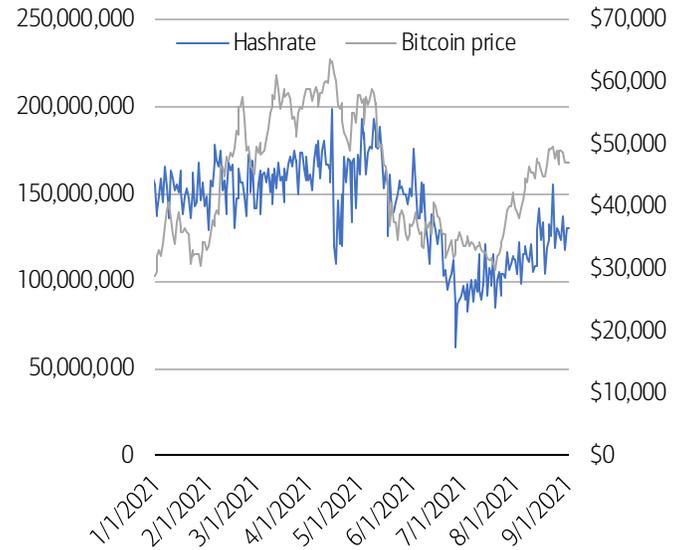


Source: CryptoCompare
 Data: 6/1/16 – 8/31/21. Hashrate measures the computing power dedicated to bitcoin mining on the network, calculated as the average difficulty divided by the average time between mined blocks for that day, expressed in TH/s.

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Exhibit 106: Bitcoin blockchain hashrate (LHS) vs bitcoin price (RHS)

Rising bitcoin prices in mid-July increased the value of block rewards and incentivized miners to participate in the network

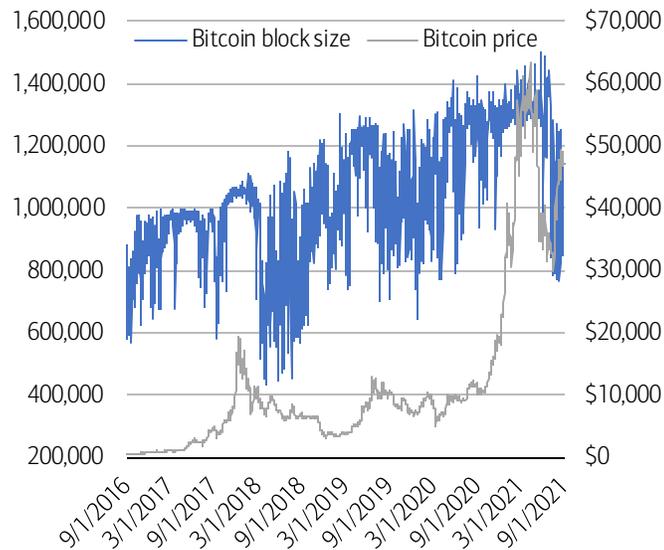


Source: CryptoCompare
 Data: 1/1/21 – 8/31/21. Hashrate measures the computing power dedicated to bitcoin mining on the network, calculated as the average difficulty divided by the average time between mined blocks for that day, expressed in TH/s.

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Exhibit 107: Bitcoin block size (LHS, bytes) vs bitcoin price (RHS)

Falling bitcoin prices incentivizes miners to mine more efficiently

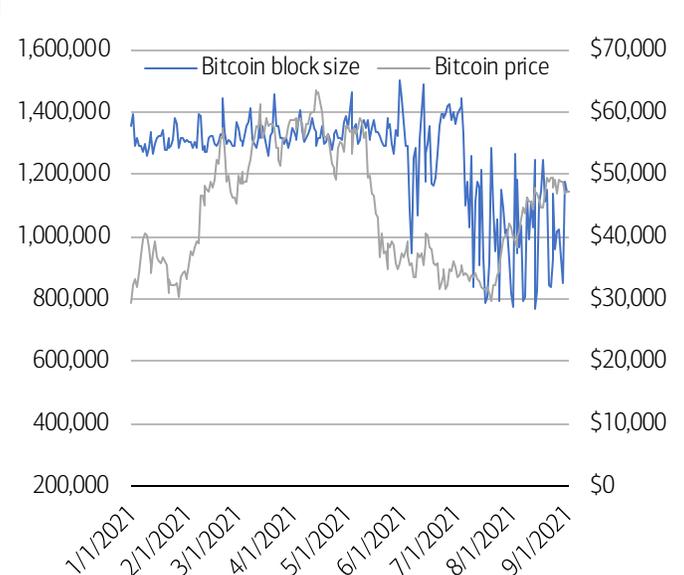


Source: CryptoCompare
 Data: 9/1/16 – 8/31/21. Bitcoin block size measures the average size in bytes of all blocks created that day.

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Exhibit 108: Bitcoin block size (LHS, bytes) vs bitcoin price (RHS)

Falling bitcoin prices in May led to a decrease in block size



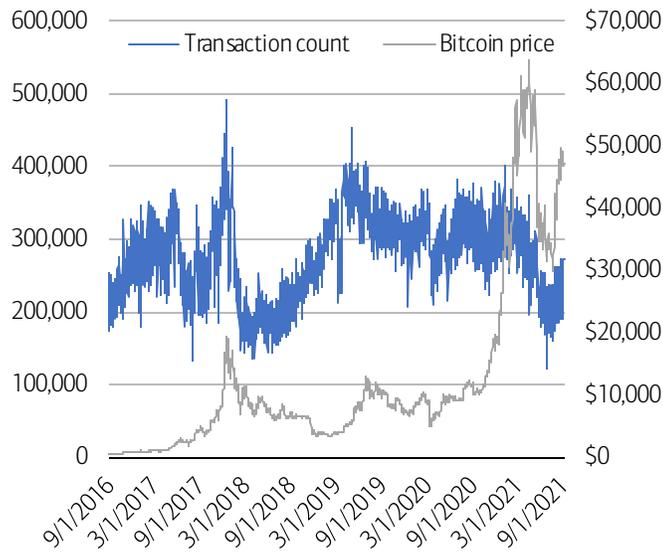
Source: CryptoCompare
 Data: 1/1/21 – 8/31/21. Bitcoin block size measures the average size in bytes of all blocks created that day.

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Exhibit 109: Bitcoin transaction count

Miners may attempt to decrease energy costs by filling blocks with fewer transactions in exchange for lower transaction fees

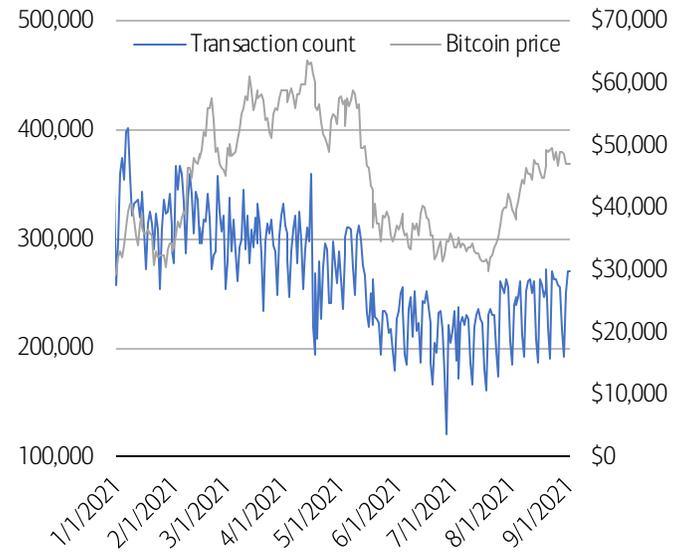


Source: CryptoCompare
Data: 6/1/16 – 8/31/21. Transactions count measures the number of valid, on-chain, transactions that day.

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Exhibit 110: Bitcoin transaction count

Falling bitcoin prices in May led to a decrease in transaction count



Source: CryptoCompare
Data: 1/1/21 – 8/31/21. Transactions count measures the number of valid, on-chain, transactions that day.

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How does proof of stake mining work?

PoS mining is an alternative consensus mechanism where staking an asset on the next block replaces the mining of blocks as in Proof of Work (PoW). Instead of miners needing to spend on electricity and equipment to win a block (PoW), validators commit capital (the stake) to attest that the block is valid. Validators that stake their digital assets are then randomly selected to propose a block. The majority of other validators need to attest to the validity of the proposed block. Validators profit by both proposing and attesting to the validity of others' proposed blocks. Malicious actors have their stake slashed.



Appendix IV: Digital Assets & ESG

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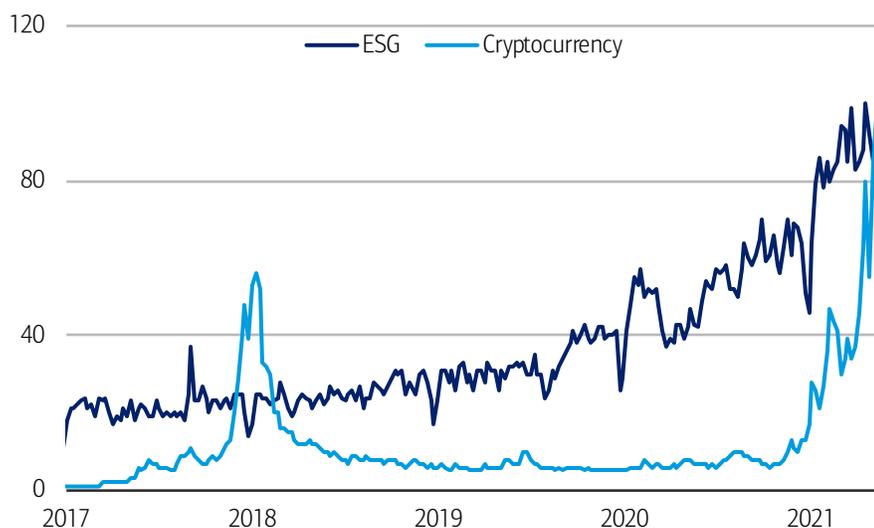
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Major trends for 2020s: ESG & digital assets

Investing in Environmental, Social and Governance (ESG) and digital assets are major themes. ESG funds have seen record high inflows in the past 24 months, while bitcoin has surprised with its performance and volatility.

Exhibit 111: Major trends for 2020s: ESG & cryptocurrencies

A significant increase in interest for ESG and cryptocurrencies in the last 24 months



Source: Google Trends, BofA Global Research

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Jumping on the digital asset bandwagon

PwC's 3rd Annual Global Crypto Hedge Fund Report 2021 found that 21% of traditional hedge funds in the world have already invested in digital assets, while digital asset-focused fast money investors doubled their assets under management (AUM) during 2020.⁵⁹ We attempted to corroborate ownership figures by looking into hard data of fund holdings from three data providers (Bloomberg, FactSet, and Refinitiv); however, the public information on digital asset holdings is patchy as a large proportion of funds are private entities or holdings from public entities are a very small percentage of their overall assets under management so digital asset holdings tend not to be disclosed.

While the focus so far has been primarily on the ESG performance of digital asset miners (given their role in the creation of digital assets and the energy requirements), the ESG performance of the broader digital asset industry is likely to come under additional scrutiny, particularly as institutional investments accelerate.

⁵⁹ PwC's 3rd Annual Global Crypto Hedge Fund Report 2021

Moreover, investors in digital asset miners or service providers have to start paying more attention as well. Even corporates that put digital assets on their balance sheets must confront the contradiction of significant digital asset holdings in the context of their own ESG principles, particularly if they obtain financing through ESG-related products (i.e., sustainability bonds).

Bitcoin and ESG: striking an uneasy truce

Digital assets have become a polarizing issue within the context of ESG. The negative environmental effects of Bitcoin are well-documented. However, social and governance factors have remained mostly off the radar, even though they are becoming increasingly important for the digital asset industry and regulators, as both become more alert to rising ESG challenges. How some of the ESG challenges are addressed is likely to determine the future of digital assets, particularly in regard to institutional investing.

To what extent are digital assets compatible with ESG principles? The answer is contingent on three major issues:

- **Environmental** repercussions of the competing models of consensus algorithm (i.e. how all the participants / nodes on a blockchain network reach a common agreement about the state of the distributed ledger): 1) proof of work (PoW) versus 2) proof of stake (PoS). This distinction is particularly relevant as the blockchain of the largest digital asset, bitcoin, is based on the PoW model, while the blockchain of the second-largest (ether) is moving to the PoS model.
- **Social** repercussions of digital assets from a short-term risk perspective (most notably illicit activities) and medium-term opportunities (most notably financial inclusion, democratization of finance, and shift towards stakeholder capitalism).
- **Governance/regulatory** reaction function towards digital assets in four areas: 1) adaptation of the traditional securities markets' regulation to the new digital asset domain; 2) ESG (particularly environmental) disclosure requirements; 3) regulatory level playing field across global jurisdictions; and 4) self-regulation by digital asset stakeholders.

E: Proof of Work vs. Proof of Stake

Mining bitcoin could consume as much as 140 terawatts annually

The environmental repercussions of Bitcoin could be worrisome. The Cambridge Centre for Alternative Finance (CCAF), a research institute, estimates that mining activity associated with Bitcoin could consume as much as 140 terawatts annually. Furthermore, the Bitcoin network emits about 60mn tons of CO₂, the same as Greece and a \$1bn fresh inflow into bitcoin may cause CO₂ to rise by the equivalent of 1.2mn internal combustion engine (ICE) cars.

PoW is mainly responsible for poor “E” characteristics

Bitcoin's negative environmental characteristics are primarily driven by Proof of work (PoW), which is the first consensus algorithm method in a blockchain network. More specifically, PoW is a way of determining who is allowed to publish blocks to a blockchain. Each miner competes to find a number, which is used to solve the cryptographic puzzle and generate a required hash (best understood as a mathematical equation that has to be solved).

The proof is easy for any node in the network to verify, but extremely computationally intensive as it requires miners to guess a complex answer by brute force using computing power. After finding the number, the successful miner is permitted to announce a new block, while being rewarded with newly created bitcoins. In addition, Bitcoin blockchain has a target rate of block production of one every 10 minutes.

An alternative consensus algorithm, proof of stake (PoS), has emerged more recently with the key advantage of reduced computational requirements that translate into



significantly smaller adverse environmental repercussions. PoS is a method that allows network participants to reach consensus according to their ownership stake in the network. In other words, the more coins participants hold, the more power they have in the network. For example, if s/he staked 10 coins in a 100-coin network, s/he would have a 10% probability of receiving the transaction fee (reward). Most importantly, without a complex cryptographic puzzle to solve, the energy consumption of PoS digital assets / networks is significantly lower (unlike PoW).

In the interest of completeness, there are other consensus algorithm methods (such as proof of authority or proof of distributed stake).⁶⁰ However, they are still at early stages – either at the conceptual level or they are applied in very small networks.

Bitcoin: putting energy consumption into context

If Bitcoin were a country, it would be ranked 35th in the world for electricity consumption. However, Bitcoin's electricity consumption is insignificant relative to large, industrialized countries like China and the US. Its electricity consumption annually is about 1.4% of China's and 2.4% of the US's. The Bitcoin network – a global network with over 100mn users – uses less than 0.1% of the world's energy consumption.⁶¹ We don't doubt that concern over Bitcoin's carbon footprint is genuine. But, claims that Bitcoin's carbon footprint is an ESG nightmare are misleading if not put into context and seem to inherently assume that Bitcoin provides no societal value and, therefore, any carbon emission resulting from Bitcoin's network is a waste.

We also remind readers that not all energy sources are equal when it comes to emissions. In fact, 76% of digital asset miners used a form of renewable energy to power their mining in 2020, although renewable energy accounted for 39% of energy consumed for PoW mining.⁶² We also note that bitcoin mining isn't generating large emissions for nothing; the "work" in Proof of Work refers to the energy consumption and, therefore, cost associated with mining. Bitcoin is considered the most secure blockchain, but the tradeoff to being the most secure is the work and inherent cost involved to mine blocks of transactions.

Exhibit 112: Bitcoin's power consumption relative to countries and companies

Bitcoin's electricity consumption is larger than Finland's, but insignificant relative to consumption in China and the US

Name	Population (mn)	Annual Electricity Consumption (TWh)
China	1,446.2	6,543
United States	333.4	3,844
All of the world's data centers	-	205
State of New York	19.3	161
Bitcoin network	-	91
Finland	5.5	84
Belgium	11.6	82
Bangladesh	166.7	71
Google	-	12
Facebook	-	5
Walt Disney World Resort	-	1

Source: Cambridge Centre for Alternative Finance, Science Mag, New York ISO, Forbes, Facebook, Reedy Creek Improvement District, Worldometer
As of August 31, 2021

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⁶⁰ Proof of authority (PoA) is a consensus method similar to PoS, but PoA leverages identity (in the form of set, pre-approved authorities, called validators) as the form of stake rather than actually staking tokens. Each network implements a system to authorize and identify validators, who will then validate transactions and blocks within the respective network. The PoA networks tend to use less computational power as they do not require communication between nodes to reach consensus. The most well-known example of PoA is Energy Web Chain with the Energy Web Token (EWT).

⁶¹ Cambridge Bitcoin Electricity Consumption Index (CBECI)

⁶² University of Cambridge's 3rd Global Cryptoasset Benchmarking Study

Exhibit 113: Distribution of digital asset mining energy sources by region

Renewable energy accounted for 39% of energy consumed for PoW mining

Energy Source	Asia-Pacific	Europe	Latin America and the Caribbean	North America
Hydroelectric	65%	60%	67%	61%
Natural gas	38%	33%	17%	44%
Coal	65%	2%	0%	28%
Wind	23%	7%	0%	22%
Oil	12%	7%	33%	22%
Nuclear	12%	7%	0%	22%
Solar	12%	13%	17%	17%
Geothermal	8%	0%	0%	6%

Source: University of Cambridge
As of Sept 2020

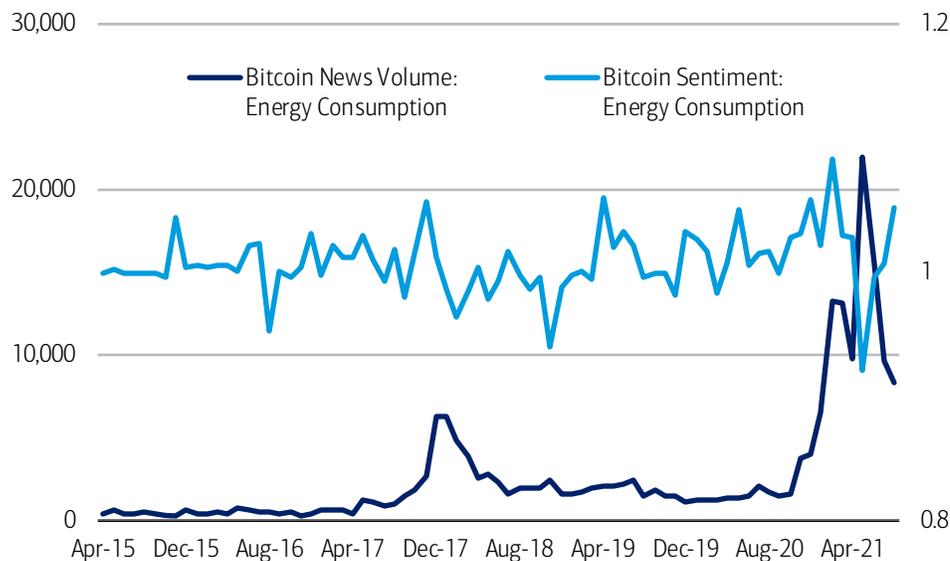
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However, as mining pools relocate from China to the United States, we expect the use of clean energy to accelerate. As you can see in the chart below, North American miners use a broader range of energy sources, including clean energy.

We also note that negative sentiment surrounding Bitcoin’s energy consumption is positively correlated with news volume, indicating that concerns over the carbon footprint of blockchains using the PoW consensus mechanism may be tied more to news coverage than to actual environmental implications.

Exhibit 114: Negative sentiment (RHS) is positively correlated with news volume (LHS)

Bitcoin sentiment on energy consumption vs Bitcoin news volume on energy consumption



Source: Ravenpack
Data through 8/31/21

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PoS digital assets appear to be more ESG friendly

Digital assets with less energy-intensive technology, such as proof of stake (PoS), are likely to address some environmental issues, particularly if they shift towards renewables. The blockchain of the second-largest digital asset by market capitalization, Ethereum, is currently transitioning to a more environmentally friendly PoS model from PoW. Binance Coin, Cardano, and Polkadot are also better known examples of PoS. That said, PoS has its own shortcomings: higher vulnerability to attacks (particularly for smaller networks) and a more oligopolistic nature. In addition, Ethereum also has to address operational challenges in regard to its transition from PoW to PoS (i.e. network safety concerns – partially addressed through the most recent Berlin upgrade – and intrinsic dissatisfaction of miners who are inclined to delay the transition in order to increase their own income).



Ethereum 2.0 to become the largest PoS digital asset

The blockchain of the second-largest digital asset by market capitalization, Ethereum, is currently transitioning to more environmentally friendly PoS model from PoW. Following the most recent environmental concerns regarding Bitcoin in May 2021, the Ethereum Foundation has accelerated its delayed transition from PoW to PoS. The new PoS total power consumption will be an estimated 99.95% lower than the current PoW model.⁶³

When it comes to prospective institutional adoption, the market capitalization and trading liquidity of digital assets is likely to play a role. Ether is the second-most traded digital asset. Only polkadot is a PoS digital asset among the top-5 most traded cryptocurrencies by fast money investors.⁶⁴ Alongside polkadot, binance coin and cardano are among the top-3 largest PoS digital assets based on market capitalization.

Exhibit 115: The largest coins and tokens by market capitalization

Bitcoin has the largest market capitalization (as of September 2021)

Name	Ticker	Mcap as % of global crypto Mcap	Circulating supply	Blockchain	Model
Bitcoin	BTC	42%	18.8M	Own Blockchain	PoW
Ether	ETH	20%	117.36M	Own Blockchain	PoW
Cardano	ADA	4%	32.15B	Own Blockchain	PoS
Binance Coin	BNB	4%	168.1M	Binance Chain	PoS
Tether	SDT	3%	65.8B	Omni	Stablecoin
XRP	XRP	3%	46.5B	Own Blockchain	-
Dogecoin	OGE	2%	131.1B	Own Blockchain	PoW
Solana	SOL	2%	290.7M	Own Blockchain	PoS/PoH
Polkadot	DOT	1%	987.5M	Own Blockchain	PoS
USD Coin	SDC	1%	27.4B	Ethereum	Stablecoin

Source: CoinMarketCap.com, BofA Global Research,

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PoS drawbacks: network safety risks & dissatisfied miners

PoS is not without its drawbacks. There are two immediate risks to how the transition process would be managed in the case of Ethereum:

- **Network safety concerns** – partially addressed through the Berlin upgrade which will introduce a complete change to the way the network processes transaction fees. Instead of having the fee sent to the miners, the fee would be sent to the network and burned. In turn, this would reduce the supply of ether.
- **Intrinsic dissatisfaction of miners with the transition** – miners are inclined to delay the transition to increase their own income (i.e. miners are particularly opposed to reduced transaction fees).

More generally, all PoS networks share similar drawbacks to the PoW digital assets:

- **Oligopolistic by design:** PoS favors the participants with high stakes over their less wealthy peers. There's also the potential to game the system if a particular interest group decides to pool or withdraw resources, even if only temporarily. A validator address may have a large stake, but since their power is based only on how much money they hold, there's no knowing who actually owns/controls that money. Furthermore, an oligopoly grows when specific participants set the rules in such a way that they can restrict entry to new players. The ability to withhold funds for large entities leads to a high barrier to entry. Somewhat similar situations are possible with PoW, but it's a lot more difficult to accomplish. Small networks are particularly vulnerable to oligopolistic behavior.
- **More vulnerable to 51% attacks** (particularly for smaller networks) – the oligopolistic nature of PoS is also more conducive to 51% attacks.

⁶³ [Blog.ethereum.org](https://blog.ethereum.org)

⁶⁴ PwC's 3rd Annual Global Crypto Hedge Fund Report 2021

A 51% attack is when one participant or a coordinated group gain majority control of the network hashing rate, enabling malicious acts like preventing new transactions from gaining confirmation or halting payments between some or all participants.

- The malicious attackers would also be able to reverse transactions completed while they were in control of the network (i.e. double spending the coins). For example, Zcoin (now called Firo) suffered a 51% attack in 2020.

What about S and G?

Social & Governance take backseat to Environment so far

While coverage has been considerable on the environmental damage caused by Bitcoin, concerns about its social and governance consequences have been somewhat off the radar. Even the assessment of social and governance aspects of digital assets has become a polarizing issue.

Short-term challenges could impede long-term benefits of digital assets

Critics overestimate the extent of illicit activities, while digital asset aficionados are preoccupied with the extent of revolutionary change. We endeavor to bridge the gap by introducing the key variable: time. We subscribe to the long-term benefits of digital assets (i.e., financial democratization and financial inclusion). However, some short-term challenges could impede long-term benefits.

An important caveat: the blockchain technology that underpins digital assets has a lot of promise in terms of providing solutions to longstanding ESG problems, such as chain traceability, renewable energy distribution, anti-money laundering and proxy voting.

Long-term benefits

- **Democratization and decentralization of money:** Satoshi Nakamoto wrote in his white paper from 2008 that “A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution.” Removing intermediaries presents some social advantages.
- **Financial inclusion:** Digital assets have the potential to allow users to make transactions in all parts of the world via a network that is robust, free of censorship, and resistant to interventions by state actors and geopolitical conflicts. Furthermore, more than half the global population lives in (semi)authoritarian regimes that do not respect human (economic) rights, which means digital assets could guarantee some economic freedom. Of course, capital controls are a part of the macroeconomic policy toolkit, so it is important to differentiate between individual rights and prospective benefits at the country level.
- **Lower transaction costs (remittances):** Digital assets have the potential to help reach the UN’s Sustainable Development Goal target 17.3. Lower costs for remittances would benefit developing nations and more disadvantaged communities. The Bank of International Settlement (BIS) reports, based on a sample of 112 countries that the average total cost of a US\$200 bank-based cross-border remittance is over 10%. This cost for EM amounts to about \$50bn annually. If it can be saved, it would be a considerable gain for the populations of many EM. For example, in countries like the Philippines or Ukraine, remittances are 10% of GDP. If current transaction costs are 10%, this would be 1% of GDP, a substantial part of which could be saved by the use of digital currencies. Currently, the main barrier to



entry is internet connection, while the volatility of digital assets also presents a significant challenge.⁶⁵

- **Stakeholder (vs shareholder) capitalism:** Digital assets have a natural propensity towards stakeholder capitalism (the idea that corporations or even broader capitalist systems should work for the benefit of all stakeholders, rather than just shareholders (i.e., owners of the capital)). The most recent push towards stakeholderism by corporate leaders and academics is already embedded in digital assets given their decentralized nature. Of course, the very concentrated ownership structure of bitcoin wallets is a clear challenge. However, from a theoretical perspective, digital assets are stakeholder-friendly by design, unlike many other parts of markets/the capitalist system.

Short-term challenges

- **Illicit activities:** Fraud, theft, ransomware, terrorism financing, money laundering, tax evasion and cyber-attacks are some of the most common crimes.

However, the extent of illicit activities might be exaggerated, at least based on available data by specialized analytics firms. Illicit blockchain activities (hacks, thefts, fraud and misappropriation) in 2020 totaled \$1.9bn, which is 57% lower than 2019's \$4.5bn estimate, according to the Ciphertrace's Cryptocurrency Crime and Anti-Money Laundering Report.

Similarly, blockchain analytics firm Chainalysis estimates that criminal activity represented 0.34% of all digital asset transactions in 2020 (\$10bn of illicit activities in absolute volumes), down from 2.1% in 2019 (\$21.4bn in absolute volumes). Chainalysis analyses a wider universe of illicit activities (scams, domestic extremism, terrorist financing, stolen funds, ransomware, darknet market and child abuse materials).

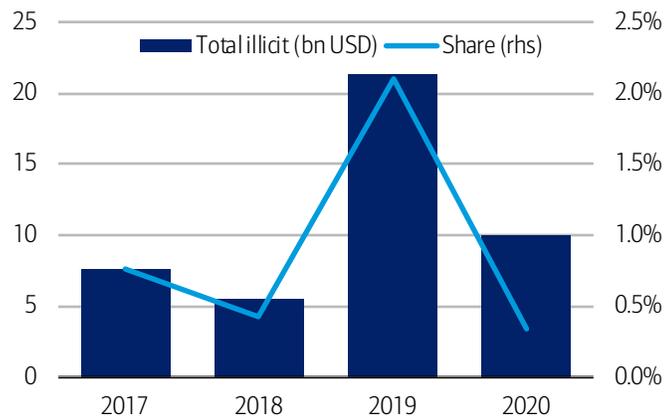
Although these two companies have some of the most advanced privately-held datasets on digital asset transactions, we acknowledge that some peer-reviewed academic research from recent years points towards a significantly higher percentage of illicit activities.

- **Volatility:** significantly higher than most assets (FX and commodities). However, momentum in digitalization, as well as prospects of wider institutional adoption, could reduce volatility over time.

⁶⁵ According to UN's International Telecommunication Union data, c.51% global population were using the internet at the end of 2019.

Exhibit 116: Chainalysis estimates of illicit activities with digital assets

Chainalysis estimates that criminal activity represented 0.34% of all cryptocurrency transactions in 2020, down from 2.1% in 2019

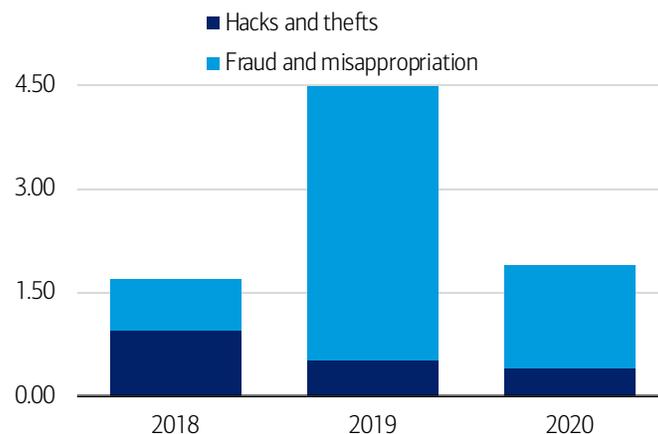


Source: Chainalysis, BofA Global Research

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Exhibit 117: CipherTrace estimates of illicit activities with digital assets

Blockchain fraud exceeds hacks and theft



Source: CipherTrace Cryptocurrency Intelligence., BofA Global Research

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Regulation in the driving seat

There are four key areas of governance/regulatory efforts: 1) adaptation of the traditional securities markets regulation to the new digital asset domain; 2) ESG (particularly environmental) disclosure requirements for miners, investors, and corporates; 3) the extent of global cooperation in achieving a level playing field across global jurisdictions; and 4) self-regulation by the digital asset industry itself.

Traditional securities regulation in the new domain

When it comes to traditional financial regulation, the key focus is on preventing illicit activities, primarily anti-money laundering (AML) and counter-terrorist financing (CTF), alongside Know-Your-Customer (KYC) rules. Adapting traditional securities markets rules to the digital asset domain is challenging. One example is how AML/KYC requirements should be adjusted to take into account the traceable nature of the blockchain (e.g., how far should a digital asset exchange go to satisfy the criterion in regards to the source of an asset?).

There is generally a negative perception of potential digital asset regulation, but digital asset trading can be done well. Notable examples of good practices are: the Swiss exchanges where all digital asset transactions comply with regulations such as customer protection and AML.

Environmental disclosures

The Paris Agreement is likely to involve aligning with the Task Force on Climate-related Financial Disclosures (TCFD), a set of recommendations on the reporting of financially material, climate-related information. Many major economies (such as the UK, the EU and Australia) are in the process of transposing TCFD into domestic regulatory frameworks. The key principle of this policy is to disclose the metrics and targets used to assess and manage relevant climate-related risks. Many digital asset miners and firms may find having to disclose their GHG emissions publicly a tricky exercise, but ultimately it should encourage long-term sustainable business practices.

The extent of the disclosure burden is even higher in the European Union, which is championing sustainable investments. A lot of regulation is still in the fine-tuning phase so it is too early to assess full implications of digital asset ESG disclosure requirements, but this is certainly a new legal frontier.



(Lack of) global cooperation

An additional regulatory issue is a lack of international cooperation, particularly as there is a wide range of early adopters of digital assets that are not necessarily traditional allies in global financial governance. Vietnam, India, Pakistan, Ukraine, Kenya and Nigeria have the highest level of adoption of digital assets, according to Chainalysis’ 2021 Global Crypto Adoption Index that is based on three metrics (on-chain value received, on-chain retail value received, P2P exchange trade volumes) adjusted for purchasing power parity per capita.

Some of these jurisdictions have rather heterogeneous approaches to regulating anti-money laundering (AML) and counter-terrorist financing (CTF) for traditional finance, let alone digital asset transactions. This in turn presents a major challenge for global cooperation in regulating digital assets.

Exhibit 118: Digital asset adoption globally, weighted by purchasing power parity per capita

US is in top 10 globally alongside many politically challenged countries

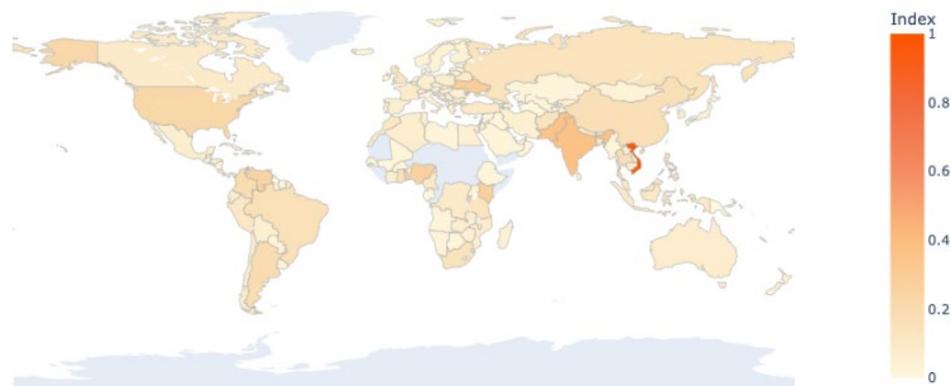
Rank	Country
1	Vietnam
2	India
3	Pakistan
4	Ukraine
5	Kenya
6	Nigeria
7	Venezuela
8	United States
9	Togo
10	Argentina

Source: Chainalysis, BofA Global Research

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Exhibit 119: Digital asset adoption globally according to Chainalysis index

Vietnam, India, Pakistan, Ukraine and Kenya have the highest level of adoption



Source: Chainalysis
Time period: July 2020 – June 2021

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FATF sets global standards

The Financial Action Task Force (FATF) has been a pivotal international AML / CTF intergovernmental body attempting to harmonize national regulations to combat global financial crimes. According to FATF’s latest report from June 2020 (new report due in June 2021), of the 54 responding member jurisdictions, 32 reported having existing AML/CFT regulations for Virtual Asset Service Providers (VASP – the term used for most custodial digital asset business), 13 reported having regulations in development, and 5 indicated the prohibition or potential near future prohibition of VASPs. Furthermore, the



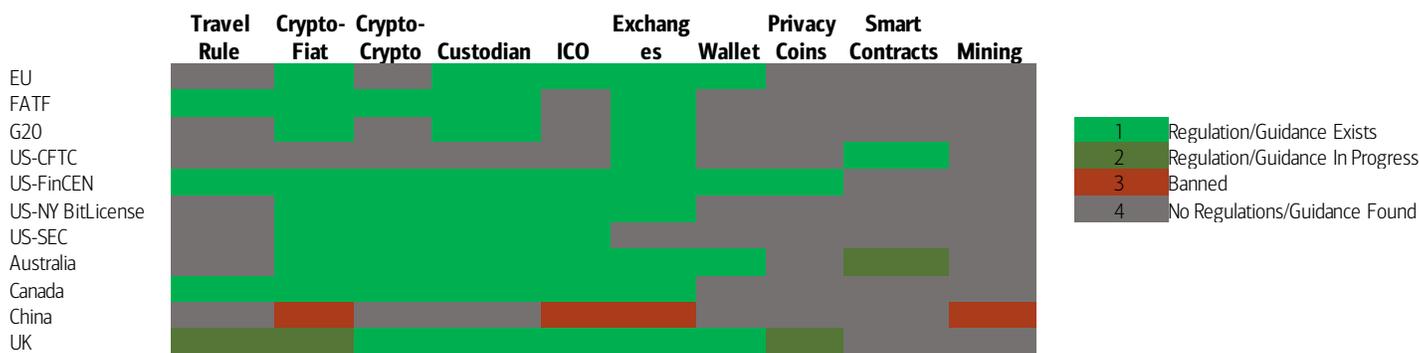
FATF has also introduced the Travel Rule (i.e. a requirement for data-sharing among VASPs).

Digital asset regulation in key jurisdictions

- China:** The National Internet Finance Association of China, the China Banking Association and the Payment and Clearing Association of China reiterated their stance on banning digital asset services. The three entities published a note in May 2021 confirming the bans originally implemented in 2013 and 2017 that prevent financial and payment institutions from providing any services related to digital asset transactions. In addition, initial coin offerings in China remain illegal.
- United States:** There is no harmonized regulatory framework for digital assets in the US as there are at least 3 independent agencies that could have legal authority over regulating digital asset-space: Securities and Exchange Commission (SEC), Commodity Futures Trading Commission (CFTC), and the Treasury Department’s Financial Crimes Enforcement Network (FinCEN). Meanwhile, New York State Department of Financial Services (NYDFS) has also taken an active role through developing digital asset regulation known as ‘BitLicense’ (initially introduced in 2015).
- European Union:** All EU states have to follow the Anti-Money Laundering Directive. In September 2020, the EU Commission published a proposal for the regulation of digital assets Markets in Crypto-Assets Regulation (MiCA). Although there is no clear timeline on implementation, the MiCA shall be transposed into the national legislations of all EU member states and regulate all issuers and service providers dealing with digital assets. Furthermore, the new rules will allow operators authorized in one Member State to provide their services across the EU (*passporting* akin to the Markets Directive in Financial Markets). The prospective safeguards include capital requirements, custody of assets, a mandatory complaint holder procedure available to investors, and rights of the investor against the issuer. Issuers of significant asset-backed digital assets (i.e. stablecoins) would be subject to more stringent requirements (e.g. in terms of capital, investor rights and supervision). In addition, there are some national-level rules, such as new licensing requirements for digital asset businesses in Germany.

Exhibit 120: Implementation of digital asset regulation in major jurisdictions

An additional regulatory issue is a lack of international cooperation and heterogeneous AML/CTF regimes globally.



Source: CipherTrace Cryptocurrency Intelligence, BofA Global Research

Self-regulation: insiders asking for a change

The digital asset industry has embarked on some ESG initiatives as well:

- Crypto Climate Accord (CCA)** is a private sector-led initiative inspired by the Paris Agreement. The CCA focuses on decarbonizing the digital asset industry, aiming for all blockchains to be powered by 100% renewable energy sources by 2025, as well as net-zero emissions for the entire digital asset industry by 2040.



- The Bitcoin Clean Energy Initiative (BCEI) was launched by Square in December 2020, which committed to invest US\$10mn to help drive the use of renewable energy within the Bitcoin ecosystem.

Digital asset funds have started committing to carbon neutrality at the fund level. For example, One River Digital Asset Management (ORDAM) and carbon credit platform are launching a 'carbon-neutral' digital asset fund, promising to offset carbon emissions by buying and "planting" MCO2 tokens for every bitcoin owned, while Argentium Digital Asset management has also committed to a carbon-neutral investment approach.



Appendix V: Digital Assets & Energy

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Regulated Utilities: spreading costs over more volume

Utilities incentivize high-volume customers like miners

The high energy consumption of digital asset mining allows utilities to spread fixed expenses, such as depreciation, O&M, and property taxes, over a larger number of kilowatt hours, thereby reducing bill increases. As a result, utilities and power companies are willing to offer favorable usage rates to incentivize operations. For reference, the US Energy Information Administration (EIA) data for June 2021 shows the split of residential, commercial, industrial, transportation and blended rates. Residential customers typically pay *premium* rates with higher margins, in contrast to industrial customers that are less profitable for utilities in isolation.

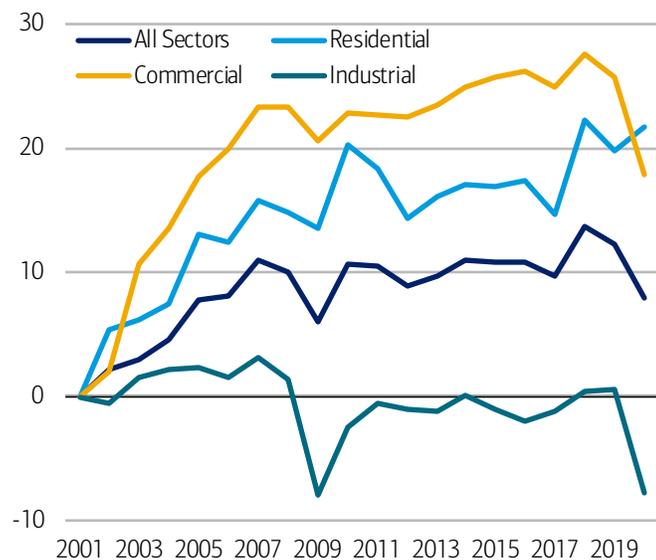
- Residential: 13.85¢/kwh
- Commercial: 11.34¢/kwh
- Blended: 11.30¢/kwh
- Transportation: 10.38¢/kwh
- Industrial: 7.27¢/kwh

US electric retail sales overall have been largely stagnant at a ~0.5% CAGR from 2001-2019/2020 with 1% residential, ~1% commercial, and slightly negative for industrial (Exhibit 121). The reason for this sluggishness has been improving energy efficiency which has caused a decoupling between GDP growth and electrical usage. The Covid impact in 2020 resulted in a sharp decline in C&I, partly offset by higher residential consumption due to work-from-home dynamics (Exhibit 121). Prospectively, most utilities forecast sales growth of +50bp with many closer to flat and a few outliers at 100bp or greater. *Due to the generally weak load forecast, the prospect of a new class of higher energy consumers in the form of digital asset mining is an interesting angle.*



Exhibit 121: Retail sales of electricity United States annual (indexed to 2001 as percent)

Overall electric consumption has been stagnant

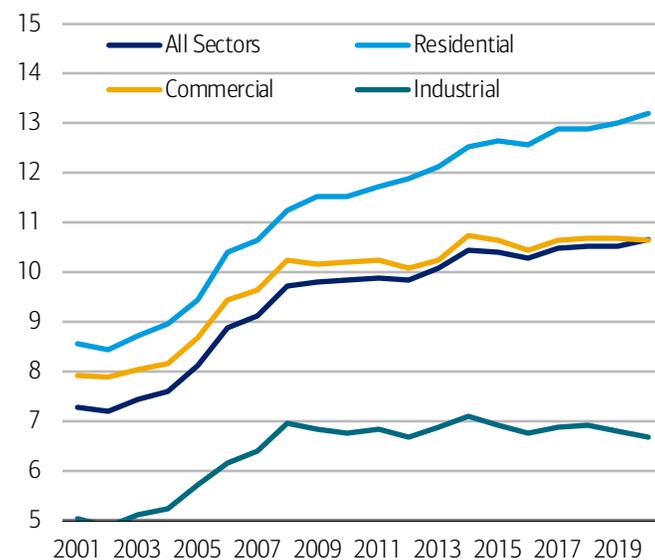


Source: U.S. Energy Information Administration

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Exhibit 122: Average Retail Price of Electricity (cents per kilowatt hour)

Residential rates have far outpaced C&I



Source: U.S. Energy Information Administration

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High energy consumption could require costly grid upgrades: who pays?

The challenge for utilities is the unpredictable nature of mining operations. Specifically digital asset operations may require grid upgrades and planning from the local utility with interconnection, etc. This process can be costly for the utility to undertake with no certainty that the company will achieve commercial operations. Consequently, some utilities require the mining company to pre-pay some aspect of the costs to avoid unintended costs for other customers if the project does not go ahead.

Underlying digital asset prices a key variable

Another consideration is that digital asset operations are very sensitive to the price of the coins mined and if the economics do not support mining, operations can cease with little notice to the utility and/or power provider. This is in contrast to other C&I operations that tend to offer more consistent baseload operations. This is similar to the refining customer that is sensitive to various energy benchmark prices to conduct operations; however, digital asset prices are far more volatile. For example, Bitmain had planned a 50MW+ Texas facility in late 2019 only to temporarily suspend plans when the price of bitcoin declined.

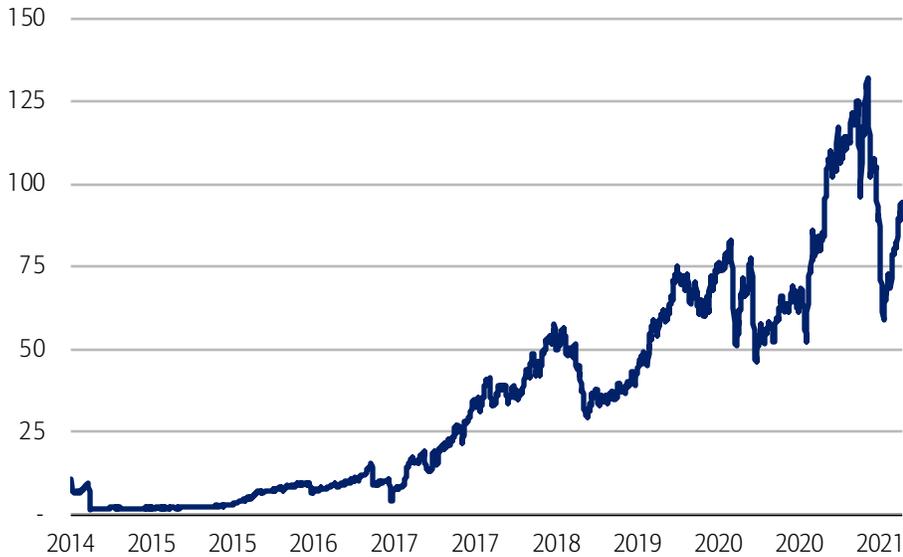
Framing Bitcoin energy demand: all about power prices

The University of Cambridge has developed its Cambridge Bitcoin Electricity Consumption Index (CBECI) to estimate Bitcoin electrical consumption. As of late August 2021 the estimated consumption was 10.6GW, which is 91TWh of annualized consumption. This is actually a -6% decrease from the start of 2021 but is +46% y/y growth from August 30th, 2020.

The CBECI base case utilizes a \$50/MWh base power assumption, which is a key variable that Cambridge estimates as the global electricity cost paid by miners (Exhibit 123). Cambridge also shows a theoretical upper and lower bound, which is sensitive to the base power assumptions. As electric costs fall, more mining is 'in the money'. For example, reducing the base power assumption to \$30/MWh would increase the annualized consumption to 97.6TWh and the theoretical upper bound to 679TWh from 341TWh.

Exhibit 123: Estimated annualized Bitcoin energy consumption assuming \$50/MWh

Cambridge shows the significant increase in power consumption



Source: Cambridge Bitcoin Electricity Consumption Index (CBECI)

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The increasing electrical demand associated with mining has led to concerns in many countries such as Iran, Iceland and China. In May, Iran announced a ban on digital asset mining due to energy shortages, but subsequently announced that it would allow mining to resume in September. Iceland was a pioneer in supporting mining, but other industries with high energy-intensity like steel have become priorities. China accounts for the majority of the world's global bitcoin production, but has been criticized publicly for its high reliance on coal generation in mining. The country has been working on developing its own state digital currency with an associated reduction in support for bitcoin mining.

Argo Blockchain has 45MW of mines operating, concentrated in Quebec due to its hydro power and what it views as favorable regulation. The company states it has the highest petahash to MW ratio of publicly traded digital asset companies. Its company's focus on energy efficiency is a potential competitive advantage, supporting lower-cost mining operations.

What jurisdictions are setup for mining? NY, WA, and WY

Some regulators have been preparing for digital asset load. We highlight a few cases where regulators have been proactive in supporting growth opportunities:

- **New York:** In 2018, the NY Public Service Commission approved digital asset rates for NY Municipal Power Agency, an association of 36 munis ranging from 1.5-122MW, as well as for Massena Electric Department, a small upstate electric utility. There is a little uncertainty for the future of New York mining due to the pending Senate Bill S6486B introduced in May 2021 that passed the Senate in June 2021. The legislation would effectively place a moratorium on new digital asset mining using fossil generation unless an environmental impact statement (EIS) was prepared.
- **Washington:** In 2018, the Grant County Public Utility District (PUD) implemented new rates for digital asset miners of ~\$0.085/kWh, roughly double the standard residential and commercial rates at the time. The new rate class is called 'Evolving Industry Rate Schedule 17'. Subsequently, in early 2021, the PUD removed digital asset mining load from the Evolving Industry classification due to the small scale of operations, returning those customers to the lower general rate structures. As of



January 2021, there was only 1.4MW of digital asset load, well below the 5% concentration (50MW threshold).

- Wyoming:** In 2018, Cheyenne Light Fuel and Power Co (Black Hills BKH subsidiary) filed with the Wyoming PSC for “an innovative tariff solution” called the Block Chain Interruptible Service (BCIS). Elements of the unique tariff include (1) 10,000kW+ load; (2) ability for the utility to interrupt service at agreed to size, notice, and duration; (3) two year fixed pricing with renegotiation every three years; (4) a retail customer credit; (5) potential credit support requirement/disclosures of financial condition; and (6) the customer paying for any new required infrastructure to serve (Docket 0003-173-ET-18). Wyoming broadly has been a leader in digital assets and passed legislation in 2019 amending the Uniform Commercial Code to include digital currencies in commercial transaction classifications.

Unregulated utilities: opportunity to sell excess power

High energy consumption meets oversupplied grid

The economics for merchant power generation have been deteriorating over the past decade due to: (1) general oversupply of generation assets as measured by reserve margins; (2) declining natural gas prices, which are the primary input in setting the marginal price of energy; and (3) the rise of zero marginal cost renewable solar and wind resources. For example, PJM 2023 PPL Zone Around the Clock (ATC) power price forwards have declined from \$45+/MWh in 2014 to below \$30/MWh in 2017-1H2021. Only recently have forward power prices recovered to \$30/MWh – still far below prices earlier in the 2010s. With renewable deployment accelerating and capital costs declining, power prices have structural downward pressure. 2023 NYMEX natural gas prices are ~\$3.00/mmbtu and, assuming a market heat rate (efficiency of converting natural gas or coal into electricity) of approximately ~8,000 (8.0x), power prices should ultimately retrace towards \$24/MWh (\$3.00mmbtu natural gas multiplied by 8.0x heat rate).

Exhibit 124: 2023 Around-the-Clock PJM PPL Zone Power \$30/MWh

PJM 2023 PPL Zone Around the Clock (ATC) power price forwards have declined from \$45+/MWh in 2014 to below \$30/MWh in 2017-1H2021. Only recently have forward power prices recovered to \$30/MWh, still far below prices earlier in the 2010s



Source: Bloomberg



A frequent criticism of digital assets is the high energy consumption and associated emissions, which has led to a push to mine using low and zero-carbon energy sources. Renewable resources offer these attributes but, except for pumped storage hydro, solar and wind, are intermittent non-dispatchable and cannot offer the needed reliability and 24/7 runtime required. Nuclear energy fits the need well.



Appendix VI: Digital Assets & Technical Analysis

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Technically explaining digital asset markets

Many technical strategies have proven valuable in timing entry into and exit from digital asset markets. We recap a few technical methods that have proven valuable in recent years including support and resistance levels, trend lines, a head and shoulders pattern, Fibonacci and the Relative Strength Index (RSI).

Technical approach explained

To engage in technical analysis is to assess market trends and find high conviction trade and investment ideas with attractive risk/reward. This can be accomplished by applying a diverse set of technical tools, strategies and theories. An aspiring technician should define technical analysis, understand and learn about its tools and implement a process.

Technical analysis defined, in our view

Technical analysis is the extraction of information from market data into objective visualizations primarily through the use of charts and mathematics with an emphasis on investor behavior and supply and demand to explain the current and anticipate the future path of markets. This definition has five specific parts, including:

- Data – prices, volume, open interest, breadth, spreads, ratios, yields, volatility, etc.
- Objective visualizations – lead with a clear, concise chart to show a view, and consider using other tables and figures to support it.
- Mathematics – apply measurements, indicators and statistics to help define trends, targets and levels. Technical indicators have a formula behind them, such as RSI.
- Investor behavior and supply/demand – identify rational and irrational market movements such as price patterns, positioning and sentiment.
- Anticipate the future – apply a process of technical tools to forecast markets, assess risk/reward, and make buy and sell decisions.

The body of “technical” knowledge is vast

There are many tools and strategies available to the technician. Taking the time to get to know them is an important step. The following table lists some tools in six categories.

Exhibit 125: The Technician’s Toolbox

A variety of technical tools broken down into six categories

Chart types	Indicators	Theories	Data	Testing	Management
Line	Trending	Intermarket	Price & volume	Rules based	Underlying or derivatives
Bar	Oscillators	Sector rotation	Accurate history	Define probabilities	Risk/Reward
Candle	Statistical	Cycles	Sentiment	Optimize	Position size
Market profile	Exhaustion	Seasonality	Breadth	Test a universe	Confirmations
KASE bars	Intraday	Dow Theory	Macro / Economic		Disciplined
Heikin-ashi	Fibonacci	Elliott Wave	Multi-time frame		
Point & figure					

Source: BofA Global Research, Bloomberg

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Technical analysis has three assumptions

1. Market actions discount everything

Prices should reflect all available information. To a technician, how markets are moving is more important than why. By observing price and other tools, a technician can assess the trend and estimate future price action.

2. Prices move in trends

Like Newton's law, it is widely believed a trend in motion remains in motion until acted upon by a large enough counterforce. Technicians follow the trend and attempt to enter and exit markets at the most opportune times.

3. History repeats itself

Whether history repeats or rhymes, there is an echo, and technicians believe market patterns and signals will repeat due to human nature such as fear and greed.

We propose a 4th: First discipline and then conviction

The tools and rules of a process should be prioritized over a current conviction and evaluated regularly. This, we think, should allow for more timely position changes and limit losses by not sticking with a losing trade for too long.

Start the process with a question

Is the market in a trend? Is it range bound? Is it leading or lagging? Or has it possibly moved too far, too fast? Many technical indicators are meant to be used in a certain type of market or interpreted differently, depending on the state of the market.

Work through a checklist

- Apply preferred indicators to multiple time frame charts. Consider those that are more applicable than the others. For example, if trending, apply moving averages, Ichimoku, MACD (Moving Average Convergence/Divergence Indicator) and ADX (Average Directional Index). If range bound, apply oscillators such as RSI (Relative Strength Index) or Stochastics. If parabolic, estimate an end with candle patterns, TD Sequential, regressions, long-term trend lines, divergences and log charts.
- Identify key levels for support, resistance and trend continuation with relevant moving averages, trend lines and Fibonacci retracements and projections.
- Review multiple time periods to identify short, medium and long term trends. Find strong trend lines, significant highs/lows and consolidation areas.
- Run some tests. Test what strategies are working and decide if they may continue. Find what odds or probabilities exist to support or contradict a view.
- Determine what other unique technical charts suggest. Analyze bar, candle, market profile or another technical charts for added color.
- Review intermarket relationships to understand the market environment. Compare trends and relationships to other markets using ratios, spreads and correlations.
- Review market breadth, volumes, flows. Use such data to assess market internals.
- Review the sentiment in the market such as positioning surveys, sentiment surveys and quantitative flow data.
- Find alignments and compare conclusions. Review conclusions with the fundamental, quant and economic view.

Make the call

Present high conviction views with a convincing chart or visual and a brief explanation of the call including key levels and potential risk/reward.



Trend lines

- A trend line is a directionally sloped line that provides support in uptrends and resistance in downtrends.
- Multiple points and time make a trend line more important and useful to identify support, resistance and changes in trend.
- We provide rules that define a trend line as broken and how to create targets using a measured move.

Trend lines imply trend direction and signal change

A trend line is a guide to the overall direction of the market in an upward, sideways or downward direction. It is present for four reasons:

1. Estimate support in an uptrend as price corrects the larger trend. Support is a level where buyers outnumber sellers resulting in prices turning up.
2. Estimate resistance in downtrends during relief rallies. Resistance is a level where sellers begin to outweigh buyers, which turns prices lower.
3. Create a parallel channel line based on 1 and 2. A support line in an uptrend can be used to estimate the top of a channel. The resistance line in a downtrend can be used to estimate the bottom of a channel.
4. When a trend line is broken, the trend has changed.

Exhibit 126: XBT/USD trend line examples

Green arrows show support, red arrows resistance, a channel formed in 2015-2017, breakouts tend to retest lines and those levels can be traded such as mid-2017 and 4Q218.



Source: BofA Global Research, Bloomberg

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Not all trend lines are created equal

A variety of characteristics help to differentiate good trend lines from not so good ones. A few ways to differentiate them are listed below.

5. Multiple touch points with time between each test.
6. Duration or age of the line increases significance. The trend line in Exhibit 126 is over four years old.
7. Not too steep, not too flat. Steep trend lines are often broken early and flatter trend lines provide confirmation signals later. A 30 to 50 degree slope is ideal.
8. If the distance from the start of the trend line to the current price level exceeds 30%, it is recommended to also consider a log scale chart in addition to an arithmetic scale. The log scale chart can result in an earlier trend line break. Many digital asset charts benefit from log scale analysis due to their large moves.



What constitutes a broken trend line?

If price were to break down through a supporting trend line, it would be ideal if at least one or more of the following conditions occurred.

9. Price closes at least 1% below the trend line.
10. Volume, if available, is greater than the average volume.
11. Two consecutive daily closes below the line occur.
12. After a break, intraday rallies test and fail to move back through the line. Such tests are more convincing if they occur on less than average volume.
13. The size of the break down is greater than the ATR value.

Average true range (ATR) is an indicator that measures the volatility of prices over the past x bars. In Exhibit 127, the five day ATR is shown below the price trend. ATR is calculated by taking the average of the largest absolute value of the following three calculations for each included period (in this case each day): the high minus low, high minus prior bars close and low minus prior bars close. If the ATR is rising when a trend is broken, it adds conviction to the direction of the break.

Exhibit 127: XBT/USD with Average True Range indicator (ATR)

When price rallied above the resistance line, the ATR was rising and confirmed the breakout.



Source: BofA Global Research, Bloomberg

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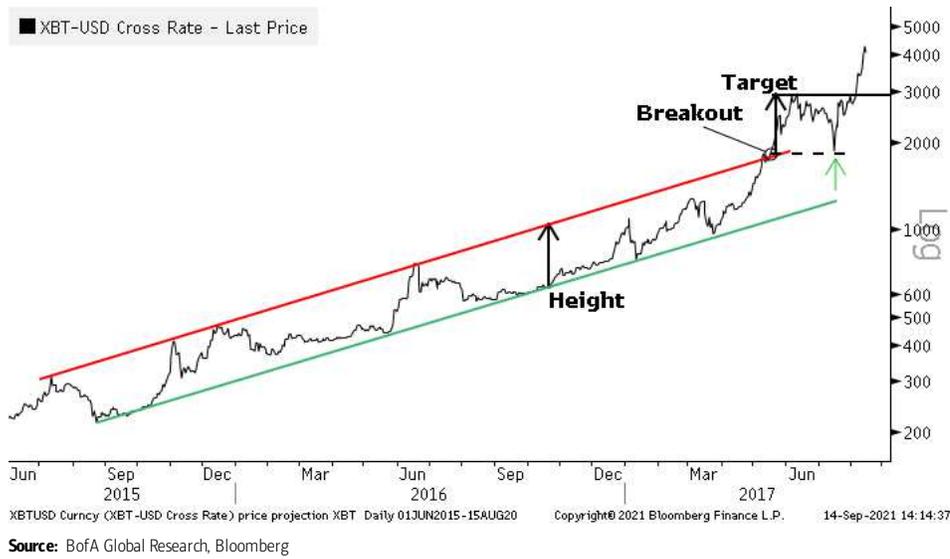
Projecting price after a qualified trend line break

There are a few ways to calculate targets after price breaks a support or resistance line. The most straight forward way is to take the height of a prior trend and add it to the breakout point. In Exhibit 128 below, we take the height of the channel and add it to the breakout point to estimate an initial target. If price broke below the support line, we would take the height of the channel and subtract it from the breakdown point to estimate an initial target.



Exhibit 128: XBT/USD - Measured move example

The height of the channel added to the breakout point approximated a target that was reached. The breakout point also offered support in the correction following the target being reached.



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A well-massaged head and shoulders

- The head and shoulders pattern is a popular chart pattern that usually implies the prior trend is changing direction.
- We explain what to expect as the pattern forms and how to use other indicators to increase conviction in the formation.
- We show how to create targets using measured moves and Fibonacci.

Spotting a head and shoulders formation

The head and shoulders formation is useful in identifying market tops and bottoms. It can also be a continuation pattern if it appears in the opposite direction of the trend. In this section we review the necessary inputs for a top pattern and summarize some additional technical criteria to increase conviction when trading it.

The basics of a head and shoulders top

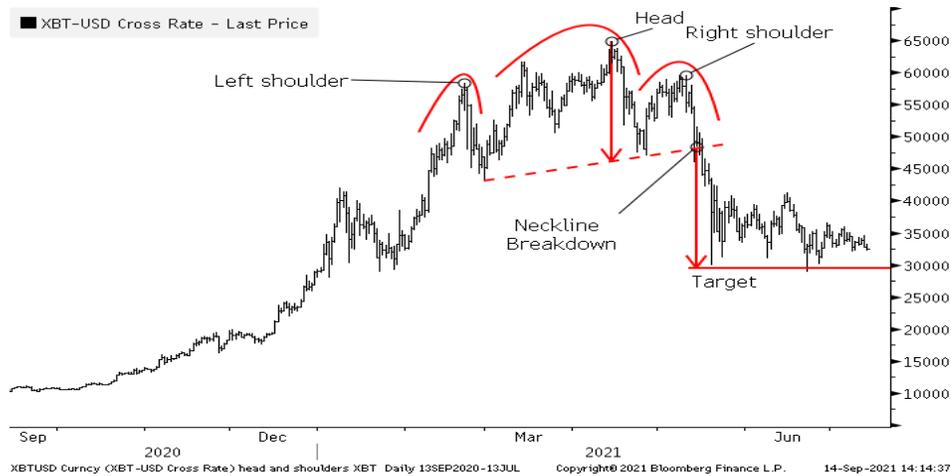
The only way there is a head and shoulders top pattern is if there is an uptrend to reverse. If there is not an uptrend prior to the formation then there is not a trend to correct or change. These are the basics inputs to a top pattern.

14. Three peaks and two troughs. The first peak is the left shoulder, the second the head and the third the right shoulder. The head is always the highest high. The troughs separate the peaks from one another and help create the neckline.
15. Estimate a neckline by drawing a trend line after the second trough forms. In a top pattern, the neckline should have a slightly positive slope or at least be flat. This is important because price will be in the earlier phase of a downtrend when the neckline breaks, making the sell entry point higher.
16. The right shoulder should make a lower high than the head. It is also ideal for the right shoulder to be similar or smaller than the left shoulder.
17. A decisive move down through the neckline with greater than average volume should occur to solidify the pattern.

18. The neckline may be tested as resistance on a light volume rally and offers a second opportunity to sell the security. An appropriate stop is often the top of the right shoulder.

Exhibit 129: XBT/USD – Head and shoulders top

The May 2021 decline was preempted by a head and shoulders top pattern.



Source: BofA Global Research, Bloomberg

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Volume can enhance the pattern

When an uptrend is coming to an end, it is preferred to see lighter volume in up moves and heavier volume in down moves. When volume is available it is better if it corresponds to a head and shoulders top pattern in the following ways:

- The rally to the head occurs on light volume. It could be compared to the volume to the top of the left shoulder or to a moving average.
- The decline down to the second trough occurs on rising volume suggesting an increase in supply or selling pressure.
- The rally to the top of the right shoulder occurs on light volume suggesting a lack of demand or little buying pressure.
- The decline from the top of the right shoulder through the neckline should occur on heavy volume.

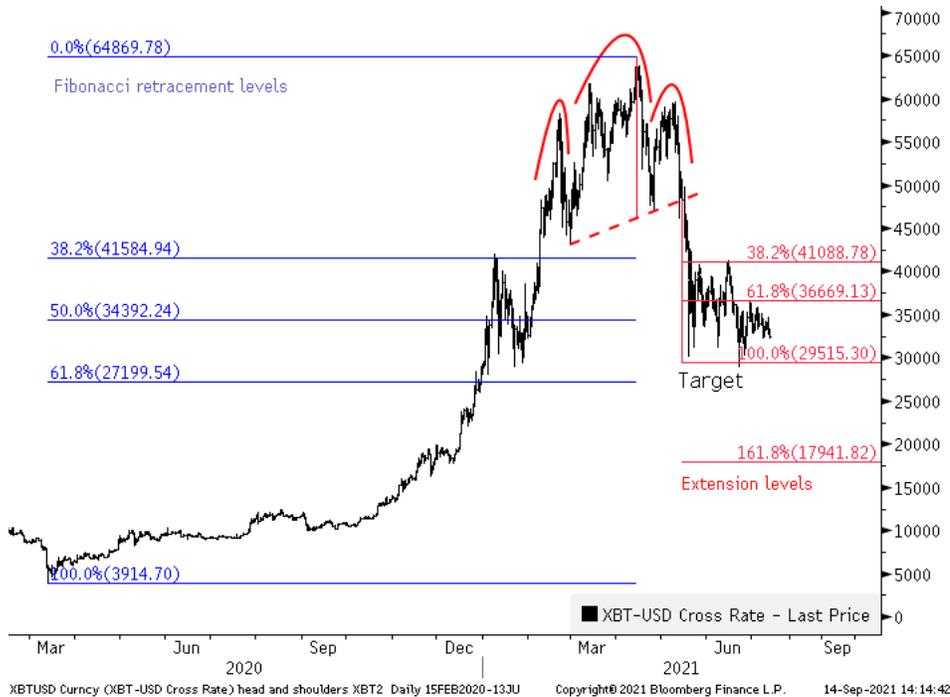
Calculate targets with measured moves and Fibonacci

There are three ways to calculate downside targets for a head and shoulders top. The first is to use a measured move projection of the height of the pattern subtracted from the breakdown point. This can be done by drawing/coping an arrow as shown in Exhibit 129. A second way to estimate multiple targets is to use a Fibonacci Extension annotation as shown in Exhibit 130. Measure the distance from the top of the head to the neckline and subtract that from the breakdown point. This will also estimate multiple target levels where the 100% line is equal to the arrow method. Shallow and deeper levels can also be estimated. A third way is to find the low and high of the uptrend preceding the head and shoulders top. Calculating a Fibonacci retracement on this distance.



Exhibit 130: Calculating a target with Fibonacci retracements and extensions

Fibonacci extension measuring downside target levels after a head and shoulders top



Source: BofA Global Research, Bloomberg

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Most Popular Technical Indicators

- RSI is the most popular technical indicator, ahead of MACD and Bollinger Bands. It is used to measure the momentum of a trend.
- We review the essence of the RSI formula, facts and myths of overbought and oversold trends and bullish / bearish divergence patterns.
- We also discuss our most preferred signals including a three troughed bullish divergence and three peaked bearish divergence.

The Relative Strength Index is very popular

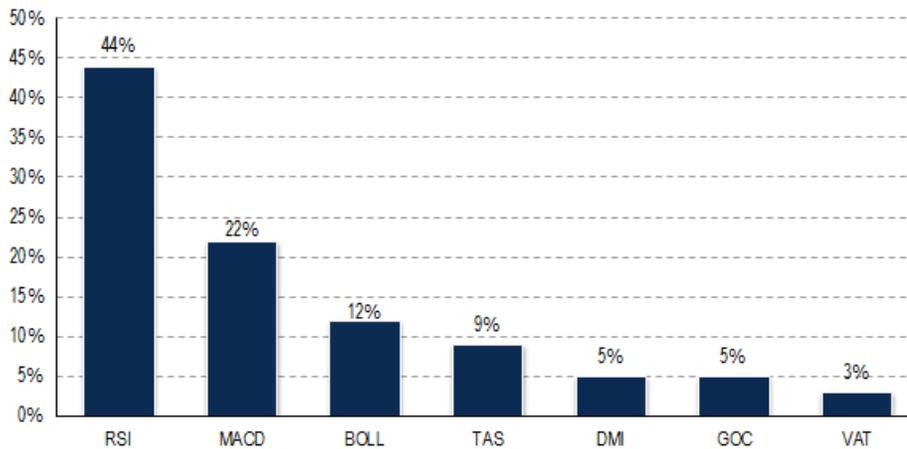
Data published in 2011 suggests the Relative Strength Index (RSI) is the most popular technical study used on the Bloomberg terminal. The Moving Average Convergence Divergence (MACD) is the second most popular, though half as popular as RSI. Third place goes to Bollinger Bands (BOLL). The top three indicators represented 78% of the seven most used indicators (Exhibit 131).

Other popular indicators include Stochastics (TAS), the Directional Movement Index (DMI) and an increasingly popular study called Ichimoku (GOC). The last is Volume at Time (VAT). Notably missing and assumed in the top 10 are simple moving averages and Fibonacci price retracements. In our view, knowing the different ways the popular indicators are used is an important step in learning and using technical analysis.



Exhibit 131: Indicator use as a percentage of the top seven most used

The most popular indicator is the Relative Strength Index (RSI)



Source: BofA Global Research, Bloomberg

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Markets use different types of indicators

The top 3 most popular indicators suggest market participants use a diverse group of indicators. RSI is a momentum oscillator offering confirmation of price breakouts, short-term buy and sell signals, and longer-term, trend-ending implications from price and momentum divergences. MACD is a trending indicator that attempts to improve upon moving averages by offering an earlier trend start and end signal. It too can provide divergence signals. Bollinger bands is a statistical indicator that attempts to identify when markets may be overdue for a volatile move when the bands are relatively narrow or when the market has moved to far too fast as price exits the bands.

Measure and trade with momentum

The Relative Strength Index (RSI), which is the most popular technical indicator used on Bloomberg, measures the momentum of a trend by comparing the average size of the up periods to the average size of the down periods over a specified timeframe, such as 14 days. Common thought suggests if momentum reaches an extreme then a reversal, or at least a consolidation, will occur. While this may be the short term outcome, sometimes the trend resumes until momentum finally depletes with a bullish or bearish divergence. In this primer, we will review RSI and the signals it can generate.

The essence of the RSI calculation and levels

If price went up \$1.00 for 10 of the last 14 days and down \$0.25 four of the last 14 days, then we know price went up on average much more than down. However, in financial markets, the up/down relationship is rarely this clear cut. This type of market may be described as overbought and the opposite as oversold. Both mean the market moved too far too fast. RSI is normalized to fall between 0 – 100. So when it is above 70, the trend is described as overbought. When it is below 30, it is described as oversold.

The facts and myths of overbought and oversold

The terms overbought and oversold mean the market may have risen or fallen too much, especially in the short term. Exiting or reversing a position solely because the market is deemed overbought or oversold may be the right trade for a short period of time but could be the wrong trade for the intermediate-term trend. One way of filtering this is to incorporate support and resistance. In theory, momentum complements a breakout similar to greater than average volume. If price and momentum break up through resistance, the expected overbought dip could be buyable. Similarly, if price and momentum break down through support, a bounce may be sold.



Momentum trades vs momentum trends

In a trend-less market, also referred to as a sideways or range-bound trend, RSI rarely moves through overbought or oversold readings. When price reaches the high end of the range and RSI is equal to or less than its prior peaks, price can be sold. If price were to breakout to new highs and RSI is still not overbought, then the breakout lacks confirmation from RSI and may soon reverse. However, when price and RSI break out together, a new uptrend is under way, and longs could be held or added to in a dip.

Price vs RSI divergences signal a trend is changing

When prices make lower lows and the RSI indicator makes higher lows, a bullish divergence is forming. Conversely, when price makes higher highs and RSI makes lower highs, a bearish divergence is forming. Think of price as a car and RSI as the foot on the accelerator. If a car is going uphill and the foot is pushing the accelerator, then the car is moving uphill. However, if the pressure on the accelerator starts to decrease, the car will be climbing the hill at a slower speed (with less momentum). Eventually the car makes it to the top of the hill, or the peak of the uptrend, and the foot comes completely off the pedal. If the bearish divergence is correct, all that's left is for the car to go down the hill.

Adjust overbought and oversold levels for trend direction

In the below chart, another important aspect of using RSI is shown. When markets are in a downtrend, naturally they should be oversold more often than not. When markets are in uptrends, they should be overbought more often. When a clearly defined trend is present, it usually makes sense to adjust the overbought and oversold levels. In uptrends, consider using 40-80 and in downtrends 20-60. If price is in a downtrend and reverses so RSI fails at 60, it is still in a downtrend. If RSI moves through 60, the downtrend may be near an end. The same goes for an uptrend and the 40 level.

Exhibit 132: RSI is the most popular technical indicator (excluding moving averages)

Historical example from March 2020 to May 2021 using RSI to confirm trend breakouts, trend tops and oversold/overbought moves.



Source: BofA Global Research, Bloomberg



Appendix VII: Digital Assets & ETFs

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ETF “proof of work” may be nearly complete

The first bitcoin ETF was proposed in 2013, when bitcoin was trading below \$100. The SEC finally rejected the proposal in 2017 after multiple amendments to the original filing. A follow-up attempt for approval was rejected again in 2018. Interest in bitcoin, other digital assets, and related companies has soared since then and today there are 20 pending filings to launch related ETFs.

BofA Global Research ETF ratings

The goal of BofA ETF research is to identify the most attractive funds for new investment. We rate both the desirability of fund categories (e.g., sectors and asset classes) and the relative attractiveness of individual funds. Today we have approximately 270 ETFs with ratings coverage and we continue to add more funds and asset classes.

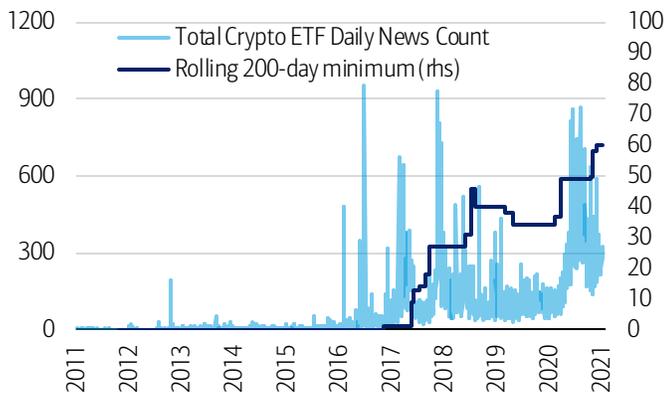
We do not yet have ratings on digital asset-related ETFs. To meet our eligibility criteria for ratings coverage, a fund must: 1) be SEC-approved and listed on a US exchange; 2) have approximately \$100mn in assets or more; and 3) have at least one year of live trading history.

The relentless demand for digital asset ETFs

Investor interest has risen dramatically in ETFs related to digital assets and digital asset-economy stocks (e.g., miners, blockchain, exchanges). Digital asset-linked ETF terms in news articles and on social media flashed higher from 2016 and 2019, but the most recent bout of interest looks more enduring as the minimum number of searches continues to rise (Exhibit 133). Interest also appears to ratchet higher each time bitcoin prices rally (Exhibit 134).

Exhibit 133: Interest in digital asset ETFs has steadily risen since 2018...

Daily counts for mentions of digital asset-related ETF search terms

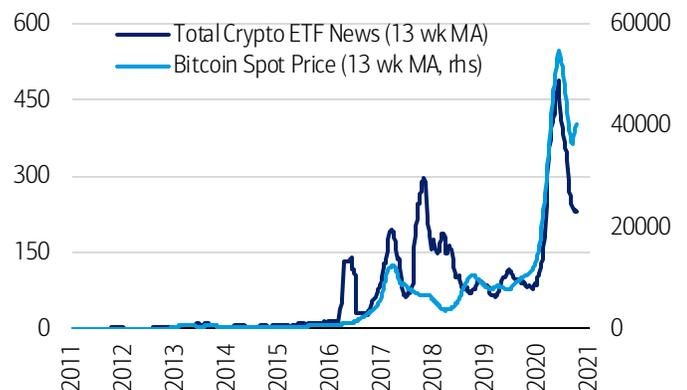


Source: BofA ETF Research, Bloomberg

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Exhibit 134: ...and has trended with Bitcoin spot prices

Total digital asset ETF news vs bitcoin spot price, 13-week moving averages



Source: BofA ETF Research, Bloomberg

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State of the market

We currently do not rate any blockchain or digital asset ETFs.

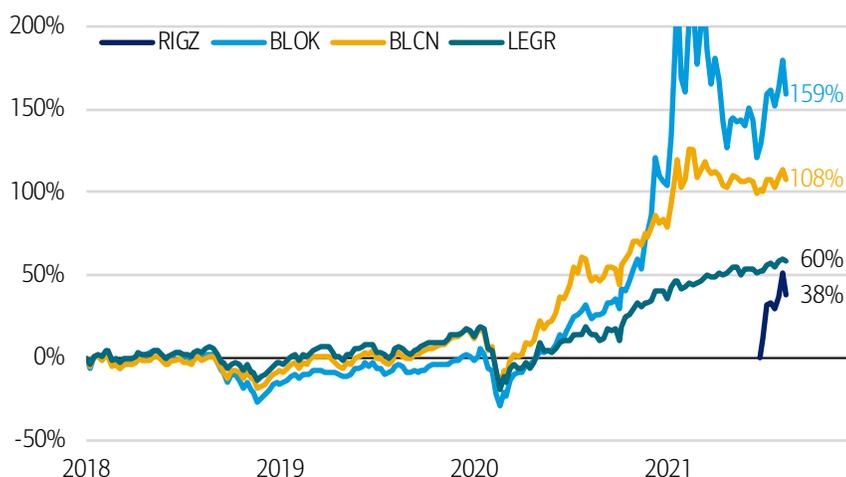
There are not yet any US-listed ETFs that track digital assets directly. There are some listed funds in the broader digital asset-economy industry, including a recently-launched digital asset miner ETF and more established “blockchain economy” ETFs.

These ETFs have generally risen significantly since inception, with the largest blockchain ETF up nearly 160% since it launched in early 2018 (Exhibit 135). RIGZ, the most recent ETF to launch, is up nearly 40% since July.

Another new listing, the Simplify Equity PLUS GBTC ETF (SPBC) targets 100% exposure to US equities along with a 10% allocation to bitcoin via the GBTC trust.

Exhibit 135: Digital asset-economy ETFs have generally risen significantly since inception

Blockchain and digital asset miner ETFs rebased at respective inception dates



Source: BofA ETF Research, Bloomberg

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We count seven blockchain-related ETFs and one digital asset mining ETF currently available in the US. Exhibit 136 contains statistics on the 3 blockchain ETFs with over \$100m AUM and the lone miner ETF. Note that the blockchain ETFs tend to have large semiconductor holdings, which likely explains the smaller correlation to bitcoin prices.

Exhibit 136: US-listed digital asset-economy and mining ETFs

US ETFs that are linked to the digital asset industry

Ticker	Name	Type	Structure	AUM (\$mn)	Avg daily value traded (3m, \$mn)	Expense Ratio	Sortino (3Y)	Wkly correl to BTC
RIGZ	Viridi Cleaner Energy Crypto-Mining & Semiconductor ETF	Miners	Equity securities	11.1	NA	0.90%	NA	0.69
BLOK	Amplify Transformational Data Sharing ETF	Blockchain	Equity securities	1260.2	17.6	0.70%	1.4	0.49
BLCN	Siren Nasdaq NexGen Economy ETF	Blockchain	Equity securities	285.6	2.1	0.68%	1.3	0.31
LEGR	First Trust Indxx Innovative Transaction & Process ETF	Blockchain	Equity securities	125.8	0.7	0.65%	0.7	0.26

Source: BofA ETF Research, Fund filings, Bloomberg

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Look north for precedent

There are now a number of ETFs in Canada that track bitcoin and ether directly. Most of these funds are structured to provide direct coin ownership and track movements in the underlying coin fairly well (Exhibit 137).



Exhibit 137: Existing digital asset ETFs in Canada

List of ETFs linked to bitcoin or ether in Canada

Ticker	Name	Digital asset	Exposure	AUM (USD, mn)	Avg daily value traded (3m, mn)	Max. Expense Ratio	Sortino (3M)	Wkly correl to underlying
BTCQ	3iQ CoinShares Bitcoin ETF	Bitcoin	Direct bitcoin ownership	941.7	0.8	1.25%	3.1	0.88
BTCC	Purpose Bitcoin ETF	Bitcoin	Direct bitcoin ownership	693.7	8.3	1.50%	2.1	0.88
ETHX/B	CI Galaxy Ethereum ETF	Ether	Direct ether ownership	624.7	18.3	0.95%	5.0	0.84
BTCX/B	CI Galaxy Bitcoin ETF	Bitcoin	Direct bitcoin ownership	281.6	4.2	0.95%	3.0	0.85
ETHH	Purpose ether ETF	Ether	Direct ether ownership	218.0	3.8	1.50%	5.4	0.86
EBIT	Bitcoin ETF	Bitcoin	Direct bitcoin ownership	105.5	2.4	0.75%	3.1	0.88
ETHR	Ether ETF	Ether	Direct ether ownership	NA	1.6	0.75%	4.9	0.84

Source: BofA ETF Research, Fund filings, Bloomberg

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Here comes everybody

The regulatory hurdle has been much higher for US-listed ETFs with direct digital asset exposure. In the past, regulators have expressed reservations about the fundamental value of digital assets and whether the technology is too sophisticated for investors to understand.

Recent months have brought some changes. In August 4th remarks at the Aspen Security Forum, SEC Chair Gary Gensler explained how his work teaching on digital assets at MIT affected his views:

“...I came to believe that, though there was a lot of hype masquerading as reality in the crypto field, Nakamoto’s innovation is real. Further, it has been and could continue to be a catalyst for change in the fields of finance and money.” – SEC Chair Gary Gensler

Gensler also implied that ETF filings limited to CME-traded bitcoin futures may receive a more favorable review from the regulator.

We found 20 outstanding filings for proposed US bitcoin ETFs since December 2020 (Exhibit 138). Most of the funds proposed were slated to have direct bitcoin ownership until Gensler’s remarks in August. Since then, all the filings we found were for funds that would own bitcoin via listed futures.

The SEC recently extended its review period for the first fund with a decision due, the VanEck Bitcoin Trust, now expected on November 14, 2021 (SEC Release No. 34-92894). However, if the regulator decides to approve funds that hold futures rather than those with direct ownership, there may not be an approval until well into 2022.

Exhibit 138: Proposed US Bitcoin ETFs since December 2020

List of current proposals for Bitcoin ETFs

Proposed Ticker	Proposed ETF Name	Filing Date	Issuer	Structure
	VanEck Bitcoin Trust	12/30/2020	VanEck	Direct Bitcoin Ownership
	Valkyrie Bitcoin Fund	1/22/2021	Valkyrie Investments	Direct Bitcoin Ownership
	NYDIG Bitcoin ETF	2/16/2021	Stone Ridge/NYDIG	Direct Bitcoin Ownership
BTCW	Wisdomtree Bitcoin Trust	3/11/2021	Wisdomtree	Direct Bitcoin Ownership
	First Trust SkyBridge Bitcoin ETF Trust	3/19/2021	First Trust/SkyBridge	Direct Bitcoin Ownership
	Wise Origin Bitcoin Trust	3/24/2021	FD Funds Management/Fidelity	Direct Bitcoin Ownership
	Kryptoin Bitcoin ETF Trust (first filed Oct 2019)	4/9/2021	Kryptoin Investment Advisors	Direct Bitcoin Ownership
	Galaxy Bitcoin ETF	4/12/2021	Galaxy Digital	Direct Bitcoin Ownership
	Teucrium Bitcoin Futures Fund	5/20/2021	Teucrium Trading	Bitcoin Futures
	One River Carbon Neutral Bitcoin Trust	5/24/2021	One River	Direct Bitcoin Ownership & Carbon Credits
ARKB	ARK 21Shares Bitcoin ETF	6/28/2021	Ark Invest/21 Shares	Direct Bitcoin Ownership
	Global X Bitcoin Trust	7/21/2021	Global X	Direct Bitcoin Ownership
	wShares Bitcoin Commodity Trust (first filed May 2019)	8/4/2021	Wilshire Phoenix	Direct Bitcoin Ownership
	ProShares Bitcoin Strategy ETF	8/4/2021	ProShares	Bitcoin Futures & Related Products



Exhibit 138: Proposed US Bitcoin ETFs since December 2020

List of current proposals for Bitcoin ETFs

Proposed Ticker	Proposed ETF Name	Filing Date	Issuer	Structure
	Invesco Bitcoin Strategy ETF	8/4/2021	Invesco	Bitcoin Futures & Related Products
	Bitcoin Strategy ETF	8/9/2021	VanEck	Bitcoin Futures & Related Products
	Valkyrie Bitcoin Strategy ETF	8/11/2021	Valkyrie Investments	Bitcoin Futures
	Galaxy Bitcoin Strategy ETF	8/17/2021	Galaxy Digital	Bitcoin Futures
	Global X Blockchain & Bitcoin Strategy ETF	8/19/2021	Global X	Equities + 25% BTC Futures
CRYP	AdvisorShares Managed Bitcoin ETF	8/20/2021	AdvisorShares/Morgancreek	Bitcoin Futures & Related Products

Source: BofA ETF Research, Bloomberg Intelligence, SEC.gov, ETF.com.

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Appendix VIII: Digital Assets & Storage

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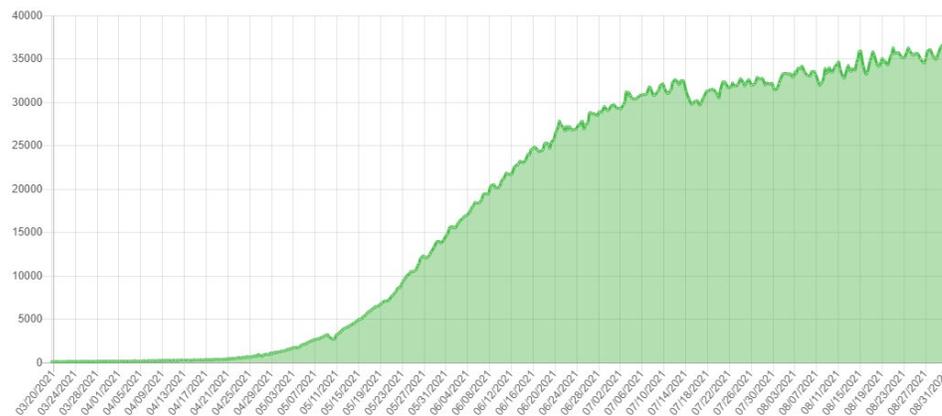
Chia Network

Chia, also known as the green digital currency, is a decentralized blockchain that is more energy efficient than others, given its use of consensus mechanisms called proof-of-space and proof-of-time. Unlike most blockchains that utilize proof of work, Chia is created or "farmed" in a storage space, hence "proof-of-space". Farming is a mining process where a participant, or a farmer, creates numerous "plots" that is then stored in the storage space. The farmer "harvests" a Chia coin when the network requests a specific plot the farmer created to validate a financial transaction as a reward. Although CPU is used in the farming process, the created plots can be stored in a drive space indefinitely until the harvest. Chia uses the network called Chialisp, a smart coin language that utilizes smart contracts and transaction functions, which allows Chia to be used in various scenarios in banking, payments and other financial applications.

To prevent potential hacking, Chia also utilizes Verifiable Delay Function, a type of proof-of-time function to ensure security and integrity of the blockchain. The payout of Chia is calculated based on percentage of total storage owned by the farmer. As more history is added to Chia's blockchain, the network will require more storage. The rise in popularity of Chia would increase the price of both HDD and solid state drives (SSD), since HDD is primarily used to store the plots, while SSD is used for plotting due to higher capacity and ability to handle large amounts of data. In order for farmers to have a higher probability of winning a block, they need a high-performance SSD to create as many plots as fast as possible.

Exhibit 139: Chia Network Netspace

Storage allocated to the Chia network increased +2600% over the last 4 months



Source: Chiaexplorer.com
Data as of August 31, 2021

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Appendix IX: Emerging token ecosystem infrastructure

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The on-off ramps to the digital asset ecosystem

What are the different types of exchange?

The most common type of exchange is a centralized exchange (CEX), which is controlled by a for-profit entity that takes custody of user funds and facilitates off-chain transactions between buyers and sellers by maintaining an order book. An estimated 99% of all coin/token trades take place on CEXs. CEXs usually allow for both fiat-to-crypto and crypto-to-crypto trades; sometimes offer features like margin trading, short sales and portfolio management tools; and have KYC/AML policies.

A decentralized exchange (DEX) is not controlled by any entity, does not take custody of user funds and operates on the Ethereum blockchain as a trustless peer-to-peer (P2P) exchange, which removes the intermediary by connecting buyers and sellers directly using smart contracts to facilitate on-chain transactions. DEXs offer only crypto-to-crypto trades, usually do not provide additional features and have limited KYC/AML policies. DEXs offer increased security, anonymity and lower transaction fees relative to CEXs, but at the cost of lower liquidity, higher latency and slippage costs, lower ease of use and the potential to lose your private key – the equivalent of having your wallet permanently glued shut. The security of your selected exchange and the potential to lose your private key should not be taken for granted or overlooked.⁶⁶

Which exchange should I use?

Given that many readers are likely first-time token buyers, we'll start by focusing on CEXs. When selecting a CEX, an investor should consider the coins offered, average daily platform volume and liquidity, security, regulation, fees, trading and withdrawal limits and availability of leveraged trading. Readers should note that some of the largest exchanges by average daily volume and weekly site visits do not allow US investors to use their platforms. We also note that US investors can use traditional exchanges like Robinhood, Fidelity, Charles Schwab, TD Ameritrade, or apps like Cash App, PayPal App and Venmo to purchase tokens. Although using an app to purchase a token is an easy way for retail investors to enter the space, we don't recommend this approach for institutional investors.

However, trading on CEXs may not be suitable for all institutional investors; instead, institutional investors looking to enter the digital asset space may need to trade on DEXs, although the need is fading. Sophisticated investors that make large digital asset trades frequently use smart-order routing to access liquidity pools on numerous CEXs in an attempt to decrease slippage costs. Moreover, CEXs frequently place limits on daily withdrawals, which may limit the flexibility that some fund managers need. For example, Coinbase Pro accounts have daily withdrawal limits of \$50,000 worth of crypto and fiat currency. In addition, trade orders on CEXs are broadcast in the order book, which can

⁶⁶ <https://www.cnn.com/2018/06/07/1-point-1b-in-cryptocurrency-was-stolen-this-year-and-it-was-easy-to-do.html>

<https://www.nytimes.com/2021/01/12/technology/bitcoin-passwords-wallets-fortunes.html>



increase slippage costs. In contrast, DEXs offer the ability to enter a trustless transaction using smart contracts that allow large trades to occur at agreed-upon prices and without slippage costs.

- Coinbase** – Founded in 2012 by current Chairman and CEO Brian Armstrong, Coinbase is a global provider of end-to-end financial infrastructure and technology for the digital asset ecosystem with around 2,176 employees. Today, COIN provides a wide range of crypto-native products, services, technology and infrastructure to over 68mn verified users, 9,000 institutions, and 160,000 ecosystem partners in over 100 countries as of 2Q21. The company went public on 4/14/21 via a direct listing on the Nasdaq, with shares of Class A common stock initially being offered at \$250. During 2020, COIN processed \$193bn in transaction volume and had over \$90bn of assets on its platform as of December 31, 2020, which has grown to over \$180bn as of June 30, 2021. The bulk of COIN's trading volumes are conducted in bitcoin and ether, which represented 24%/26% of total trading volume in 2Q21, though the company supports investing in over 83 cryptocurrencies and stores over 142 types of digital assets in custody. The bulk of net revenues continues to be driven by retail digital asset trading, which generated around 95% of net revenues in 2Q21.
- Binance** – Founded in 2017 by Changpeng Zhao, Binance is the world's largest crypto exchange by trade volume. The company has over 320 cryptocurrencies on its platform and, according to a Bloomberg report on 12/4/20, Binance earned between \$800mn and \$1bn of adj. EBITDA in 2020. In July 2017, the company also launched Binance Coin (BNB) through an initial coin offering (ICO), which is the 4th largest token by market value today. In May 2019, the company announced that it had been hacked and the perpetrators had stolen 7,000 bitcoin worth around \$40mn. In 2019, Binance was banned in the US for regulatory reasons, which led to Binance creating a separate exchange that complied with US laws known as Binance.US, though Binance.US is currently banned in 7 states including New York. As of May 2021, the company was being investigated by the Department of Justice (DOJ) and Internal Revenue Service (IRS) for allegations of money laundering and tax offenses. On 8/6/21, the CEO of Binance.US, Brian Brooks (former acting US Comptroller of the Currency), abruptly announced his departure from the company after just 3 months on the job, citing differences in strategic direction.
- Huobi Global** – Founded in 2013 by Leon Li, Huobi Global is one of the world's largest cryptocurrency exchanges by trading volume and is primarily centered in the Asia Pacific region. In 2018, the company acquired a controlling stake of Pantronics, a Hong-Kong based electronics manufacturer, in a reverse takeover and listed on the Hong Kong Stock Exchange. The company halted operations in the US after regulatory concerns in December 2019, but announced in December 2020 it would resume US operations sometime in 2021.
- OKEx** – OKEx is a global cryptocurrency exchange operating in over 100 countries, excluding the US, Hong Kong, Malaysia, among others. According to the company, it deals with \$1.5bn daily BTC futures trading volume, and offers spot, margin, options, perpetual swaps, DeFi, lending and mining services.
- Kraken** – Kraken is a global cryptocurrency exchange that supports over 70 assets on its platform across 176 countries. The company was founded in 2011 and launched trading operations in 2013. Like COIN, it offers a Kraken and Kraken Pro platform, the latter of which is used for professional trading. In 2015, Kraken was hit by Distributed Denial of Service (DDOS) attacks, which led to losses for users and led to lawsuits being filed against Kraken. In 2017, the company acquired Cryptowatch, which expanded its capabilities to provide real-time market information.



- **Gemini** – Gemini is a privately-owned cryptocurrency exchange that allows users to transact in and store over 40 digital assets on its platform. Gemini was created in 2015 and allows users to engage with the platform with its mobile app, payment app and its own currency, the Gemini Dollar, which is a stablecoin tied to USD.
- **Voyager Digital** – Voyager Digital is a Canadian-based crypto-asset broker that provides retail and institutional investors with solutions for trading digital assets. The company is publicly traded on the Toronto stock exchange and as of 1Q21, it had over 1mn verified users and over \$2.4bn in AUM with \$2.5bn in principal value traded in March 2021. As of 1Q21, the company had over 50 altcoins on its platform.
- **Robinhood** – Robinhood is a retail trading platform that had \$63bn of assets on its platform and 11.7mn monthly transacting users (MTUs) as of the end of 2020. The company generated \$958.8mn in revenue and \$155mn in adj. EBITDA in 2020, representing 16.2% margins. In 2019, the company announced plans to launch cryptocurrency trading features and continued to roll-out in new states. In 2021, Robinhood expanded its features to include withdrawing and storing digital assets on the platform, and in February 2021 the company announced it had added 6mn new digital asset customers in the first 2 months of 2021. The platform currently supports 7 digital assets. Robinhood IPO'ed on 7/28/21 with a share price of \$38.
- **PayPal** – On 10/21/20, PYPL announced the launch of two cryptocurrency services: 1) PYPL users are able to buy, sell and hold cryptocurrencies (including bitcoin and others) in their PayPal wallet, functions which have since been expanded to the Venmo wallet, with plans to add other geographies, and 2) PayPal users can also use cryptocurrency stored in their PayPal account as a funding source to make purchases at any of PYPL's merchants (Pay With Crypto). Cryptocurrency balances funding PYPL transactions will first be converted into fiat currency by PYPL and then paid to the merchant, who will not have to do any integration work. Neither consumers nor merchants will pay any incremental fees for this service.
- **Square** – SQ first allowed bitcoin trading on the Cash App platform in 2018, which has since grown to \$4.6bn of transaction volume by 3mn MTUs in 2020. Cash App allows users to use their Cash App balance to buy and sell bitcoin, and charges users a service fee of ~2% for these transactions (increased from mid-1% in 3Q19), along with additional fees depending on differences in prices across exchanges. That said, Square passes through most of these fees to the bitcoin exchanges.

Exhibit 140 shows app download and ratings for leading digital asset exchanges on the Google and Apple stores.

Exhibit 140: Selected digital asset exchange apps – downloads and ratings

Data as of 7/22/21

	Number of downloads		Number of ratings		Rating		Ranking
	Google	Apple	Google	Apple	Google	Apple	Apple
Coinbase	10M+	481K	1.4M	4.3	4.7	#15 in Finance	
Coinbase Pro	1M+	13K	97K	4.0	4.7	#120 in Finance	
Binance	10M+	313K	67K	4.5	4.7	#77 in Finance	
Binance.US	1M+	5K	70K	2.4	4.2	#85 in Finance	
Kraken / Pro	100K+	3K	8.9K	4.2	4.7	N/A	
Crypto.com	10M+	138K	22K	4.1	3.9	#22 in Finance	
Gemini	1M+	19K	52K	4.5	4.8	#138 in Finance	
Voyager	500K	5K	70K	3.7	4.7	#89 in Finance	
Robinhood	10M+	421K	3.7M	3.9	4.1	#11 in Finance	

Source: Google Play Store, Apple App Store

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Security & custody critical

In traditional finance, a financial institution is the custodian that stores securities and other assets on behalf of institutional investors to minimize risk of loss or theft. Accelerating institutional adoption since 2019 has resulted in the rise of digital asset custody providers. A digital asset custodian stores digital asset holdings on behalf of professional and institutional investors by providing a secure storage facility for a small fee. The largest digital asset custodians by assets held include BitGo (recently acquired by Galaxy), Coinbase Custody, Anchorage and Gemini. Digital asset custodian ecosystem vendors include Fireblocks, Copper, Paxos and others.

Digital asset custodian growth is driven by 1) investors outsourcing the technical issues of securely storing digital assets and 2) enabling institutional investors that are required to store investments at a regulated custodian to enter the digital asset ecosystem. Another benefit that digital asset custodians provide is that investors need to undergo AML/KYC checks before sending their digital assets to wallets hosted by the custodians. Clients' digital assets are usually held in multi-signature cold storage (offline) wallets for security.

Data & analytics

An entire marketplace of digital asset-specific information vendors exists and is growing. The blockchain is permissionless and transparent and analytics can be applied directly to blockchain information (on-chain) as well as reported information from exchanges (off-chain). Although token price movements at times may appear to be just momentum-related, on-chain analytics can provide data that can support (or refute) fundamental expectations. Also, since all transactions on the blockchain are available for all to see, it's possible to track digital asset/bitcoin flows potentially used in illicit activities which is likely the reason illicit activities dropped to under 1% of transactions in 2020. Companies involved in this segment include Chainalysis, Coinmetrics, Elliptic, CipherTrace and many others.



Appendix X: Digital Assets & Data Analytics

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On-chain data analytic insights

On-chain data (transactions on the blockchain) enables investors to analyze flows and positioning and assess sentiment within large blockchain networks. Blockchains are open and transparent by design and provide data that can be used to analyze miner incentives, token usage and performance. On-chain data also provides insight on volume and transaction size for decentralized exchanges and on borrowers, lenders and volume for lending protocols. For future reports, we plan to use on-chain data, exchange and derivatives flows, technical price action and social media to assess market sentiment.

There are hundreds of different on-chain metrics. Two popular examples to measure market sentiment for bitcoin are Net Unrealized Profit/Loss (NUPL) and the Puell Multiple.

- NUPL measures the difference between the price of bitcoin when bought and the price of bitcoin currently for all bitcoin held in wallets. Put another way, the net unrealized profit or loss for all bitcoin held in wallets. NUPL generally tends to be positively correlated with the price of bitcoin, but can act as a contrarian indicator when it reaches extremes.
- The Puell Multiple, created by David Puell, measures the daily value in USD of bitcoin mined divided by the 365-day moving average. Similar to the NUPL metric, the Puell Multiple generally has a positive correlation with the price of bitcoin, but can act as a contrarian indicator when it reaches extremes.



Figures

Exhibit 141: Public digital asset companies

Companies have emerged throughout the digital asset ecosystem

Company	Ticker	Mkt Cap (US\$)	Description
Coinbase	COIN (US)	\$54.6bn	Regulated digital asset company that provides a platform for buying, selling, transferring and storing digital assets.
Westone Information	002268 (CH)	\$6.3bn	Provides information security equipment using cryptography technology. Provides digital asset devices, including communication digital asset devices, network digital asset devices, main frame digital asset devices and digital asset modules, general security products and information terminals.
Galaxy Digital Holdings	BRPHF (US)	\$5.3bn	Merchant banking institution that focuses on digital assets and blockchain technology and provides asset management, trading, principle investment and advisory services.
Marathon Digital	MARA (US)	\$4.0bn	Digital asset tech company that mines digital assets with a focus on the blockchain ecosystem and the generation of digital assets.
Riot Blockchain	RIOT (US)	\$3.6bn	Digital currency company that focuses on buying digital asset and blockchain businesses, as well as supports blockchain tech companies. Used to be in the biotech space.
Voyager Digital	VGVF (US)	\$2.1bn	Provides digital asset brokerage services and offers assets and commission-free trading. Services retail and institutional clients.
Monex Group	MNXBF (US)	\$1.6bn	Online financial services holding company that manages brokerage firms and digital asset exchanges in Japan and abroad. Also offers investment advisory services.
Northern Data	NB2 (GR)	\$1.4bn	Info tech company that provides solutions for digital assets and offers infrastructure services for the blockchain.
Hive Blockchain	HIVE (US)	\$1.2bn	Digital asset mining firm that validates transactions on blockchain networks, provides digital asset mining and connects digital asset and traditional capital markets.
HUT 8 Mining	HUT (US)	\$1.1bn	Digital asset mining company that offers blockchain infrastructure and technology solutions.
Bitfarms Ltd	BITF (US)	\$996.0mn	Digital asset mining company that provides computing power to networks such as Bitcoin and earns fees from each network for securing and processing transactions.
Athena Bitcoin	ABIT (US)	\$828.8mn	Digital asset tech company that mines digital assets with a focus on the blockchain ecosystem and generation of digital assets.
Mawson Infrastructure	MIGI (US)	\$806.1mn	Digital infrastructure provider that operates physical infrastructure assets and provides digital asset mining and digital asset management services.
Argo Blockchain	ARBKF (US)	\$710.2mn	Digital asset mining company with mining infrastructure located in Quebec.
Koal Software	603232 (CH)	\$503.6mn	Information security solution provider that develops, produces and sells public key infrastructure commercial cryptographic software products.
Sinosun Tech	300333 (CH)	\$389.5mn	Develops and applies modern cryptographic techniques. Main products include electronic payment password systems, password chips and fiscal security components.
Arcane Crypto	ARCANE (SS)	\$217.8mn	Venture capital firm that develops and invests in projects focusing on Bitcoin and digital assets.
Diginex	EQOS (US)	\$203.0mn	Digital assets financial services company that focuses on delivering a digital asset ecosystem offering innovative products and services.
Bigg Digital Asset	BBKCF (US)	\$179.0mn	Designs and develops application software. Develops agnostic search and analytics engine to track, trace and monitor digital asset transactions at a forensic level.
Quantum Solutions	2338 (JP)	\$83.7mn	Internet financial platform operator and services provider that offers digital asset exchange, blockchain application development and software outsourcing services.
Goobit Group	BTCX (SS)	\$74.0mn	Provides financial services and offers digital asset trading and other related services.
Quickbit	QBIT (SS)	\$73.4mn	Digital asset payment services and solutions company that provides user-friendly and secure digital asset payments methods for e-merchants and consumers.
Xpecunia Nordic	XPEC (SS)	\$34.6mn	Greentech digital asset company that owns and operates renewable energy-driven digital asset mining plants.
SmartDisplayer Technology	6717 (TT)	\$12.8mn	Manufactures and distributes display cards. Produces one-time programmable and digital asset cards, as well as circuit boards, batteries, microprogrammed control units and integrated circuits.

Source: BofA Global Research
Market caps as of 8/31/21

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