

Digital Assets: Beauty Is Not in the Eye of the Beholder



Parsing the Beauty from the Beast.



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Dear Clients,

There has been enormous change in the world of cryptocurrencies and blockchain technology since we first wrote about it in 2017.

The number of cryptocurrencies has increased from about 2,000, with a market capitalization of over \$200 billion in late 2017, to over 8,000, with a market capitalization of about \$1.6 trillion. For context, the market capitalization of global equities is about \$110 trillion, that of the S&P 500 stocks is \$35 trillion and that of US Treasuries is \$22 trillion.

Reported trading volume in cryptocurrencies, as represented by the two largest cryptocurrencies by market capitalization, has increased sixfold, from an estimated \$6.8 billion per day in late 2017 to \$48.6 billion per day in May 2021.¹ This data is based on what is called “clean data” from Coin Metrics; the total reported trading volume is significantly higher, but much of it is artificially inflated.^{2,3} For context, trading volume on US equity exchanges doubled over the same period.

Additionally, the ecosystem around cryptocurrencies and blockchain has grown exponentially and become increasingly complex:

- The market has broadened from a handful of cryptocurrencies to now include stablecoins, utility tokens, non-fungible tokens (NFTs) and central bank digital currencies (CBDCs). The Bank for International Settlements reports that most central banks are researching CBDCs.⁴
- Cryptocurrency asset management firms have been launched. The largest firm, Grayscale Investments LLC, has reported about \$32 billion of assets under management.
- About 400 cryptocurrency exchanges have set up shop. The largest US-based exchange, Coinbase Global Inc., recently listed on Nasdaq. The irony of a cryptocurrency exchange seeking liquidity through a traditional dollar-based equity exchange has not gone unnoticed.

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- Crypto-based derivatives, such as futures and options on cryptocurrencies, are now readily available on the CME, the world's largest financial derivatives exchange.
 - Dozens of new companies designed to compile and analyze crypto market data have been launched. For example, Coin Metrics Inc. and Crypto Coin Comparison Ltd. (CryptoCompare) provide extensive data on cryptocurrency prices and trading volumes, evaluate data on the quality of the exchanges and produce a series of indices. Chainalysis Inc. provides transaction analysis and data to government agencies and other institutions for risk management, for regulatory compliance and, notably, to combat cybercrime.
 - Multinational companies across industries are leveraging blockchain technology to improve everyday operations and increase efficiencies. For example, A.P. Moller-Maersk, a Danish shipping company, uses the technology to track shipments, containers and documents around the world. Walmart uses the technology to track its food products in order to maintain safety standards and minimize risk of contamination. French luxury goods company LVMH uses the technology to track its own products and combat counterfeits. Hospitals have used it to keep track of COVID-19 vaccines. These companies are primarily using private blockchains that can be accessed only with permission granted by a centralized source, unlike public blockchains, such as those of Bitcoin and Ethereum, which are permissionless. The adoption of blockchain technology is expanding so rapidly that Forbes now produces an annual publication called "Forbes Blockchain 50" that features leading multinational companies using this technology.
 - Hundreds of blockchains and related software have been built. Bitcoin was the first blockchain of its kind, and Ethereum is the most actively used blockchain for decentralized applications. However, the technology is evolving rapidly. Faster platforms such as Algorand and Solana have also been introduced, as have second-layer networks.
 - Software such as Corda and Quorum has been designed to run on private blockchains for companies where cryptocurrencies are not required. Hyperledger is a nonprofit collaboration that supports the development of blockchains and related tools for businesses.
 - Professional services firms such as Accenture, Deloitte, EY and IBM have dedicated digital asset teams that offer a broad range of services to support the use of blockchain technology.

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- Mainstream financial institutions such as Goldman Sachs have formed units dedicated to providing traditional financial services and market liquidity to clients using blockchain technology and to trading cryptocurrency derivatives.

In the meantime, crypto-billionaires are being minted and an extensive new vocabulary has been developed around cryptocurrencies and blockchain technology (e.g., distributed ledger, proof-of-work, proof-of-stake, blockchain forks, stablecoins, utility tokens, HODL (hold on for dear life), decentralized investment pools and second-layer protocols).

The growth of this digital asset ecosystem has garnered significant attention from a broad range of financial market participants with extreme, even extremist, views, on both sides of the ledger.

At one end of the spectrum are the proselytizers who oftentimes talk up the value of many components of this ecosystem. They point to new developments in the ecosystem as a confirmation of the value of cryptocurrencies, especially Bitcoin, as a legitimate asset class, including for diversified portfolios. This group is generally comprised of hedge fund traders and technology entrepreneurs with a vested interest in the success of the ecosystem, either as owners of digital asset businesses or as significant holders of cryptocurrencies.

Their belief in the value of cryptocurrencies is driven by a view that centralized systems in the world of finance cannot be trusted. They do not differentiate between emerging market country currencies, such as those of Argentina and Turkey, and that of the US, which is the reserve currency of the world.

In its simplest form, the proselytizers' basic premise is that the US government, the US Treasury and the Federal Reserve together cannot be trusted to maintain the reserve currency status of the dollar because their policies will lead to high inflation that will debase the value of the dollar. Hence, they argue, the world needs alternatives—and cryptocurrencies, theoretically decentralized and devoid of any ruling body, offer that alternative. This reasoning ignores that the reserve currency status of the US dollar is arrived at by world consensus and backed by a \$21 trillion economy. It is not any one US president or administration or Federal Reserve chair who dictates that status.

At the other end of the spectrum are the naysayers who are dismissive of both cryptocurrencies and the blockchain technologies that underpin the cryptocurrencies. Their basic premise is that a digital coin, created through a series of computer protocols using enormous and growing amounts of energy (largely fossil

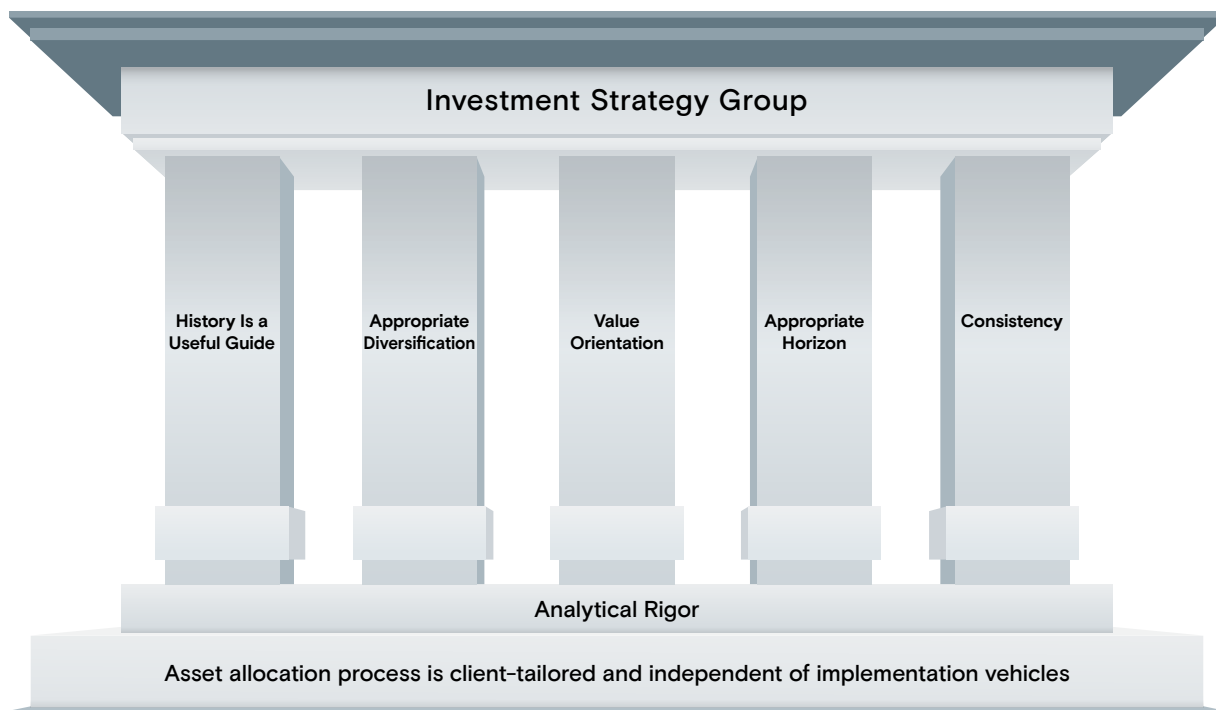
fuels), has no tangible value or utility outside the digital asset ecosystem, nor does it have any intrinsic value, nor is it an investable asset class. All point to the nearly sixfold appreciation in the price of Bitcoin over the 12 months through its peak in April as evidence of a bubble that will eventually burst.

Many of the naysayers are long-only equity investment professionals with long tenures in the financial industry. They invest based on valuation methodologies and, as we discuss later in the report, cryptocurrencies do not lend themselves to such valuation.

The rapid price appreciation of cryptocurrencies; the media (and Twitter) blitz on bitcoin, ether, and even dogecoin; and the diametrically opposing views of high-profile market participants have confounded many of our clients. The most important question on their minds with respect to the digital asset ecosystem is whether cryptocurrencies form a legitimate asset class and therefore play a role in their investment portfolio.

The purpose of this *Insight* is to address our clients' questions by analyzing the desirability, even viability, of cryptocurrencies as an investment asset class and

Exhibit 1: Pillars of the Investment Strategy Group's Investment Philosophy



examining a possible role for cryptocurrencies in our clients' customized strategic asset allocation process, within the framework of our investment philosophy (see Exhibit 1).

We have followed the digital asset ecosystem for several years. In preparing for this report, we have broadened and deepened our understanding and expanded our network; no stone was left unturned. We have:

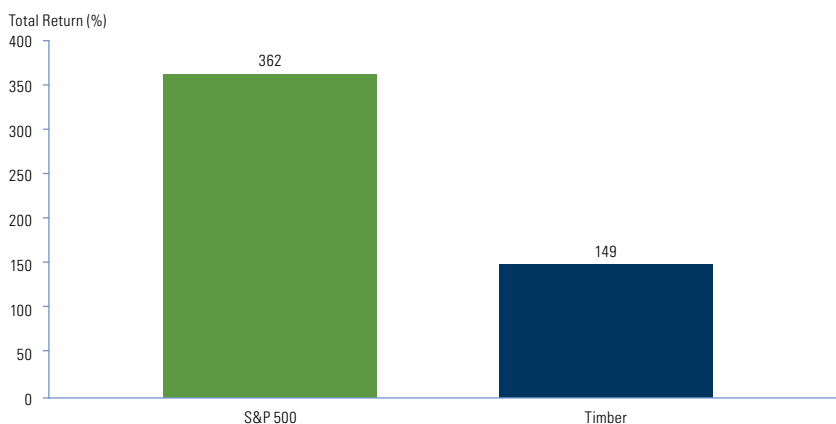
- Benefited from the insights of Goldman Sachs' digital asset and engineering teams
- Engaged with high-profile cryptocurrency and blockchain stakeholders
- Listened to the views of some of the largest cryptocurrency holders
- Exchanged views with peers in the industry
- Garnered insights from former and current central bankers
- Leveraged the expertise of professional services firms such as Deloitte and EY that are among leading service providers in the digital asset ecosystem
- Listened to 29 hours of publicly available lectures by SEC Chairman Gary Gensler from 2018, when he taught the course "Blockchain and Money" at the Massachusetts Institute of Technology
- And, of course, talked to many naysayers and proselytizers

We have also leveraged our team's extensive experience in evaluating the viability and relevance of various asset classes for our clients' portfolios. Since the founding of the Investment Strategy Group in 2001, we have evaluated the role of timber, gold, and commodities more broadly, and emerging market equity and local debt in our clients' strategic asset allocation. For clients who may not be familiar with our past asset class *Insight* reports, we briefly summarize below the key takeaways from those reports and share the impact of our asset allocation recommendations, so that clients can evaluate our track record for themselves.

Our first *Insight* report on a nontraditional asset class covered timber and was published in June 2005, when recommendations by some consultants and the allocation of timber by Harvard University's endowment led to broad interest in the asset. Timber funds were launched with the understanding that they provided diversification and enhanced returns. Our analysis showed that timber did not add

Exhibit 2: Total Return Since Timber *Insight* Publication

US equities have far outperformed timber since June 2005.



Data through Q1 2021.

Source: Investment Strategy Group, Bloomberg, Datastream.

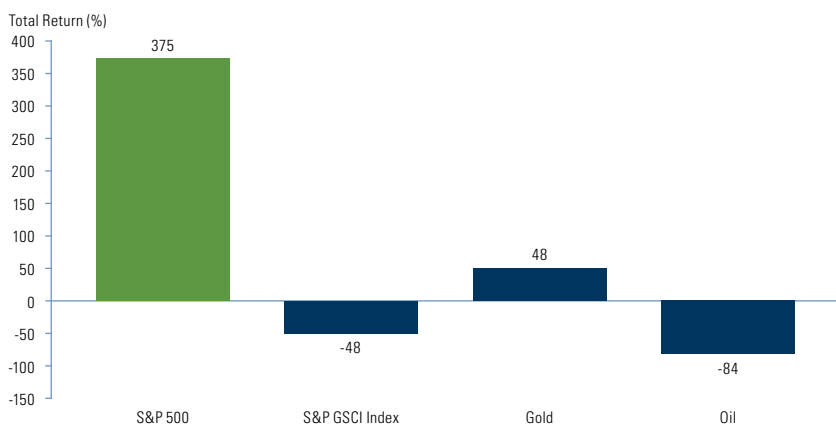


any value to our clients' portfolios, and we recommended against investing in timber funds. As shown in Exhibit 2, the S&P 500 Index has outperformed timber by 213 percentage points, or 4.1 percentage points annualized, over the past 16 years.

The second *Insight*, published in January 2010, focused on commodities, specifically oil and gold. Gold was touted as a much-needed asset to hedge against the inflationary impact of loose monetary and fiscal policies after the global financial crisis (GFC) and therefore against the likely debasement of the dollar. The argument for gold in the aftermath of the GFC was identical to the argument for cryptocurrencies

Exhibit 3: Total Return Since Commodities *Insight* Publication

Commodities have meaningfully lagged US equities since January 2010.



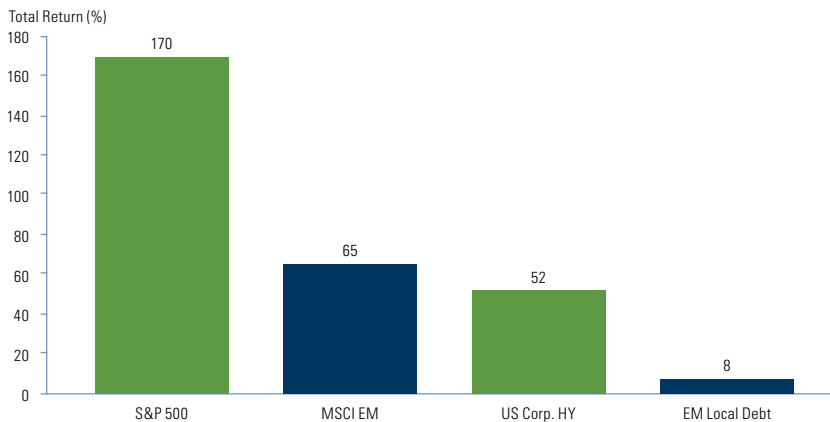
Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg.

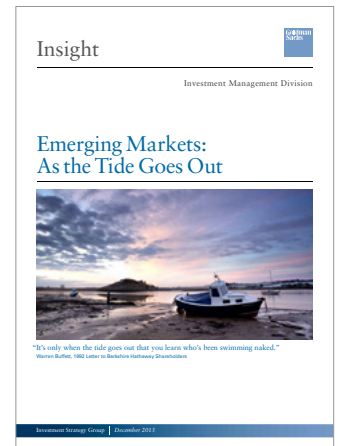


Exhibit 4: Total Return Since Emerging Markets *Insight* Publication

EM assets have underperformed their US counterparts since December 2013.



Data through May 31, 2021.
Source: Investment Strategy Group, Bloomberg, Datastream.



(cleverly marketed by some as “digital gold”) as a result of the pandemic. We recommended against an allocation to gold, oil or commodities in aggregate, showing that they were not an inflation hedge and that gold was not a store of value. The S&P 500 Index has outperformed gold by 327 percentage points, or 10.7 percentage points annualized, over the past 11.5 years, as shown in Exhibit 3. We will expand on our recommendation against gold later in the report, since many have touted holding cryptocurrencies as an alternative to holding gold.

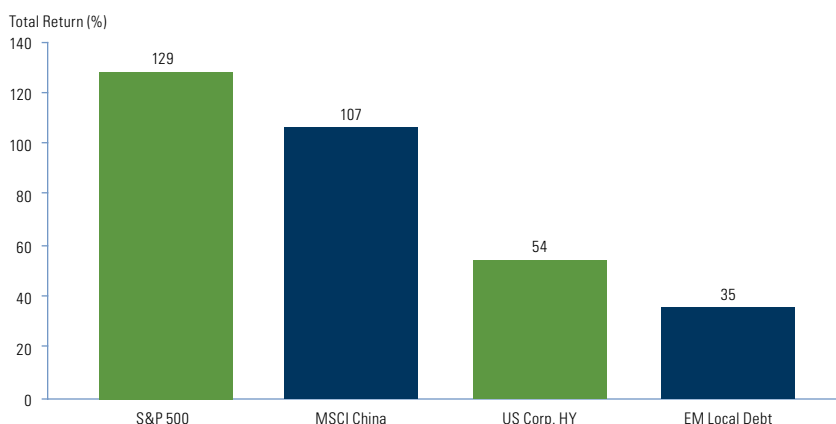
The third *Insight*, published in December 2013, made the case for a substantially lower allocation to emerging market local debt and equity. We highlighted the structural fault lines of the largest eight emerging market countries and showed that they would not be able to address these fault lines going forward. Since then, the S&P 500 Index has outperformed emerging market equities by 105 percentage points, or 7.0 percentage points annualized, and US corporate high yield bonds have outperformed emerging market local debt by 44 percentage points, or 4.5 percentage points annualized, as shown in Exhibit 4.

The fourth *Insight*, published in January 2016, focused exclusively on China and its declining growth trajectory at a time of mounting debt. We eliminated our remaining allocation to emerging market local debt at the time. As shown in Exhibit 5, US corporate high yield debt has outperformed emerging market local debt by 19 percentage points, or 2.5 percentage points annualized, since then.

The purpose of this *Insight* is to provide an objective and balanced view on the role of cryptocurrencies in a portfolio.

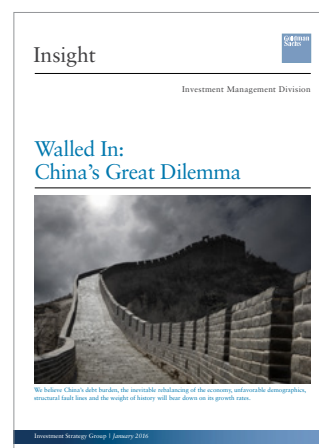
Exhibit 5: Total Return Since China *Insight* Publication

US equities and high yield have outperformed Chinese equities and EM local debt, respectively, since January 2016.



Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg, Datastream.



Such an undertaking was not easy. The technology underlying blockchains is revolutionary, complex and rapidly evolving. The industry uses new jargon. There is a significant amount of misinformation and disinformation. Industry experts have conflicting views. The digital asset ecosystem is nascent; Bitcoin, the first cryptocurrency, was launched in 2009. Finally, both the proselytizers and the naysayers often conflate the role of cryptocurrencies with the role of blockchain technology, making it difficult to separate the noise from true signals; the noise drowns out the important question of how blockchain technology contributes to economic growth and value creation.

We begin with a brief review of the origins and original purpose of Bitcoin and the Bitcoin blockchain. We explain the initial technology and follow with a review of subsequent technological innovations and cryptocurrencies. We also present our views on the impact of this digital asset ecosystem on various businesses. We then focus on the role—or, in our view, the lack thereof—of cryptocurrencies as an asset class in a diversified portfolio. We discuss the basic requirements of an asset class and examine the extent to which cryptocurrencies meet (or do not meet) those requirements. We conclude with the risks to the cryptocurrency and blockchain ecosystem.

The digital asset vernacular is quite extensive. Throughout this report, we will do our best to define the terms so that our clients can be better informed and can avoid being swayed by the extremist proselytizers or extremist naysayers.

We typically end our annual economic and financial market *Outlook* reports with a comment about presenting our views with a strong dose of humility; it is even more imperative that we do so when discussing our views of cryptocurrencies and our outlook for the digital asset ecosystem. There is tremendous uncertainty with respect to the evolution and impact of such technology. In less than 13 years, newer blockchains have been introduced that are reportedly 14,000 times faster when processing transactions than the Bitcoin blockchain. It is likely that blockchain technology will be as high impact in the future as the internet has been over the past several decades.

Of course, we do not have the benefit of a proverbial orbuculum. But neither do the proselytizers or the naysayers. We aim to be objective, and our judgment is based on our extensive investment experience—and now, on our extensive research on the rapidly evolving digital asset ecosystem.

With our best wishes,

The Investment Strategy Group

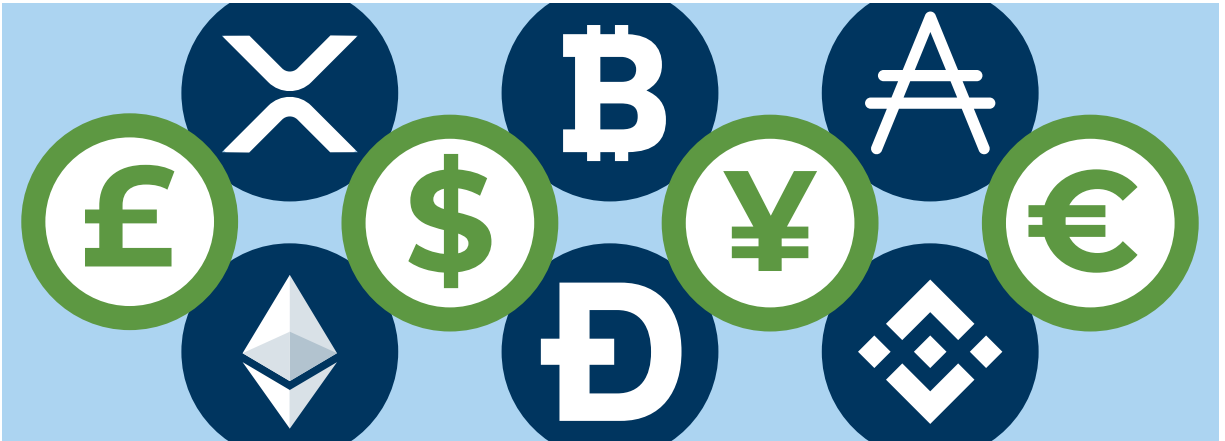
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Understanding the Digital Asset Ecosystem: Bitcoin, Blockchains and Web 3.0

MANY MARKET PARTICIPANTS AND COMMENTATORS conflate some components of the digital asset ecosystem. We believe it is important for our clients to understand the basics of blockchain technology and the broader distributed ledger technology (DLT) so that they can differentiate between those components that create real economic value and are worthy of investing, and those that do not create any value and should be avoided. Market participants may encounter a lot of conflicting, and sometimes intentionally misleading, information about this ecosystem. Our objective is to help our clients make informed investment decisions, driven more by an increased understanding of the ecosystem and less by the assertions of various stakeholders.

We begin with a brief review of the origins of Bitcoin and blockchain technology, highlighting the initial intent of the still-unidentified designer or designers of Bitcoin. This information bears on the value of Bitcoin, which has the largest market capitalization of any cryptocurrency. We follow with a review of subsequent developments in the ecosystem: other cryptocurrencies and digital assets, including non-fungible tokens (NFTs), other blockchains, and the real-world uses of

blockchain and DLT. We provide specific examples of the uses to help bring this opaque and complex ecosystem to life, but we also provide examples of cryptocurrencies whose value is uncertain. We review scenarios for the possible impact of blockchain on the future of everything.

Bitcoin and the Bitcoin Blockchain

Bitcoin and the Bitcoin blockchain were conceived by some unknown person or group of people using the pseudonym Satoshi Nakamoto in October 2008 and described in a nine-page white paper titled “Bitcoin: A Peer-to-Peer Electronic Cash System.”⁵ The first Bitcoin transaction occurred in January 2009.

The purpose of this innovation was to allow anyone on the Bitcoin platform to electronically transfer money that is not tied to any central government from one source to another without going through a centralized financial institution. The key objectives are:

- **Decentralization of money** by avoiding currencies of any one government
- **Decentralization of the network** on which the money is transferred
- **Transparency** so that every transfer is visible to everyone on the platform while the actual identities of the transferor and transferee are hidden
- **Security of transactions** (referred to as **immutability**) because verified transactions cannot be reversed and the data cannot be changed or censored
- **Accessibility**, as a result of which the platform is open to everyone and no government or other entity can withhold permission or sanction access (this is referred to as being “permissionless”)

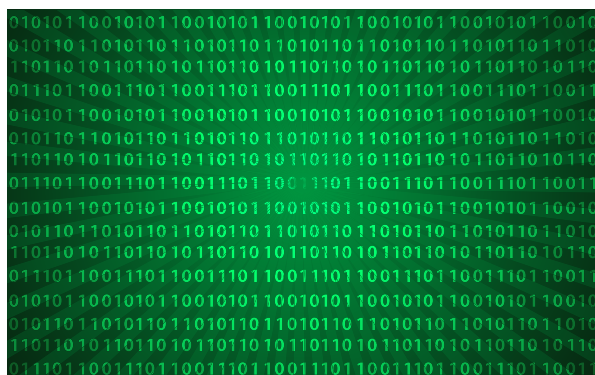
This innovation built upon the research of others, such as:

- Stuart Haber and W. Scott Stornetta,⁶ who are credited with inventing the first blockchain
- Adam Back, who invented Hashcash, initially used to reduce email spam⁷
- Ralph C. Merkle, who invented the Merkle Tree for efficient and secure verification of data⁸
- Wei Dai, who described a protocol for non-government-backed money (“b-money”);⁹ one

of Dai’s stated objectives is providing “a step toward making crypto-anarchy a practical as well as theoretical possibility,” where crypto-anarchy is described as a thesis that “government is not temporarily destroyed but permanently forbidden and permanently unnecessary”¹⁰

Bitcoin and the Bitcoin blockchain technology, in their simplest form, achieved the following:

- Created a decentralized platform or network that is similar to the internet in that everyone can access it.
- Developed a methodology in which transactions can be verified by a decentralized group of computers, each of which is referred to as a **node** on this network. The process for effecting a transaction involves the following steps:
 1. A proposed transaction using Bitcoin is broadcast to the nodes on the network very much like a global bulletin board.
 2. The nodes select a group of proposed transactions and compile them into a **block** (like a container)—hence the term “block” in “blockchain.” These transactions are prioritized based on the fees paid by the users in Bitcoin. These nodes can accept or reject the validity of all transactions in that particular block. They have to confirm that no one is **double spending** (i.e., spending more coins than they have).
 3. Each mining node uses extensive computing power to solve a mathematical puzzle that is based on a cryptographic algorithm created by the US National Security Agency in 2002 called SHA-256. This process is called **proof-of-work** and generates a unique



SHA-256 Hash Algorithm turns data into irreversible fingerprint of zeros and ones.

hash—simply a series of zeros and ones that represent the transactions in that block. Whichever node solves the puzzle first will broadcast its validation of that block to other nodes. The protocols on the Bitcoin blockchain were designed for this verification process to take about 10 minutes per block.

4. If the nodes confirm the validity of the block, it is added to the **chain** of prior blocks—hence the term “chain” in “blockchain.”
- Designed an incentive system so that those who are operating the nodes and expending time, computing equipment and electricity to validate transactions can be rewarded. The validation of every block is rewarded with a preset number of new bitcoins, along with transaction fees, which are paid by the users. To date, about 18.8 million bitcoins have been generated since Nakamoto created the first one. Nakamoto set a limit of 21 million bitcoins. Once all the bitcoins have been minted, the only reward for the validators will be the transaction fee.
 - Offered privacy by hiding individual identities using cryptography—hence the term **cryptocurrencies**. Each transaction is sent to a Bitcoin address—like an email address but for receiving Bitcoin payments—and can only be spent by whoever has the associated **private key**, which functions like a password. Bitcoin owners keep their private keys in a **wallet**, an application meant for securely storing private keys. No personal identification is required to set up a wallet, receive bitcoins, or send bitcoins.

However, while the public key is not linked to any identifiable owner on the blockchain, experts can generally identify the original owner by analyzing multiple transactions from the same public key over time; hence the term **pseudo-anonymity**.

Nakamoto compared nodes that are using computing power and electricity to earn Bitcoin payments for validating blocks to gold miners

using mining equipment and resources to mine for gold. Hence, the use of the term **miners** for those who validate transactions and extend the blockchain.

The Bitcoin proselytizers have expanded upon this terminology and the limited supply of bitcoins to declare that Bitcoin is digital gold and is therefore a store of value and an effective inflation hedge. As we will show in Section II on the role of cryptocurrencies in an investment portfolio, real gold (atomic number 79 with the symbol Au) is neither a store of value nor an inflation hedge.

Of the three roles that Bitcoin was purported to play in the real world, we believe that none has materialized:

1. The primary original objective of Bitcoin was a peer-to-peer payment system—in other words, a medium of exchange between two parties, like a currency. However, Bitcoin cannot fulfill that role since processing a transaction is too slow. Bitcoin is estimated to currently handle no more than 10 payments per second. Visa currently handles thousands of payments per second and it states that it has the capacity to handle as many as 65,000.¹¹

Other digital payment methods have also been developed since Bitcoin was first launched. PayPal, Venmo and Apple Pay are examples of easy and efficient online payment systems. However, most such payment systems eventually tie into centralized financial networks, such as the US financial network known as Automated Clearing House (ACH) or the global network called the Society for Worldwide Interbank Financial Telecommunication (SWIFT), which has oversight from the central banks of 10 major developed economies.

Bitcoin is also too volatile to be a medium of exchange. Its annualized volatility was 65% over the past 12 months and 71% over the past three months. To put Bitcoin’s volatility in context, the annualized volatility of the S&P 500 Index is 17% for the past 12 months and 15% for the past three months. The volatility of the dollar against a weighted basket of developed market currencies as measured by the DXY Index is 5.5% and 5.6% over the same periods, respectively.

While companies like Microsoft, BMW, Whole Foods, Home Depot and Overstock.com, to name a few, accept Bitcoin as a form of payment,

Of the three roles that Bitcoin was purported to play in the real world, we believe that none has materialized.

it is unlikely that it will be used broadly and extensively because of its volatile nature. Imagine using one bitcoin to pay for a BMW 2 Series car in January 2021. On April 15, 2021, one would regret having used that bitcoin, since one could have bought a more expensive BMW 5 Series car with that same bitcoin.

Alternatively, imagine if the Miami-Dade Board of County Commissioners that is evaluating the use of Bitcoin had already approved paying city employees in Bitcoin. If the city employees received their salaries on April 15, 2021, in bitcoins and had not sold or hedged their bitcoins, their salaries would be lower by 30% just a month later—not an ideal situation for someone who has to make a rent or mortgage payment.

2. The same volatility that hinders the use of Bitcoin as a medium of exchange also hinders its use as a unit of measurement. For example, one cannot quote the price of crude oil in Bitcoin. Oil is the most widely traded commodity in the world, with an average daily volume of \$163 billion in the two years prior to the pandemic.¹² It has always been quoted in dollars in the post-WWII period, irrespective of the quality of the crude or the country of origin. It is virtually impossible for producers and consumers to use a unit of measurement to value the price of a barrel of crude oil with something whose volatility has ranged from 43% to 178%.
3. We also do not believe that Bitcoin is a long-term store of value or an investable asset class for diversified portfolios, as discussed in the next section of the report. Likewise, we do not believe that gold is an investable asset class as a store of value, so claims that Bitcoin is “digital gold” do not confer any value to Bitcoin. That is not to say that other assets in the digital asset ecosystem do not have value. For example, buying an NFT as a collectible is similar to buying a rare physical Pokémon card. The highest reported American football NFT sale was for a live-action card of Rob Gronkowski’s career highlights for \$431,000 on March 14, 2021 (see Exhibit 6), and the highest reported Pokémon card sale was for \$360,000 on January 20, 2021. Using a token to represent a live-action shot has whatever value the collector attributes to that item—very much as a collector attributes a certain value to Pokémon cards or

Exhibit 6: Rob Gronkowski’s Career Highlights Card

This NFT sold for \$431,000 in March 2021.



By permission of Medium Rare, which helped to develop and launch this NFT.

fine art. These tokens derive their value from something in the real world.

Cryptocurrencies that are used as tolls to access a blockchain, similar to tolls paid to drive on a highway, can also have value. The value is derived from how the user leverages that blockchain. Those cryptocurrencies are more appropriately referred to as **utility tokens**. If a utility token becomes too expensive, then the user will select alternative blockchains. Some blockchains address this issue by having an internal exchange rate in which the toll rate is independent of the value of the token.









We discuss investing in the digital asset ecosystem in greater detail in Section II.

The Next Generation of Blockchains

The Bitcoin blockchain technology has proved not to be effective in replacing fiat currencies such as the dollar or the euro in global transactions. Its greatest success has been in inspiring the development of blockchains with faster transaction speeds and far greater functionality.

Exhibit 7: Next-Generation Decentralized Platforms

Blockchain technology has continued to evolve and several high-impact innovations have been introduced.

Name	Token	Launch Date	Consensus Mechanism	Description
Public Blockchain				
 Ripple	XRP	Jan-13	UNL (trusted list of peers)	Payments-oriented blockchain; integrates with banking system. Pros: Cheap and fast settlement for global transfers. Cons: Somewhat centralized, ongoing SEC lawsuit.
 Algorand	ALGO	Jun-19	Proof of Stake ("pure")	Decentralized app platform aiming to be fast, secure and decentralized. Pros: Fast, robust and developer-friendly. Cons: Immature, small ecosystem.
 Solana	SOL	Mar-20	Proof of Stake + Proof of History	Challenger to Ethereum focusing on efficiency. Pros: Fastest public blockchain, cheap transactions, developer-friendly. Cons: Smaller ecosystem.
 Polkadot	DOT	May-20	Proof of Stake (nominated)	Blockchain enabling creation of customized, parallel chains. Pros: Scalable, interoperable, customizable. Cons: Complex, functionality remains incomplete.
 Dfinity Internet Computer	ICP	May-21	Distributed Notary	An attempt to revamp the internet as a decentralized platform. Pros: Innovative, could pave the way to the future. Cons: Untested, early stage, complex.
 Ethereum 2.0	ETH	Upgrade expected by early 2022	Proof of Stake	A faster, energy-efficient version of the original decentralized app platform. Pros: First-mover, vibrant developer community. Cons: Upgrade is complex, risky and overdue.
Other-Permissioned				
 Hyperledger	n/a	Dec-15	Varied. Voting or lottery	Enterprise blockchain software with extensive features. Pros: Highly customizable, fast. Cons: Getting buy-in from all parties often stalls.
 Corda	n/a	Nov-16	Notary (pluggable algorithm)	Finance-focused distributed ledger for inter-organization transactions. Pros: Configurable, energy-efficient, enables privacy. Cons: Requires consortium or buy-in from parties, slower.

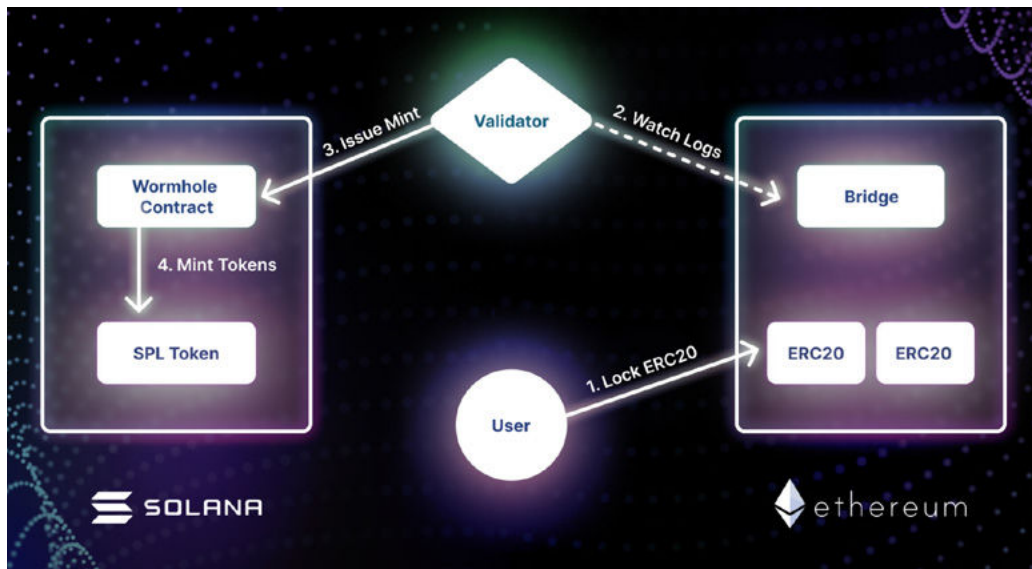
Data as of May 31, 2021.

Note: For illustrative purposes only.

Source: Investment Strategy Group.

The Ethereum blockchain was introduced in 2015 and has become the most widely used blockchain for various applications. Just like the Bitcoin blockchain, it has its own cryptocurrency, called ether, and shares the three primary tenets of the Bitcoin blockchain:

- It is decentralized with no central decision-making body. However, Vitalik Buterin, author of the Ethereum white paper and co-founder, and Joe Lubin, CEO of ConsenSys and another co-founder, exert some leadership on the Ethereum community, as they are doing now to upgrade to a new version that is referred to as Ethereum 2.0.
- The blocks are generally immutable, which means validated blocks and the entire blockchain cannot be altered without a majority of the nodes agreeing to do so. If they do not agree, some nodes can spin off and create what is called a fork in the blockchain. The Bitcoin blockchain has had several forks, but the original fork remains dominant. Ethereum had a fork (known as the "DAO Hard Fork") in 2016 in response to a hacker who stole \$55 million of ether. The stolen funds were retrieved by creating the fork that is now dominant.
- The blockchain is accessible to the public: anyone can go online and join the Ethereum community.



By permission of Solana. <https://solana.com/wormhole>

However, there is one very significant difference between Bitcoin's blockchain and Ethereum's. The Bitcoin blockchain supports only very simple transaction instructions, while Ethereum provides extensive functionality to build decentralized applications (dApps) on its blockchain. The applications are built through what are called **smart contracts**—basically computer programs that are executed on the blockchain.

The term used to describe this Ethereum advantage is that it is "Turing complete," which means the blockchain can run programs that operate like a computer. Some of you may recall that Alan Turing was the mathematician and computer scientist who helped decode German communications during World War II; the A.M. Turing Award is the highest award in computer science.

Blockchain technology has continued to evolve, and several high-impact innovations have been introduced. We highlight some key ones in Exhibit 7.

For example, in 2017, Turing Award winner and MIT professor Silvio Micali launched the Algorand blockchain with some meaningful improvements to blockchain technology:

- It replaced the proof-of-work validation process of Bitcoin and Ethereum 1.0 with proof-of-stake. A randomly selected committee of

validators validates a transaction, a process that requires less energy and is faster than the proof-of-work process that requires validation by every node.

- Algorand can process 1,000 transactions per second, but that is expected to increase to 46,000 later this year.¹³ Ethereum 2.0 is expected to provide scalability at 10,000 transactions per second as it adopts a proof-of-stake approach.¹⁴ While speed is not the determining factor of the effectiveness of a blockchain, it is one of many factors that users consider and conveys the capacity of a network to meet utilization demand.
- Algorand supports multiple programming languages, such as Python, Java, JavaScript and Go, while Ethereum developers have to use the Ethereum languages, primarily Solidity.
- The average cost of a transaction is very low, at 1/20 of a penny, compared with about \$20 on Ethereum.

"We can only see a short distance ahead, but we can see plenty there that needs to be done."

— Alan Turing

The Solana blockchain was launched in 2020 with some further improvements:

- It added a proof-of-history feature to its validation process to efficiently track the order of transactions, which many would consider a significant breakthrough in speed and capacity. Its proof-of-history complements the proof-of-stake process and makes it much more efficient for validators to confirm each block.
- It allows validators to run thousands of smart contracts in parallel.
- Solana can process 50,000 transactions per second.¹⁵
- Interoperability—the ability of different blockchains to communicate with one another—has been enhanced by its own unique bridge to Ethereum called “wormhole.” While other interoperability solutions exist, such as the ones offered by Polkadot and Cosmos, Solana’s development of its own interoperability function allows users to leverage Solana’s speed while having access to interoperability.
- Developers can use popular programming languages such as C/C++ or Rust on the Solana blockchain. These languages are among the world’s fastest.
- The average transaction cost is very low, at 1/40 of a penny.

The blockchains discussed above are public blockchains that are, by definition, permissionless; anyone can join the blockchain and build smart contracts and/or validate transactions for the cryptocurrency of that blockchain. However, many companies have elected to use private blockchains of which they are the sole user and/or the sole decision-maker in permitting others to join.

The Role of Private Blockchains, Permissioned Blockchains and Consortium Blockchains

As with everything else involving cryptocurrencies and blockchains, there is considerable debate about the value of private blockchains. An enterprise that currently relies on internal systems such as enterprise resource planning (ERP) or customer relationship management (CRM) might like to develop its own private blockchain to streamline

its operations and improve efficiencies. Some examples of expected blockchain efficiencies would be less time spent on tracking data from different vendors, better inventory management, and better invoice reconciliation and payment systems.

An enterprise may require **permissioned** access to its private blockchain. And some companies may work together to form a consortium blockchain exclusive to members of the consortium. Firms like Hyperledger and Corda provide the technology to support such private or consortium blockchains.

As mentioned earlier, Forbes Blockchain 50 publishes an annual listing of 50 large companies that use blockchain technology, many of which use private blockchains.

Some blockchain technology leaders have argued that private and consortium blockchains do not leverage the advantages of blockchain technology. Paul Brody, EY global blockchain leader, believes that “anything you can do on a blockchain, you can do better, faster and cheaper on a private database or web server. The only thing blockchains really do that is special and unique is their ability to operate in a truly decentralized fashion.”¹⁶

Instead, he suggests using a platform called Baseline Protocol—formed by EY and ConsenSys in collaboration with Microsoft. This protocol’s stated goal is to enable companies to work together, leveraging the full capabilities of public blockchains while keeping all private corporate and personal data off the blockchain.

Linda Pawczuk, global blockchain leader at Deloitte, has a more nuanced view. She believes that the decision to be on public or private chains is not binary. “A network of interoperable chains is evolving, fit for different business purposes, security models and regulatory regimes, among other benefits. Effectively they will coexist by making some of their assets publicly available, as needed, or create a public-permissioned model,” she says.¹⁷

Use Cases of Blockchain Technology

The outcome of the debate about public versus private/consortium blockchains will be particularly relevant for decentralization of finance. One of the much-touted uses of blockchain technology has been decentralized finance—or **DeFi**.

Decentralized finance refers to financial services and products built on public blockchains or on DLT networks that do not require intermediaries.

Exhibit 8: Transition of Technology-Driven Services Over Time

The evolution of technology allows for faster processes, greater operational efficiencies and increased ease of implementation.

	Web 1.0 1991-2004	Web 2.0 2004-Present	Web 3.0 Possible Vision of the Future
Social Networks	Blogs, AOL, SixDegrees.com	Facebook, Instagram, Twitter, LinkedIn	<ul style="list-style-type: none"> • Community-driven, decentralized social networks. • Users control and monetize personal data. • Users are paid for content or watching ads. • Examples: Social.Network, Minds, Distrikt.
Arts & Entertainment	Napster, LimeWire	iTunes, Netflix, Hulu, Spotify	<ul style="list-style-type: none"> • Artists monetize copyrights through NFTs. • Artists deliver directly to their audience. • Examples: Ujo Music, LBY, Rarible.
Ticket Sales	Ticketmaster	Ticketmaster, StubHub, SeatGeek	<ul style="list-style-type: none"> • Event planners create a unique NFT for each ticket. • They can track ticket ownership to prevent fraud. • They can set fees and conditions for resale. • Example: Blocktix.
Browsers	Netscape	Chrome, Safari, Firefox	<ul style="list-style-type: none"> • Users can control personal data and restrict ads. • Ad campaigns are driven by tokens. • Users earn rewards for viewing ads. • Example: Brave.

Data as of May 31, 2021.

Source: Investment Strategy Group.

To date, all DeFi has revolved around trading, leveraging and lending of digital assets without the participation of the major traditional financial institutions. However, that may change in the future. Financial institutions are now exploring how blockchain can improve market efficiencies. Examples include:

- Shorter or simultaneous settlement cycles, commonly referred to as atomic settlement
- Reduction in settlement, counterparty, liquidity and operational risks
- More efficient management of bank capital and liquidity (driven by above)
- Reduced need for intermediaries and reconciliations because the blockchain/distributed ledger assumes that role
- Greater transparency of activity while allowing investors to remain private within the network
- Greater liquidity
- Extended market hours/24-hour active trading across currencies and financial assets
- Automation of corporate actions via smart contract functionality

In addition, there have been a limited number of blockchain-based debt issuances of relatively small size, designed to test blockchain technology and

determine how it can be integrated with current systems. Issuers have included Société Générale, Santander Bank and the European Investment Bank (EIB).

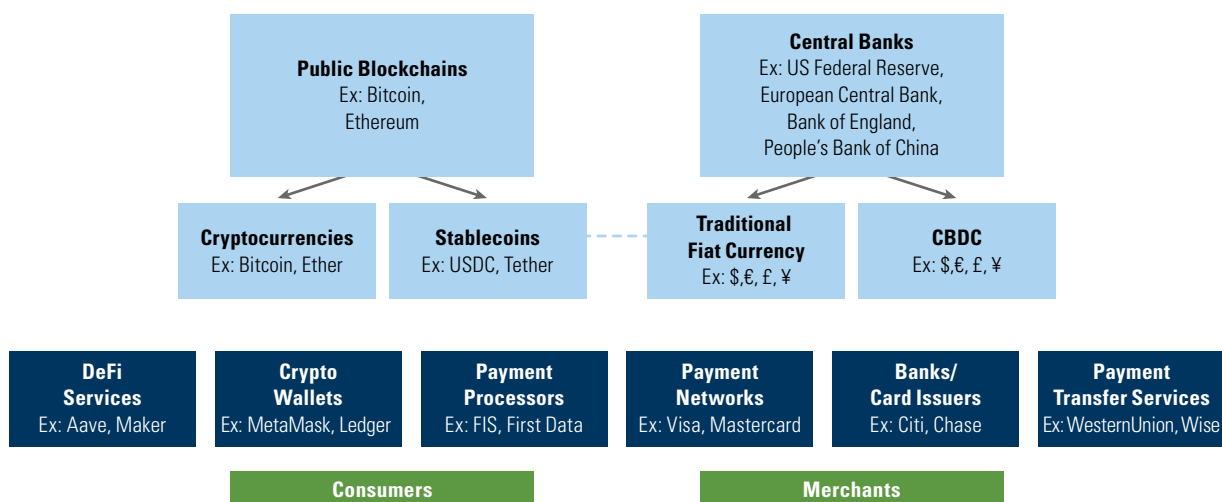
Our colleague Mathew McDermott, who is the global head of digital assets at Goldman Sachs, believes that “some of the early applications of DeFi will be in derivatives, lending/leverage and trading/exchanges, with other sectors like insurance, asset management and payments to follow. The recent EIB digital debt issuance Goldman Sachs participated in, while not pure DeFi, does provide some insight as to the direction of travel, where peer-to-peer secondary trading on a permissioned application on a public blockchain is possible.”¹⁸

Other use cases are driven by moving real-world operational processes onto the blockchain. For example, at the EY Blockchain Global Summit that took place in May 2021, EY showcased Microsoft’s expected benefits from using a blockchain-based solution for managing gaming rights and royalties for its Xbox video game network.¹⁹ The time to calculate rights and royalties owed to developers is reduced from 45 days to 4 minutes, the costs of administering the system are reduced by 40% and transparency of transactions is increased.

While no one knows with any certainty how the digital asset ecosystem will evolve, it is highly

Exhibit 9: The Payments Landscape

A tug-of-war is likely to evolve between more traditional methods of payment and blockchain-driven payment systems.



Data as of May 31, 2021.
Source: Investment Strategy Group.

likely that this technology—both blockchain and the broader distributed ledger technology—will impact most businesses.

Consider how Amazon, which started selling books online in 1994, and Netflix, which started renting out movies on DVDs in 1997, transformed the retail and movie industries. It is likely that blockchain will have a similar impact: faster processes, greater operational efficiencies and increased ease of implementation.

If one thinks of Netscape as a Web 1.0 innovation and Google Chrome and Firefox as Web 2.0 innovations, a new browser called Brave can be considered a Web 3.0 innovation that leverages blockchain technology. It enables individuals to protect their personal information and get paid with Basic Attention Tokens (BATs) for allowing companies to show advertisements to them: individuals can, in effect, wrest control of their data from the more established search engines on the web. Should such control of data become the norm, the business model of enterprises that depend on selling other people's data for advertising revenue will be disrupted. In this case, individuals would be the winners and large technology companies that sell people's data would be the losers.

This technology will also disrupt the business of many intermediaries. Probably one of the best examples is the use of blockchain to streamline

ticket sales, which would hinder the business of ticket scalpers. If every seat at an event—be it a concert or a sports event—is represented by a token, the original buyer of the seat can then resell the ticket if he or she no longer wants it, but the event promoter and the artists or the sports team can receive some of the portion of the resale value. Scalpers, as intermediaries, will be prevented from buying and hoarding tickets in bulk and capturing all the resale value. A company called Blocktix is offering such a service.

As with all other blockchain ventures, the success of this innovation depends on broad adoption by users across the “event” supply chain, including artists, sports team owners, venue owners, promoters and event attendees, who have to be willing to buy their tickets with conditions on resale and identification.

Jonathan Johnson, CEO of Overstock.com, also believes that “blockchain technology will eliminate the need for intermediaries in many industries, thus allowing people to transact directly with each other.”²⁰ Overstock.com started accepting Bitcoin as payment in 2014, albeit it is a small portion of its revenues. The company has also invested in a portfolio of blockchain companies.

Exhibit 8 shows the transition of a few technology-driven services over time. It is too early to know how technology companies will evolve

to adapt their business models, but it is likely that the status quo of technology companies usurping people's private information will be disrupted by blockchain.

Another example of the disruption caused by blockchain technology is captured in Exhibit 9, which shows the tug-of-war that is likely to evolve between more traditional methods of payment and blockchain-driven payment systems. Ran Goldshtein, the CEO of First—a Web 3.0 payments company—refers to this tug-of-war as “the battleground.”

As one of our colleagues, George Lee, co-chief information officer of Goldman Sachs, who formerly headed up technology, media and telecom investment banking, said, “What is going on now feels very familiar for people who were in Silicon Valley in the mid-1990s and witnessed the birth of the commercial internet—the emergence of a new platform which garners a critical mass of great developers who are attracted by the ability to build, deploy and scale new services and applications quickly and without permission. And this new class of developers will have to solve a similar set of problems: establishing new notions of trust, addressing performance limitations and enabling scale.”²¹

While the digital asset ecosystem may well revolutionize the future of everything, that does not imply that cryptocurrencies are an investable asset class. In the next section, we examine the role of different assets in the digital asset ecosystem.

The Role of Digital Assets in Clients' Portfolios

AS NOTED EARLIER, CRYPTOCURRENCIES elicit strong reactions at both ends of the spectrum. In fact, the investment value of cryptocurrencies is easily the most controversial topic of the digital asset ecosystem. At one extreme, the proselytizers throw out price targets for Bitcoin that are more than 10 times higher—in one case 25 times higher—than current prices and assert that Bitcoin is a store of value. At the other extreme, the naysayers say the value is zero. And in the middle, some argue that the value of a cryptocurrency should be commensurate with the value of the utility it provides.

We address the question about the role of digital assets in a portfolio by breaking the broader question into three distinct questions:

- First, which assets actually fall into the broad category of cryptocurrencies and how are they different? In turn, what does that mean for the role of these different cryptocurrencies in a client’s portfolio?
- Second, are there other assets in the digital asset ecosystem beyond cryptocurrencies that offer value to investors?
- Third, what are the investment opportunities—or, as one colleague put it, the “picks and shovels”—in the digital asset space should blockchain and distributed ledger technology become an integral part of the internet landscape?

It is imperative not to conflate the value of cryptocurrencies with the value of blockchain/DLT, and not to conflate the value of the first two with the value of ventures that aim to commercialize this technology. For example, the value of the cryptocurrency ether is not the same as the value of its host blockchain, Ethereum, and neither value is the same as that of an exchange on which ether is traded.

We address all three questions below. Our goal is to determine whether any of these assets is what we would deem a strategic asset class that has a role to play in our clients’ portfolios.

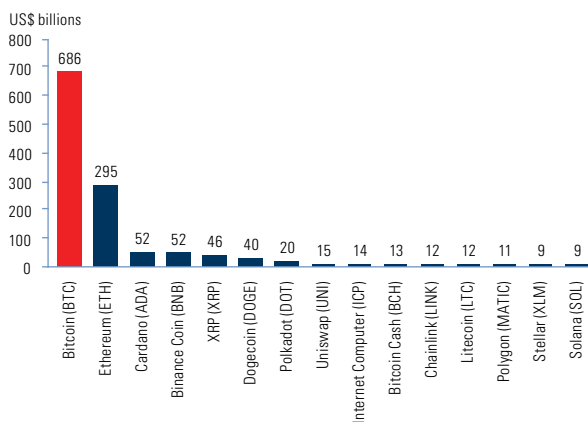
The Role of Cryptocurrencies, Coins and Tokens in Clients’ Portfolios

While many market participants often use the term “cryptocurrencies” to include not only cryptocurrencies but also other digital coins and tokens, these assets are quite different and should not be bundled into one term for the purposes of evaluating their role as a strategic asset class.

Two types of digital assets have currency-like characteristics: digital coins and digital tokens.

Digital coins: These assets function as a form of payment and either establish their value independently or derive their value from an existing currency. There are three subcategories of digital coins:

Exhibit 10: Top 15 Cryptocurrencies by Market Cap
Bitcoin and Ethereum are the two cryptocurrencies with the largest market caps.



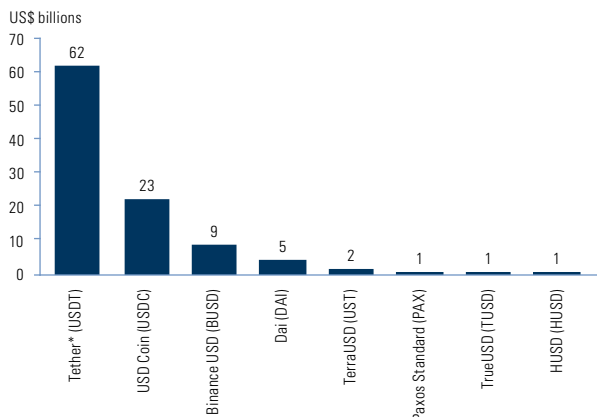
Data as of May 31, 2021.
Source: Investment Strategy Group, CoinMarketCap.

- *Cryptocurrencies* establish their value, ownership and issuance through cryptography on a decentralized platform—generally a public blockchain—rather than through a government. There are over 8,000 cryptocurrencies—many of negligible value. Exhibit 10 shows the 15 largest cryptocurrencies by market capitalization.
- *Stablecoins* attempt to peg their value to a fiat currency. They may be called tokens on a public blockchain, such as ERC-20 tokens on Ethereum or coins on a permissioned distributed ledger such as JPM Coin. Exhibit 11 shows the eight largest stablecoins by market capitalization.
- *Central bank digital currencies* (CBDCs) are issued by a central bank and represent the fiat currency of that central bank’s country. They can be exchanged for other forms of that currency. They are used on a permissioned DLT and are clearly controlled by a centralized authority. As shown in Exhibit 12, the Bahamas and Cambodia have already launched CBDCs, China and Sweden have launched pilot projects, and several others are at various stages of development.

Digital tokens: These assets give the holder either whole, partial or potential ownership of another asset, or the right to use a service, or the right to carry out a function. Such tokens are created by smart contracts on a public blockchain or permissioned distributed ledger. For instance, ERC-

Exhibit 11: Top 8 US Dollar Stablecoins by Market Cap

Tether and USD Coin are the two stablecoins with the largest market cap.



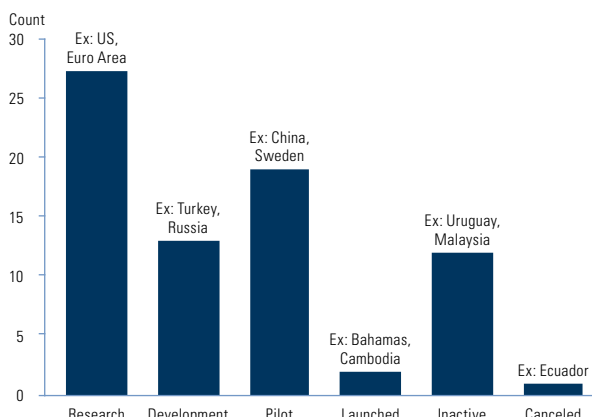
Data as of May 31, 2021.

Source: Investment Strategy Group, CoinMarketCap, CoinDesk.

* Tether is not fully backed 1-for-1 by cash, cash equivalents or high-quality bonds like Treasury bills. Instead, it is backed 50% by unspecified commercial paper; 18% by fiduciary deposits; 13% by secured loans to unaffiliated entities; 10% by corporate bonds, funds and precious metals; 3% by cash; 3% by reverse repo notes; 2% by Treasury bills; and 2% by other investments, including digital tokens like Bitcoin. (Values may not sum to 100% due to rounding.)

Exhibit 12: Number of Country CBDC Projects by Stage of Development

Many countries have active CBDC pilot projects, and a couple have launched CBDCs for public use.



Data as of May 2021.

Note: Research = Established working groups to explore the use cases, impact and feasibility of CBDC. Development = Initiated technical build and early testing in controlled environments. Pilot = Initiated small-scale testing of CBDC in a real environment with limited number of participants. Launched = Issued CBDC for widespread retail and/or wholesale use. Inactive = Previously announced research or testing of a CBDC, but with no new developments for several years. Canceled = Canceled a previously launched CBDC.

Source: Goldman Sachs Global Investment Research, Bank for International Settlements.

20 is a commonly used token standard for many digital tokens residing on the Ethereum blockchain. There are four subcategories of digital tokens:

- **Utility tokens** can be exchanged for some goods or services within a digital network. The Basic Attention Token (BAT) associated with the Brave browser is an example of a utility token. Another is Filecoin, which allows owners to rent unused hard-drive space.
- **Security tokens** represent ownership in tangible assets such as real estate or business ventures that are expected to generate profits. These tokens pass the Howey Test, which refers to the US Supreme Court case for determining whether a transaction qualifies as an “investment contract,” and therefore would be considered a security. The Securities and Exchange Commission (SEC) considers these tokens an investment contract when money is invested in a “common enterprise with a reasonable expectation of profits derived from the efforts of others.”²² The Aspen Digital Token (ASPD), which represents indirect ownership of a portion of the St. Regis Aspen Resort, is an example of a security token.

- **Governance tokens** give the right to vote on the policies, upgrades or issuance of tokens within a decentralized platform. Such tokens enable the formation of a decentralized autonomous organization (DAO). MakerDAO is an example of a decentralized lending platform that uses a governance token called Maker (MKR) so that the holders can make decisions on the operation of the lending platform.
- **Non-fungible tokens (NFTs)** are unique and non-interchangeable and represent rights to tangible assets or digital intellectual property. NFTs are implemented through smart contracts that guarantee the uniqueness of each token. Many of the NFTs reside on the Ethereum blockchain, but they can also reside on other blockchains such as Solana. NFTs usually conform to ERC-721 as a standard for NFTs on Ethereum. The National Basketball Association has created NBA Top Shot, which is a marketplace for selling highlight videos of basketball in the form of NFTs—the digital analog of basketball trading cards. The highest price paid for an NBA Top Shot NFT was \$210,000 for a LeBron James live-action shot.

Given this diversity of digital currencies, coins and tokens, one must evaluate each subcategory separately, based on its unique characteristics, to determine whether it is a strategic asset class.

We begin with cryptocurrencies. We do not believe that cryptocurrencies are a strategic asset class that adds value to our clients' portfolios. Given that Bitcoin is the oldest and has the largest market capitalization among cryptocurrencies, we will focus on Bitcoin to present the analysis that leads us to this conclusion.

Let us first review what we believe are five criteria necessary for an asset to be considered a viable asset class to be considered for a client's strategic asset allocation. We expect an investable asset to meet at least three (more than half) of these criteria:

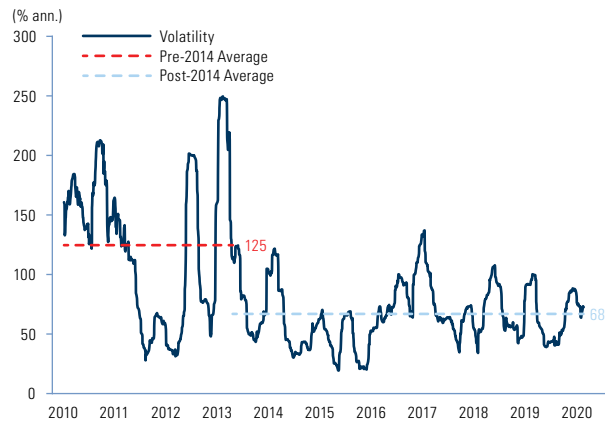
- Generate steady, reliable cash flow on a contractual basis, like bonds
- Generate earnings through exposure to economic growth, like equities
- Provide consistent and reliable diversification benefits to a portfolio
- Dampen volatility
- Provide consistent and reliable evidence of hedging inflation or deflation as a store of value

We examine Bitcoin to see if it meets one or more of these criteria. There are many assets in the world that do not meet enough criteria to be included in our clients' portfolios. As mentioned earlier, we did not recommend timber as a strategic asset class even though it is an invaluable asset for consuming carbon dioxide and emitting oxygen, constructing homes, building furniture, making musical instruments, building fences and sculpting, among various uses. Similarly, we did not recommend investing in crude oil as a commodity even though it is an invaluable asset for air, ground, and sea transportation; heating; and petroleum products that are used to manufacture car tires, eyeglasses, dishwashing liquids, kayaks, and even solar panels. Simply being an asset, even a very useful one, does not make that asset a viable investment for a client's portfolio.

We do not believe that cryptocurrencies are a strategic asset class that adds value to our clients' portfolios.

Exhibit 13: 3-Month Rolling Bitcoin Annualized Volatility

Bitcoin's volatility has shifted downward following very high levels from 2010 to 2013.



Data through May 31, 2021.
Source: Investment Strategy Group, Bloomberg.

The Limited History and Quality of Cryptocurrency Data

Before we present our analysis, a word of caution is required. The data on cryptocurrencies is extremely limited and not always of the highest quality. The first bitcoin was mined in January 2009, the first ether was minted in July 2015, the first ADA (on the Cardano blockchain) appeared in September 2017 and the first Binance Coin was launched in July 2017. They are the four largest cryptocurrencies by market capitalization. The price data is very limited, so one has to be careful about drawing any strong conclusions based on data alone. Furthermore, the first few years of Bitcoin's price history are not reflective of its risk/return characteristics post-January 2014. As shown in Exhibit 13, volatility was extremely high, at 125%, from July 2010 to December 2013 and had a material shift downward to 68% after 2013. A rigorous analytical tool called the Hidden Markov Model confirms our observation that there has been a regime shift in volatility.

We have seen such regime shifts in data series of other assets in the past. In such cases, we opt to use the more relevant data because we expect it to be more reflective of the future. We do not expect Bitcoin to have a long-term volatility of 125%. We have therefore used data since 2014 and used only

Exhibit 14: Monthly Top Tier vs. Lower Tier Cryptocurrency Exchange Volume

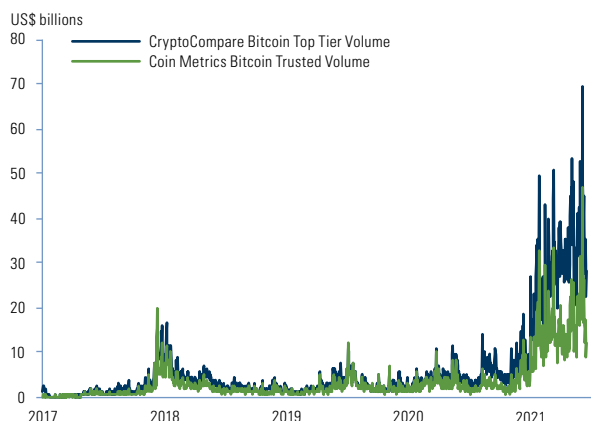
The quality of cryptocurrency trading volume data changes over time.



Data through May 31, 2021.
Source: Investment Strategy Group, CryptoCompare.

Exhibit 15: Clean Data Comparison of Bitcoin Trading Volumes

Dispersion in reported volume data is sometimes high even among reliable data sources.



Data through May 31, 2021.
Source: Investment Strategy Group, CryptoCompare, Coin Metrics.

Bitcoin data as it has not only the largest market capitalization but also the longest history. The other larger-capitalization cryptocurrencies do not even go back to 2014.

In addition to the history of cryptocurrency data being limited, we should note that the quality of reported data—both volume and price—has been poor. Three factors account for this poor quality: fake volumes, varying reliability of data from exchanges and the use of different methods for compiling data.

We examine the quality of the data:

- In a March 2019 presentation to the US Securities and Exchange Commission, Bitwise Asset Management estimated that 95% of the reported volume of Bitcoin trading was fake and/or non-economic in nature.²³
- In a March 2021 academic research paper, “Crypto Wash Trading,” Lin William Cong et al. concluded that wash trading—or fake trades—accounted for over 70% of the reported volume on unregulated exchanges (those that do not have a New York State BitLicense).²⁴
- In a January 2021 academic research paper, “Competition and Product Quality: Fake Trading on Crypto Exchanges,” Dan Amiram et al. concluded that the mean proportion of fake trading on an exchange is 19% and the maximum is 87%.²⁵

To better understand the reliability of the data, we compared volume data from CryptoCompare, a UK-based global cryptocurrency market data provider, and Coin Metrics, a US-based global cryptocurrency market data provider. Both offer a series of market indices as well.

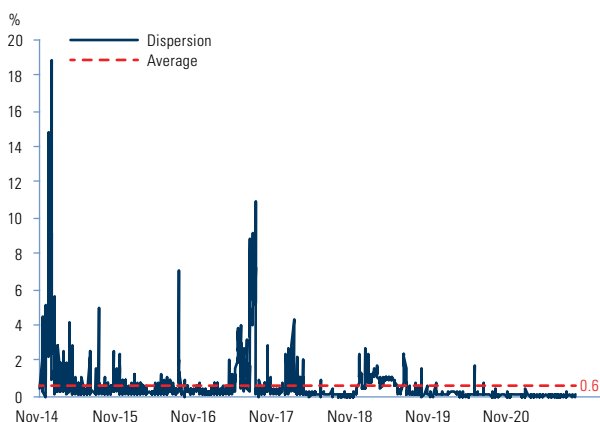
CryptoCompare breaks up volume data into two parts: data from what it calls “Top Tier” exchanges rated AA, A, BB or B, and data from “Lower Tier” exchanges that are lower ranked or unrated. As shown in Exhibit 14, the quality of data changes over time. Between August 2019 and June 2020, more than 70% of the cryptocurrency trading volumes were occurring on Lower Tier exchanges, which implies less reliable data. In the past five months, however, about 75% of the volumes were occurring on Top-Tier exchanges, which implies higher-quality data.

Coin Metrics uses the volume reported by what it considers trusted exchanges. Trustworthiness of exchanges is determined by “volume correlation, web traffic analytics and qualitative features.”²⁶

We have compared CryptoCompare Top-Tier data on Bitcoin trading volume with Coin Metrics’ Trusted Volume Framework index based on data from the exchanges that meets their criteria for being trusted exchanges—in other words, we are comparing high-quality data across two data providers. As shown in Exhibit 15, even among high-quality data providers there is a difference in reported volumes.

Exhibit 16: Daily Dispersion of Bitcoin Prices

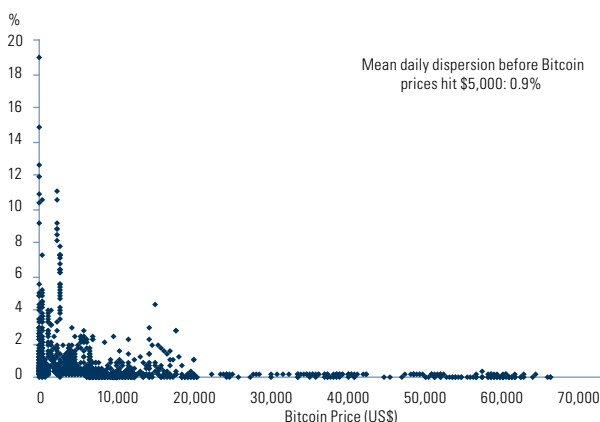
The difference in daily Bitcoin prices between exchanges has averaged 0.6% since November 2014.



Data through May 31, 2021.
Source: Investment Strategy Group, CryptoCompare.

Exhibit 17: Daily Dispersion vs. Bitcoin Prices

The dispersion in Bitcoin prices between exchanges is much higher at lower prices.



Data through May 31, 2021.
Source: Investment Strategy Group, CryptoCompare.

There is a similar concern about reported prices. Because Bitcoin trades continuously across many exchanges over 24 hours, matching price data even among more reliable exchanges is complicated.

Using daily Bitcoin data from CryptoCompare since 2014 (the earliest date for its data), we constructed dispersion data as a measure of differences in daily prices between exchanges (see Exhibit 16). The average daily dispersion over this period was 0.6%. This corresponds to an annualized dispersion of 10.8% solely from differences in prices between exchanges.

Two additional related observations help underscore the impact of the poor quality of data and the fact that the digital asset ecosystem is in its infancy.

First, the dispersion is much greater at lower prices, as shown in Exhibit 17. The dispersion, at 0.9% (or 17.5% annualized), is much higher when Bitcoin prices are \$5,000 or below. Prices did not reach \$5,000 until October 2017. Hence, the price data before that period is much less reliable.

Second, the dispersion has decreased over time. The mean daily dispersion in the first 12 months of this data series is 1.2% (22.0% annualized); it dropped to 0.1% (1.3% annualized) for the 12 months ended in May 2021. Again, earlier data is less reliable than more recent data.

Given the limited history and variable quality of cryptocurrency data, our goal is to avoid conveying false precision and instead provide some general observations, all of which point in the same direction.

Strategic Asset Allocation Analysis

Basing it on the most reliable data possible and using our multi-factor asset allocation model, we estimate the risk premium of Bitcoin to be 1.9% per annum, with an extremely wide uncertainty (one standard error estimated range between -35.2% and 39.1%) and volatility of 93.0%. This data implies a Sharpe ratio (excess return per unit of risk) of 0.02. Based on this analysis, we believe that the risk premium in Bitcoin is not statistically different from zero.

We also conclude that the risk, return and uncertainty characteristics of Bitcoin based on our multi-factor model do not support an allocation to Bitcoin. In fact, our robust optimization model suggests that to strategically allocate 1% of a moderate-risk portfolio to Bitcoin, Bitcoin has to offer an expected return of 165% per annum on a long-term basis. A 2% allocation requires a return of 365% per annum. Since January 2014, Bitcoin has provided an annualized return of 69%—far from the levels required to justify an allocation.

We also used three different sources for the Bitcoin price history to see if a difference in the data would have any impact on our conclusion. The results, summarized in Exhibit 18, confirm that the risk premium in Bitcoin is not statistically different from zero.

Irrespective of the data source and the time period examined, the data does not support an allocation to cryptocurrencies as represented

Exhibit 18: Bitcoin Risk, Return and Uncertainty Characteristics

We believe that the risk premium in Bitcoin is not statistically different from zero.

	Realized Return (Annualized)	Model-Based Estimates				Return Required for 1% Allocation	Return Required for 2% Allocation	
		Risk Premium	Volatility	Sharpe Ratio				
Bloomberg	69%	-35.2% ◀	1.9% ▶	39.1%	93.0%	0.02	165%	365%
CryptoCompare	67%	-38.8% ◀	-2.0%	34.9%	92.0%	-0.02	162%	353%
Coin Metrics	69%	-35.2% ◀	1.2%	37.5%	90.9%	0.01	160%	352%

Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg, CryptoCompare, Coin Metrics.

* The last two columns show the expected long-term annualized Bitcoin return required for the Investment Strategy Group's robust optimization model to allocate 1% or 2% of a moderate-risk portfolio to Bitcoin.

Past performance is not indicative of future results.

by Bitcoin. Furthermore, our view is that cryptocurrencies do not meet any of the five criteria highlighted above that we believe are required to justify an allocation to such assets:

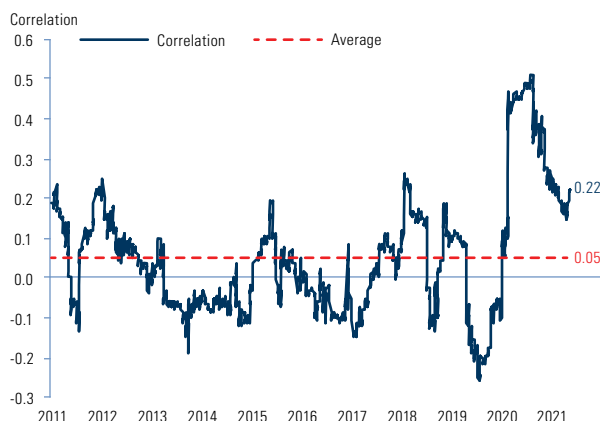
Steady cash flow: Cryptocurrencies do not contractually generate a steady stream of cash flows like a bond. While they may earn a yield when used for staking in the proof-of-stake process, this yield is not a contractual obligation.

Generate earnings: Unlike equities, cryptocurrencies, as currently structured, do not generate earnings tied to economic growth. So there is no economic rationale that underpins an upward trajectory of prices. For example, S&P 500 companies, in aggregate, have a long-term upward price trajectory because positive global growth enables them to generate growth in their earnings. There is no parallel to this growth in earnings with cryptocurrencies. Requiring that a cryptocurrency be used to pay the toll to a blockchain does not entail a long-term increase in that cryptocurrency's price.

Diversification benefits: Irrespective of whichever data series in Exhibit 18 we use, there is currently absolutely no diversification benefit from adding cryptocurrencies to the portfolio. While many market commentators have asserted some diversification benefits due to the price increase of Bitcoin since its inception in 2009, we have already shown that data to be unreliable. Others have pointed to the low correlation of Bitcoin to the S&P 500. As shown in Exhibit 19, the correlation has averaged 0.05 and ranged from -0.26 to 0.51. Low correlation alone does not justify an allocation if the low correlation is not

Exhibit 19: 6-Month Rolling Correlation Between S&P 500 and Bitcoin

The correlation between the S&P 500 and Bitcoin has ranged from -0.26 to 0.51.



Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg, Datastream.

paired with an attractive risk/reward profile. Many assets are uncorrelated but are not viable for investment purposes.

Dampen volatility: Even if we use the post-2014 level of volatility for Bitcoin, which stands at 68%, everyone would agree that cryptocurrencies do not dampen volatility.

Hedge inflation or deflation as a store of value: The history of Bitcoin is limited, so we have no evidence that cryptocurrencies are a reliable inflation or deflation hedge that will store value in either an inflationary or deflationary environment. Equities are the most consistent and reliable

inflation hedge, and high-quality bonds are the most consistent and reliable deflation hedge.

As noted previously, some have posited that Bitcoin is a store of value and is therefore the digital form of gold. They recommend a 1–2% allocation of a portfolio to Bitcoin to hedge against higher inflation arising from the extremely loose monetary and fiscal policies still in place around the world today. Policy interest rates are at zero or negative in most developed economies, and global debt-to-GDP increased from 323% at the end of 2019 to 360% by the end of the first quarter of 2021 as a result of the COVID-19 pandemic. We do not agree that the major developed economies—the US, the UK, the Eurozone and Japan—are entering a period of higher sustained inflation because of these policies.²⁷

However, even if sustained higher inflation were to materialize, the argument that Bitcoin is digital gold and a store of value has three major shortcomings:

- The data does not support the contention that gold is the optimal store of value during periods of inflation.
- The frequency and magnitude of Bitcoin price declines are too high to provide the peace of mind that a store of value should provide.
- For the real gold bugs, Bitcoin and other cryptocurrencies do not share the key attributes of gold that, in their view, make it a better store of value and insurance policy than other financial assets.

We examine the evidence that undermines the arguments for Bitcoin and other cryptocurrencies as a store of value.

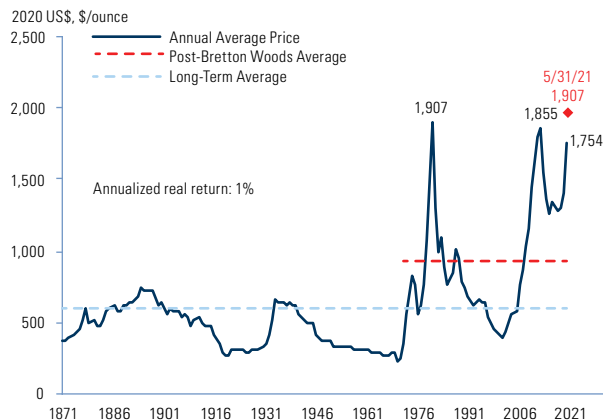
Gold Is Not the Optimal Store of Value

In the Investment Strategy Group, we believe that gold is not a long-term store of value, for the following reasons:

- Since the inception of pricing data, gold has provided an annualized real return of 1%, barely outperforming inflation (see Exhibit 20). Adjusting for storage and insurance costs, the estimated excess return drops to zero.
- The only asset class that hedges inflation on a consistent and reliable basis is US equities. As shown in Exhibit 21, US equities have

Exhibit 20: Annual Average Real Gold Prices

Gold has barely outperformed inflation over the long term.



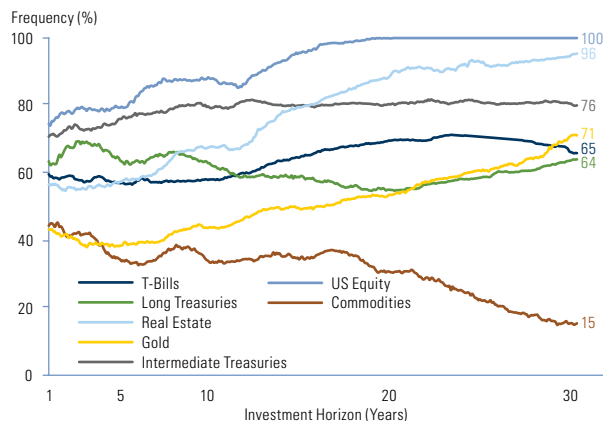
Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg.

Past performance is not indicative of future results.

Exhibit 21: Historical Frequency of Different Asset Classes Outperforming Inflation

US equities are a better long-term inflation hedge than gold.



Data as of 2020.

Note: Based on data since 1926. T-Bills: Ibbotson US 3M T-Bills / Barclays Capital US 1-3M T-Bills; Intermediate Treasuries: Ibbotson US Intermediate Treasuries / Barclays Capital US Intermediate Treasuries; Long Treasuries: Ibbotson US Long Treasuries / Barclays Capital US Long Treasuries; US Equity: Ibbotson US Large Cap, S&P 500; Real Estate Prices: Robert Shiller Nominal Price Index / S&P/Case-Shiller National Home Price Index; Commodities Prices: the Economist Industrial Commodity Price Index / CRB Spot Price Index / S&P/GSCI Commodity Spot Returns; Gold Prices: Bloomberg Gold Spot, S&P/GSCI Gold Spot Returns.

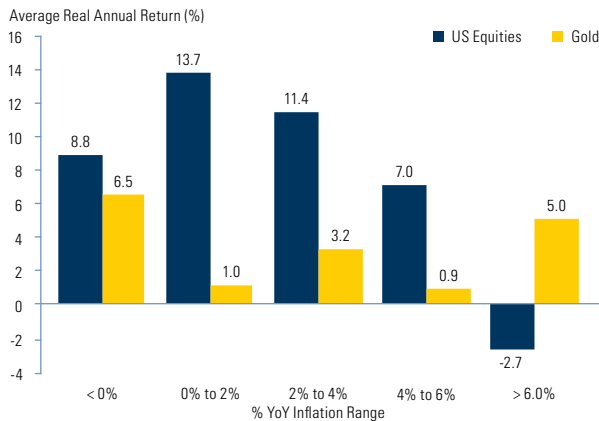
Source: Investment Strategy Group, Bureau of Labor Statistics, *Economist*, Datastream, Bloomberg, Ibbotson, Robert Shiller (Yale University).

Past performance is not indicative of future results.

outperformed inflation 100% of the time over any 19-year window. Gold outperforms inflation only about 50% of the time over a 19-year window. So owning US equities is a better long-term inflation hedge.

Exhibit 22: S&P 500 and Gold Average Real Annual Returns by Inflation Cohort

US equities have outperformed gold in most periods of positive inflation.

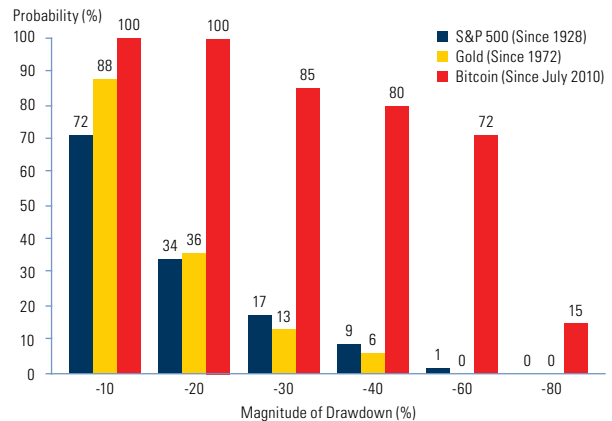


Data through May 31, 2021.

Source: Investment Strategy Group, Datastream, Bloomberg, Robert Shiller (Yale University). Past performance is not indicative of future results.

Exhibit 23: One-Year Probability of Drawdowns

Bitcoin has had more frequent and larger declines than US equities and gold.



Data through May 31, 2021.

Note: Based on returns from peak to trough within the year.

Source: Investment Strategy Group, Bloomberg.

- On a shorter-term basis, US equities have outperformed gold in most periods of positive inflation, as shown in Exhibit 22. Even when inflation was greater than 6%, gold outperformed only between January 1970 and June 1970, and again between August 1973 and July 1982.

The argument that Bitcoin and cryptocurrencies are a digital version of gold does not confer any value to Bitcoin and other cryptocurrencies, because gold itself is not a consistent or reliable store of value. US equities have proved to be a much better store of value.

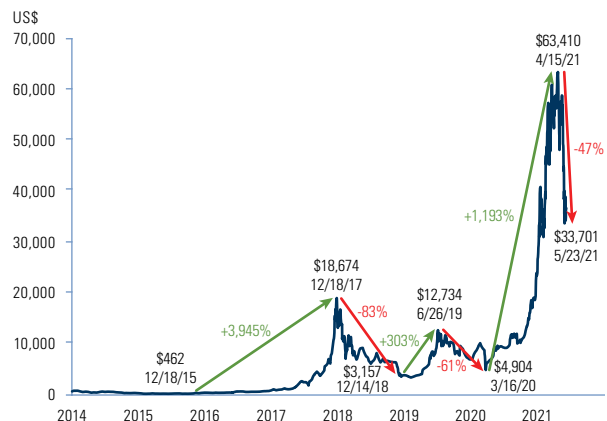
Frequent and Large Price Declines

We believe that a consistent and reliable store of value should not have frequent and large price declines. As shown in Exhibit 23, Bitcoin has had more frequent and larger declines in the 12.5 years of its existence than US equities have had since 1928 and gold has had since 1972 in the post-Bretton Woods era.

Some may point to this frequency and magnitude of drops and say that the cryptocurrency markets have always recovered from such declines. And they very well may do so again. But someone bought Bitcoin at peak prices in April 2021 and someone sold at the lower prices later in May, so some real value was actually lost. In fact, the more recent drops have occurred when the outstanding

Exhibit 24: Bitcoin Price Time Series

The latest 47% drop in the price of Bitcoin equated to a \$554 billion loss of market capitalization.



Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg.

number of bitcoins has increased and the drops have occurred from higher prices. As a result, the declines have signified a much larger loss of market capitalization. The latest 47% plunge in the price of Bitcoin, shown in Exhibit 24, equated to a \$554 billion loss of market capitalization. While that entire market loss was not realized, it is hard to say that such frequent and large losses do not weaken

the store-of-value argument for Bitcoin. US equities drop as well but, as shown in Exhibit 23, not as frequently and not at the same magnitude.

Such large declines can shake the faith of even the staunchest supporters. In a recent interview with *Insider*, Jesse Powell, the CEO of Kraken, a US-based cryptocurrency exchange, shared that the downdrafts sometimes prompt him to reread the Satoshi Nakamoto white paper: “It’s like when you have like a crisis of faith as a religious person, maybe you go and read the Bible or Quran,” he said. “Here, you go back and read the Bitcoin white paper and you’re like, yeah, this still makes sense.”²⁸

Gold’s Attributes Are Not Found in Cryptocurrencies

While we prefer US equities to gold as a better store of value, many in the investment community believe that gold should play a role in investment portfolios as a safe haven and as an insurance policy for times of economic and political crisis. This cohort strongly disagrees with the view that cryptocurrencies like Bitcoin are digital gold.

One such believer in holding gold reserves is Simon Mikhailovich, the founder of TBR, The Bullion Reserve. He has argued that “digital gold is a non sequitur. Gold is truly lasting while the long-term resiliency of digital assets has yet to be tested—untested assets are not safe havens by definition. Every technology has evolved and been replaced and today’s digital asset technology is bound to evolve and be replaced as well.”²⁹

Mikhailovich points out that gold is independent of everything; its existence does not rely on people or systems. However, “cryptocurrencies such as Bitcoin cannot exist independently and rely on networks and a functioning digital ecosystem.” He also contends that “gold is absolutely scarce while Bitcoin’s current stated limit of 21 million creates relative scarcity since there are many cryptocurrencies and some are functionally superior.”

Our colleague Jeff Currie, who heads up Commodities Research at Goldman Sachs, has also stated that Bitcoin is not like gold, because gold has value and use beyond being a store of value.³⁰ He believes that the real use of gold smooths out the volatility of the price of gold as real demand adjusts to absorb swings in

investment demand. Such real use also means that gold is unlikely to go to zero.

We also have to remember that 17.5% of the stock of gold is held by central banks and the International Monetary Fund, including the US Federal Reserve, the Bank of England, the European Central Bank, the People’s Bank of China and the Bank of Russia. It is virtually impossible to think that these central banks will buy Bitcoin to supplement their reserves. In fact, as we discuss in the next section, the regulatory risks from governments across the world that would affect cryptocurrencies are rising rapidly.

Additionally, 46% of the stock of gold is held as jewelry, one-quarter of which is in India. Cryptocurrencies will not displace jewelry demand. Of course, that does not mean that individuals will not want to own cryptocurrencies for the sake of owning them and for having bragging rights, but that does not make them as valuable as gold.

Finally, we note that the extremely low correlation of Bitcoin to gold, as shown in Exhibit 25, further supports the argument that during its limited history, Bitcoin has not behaved like gold.

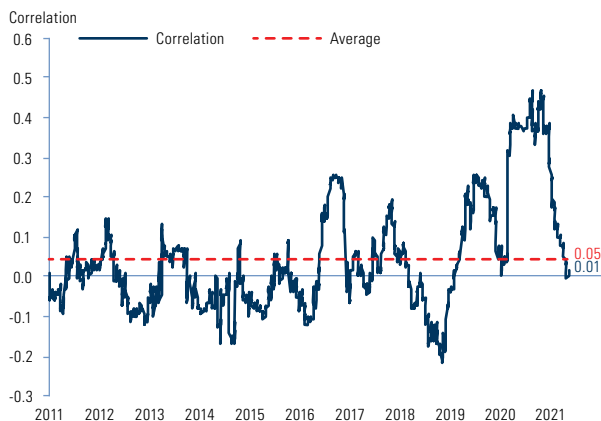
Based on the risk/return characteristics of Bitcoin, and the fact that it does not meet any of the criteria required to be a strategic asset class in a client’s investment portfolio, we do not recommend investing in cryptocurrencies as an asset class. That is not to say that it cannot be an ideal asset for speculation or for active traders. Or simply, as pointed out by Scott Melker—whom *Insider* (formerly *Business Insider*) calls a



By permission Chip Bok and Creators Syndicate, Inc.

Exhibit 25: 6-Month Rolling Correlation Between Gold and Bitcoin

The correlation between gold and Bitcoin has ranged from -0.22 to 0.47.

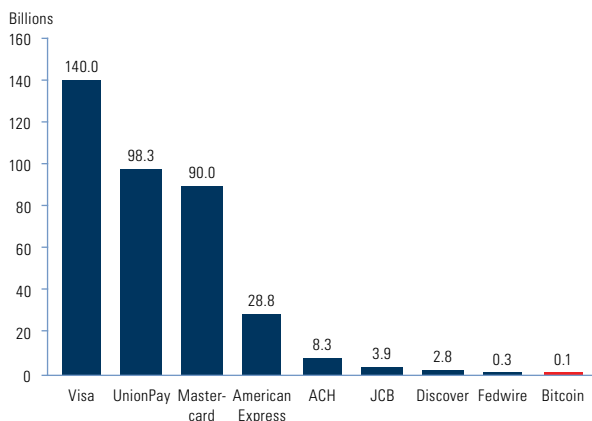


Data through May 31, 2021.

Source: Investment Strategy Group, Bloomberg, Datastream.

Exhibit 26: Annual Transactions of Various Payment Systems

Visa processes 140 billion transactions annually, while Bitcoin processes only about 100 million transactions.



Data as of 2020.

Note: ACH stands for Automated Clearing House, a US financial network used for electronic payments and money transfers.

Source: Investment Strategy Group, ACH Network, Visa, Federal Reserve, Mastercard, CardRates, American Express.

legend in the world of cryptocurrency trading—trading cryptocurrencies like Dogecoin can be for “gambling and having fun.”³¹

Valuing Cryptocurrencies

After examining six different approaches, we believe that it is virtually impossible to build a defensible framework for valuing cryptocurrencies. We review the six approaches:

Cash flow analysis: If cryptocurrencies do not generate any cash flows, either contractually like bonds or in the form of earnings like equities, one cannot discount a stream of cash flows to estimate a present value.

Gold comparison: If cryptocurrencies are not tied to any other asset class, one cannot derive a value indirectly from other assets. For example, since we do not believe that cryptocurrencies are digital gold and, as shown above, they have no correlation to gold and lack many of the qualities of gold, there is no analytical grounding for tying their value to gold.

Money supply: If cryptocurrencies are not really currencies serving as mediums of exchange or units

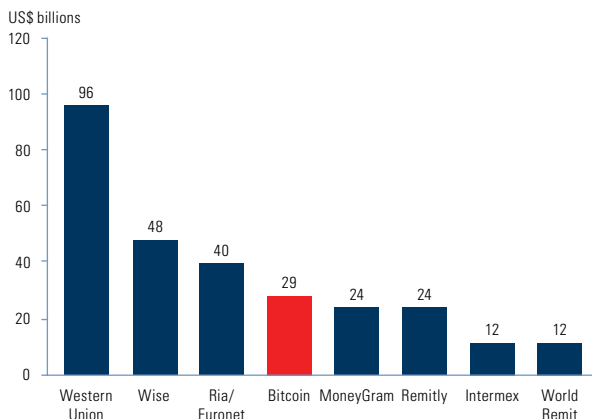
of measurement given their current volatility and slow processing, applying economic equations related to money supply to value these assets is meaningless.

Payment systems: If cryptocurrencies are considered to function as payment systems, similar to Visa, Mastercard and other payment networks, they should be valued comparably to these other systems. But as shown in Exhibit 26, Visa processes an estimated 140 billion transactions per year, while Bitcoin processes about 100 million transactions per year. Major credit cards are currently valued at about \$3.30 per annual transaction. Using the same pricing used by the market to price other credit card payment systems, the price of Bitcoin is estimated to be about \$22. However, this approach does not take into account the fact that there are many cheaper and faster payment networks, even among cryptocurrencies.

Money-transfer services: One can similarly value cryptocurrencies on the basis of their money-transfer services. Bitcoin has been used for remittances, especially for remittances to emerging market countries where transaction fees often exceed the global average of about 7%, according to the World Bank.³² If we use the valuations of

Exhibit 27: Annual Transaction Volume of Various Money-Transfer Services

One can value Bitcoin on the basis that it provides a money-transfer service, such as remittances.



Data as of 2020.

Source: Investment Strategy Group, Wise, Euronet, MoneyGram, Western Union, Remitly, Intermex, WorldRemit.

major money-transfer services shown in Exhibit 27, and apply it to Bitcoin for the \$28.8 billion of annual transfers, the price of Bitcoin is estimated to be about \$151, assuming that all transactions below \$10,000 are used for retail money transfers. Further, it does not factor in the reality that other cryptocurrencies provide cheaper and faster options. We note that Coinbase’s remittance service chooses two other cryptocurrencies, XRP and USDC, not Bitcoin, for international transfers.

Commodity cost of production: Finally, if one views the blockchain mining process as mirroring real-world mining activities, one can value Bitcoin based on the cost of mining plus a reasonable return on equity for the miners. Based on this approach, the cost of mining will vary with the cost of capital expenditures such as mining equipment and operating expenditures such as electricity. One such model estimated the price of Bitcoin to be \$10,000 in March 2020.³³ As the cost of production changes, the price of Bitcoin would similarly change. The problem with such analysis is that Bitcoin is not a commodity in that it is not a raw material used as an input for other goods. Oil, agricultural products and industrial metals all have to be produced, so the cost-of-production approach establishes a long-term floor for the commodities. Cost-of-production models are not relevant to the price of Bitcoin, in our opinion, because Bitcoin

is not a commodity and Bitcoin does not have to be mined for human survival. Furthermore, unlike commodities, the cost of production of Bitcoin is actually driven by the price of Bitcoin: a higher price attracts more miners, which in turn increases the difficulty of mining and thus the required electricity consumption.

All six of these approaches present major shortcomings and none yield a useful valuation framework for cryptocurrencies—hence our view that cryptocurrencies generally, and Bitcoin specifically, cannot be valued.

However, they can obviously be priced. As Aswath Damodaran—a professor of finance at the Stern School of Business at New York University who is considered a leading authority on equity valuation—has argued, “You cannot value Bitcoin or invest in it. You can only price it and trade it.”³⁴ He differentiates between a “pricing game” for assets such as Bitcoin and an “investing game” for assets such as equities.

Damodaran has put forth a list of tools and skills needed to price assets that are not investment assets. They include technical indicators, price charts and investor psychology. A particularly useful tool is “the capacity to move prices (with lots of money and lots of followers).” He expands further and suggests that “gambling instincts” are a key personality trait for trading assets such as Bitcoin. For clients who would like to trade Bitcoin, we highly recommend reading his blog post, “The Bitcoin Boom: Asset, Currency, Commodity or Collectible?” where he describes “the ingredients needed for good trading.”

With these tools, Bitcoin proselytizers can impact investor psychology and move prices. In fact, based on the tenets of the pricing game, the price of Bitcoin is driven solely by investor psychology, not by any real long-term value that is attributed to Bitcoin. Damodaran writes that any trader who thinks he is trading based on value is a “most delusional player.”

We agree with the Damodaran view of trading Bitcoin based on prices rather than investing in Bitcoin based on value. Furthermore, we believe that an asset whose appreciation is primarily dependent on whether someone else is willing to pay a higher price for it is not a suitable investment for our clients.

Staying focused on prices, we make two observations that suggest the price of Bitcoin is still too high.

Exhibit 28: Probability of Explosive Behavior in the Price of Bitcoin

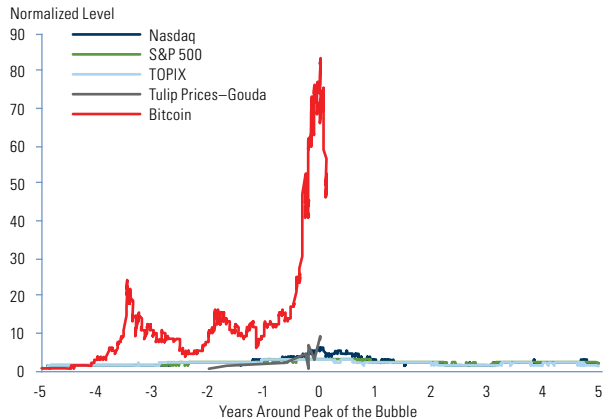
When the probability of explosive behavior reached 100% in 2017 and in 2020, a decline in the price of Bitcoin followed.



Data through May 31, 2021.
Source: Investment Strategy Group, Bloomberg.

Exhibit 30: Bitcoin in the Context of Equity Market Bubbles and Tulips

Compared with Bitcoin's price move, those of equities and tulips are barely visible.



Data through May 31, 2021.
Source: Investment Strategy Group, Datastream, Bloomberg, Peter M. Garber, "Famous First Bubbles: The Fundamentals of Early Manias," 2000, MIT Press, Cambridge MA. Anne Goldgar, "Tulipmania: Money, Honor, and Knowledge, in the Dutch Golden Age," 2007, University of Chicago Press, Chicago. E.H. Krelage, "Bloemenspeculatie in Nederland. De Tulpomanie van 1636-'37 en de Hyacintehandel van 1720-'36," 1942, P.N. Kampen & Zoon, Amsterdam."

Exhibit 29: Equity Bubbles

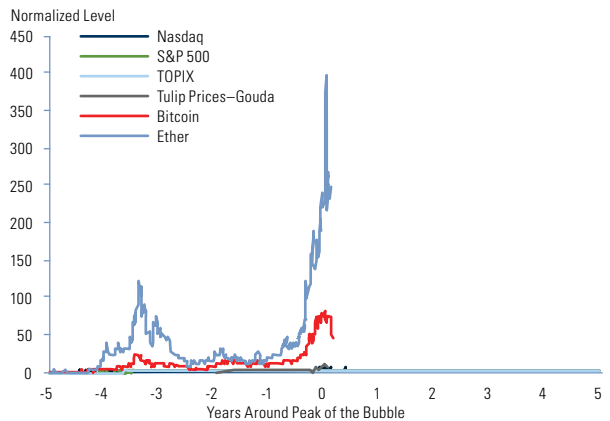
The Nasdaq, S&P 500 and TOPIX all experienced bubbles toward the end of the 20th century.



Data through May 31, 2021.
Source: Investment Strategy Group, Bloomberg.

Exhibit 31: Ether in the Context of Equity Market Bubbles, Bitcoin and Tulips

The equity, tulip and Bitcoin bubbles are all dwarfed by the price moves in Ether.



Data through May 31, 2021.
Source: Investment Strategy Group, Datastream, Bloomberg, Peter M. Garber, "Famous First Bubbles: The Fundamentals of Early Manias," 2000, MIT Press, Cambridge MA. Anne Goldgar, "Tulipmania: Money, Honor, and Knowledge, in the Dutch Golden Age," 2007, University of Chicago Press, Chicago. E.H. Krelage, "Bloemenspeculatie in Nederland. De Tulpomanie van 1636-'37 en de Hyacintehandel van 1720-'36," 1942, P.N. Kampen & Zoon, Amsterdam."

Exhibit 28 shows the probability of explosive behavior in Bitcoin prices. The probability that prices were exhibiting explosive behavior reached 100% in May 2017 and again in December 2020.

Both times, a decline in Bitcoin prices followed. While that probability of explosive price behavior has declined, it is still high today, at 86%.

Exhibits 29, 30 and 31, which we first used in our economic and investment *Outlook* report for 2018, compare bitcoin and ether pricing to that of other assets during price bubbles. They should be viewed as a triptych. Exhibit 29 shows the prices of Nasdaq, the S&P 500 Index and Japan's TOPIX five years before and after their respective peaks, which by all measures were considered to be in bubble territory.

Exhibit 30 adds the prices of Bitcoin with its recent peak in April 2021 and the prices of tulip bulbs during the Dutch “tulipmania” between 1634 and early 1637. We used the Gouda variety of bulbs. The price increases in Bitcoin dwarf those of the equity bubbles—the dot-com-era bubble of the early 2000s is flatlined—and the prices during the tulipmania are barely visible. Exhibit 31 adds ether prices, flatlining even Bitcoin prices.

We think this triptych provides some perspective on the recent price moves of cryptocurrencies into bubble territory.

It is not unusual to see bubbles during periods of significant innovation. Professor Robin Greenwood of Harvard Business School, who has focused on asset price bubbles, has noted that “periods of great innovation are interesting from an investor’s perspective because you can justify a wide range of valuations ... oftentimes, the financial innovation itself might survive the bubble and crash.”³⁵

Willem Buiters, visiting professor at Columbia University, former member of the Bank of England’s Monetary Policy Committee and former international advisor to Goldman Sachs International, has a similar view. He warns that the new instruments of “financial innovation during bubbles ... become devices for speculation and excess. The innovation itself might not be the problem.”³⁶

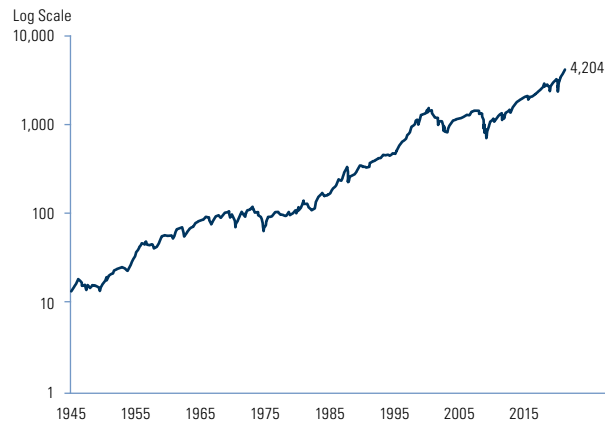
We echo these sentiments. We believe that blockchain technology is a significant innovation that is likely to have a far-reaching impact across the global economy.

However, we do not have a tactical view on whether prices will rise or fall from these levels. We do not play the pricing game; we are in the investing business.

There are wide-ranging views about the long-term prospects for Bitcoin. Wences Casares, CEO and co-founder of

Exhibit 32: S&P 500 Price Time Series

The S&P 500 has generated positive total returns 97% of the time over rolling 10-year periods in the post-WWII period.



Data through May 31, 2021.
Source: Investment Strategy Group, Bloomberg.

Xapo and PayPal board member, shared his views: he believes that “Bitcoin has a higher-than-60% chance of succeeding and being worth more than \$1 million in less than 10 years, a 25–30% chance of not disappearing but becoming irrelevant (in which case it will still have a price, but much lower than what it is today, and probably less than \$1,000 per bitcoin), and a 10–15% chance of failing and being worthless.”³⁷

For context, the S&P 500 has generated positive total returns 97% of the time over rolling 10-year periods in the post-WWII period (see Exhibit 32). In our view, there is near certainty that the S&P 500 will rise over the coming decade, near zero odds that it will lose 97% of its value and zero probability that it will become completely worthless over this period. Of course, that is

“Periods of great innovation are interesting from an investor’s perspective because you can justify a wide range of valuations ... oftentimes, the financial innovation itself might survive the bubble and crash.”

— Robin Greenwood,
Harvard Business School Professor

barring a global catastrophe such as a nuclear war or an asteroid hitting the earth, but in that case those bitcoins will have evaporated into the ether.

Investing in Other Digital Coins and Tokens

With respect to other digital coins and tokens, there are no compelling arguments that they are investable assets for a diversified portfolio, except for security tokens.

Stablecoins and forthcoming CBDCs derive their value from the fiat currency they represent. They are not designed to be appreciating assets.

Security tokens already have security status and their value will be derived from the underlying asset, such as shares in a real estate property, so clients can selectively invest in security tokens as they would in a private real estate or a private equity asset. In the case where the underlying asset is a decentralized application, the security token would be analogous to a share in a technology venture.

Utility tokens are designed to provide a utility, and their value is derived from the value of the utility they provide. It is true that many utility tokens, such as those underpinning decentralized lending applications, are designed to appreciate as their associated services become more popular. In many such cases, the tokens have properties similar to those of securities, such as voting rights, participation in fee revenue and compensation for founders. As we discuss in the next section, this introduces a substantial regulatory risk for many popular utility tokens as the SEC considers whether they are unregistered securities. Therefore, we do not consider such utility tokens to be investable assets until their regulatory status is clarified.

Governance tokens can be analogous to voting rights that are separate from equity ownership; while there may be some value to voting rights, we do not recommend them as a viable asset class.

And finally, NFTs are collectible items like art, watches, baseball and Pokémon cards, and sports memorabilia. Their value will fluctuate based on demand for each specific digital collectible at any point.

Investing in the “Picks and Shovels” of the Digital Asset Ecosystem

Our positive view of the long-term impact of blockchain technology, combined with our unfavorable view of cryptocurrencies as an investable asset class, inevitably leads to the question of how our clients can prudently invest in the digital asset ecosystem.

We think there are two possible approaches, depending upon the client:

- Private equity through venture capital firms that invest in innovators in the digital asset ecosystem. Such investments do not have to be limited to blockchain companies: a centralized cryptocurrency exchange is an example of a venture that is itself not a blockchain company but that benefits from the trading of cryptocurrencies. We do not underestimate the difficulty of finding such investments and evaluating their viability and suitability.
- Public equities exposed to the digital asset ecosystem. An example is a basket of stocks with high blockchain exposure.

We should note that these possible approaches are not always highly correlated to price movements of cryptocurrencies. Furthermore, they all come with varying levels of risk and illiquidity.

While we have shared a positive view of the long-term impact of blockchain technology, the whole digital asset ecosystem faces considerable risks. We discuss these risks in Section III.

Risks to the Digital Asset Ecosystem

The digital asset ecosystem faces a considerable number of risks that may pose a significant threat to some of its components.

While there are a number of risks, we view the following as the five most significant ones:

- Regulatory risks, because governments can have huge impacts on the entire digital asset ecosystem. These risks include governments banning trading or mining of cryptocurrencies and regulating cryptocurrencies as securities.
- Heightened concerns about the environmental, social and governance (ESG) impact of various parts of this ecosystem. These concerns include high energy consumption and increased use of cryptocurrencies for ransomware from cyberattacks on health-care facilities, energy facilities and, most recently, food facilities.

- Rapid technological innovation that could displace any major player in the ecosystem.
- Destruction of confidence in the ecosystem due to cyberattacks or major computer programming errors.
- A credit crisis. Like any other financial system driven by human psychology (and the associated fear and greed), the cryptocurrency market will inevitably have a credit crisis, especially as leverage increases in the system. In the absence of a lender of last resort, the destruction of wealth and confidence could be enormous, and it is unclear whether and how a recovery would be orchestrated.

Below, we examine each risk in greater detail.

Regulatory Risks

We believe the regulatory risks are high and complex across all major countries, both developed and emerging. Not all regulations are clear, and many are in a state of flux. Major countries such as the United States, China and India are at different stages of regulating cryptocurrencies.

Many of the cryptocurrency proselytizers claim that regulators and the central banks want to regulate the digital asset ecosystem to protect their control of the money supply, maintain the seigniorage and, obviously, effectuate monetary policy. While those reasons alone are valid enough, regulation is needed to maintain financial stability, protect less-informed market participants—many of whose cryptocurrency accounts were wiped out in the 47% drop between April 15 and May 23, 2021, in Bitcoin prices—minimize fraud and market manipulation, and provide a consistent regulatory framework across financial institutions.

During the depths of the pandemic, the US Federal Reserve introduced and expanded a number of liquidity facilities that totaled over \$2.6 trillion: Primary Dealer Credit Facility, Commercial Paper Funding Facility, Money Market Liquidity Facility, Term Asset-Backed Loan Facility, and Primary and Secondary Market Corporate Credit Facilities, among others. The introduction of these liquidity facilities prevented the seizing up of the financial markets and enabled the gradual normalization of trading in

non-Treasury securities. It is virtually impossible to imagine that the cryptocurrency proselytizers do not appreciate the importance of such a lender of last resort. Ironically, the vast majority of high-profile cryptocurrency proselytizers have benefited from the existence of the US Federal Reserve.

Let's review some of the regulatory actions directed to the digital asset ecosystem.

China: China has the most stringent restrictions on cryptocurrencies. It was the first major country to regulate Bitcoin: it prohibited financial and payment institutions from providing Bitcoin-related services, including Bitcoin transactions, in 2013. It is also the largest country to pilot a central bank digital currency. Importantly, according to the Cambridge Centre for Alternative Finance, China accounted for about 70% of global Bitcoin mining, so its regulations matter beyond its own borders.³⁸



In 2017, China imposed a ban on initial coin offerings (ICOs), and in 2019, the People's Bank of China issued a statement that it would ban access to all domestic and foreign cryptocurrency exchanges and ICO websites.³⁹

In May 2021, Chinese regulators banned financial institutions from providing any services related to cryptocurrencies and expanded the 2017 ruling prohibiting "exchange services between cryptocurrencies and the yuan or other foreign currencies."⁴⁰ They also prohibited financial institutions from using cryptocurrencies for savings or investment accounts.

On May 21, 2021, Liu He, the Chinese vice premier, hosted a meeting of the Financial Stability and Development Committee of the State Council in which officials called for a crackdown on Bitcoin mining and trading activities.⁴¹

We believe the regulatory risks are high and complex across all major countries, both developed and emerging. Not all regulations are clear, and many are in a state of flux.

In February 2021, Inner Mongolia, which accounted for about 8% of global cryptocurrency mining, announced plans to ban new mining projects and shut down existing ones by April. In May, it announced further measures, including targeting telecommunications companies and internet firms and revoking licenses if they were found to be involved in cryptocurrency mining.⁴²

The province of Sichuan, another mining hub in China, is also considering the impact of a ban on cryptocurrency mining.⁴³

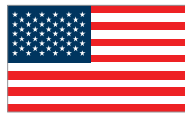
It seems highly likely that China's ban on financial and payment institutions' facilitation of cryptocurrency transactions will negatively impact the demand for cryptocurrencies.

India: The Reserve Bank of India (RBI) was among the earliest of central banks to caution its citizens about the speculative nature of cryptocurrencies; it issued a press release on the subject in 2013.⁴⁴ Still, the current regulatory framework is in a state of flux. In April 2018, the RBI issued a notice preventing financial and payment institutions from dealing in cryptocurrencies and from providing services to any entity dealing with cryptocurrencies.⁴⁵ Yet India's Supreme Court overturned the ban in March 2020.⁴⁶



In early 2021, the government proposed a bill to create an Indian public digital currency (an Indian CBDC) and to ban the use of private cryptocurrencies (that is, those not issued by the state).⁴⁷ In the meantime, the RBI also reminded Indian banks of the Supreme Court decision to overturn the RBI's 2018 ban. It seems likely that the government will issue some type of ban, but the details and timing are as yet unclear.

United States: As many of our clients know, US Preeminence has been one of our investment themes since the global financial crisis. We believe that the US regulatory framework will probably have the greatest impact on the digital asset ecosystem.



To date, most of the regulatory actions have been directed by the Securities and Exchange Commission (SEC), with the first cryptocurrency SEC action taken in 2013. Many SEC actions have focused on determining which securities pass the Howey Test. For example, many ICOs

were determined to be securities. An important outstanding case is the one against Ripple Lab Inc. related to its \$1.3 billion ICO of XRP tokens launched in 2013. While the case is pending, the expectation is that if the SEC and Ripple choose not to settle, the courts will not reach a conclusion before next year.⁴⁸

Most recently, in an appearance before Congress, Gary Gensler, chairman of the SEC, suggested that Congress assume the role of bringing greater regulatory structure to the digital asset ecosystem.⁴⁹

Another recent case was brought by New York Attorney General Letitia James against iFinex regarding its stablecoin, Tether, and its cryptocurrency exchange, Bitfinex. James said in a statement in February 2021 that "Bitfinex and Tether recklessly and unlawfully covered up massive financial losses to keep their scheme going and protect their bottom lines. Tether's claims that its virtual currency was fully backed by US dollars at all times was a lie."⁵⁰ The case was settled for \$18.5 million. Tether recently disclosed that only 8% of its reserves are in cash, Treasury bills and reverse repos.⁵¹

The Commodity Futures Trading Commission (CFTC) has also provided guidance to members of the digital asset ecosystem. In November 2020, Coinbase stopped allowing margin trading on its exchange in response to guidance from the CFTC.⁵²

Lew Lukens of Signum Global has suggested that regulatory clarity may be a year away because of the various federal agencies involved in some aspect of the digital asset ecosystem and what falls under their purview:⁵³

- SEC: Some digital assets are already considered securities and more may fall into that category, such as utility tokens that are issued to raise capital for decentralized applications. Use of exchange-traded funds would also fall under the purview of the SEC.
- CFTC: Some assets, including futures on cryptocurrencies, are viewed as commodities. The references by the proselytizers to digital gold probably reinforce this view.
- Office of the Comptroller of the Currency (OCC): In its responsibility for oversight of financial institutions, the OCC will focus on the increasing involvement of financial institutions in the trading and custody of digital assets and the use of blockchain-technology debt issuance.

- Internal Revenue Service (IRS): The US Treasury Department issued a requirement in May 2021 that any transfer of cryptocurrencies worth \$10,000 or greater be reported to the IRS.
- Financial Crimes Enforcement Network: Cryptocurrencies are in the “money service business” covered by the Bank Secrecy Act.
- Federal Trade Commission: This agency has jurisdiction over fraud and investment scams involving cryptocurrencies.
- Federal Deposit Insurance Corporation (FDIC): Some cryptocurrencies may be covered by FDIC insurance, depending on where they are held.

It is possible that regulators and Congress will set up a new regulatory agency dedicated to cryptocurrency oversight.

In May alone, several Federal Reserve governors and regulators commented about the need for further regulation. For example, Governor Lael Brainard said that “a predominance of private monies may introduce consumer protection and financial stability risks because of their potential volatility and the risk of run-like behavior,”⁵⁴ and Federal Reserve Vice Chair for Supervision Randal Quarles said that they, “along with the OCC and the FDIC, are engaged right now in what we are calling a sprint in seeking to pull together views on exactly that [cryptocurrency regulation].”⁵⁵

We believe the impact of increased regulation, especially from the US, should not be underestimated.

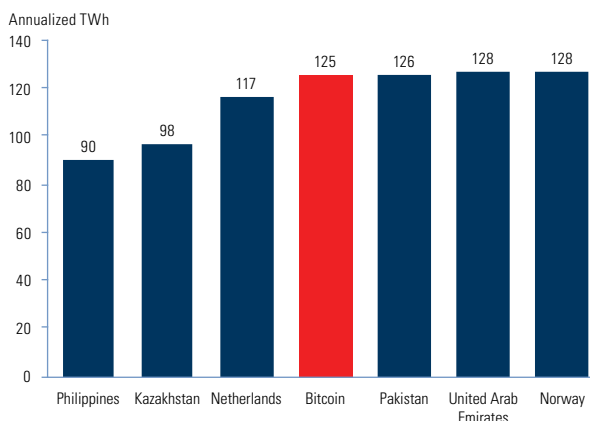
Other: A long list of countries have regulated but not banned cryptocurrencies: Germany, Switzerland, Canada, Singapore and South Korea are among them. Most have anti-money laundering (AML) and Know Your Customer (KYC) requirements for cryptocurrency transactions and services. As the digital asset ecosystem grows and affects more individual investors, we believe the regulatory landscape will likely evolve.

In the UK, all businesses engaged in cryptocurrency activities must register with the Financial Conduct Authority and comply with all the requirements for AML/combating financing of terrorism.⁵⁶ Still, Bank of England Governor Andrew Bailey has warned cryptocurrency buyers about losses: “Buy them only if you’re prepared to lose all your money.”⁵⁷

The Bank for International Settlements launched a consultation on June 10, 2021, calling

Exhibit 33: Energy Consumption by Country and from Bitcoin Mining

Bitcoin mining’s energy consumption is in line with that of countries such as Pakistan and the Netherlands.



Data as of May 31, 2021.
Source: Investment Strategy Group, Digiconomist.

for digital assets to carry tough bank capital rules given concerns about financial stability. The proposed requirements include a 1,250% risk weight for cryptocurrencies. Given the 8% minimum capital adequacy ratio that banks must maintain, this risk weight implies that banks would be “required to hold risk-based capital at least equal in value to their ... cryptoasset exposures.”⁵⁸

Environmental, Social and Governance (ESG) Considerations

Two aspects of the digital asset ecosystem run counter to ESG principles: energy consumption and ransomware.

Energy Consumption: Mining Bitcoin is a very energy-intensive process. Over the past four years, Bitcoin’s energy use has increased tenfold. On May 31, 2021, for example, Bitcoin mining consumed electricity at an annualized rate of about 120 terawatt-hours per year. As shown in Exhibit 33, Bitcoin mining’s energy consumption is in line with that of several countries, such as Pakistan and the Netherlands. To put these numbers in another context, the energy consumed to confirm one Bitcoin transaction can power over 1 million Visa transactions. If one adjusts for the carbon footprint of that energy consumed, the number of comparable Visa transactions increases to 1.5 million.⁵⁹

Most Bitcoin mining has occurred in regions that rely heavily on coal-based electricity generation. For example, in Inner Mongolia, which is now banning Bitcoin mining, 84% of the energy production comes from coal.

Even in the US, older coal-powered plants are being revived for Bitcoin mining. A coal-fired plant in Montana, the Hardin Generating Station, is being transformed into a Bitcoin mining hub by Marathon Digital Holdings Inc.⁶⁰ Similarly, in Dresden, New York, a coal-fired plant has been converted to natural gas for mining Bitcoin.⁶¹

In response to growing concerns about Bitcoin’s carbon footprint, some proponents have argued that Bitcoin can spawn a renewed push for renewable energy. Alex de Vries, who founded the platform Digiconomist, has argued that renewable energy will not solve Bitcoin’s carbon footprint problem because renewables, in their current form, are an intermittent source of energy, and Bitcoin miners need energy on a continuous basis.⁶²

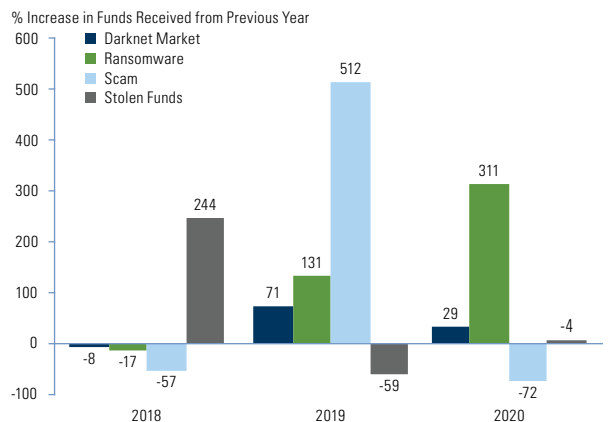
Moreover, if Bitcoin prices rise significantly, the prospect of mining rewards will simply attract more miners. And more miners leave an even greater carbon footprint.

While Bitcoin’s energy consumption has garnered the most attention, de Vries estimates that Ethereum and Litecoin add another 50% to Bitcoin’s energy consumption.⁶³ Should Ethereum switch from a proof-of-work to a proof-of-stake process for validating blocks and adding them to the blockchain, as is planned for Ethereum 2.0, the energy consumption would decline significantly.

Ransomware: Cryptocurrencies are particularly useful for criminals and their illicit activities because of the pseudo-anonymity of cryptocurrency users and the ease with which users can send funds anywhere in the world, beyond the reach of authorities. The illicit activities include terrorism financing, use of darknet markets to buy and sell illegal goods such as drugs or weapons, scams, theft of funds, and ransomware.

According to Chainalysis, the total value of illicit cryptocurrency activities was just over \$20 billion in 2019 and \$10 billion in 2020.⁶⁴ Chainalysis also points out that the value involved in cryptocurrency-related crime is less than the value of illicit funds involved in traditional finance. However, data compiled by the company also shows that ransomware is on the rise. Ransomware is malicious software that encrypts, and thus

Exhibit 34: Annual Change in Cryptocurrency-Based Crime Categories
Ransomware is on the rise.



Data through 2020.
Source: Investment Strategy Group, Chainalysis.

renders unusable, a victim’s valuable data (such as operational data) and demands payment, often in cryptocurrency, in order to decrypt it. As shown in Exhibit 34, ransoms paid due to ransomware attacks increased 131% in 2019 and 311% in 2020, reaching nearly \$350 million in 2020. As discussed in Chainalysis’ 2021 Crypto Crime report, this dollar estimate is a lower-bound number, since many ransomware attacks are not reported.⁶⁵

We have highlighted ransomware for two reasons. First, while cryptocurrencies provide some advantages for most criminals relative to traditional finance, we believe that cryptocurrencies enable more ransomware on an international scale.

Second, we thought it important for our clients to be aware of how cryptocurrency criminals are becoming more aggressive in affecting our daily lives. For example, ransomware criminals attacked hospitals in 2020 during the depths of the pandemic as the health-care system was overwhelmed with COVID-19 patients.⁶⁶ This year, the Colonial Pipeline ransomware attack in May affected gasoline availability on the East Coast of the US, and the JBS ransomware attack, also in May, affected meat processing in the US and Canada.

In March 2021, US Secretary of Homeland Security Alejandro Mayorkas announced a “sprint” to fight against ransomware, which he deemed “a national security threat.”⁶⁷ He proposed a series of measures that his department would take to minimize ransomware incidents and to respond to ransomware attacks.

According to Chainalysis, “ransomware exploits gaps in technology controls ... This gap is closing quickly as law enforcement and private businesses develop the knowledge required to identify, seize and return funds.”⁶⁸

In early June 2021, 63.7 of the 75 bitcoins paid by Colonial Pipeline to the ransomware group DarkSide were seized by the FBI. Although this represents only a small portion of the total ransomware payments made, it shows that law enforcement is using the public nature of the Bitcoin blockchain—along with the occasional missteps of the attackers—to combat this type of crime.

At some point, proponents of ESG may consider divesting their cryptocurrency activities because of the energy usage and the extent of the illicit activities for which cryptocurrencies are used.

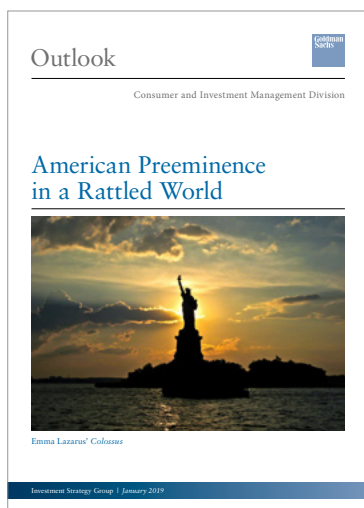
Cryptocurrencies pose an additional social and governance dilemma. As we discussed in Section I, the premise on which the Bitcoin blockchain was built is one of “crypto-anarchy,” where “government is not temporarily destroyed, but permanently forbidden and permanently unnecessary.”⁶⁹ It is incongruous for the Investment Strategy Group to endorse such a call for anarchy when US Preeminence has been one of our most important and effective investment themes since the March 2009 trough of the global financial crisis.

Exponential Increase in the Pace of Technological Progress

The law of accelerating returns described by American inventor and futurist Ray Kurzweil implies that the pace of technological progress increases exponentially over time. Should such progress materialize in this area, current blockchain technology may become obsolete.

One of the possible threats is quantum computing—albeit not in the near future. Deloitte has highlighted how quantum computers may be able to derive a user’s private key from the corresponding public key and break the cryptography that underpins the Bitcoin blockchain.⁷⁰

Another threat posed by the rapid pace of innovation is simply the displacement of current blockchains with more effective ones. As we highlighted in Section I, since Bitcoin was launched in 2009, many blockchains have emerged with much greater capabilities and faster speeds. Ethereum, launched in 2015, introduced the notion of decentralized applications. Since then, many new blockchains have emerged that are faster and more scalable, such as Algorand, Solana and Polkadot. Recently, a still more ambitious blockchain-based platform, the Dfinity Internet Computer, proposes replacing the current internet with a new paradigm in which all data and applications are hosted in a cohesive manner. Decentralized applications are already being launched with the goal of replacing centralized technology platforms such as Facebook, Google and LinkedIn.



Loss of Confidence

Cyberattacks in the digital asset ecosystem occur frequently. For example, private keys are stolen, data is stolen from servers, and accounts are compromised when malicious actors take control of someone's smartphone. These cyberattacks happen in the traditional financial system as well. The difference is that, usually, large financial institutions protect clients' assets against third-party cyberattacks, whereas in the decentralized digital asset ecosystem, there is no central authority to approach. Furthermore, cryptocurrencies are bearer instruments, where the owner of the private key owns the digital asset. Once the private key is stolen, it is virtually impossible to recover the assets due to the immutability of the blockchain

ledger. A saying has emerged to describe this risk in the world of cryptocurrency: "Not your keys, not your coins."⁷¹

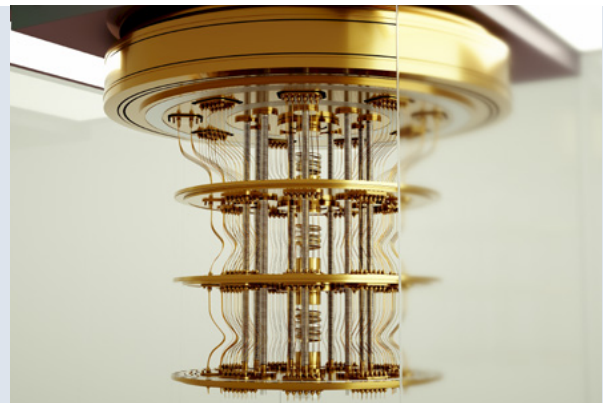
Some traditional and nontraditional institutions provide custodial services to hold private keys. However, as the assets under custody grow, these institutions will likely become a target for cyberattacks. For example, Bitfinex, an exchange that offers custodial services, was hacked in 2016 and over \$72 million worth of bitcoin was stolen.⁷² We should note the paradox of a decentralized ecosystem relying on centralized custodial services.

Additionally, digital assets are built with computer code, and where there is computer code, there is a chance of programming errors (or bugs) that could negatively impact a program on a blockchain. If there are too many of these

Quantum Computing and Cryptocurrencies

Quantum computers have the potential to process data more rapidly than traditional computers. Traditional computing uses basic logic operations on **bits** (basic units of information representing 0 or 1) and is the foundation of most computing such as cloud computing, desktop computing, and computing on mobile and wearable devices. Quantum computing uses more complex operations on **qubits** (quantum bit) that allow for the simultaneous existence of two states and is particularly effective in calculations based on probabilities.

Theoretically, quantum computers can break RSA security protocols (among the most widely used cryptographic methods), other protocols based on what is called elliptic curve cryptography which is used in many blockchains, and the SHA-256 hash used by blockchain technology to secure wallets, post transactions,



A Quantum Computer

and protect digital signatures. Given the potential resources needed, many believe that SHA-256 is quantum-resistant (secure against quantum computer attacks).

While breaking the blockchain cryptography is theoretically possible, quantum computing is not yet sufficiently advanced to pose a real threat at this time. In fact, even though companies like IBM, Google, and Microsoft have heavily invested in quantum computing, there are skeptics who believe that quantum computing "is something of a mirage."⁷³

cyberattacks or bugs, they could diminish trust in decentralized systems.

This risk is amplified when the computer code controls outcomes in ways that cannot be reversed by humans. Although proselytizers extol the virtues of “immutable” blockchains, erroneous outcomes caused by the ever-present possibility of bugs are just as permanent as intended outcomes.

Take, for example, the well-documented case of the Parity wallet on Ethereum. The wallet software had a previously unknown bug that, in November 2017, led to over 500,000 ETH, worth approximately \$160 million at the time, being rendered inaccessible.⁷⁴

Finally, cryptocurrency proselytizers often state that this ecosystem does not require trust in a centralized authority. However, we believe that the whole ecosystem is built on layers of trust:

- Trust in the social construct that in the future others will place a value on cryptocurrencies that is greater than their value today
- Trust in the sustainability of the current incentive structure for miners/validators
- Trust in the viability of the exchanges to provide liquidity
- Trust in the commitment of the developers to follow through with their projects
- Trust in the safekeeping of private keys

Erosion in any of these layers of trust could severely damage components of this ecosystem.

Risk of a Credit Crisis

The full extent of leverage in the digital ecosystem is hard to ascertain. What is clearer is the amount of leverage some exchanges provide their clients. As shown in Exhibit 35, several exchanges—both AA- and A-rated by CryptoCompare—offer

“If you think cryptography will solve your problem, either you don’t understand cryptography, or you don’t understand your problem.”

— Peter G. Neumann

Exhibit 35: Leverage Provided by Various Crypto Exchanges

Several exchanges provide meaningful leverage to their clients.

Exchange	Location	CryptoCompare Rating	Margin/ Leverage Trading
Binance	Cayman Islands	A	10x (50x for futures)
Coinbase Pro	US	AA	No
Bitfinex	Hong Kong	A	10x
FTX	Antigua and Barbuda	A	101x
Kraken	US	AA	5x
LMAX Digital	Gibraltar	A	No
Bitstamp	Luxembourg	AA	No
GOPAX	Korea	A	No
bitFlyer	US	A	2x
Gemini	US	AA	No
Liquid	Japan & Singapore	A	100x
Poloniex	US	A	2.5x (100x for futures)
Bittrex	US	A	3x (Outside the EU and the EEA)
AAX	Malta	A	100x
OKCoin	US	A	3x

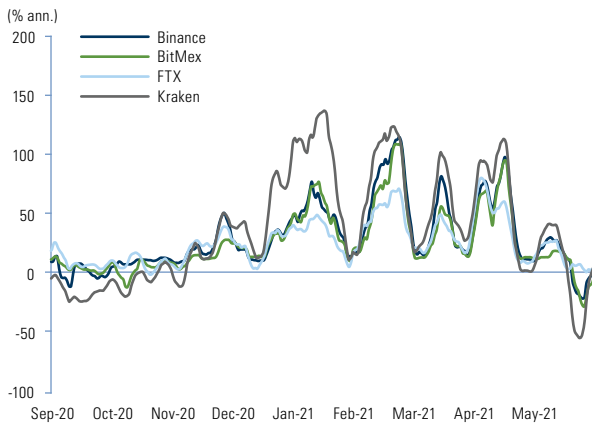
Data as of June 2021.
Note: Exchanges sorted by volume.
Source: Investment Strategy Group, CryptoCompare, exchanges.

significant leverage. Kraken, for example, offers five times leverage, and Binance and Bitfinex offer as much as 10 times leverage. Some of these exchanges have quite hefty fees. For example, Kraken offers leverage on ether at a cost of 0.02% for every four hours. Although 0.02% may seem minuscule, one should consider that this rate annualizes to about 44%. These margin loans have term limits, but they can be rolled over.

Futures (and perpetual futures) trading provides another form of leverage in the cryptocurrency space. Some exchanges

Exhibit 36: Annualized Average Funding Rates of Bitcoin Perpetual Futures

Average funding rates to enter the perpetual futures contracts can reach 100% or more.



Data through May 31, 2021.

Source: Investment Strategy Group, Coin Metrics.

offer very low initial margin requirements resulting in 100x (and higher) leverage ratios in the futures market. Average funding rates to enter the perpetual futures contracts can occasionally be very high and reach above 100% annualized, as shown in Exhibit 36. Most of the futures contracts do not feature margin calls, but the exchange liquidates these positions when the margin funds fall below required levels.

This leverage exacerbated the sharp downdraft in cryptocurrencies in April and May of 2021. As the markets traded off, possibly triggered by comments from Elon Musk, CEO of Tesla and SpaceX, regarding not accepting Bitcoin as payment for Tesla due to environmental concerns, and possibly further affected by negative comments from central and local government officials in China, leveraged accounts were forced to sell, putting further downward pressure on the markets.

According to bybt.com, Bitcoin traders liquidated \$12 billion in leveraged positions, and 800,000 cryptocurrency accounts were wiped out.⁷⁵ Should the digital asset market get substantially larger and these levels of leverage continue to be offered, the downdrafts could be larger than the 47% drawdown seen between April and May 2021 in Bitcoin. Given the decentralized nature of the ecosystem, and the absence of a lender of last resort to stabilize the markets, not only will accounts likely be wiped

out, but exchanges, other entities in the digital asset ecosystem and stablecoins that are partially backed by cryptocurrencies could be wiped out as well.

We have outlined a series of risks that could negatively impact the digital asset ecosystem. Among these, government regulation poses the biggest risk. The ESG considerations may also dampen further adoption; as institutions establish ESG policies, it will be incongruent to invest in cryptocurrencies. Other factors, such as technological innovation, loss of confidence in the ecosystem due to cyberattacks or computer programming errors, and too much leverage, pose additional risks.

Key Takeaways

In researching and writing this report, we had one goal in mind: to provide a thorough, balanced and objective examination of the digital asset ecosystem for our clients. In the first part of the report, we describe the components of this ecosystem and separate blockchain technology from cryptocurrencies; the two should not be conflated. We then share our conclusion that while many components of the ecosystem, notably blockchain technology, are likely to contribute to long-term economic growth, cryptocurrencies are not a viable investment for inclusion in our clients' diversified portfolios. And finally, we focus on the risks that are likely to confront and help shape this ecosystem.

We have refrained from repeating the positive and negative hype that surround this ecosystem because we do not want clients to be seesawed, even swayed, by a cacophony of assertions, many of them unsubstantiated.

We have eight key takeaways:

- The digital asset ecosystem, even though still in its infancy, is extremely complex.
- Given the scarcity of regulated exchanges requiring rigorous and verifiable reporting standards, the quality of available data since the inception of the first bitcoin in January 2009 is poor though improving. Therefore, one has to be cautious about any analysis that relies solely on historical data.
- We are optimistic that blockchain technology will lead to efficiencies in enterprise operations and will also hinder the use and abuse of personal data by dominant technology companies. The role of certain intermediaries will be reduced.
- Technological advances could make the current blockchain technology obsolete.

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- High energy consumption in mining and the use of cryptocurrencies in ransomware could discourage the adoption of cryptocurrencies by those with meaningful environmental, social and governance objectives.
 - The biggest risk to the speculative aspects of this ecosystem is greater regulatory oversight, especially in the US. As noted by Gary Gensler, chair of the Securities and Exchange Commission, in his May 26, 2021, testimony before the House of Representatives Subcommittee on Financial Services and General Government, in the cryptocurrency market there is “substantially less investor protection than in our traditional securities markets,” which has led to “correspondingly greater opportunities for fraud and manipulation.”⁷⁶
 - Cryptocurrencies and blockchain technology are built on layers of trust that could be eroded.
 - After analyzing various valuation methodologies and applying our multi-factor strategic asset allocation model, we have concluded that cryptocurrencies are not a viable investment for our clients’ diversified portfolios.

Abbreviations Glossary

ACH: Automated Clearing House

AML: anti-money laundering

BATs: Basic Attention Tokens

CBDC: central bank digital currency

CFTC: Commodity Futures Trading Commission

CRM: customer relationship management

dApps: decentralized applications

DAO: decentralized autonomous organization

DLT: distributed ledger technology

EIB: European Investment Bank

EM: emerging market

ERP: enterprise resource planning

ESG: environmental, social and governance

GFC: global financial crisis

GSCI: Goldman Sachs Commodity Index

HY: high yield

ICO: initial coin offering

IRS: Internal Revenue Service

KYC: Know Your Customer

NFT: non-fungible token

OCC: Office of the Comptroller of the Currency

RBI: Reserve Bank of India

SEC: Securities and Exchange Commission

SWIFT: Society for Worldwide Interbank Financial Telecommunication

TBR: The Bullion Reserve

TOPIX: Tokyo Price Index

TWh: terawatt-hour

Notes

1. Based on seven-day moving averages.
2. Lin William Cong, Xi Li, Ke Tang and Yang Yang, "Crypto Wash Trading," December 2019.
3. Dan Amiram, Evgeny Lyandres and Daniel Rabetti, "Competition and Product Quality: Fake Trading on Crypto Exchanges," March 14, 2021.
4. Codruta Boar and Andreas Wehrli, "BIS Papers No. 114: Ready, Steady, Go? Results of the Third BIS Survey on Central Bank Digital Currency," Bank for International Settlements, January 27, 2021.
5. Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," October 2008.
6. Stuart Haber and W. Scott Stornetta, "Secure Names for Bit-Strings," Proceedings of the 4th ACM Conference on Computer and Communications Security, April 1997.
7. Adam Back, "Hashcash—A Denial of Service Counter-Measure," August 2002.
8. Ralph C. Merkle, "Protocols for Public Key Cryptosystems," 1980 IEEE Symposium on Security and Privacy, April 1980.
9. Wei Dai, "B-Money," November 1998.
10. Ibid.
11. "Visa Fact Sheet," Visa Inc., April 2019.
12. Investment Strategy Group calculations based on Bloomberg data.
13. Silvio Micali, "Algorand 2021 Performance," Algorand, December 7, 2020.
14. Andrew Asmakov, "Vitalik Buterin Touts 100x Scaling Solution for Ethereum," Decrypt, March 10, 2021.
15. Solana, "Break Solana," accessed on June 6, 2021.
16. Paul Brody (EY global blockchain leader), in an email exchange with the Investment Strategy Group, May 23, 2021.
17. Linda Pawczuk (global blockchain leader at Deloitte), in an email exchange with the Investment Strategy Group, May 26, 2021.
18. Mathew McDermott (global head of digital assets at Goldman Sachs), in an email exchange with the Investment Strategy Group, May 26, 2021.
19. Paul Brody, "Assembling the Ecosystem," EY Global Blockchain Summit 2021, May 2021.
20. Jonathan Johnson (CEO of Overstock.com), in a Zoom call with the Investment Strategy Group, May 25, 2021.
21. George Lee (co-chief information officer of Goldman Sachs), in an email exchange with the Investment Strategy Group, May 29, 2021.
22. US Securities and Exchange Commission, "Framework for 'Investment Contract' Analysis of Digital Assets," April 3, 2019.
23. Lauren Yates, "Memorandum: Meeting with Bitwise Asset Management, Inc., NYSE Arca, Inc., and Vedder Price P.C.," US Securities and Exchange Commission, March 20, 2019.
24. Lin William Cong, Xi Li, Ke Tang and Yang Yang, "Crypto Wash Trading," March 2021.
25. Dan Amiram, Evgeny Lyandres and Daniel Rabetti, "Competition and Product Quality: Fake Trading on Crypto Exchanges," Tel Aviv University, January 2021.
26. Jon Geenty, "Introducing Coin Metrics' Trusted Volume Framework," Coin Metrics, July 2020.
27. For a more detailed discussion on the Investment Strategy Group's view on inflation, please refer to our May 27, 2020, client call, "US Economic Outlook & Implications of Current Policies for Inflation, Gold and Bitcoin."
28. Vicki Ge Huang, "The CEO of Crypto Exchange Kraken Breaks Down Why He Still Stands by His \$200,000 Year-end Price Target for Bitcoin Amid Recent Corrections—and Shares 5 Tokens that Intrigue Him Right Now," *Insider*, June 10, 2021.
29. Simon Mikhailovich (founder of The Bullion Reserve), in an email exchange with the Investment Strategy Group, June 1, 2021.
30. Jeffrey Currie, "Commodity Watch: Starting the Next Leg Higher," Goldman Sachs Global Investment Research, April 28, 2021.
31. Kari McMahon, "'Wolf of All Streets' Crypto Trader Scott Melker Shares How He Plays the 'Beloved' and 'Predictable' Dogecoin Trade—and His 2 Tips for Rookie Traders," *Insider*, May 30, 2021.
32. World Bank, "World Bank Predicts Sharpest Decline of Remittances in Recent History," April 22, 2020.
33. Data Dater, "Bitcoin's Cost of Production—A Model for Bitcoin Valuation," *Medium*, March 7, 2020.
34. Aswath Damodaran, "The Bitcoin Boom: Asset, Currency, Commodity or Collectible?" October 24, 2017.
35. Jon Hilsenrath, "From Dutch Tulips to Internet Stocks, How to Spot a Financial Bubble," *Wall Street Journal*, May 7, 2021.
36. Ibid.
37. Wences Casares (CEO and co-founder of Xapo and PayPal board member), in an email exchange with the Investment Strategy Group, June 4, 2021.
38. Cambridge Centre for Alternative Finance, "Bitcoin Mining Map," https://cbeci.org/mining_map.
39. "China Bans Financial, Payment Institutions from Cryptocurrency Business," Reuters, May 18, 2021.
40. "Explainer: What Beijing's New Crackdown Means for Crypto in China," Reuters, May 19, 2021.
41. "China Vows to Crack Down on Bitcoin Mining, Trading Activities," Reuters, May 21, 2021.
42. Coco Feng, "China Bitcoin: Inner Mongolia Reinforces Beijing's Ban on Mining with Strict Rules as More Operators Prepare to Relocate Offshore," *South China Morning Post*, May 26, 2021.
43. "In Widening Chinese Bitcoin Crackdown, Sichuan to Probe Cryptomining—Official," Reuters, May 27, 2021.
44. Ajit Prasad, "RBI Cautions Users of Virtual Currencies Against Risks," Reserve Bank of India, December 24, 2013.
45. Saurav Sinha, "Prohibition on Dealing in Virtual Currencies (VCs)," Reserve Bank of India, April 6, 2018.
46. Upmanyu Trivedi, "Cryptocurrency Bourses Win India Case Against Central Bank Curbs," Bloomberg, March 4, 2020.
47. Ankita Chakravarti, "RBI Plans Its Own Cryptocurrency, Proposed Crypto Law May Ban Bitcoins and Dogecoins in India," *India Today*, January 30, 2021.
48. Andrea Tinianow, "What Will the Ripple Effect Be in the Crypto Space?" *Forbes*, May 7, 2021.
49. John McCrank, "U.S. SEC Chair Says More Investor Protection Needed on Crypto Exchanges," Reuters, May 20, 2021.
50. Letitia James, "Attorney General James Ends Virtual Currency Trading Platform Bitfinex's Illegal Activities in New York," New York State Office of the Attorney General, February 23, 2021.
51. Tether, "Reserves Breakdown at March 31, 2021," May 13, 2021.
52. Nikhilesh De, "Coinbase Will Suspend All Margin Trading Tomorrow, Citing CFTC Guidance," Yahoo Finance, November 24, 2020.
53. Lew Lukens, "US: Crypto Regulation in Focus, but Hampered by Bureaucratic Overlap; Clarity at Least One Year Off," Signum Global Advisors, June 3, 2021.
54. Governor Lael Brainard, "Private Money and Central Bank Money as Payments Go Digital: An Update on CBDCs," Speech at the Consensus by CoinDesk 2021 Conference, May 24, 2021.
55. "Fed, OCC, FDIC in 'Sprint' on Regulation for Crypto, Quarles Says," Reuters, May 25, 2021.
56. Financial Conduct Authority, "FCA Establishes Temporary Registration Regime for Cryptoasset Businesses," December 16, 2020.
57. Ryan Browne, "Cryptocurrency Investors Should Be Prepared to Lose All Their Money, Bank of England Governor Says," CNBC, May 7, 2021.
58. Bank for International Settlements, "Consultative Document: Prudential Treatment of Cryptoasset Exposures," June 2021.
59. Digiconomist, "Bitcoin Energy Consumption Index," <https://digiconomist.net/bitcoin-energy-consumption/>.
60. Brian Spegele and Caitlin Ostroff, "Bitcoin Miners Are Giving New Life to Old Fossil-Fuel Power Plants," *Wall Street Journal*, May 21, 2021.
61. Ibid.
62. Digiconomist, "Bitcoin Energy Consumption Index," <https://digiconomist.net/bitcoin-energy-consumption/>.

63. Alex de Vries, "Bitcoin Boom: What Rising Prices Mean for the Network's Energy Consumption," *Joule*, March 17, 2021.
64. Chainalysis, "Crypto Crime Summarized: Scams and Darknet Markets Dominated 2020 by Revenue, but Ransomware Is the Bigger Story," January 19, 2021.
65. Ibid.
66. Patrick Howell O'Neill, "A Wave of Ransomware Hits US Hospitals as Coronavirus Spikes," *MIT Technology Review*, October 29, 2020.
67. Alejandro Mayorkas, "Secretary Mayorkas Outlines His Vision for Cybersecurity Resilience," US Department of Homeland Security, March 31, 2021.
68. Chainalysis, in an email exchange with the Investment Strategy Group, June 8, 2021.
69. Wei Dai, "B-Money," November 1998.
70. Itan Barmes and Bram Bosch, "Quantum Computers and the Bitcoin Blockchain," Deloitte, <https://www2.deloitte.com/nl/nl/pages/innovatie/artikelen/quantum-computers-and-the-bitcoin-blockchain.html>.
71. Ledger Academy, "Not Your Keys, Not Your Coins: Why It Matters," September 4, 2020.
72. "Bitcoin Worth \$72M Was Stolen in Bitfinex Exchange Hack in Hong Kong," Reuters, August 3, 2016.
73. Katia Moskvitch, "The Argument Against Quantum Computers," *Quanta Magazine*, <https://www.quantamagazine.org/gil-kalais-argument-against-quantum-computers-20180207>.
74. Jen Wieczner, "Ethereum Fork Could Help Restore Frozen Parity Cryptocurrency," *Fortune*, March 4, 2019.
75. Kate Rooney and Maggie Fitzgerald, "Bitcoin Traders Using up to 100-to-1 Leverage Are Driving the Wild Swings in Cryptocurrencies," CNBC, May 25, 2021.
76. Gary Gensler, "Testimony Before the Subcommittee on Financial Services and General Government, U.S. House Appropriations Committee," US Securities and Exchange Commission, May 26, 2021.

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Period	Gross Return	Net Return	Differential
1 year	6.17%	4.61%	1.56%
2 years	12.72%	9.43%	3.29%
10 years	81.94%	56.89%	25.05%

A description of fees is available in Part 2A of the GS&Co. Form ADV. Past performance does not guarantee future results.

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