



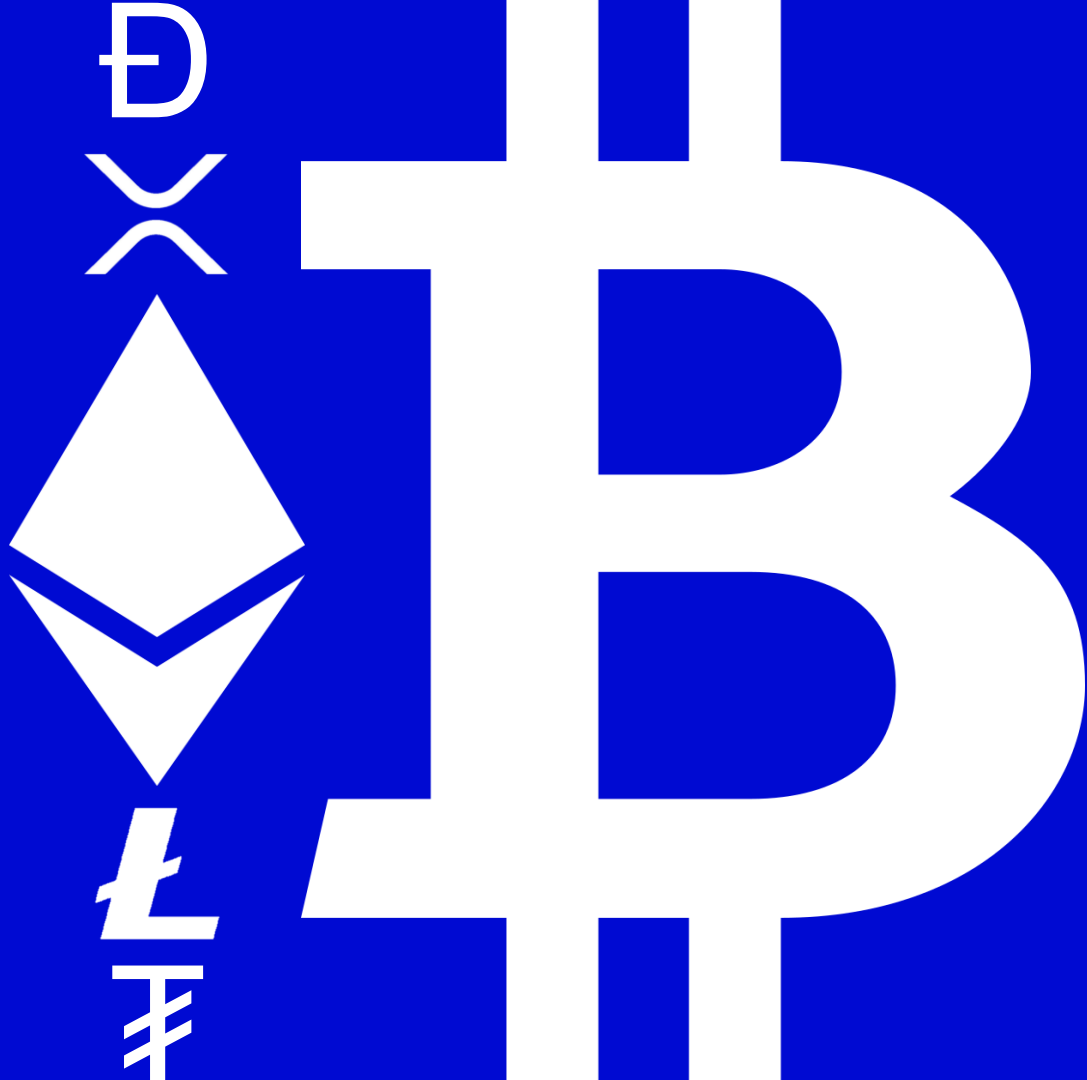
Exploring Cryptocurrencies

Trending Conversations
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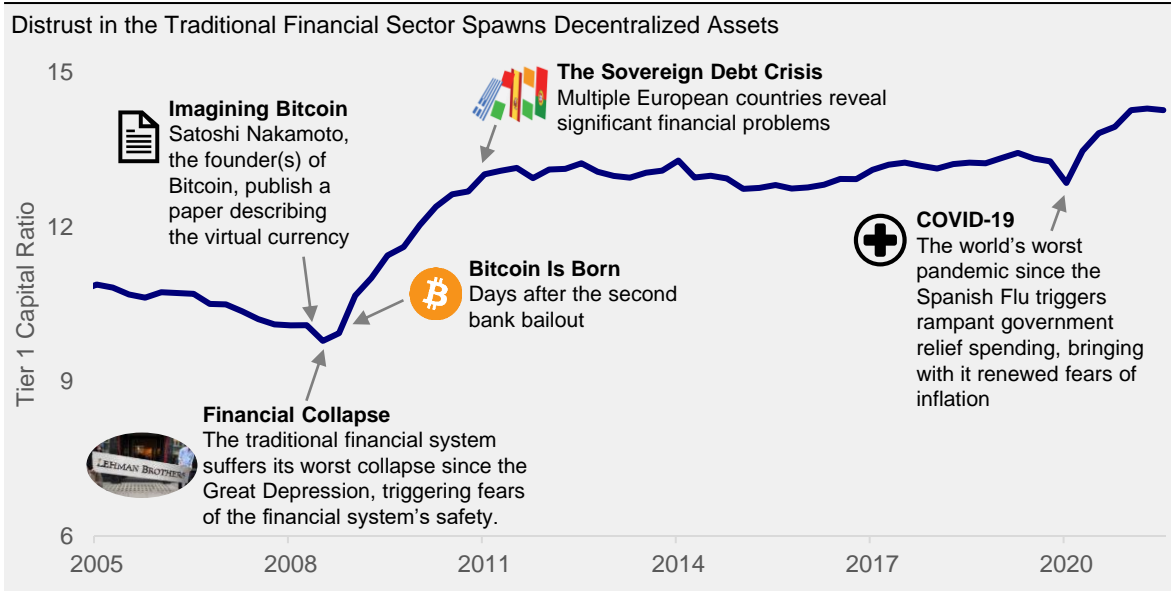


What Started It All?

A financial crisis and a distrust in institutions

Bitcoin, the first cryptocurrency, was invented in the depths of the financial crisis to offer an alternative to the traditional banking system. Satoshi Nakamoto, the anonymous author(s) of the research paper, *Bitcoin: A Peer-to-Peer Electronic Cash System*, approached the impending financial crisis like any other technologist: Take something fragile, inefficient, and far too large, and disrupt it. As the banks were failing, Satoshi inscribed in the code of the first mined bitcoin a message that reads, "The Times 3 January 2009 Chancellor on brink of second bailout for banks."

Since 2009, cryptocurrencies have developed well beyond Bitcoin into a vast and rapidly changing ecosystem. This paper offers an overview of the trend and technology behind cryptocurrencies, as well as an assessment of the risks, valuation, and potential long-term outcomes of cryptocurrencies, with a focus on Bitcoin. No matter Bitcoin's outlook, 13 years after authorship and in spite of a pandemic, Satoshi would be surprised to see well-capitalized banks, U.S. equities up 400%, and a booming economy.



Sources: Macrobond, US Federal Deposit Insurance Corporation, latest available data as of 31 December 2021.

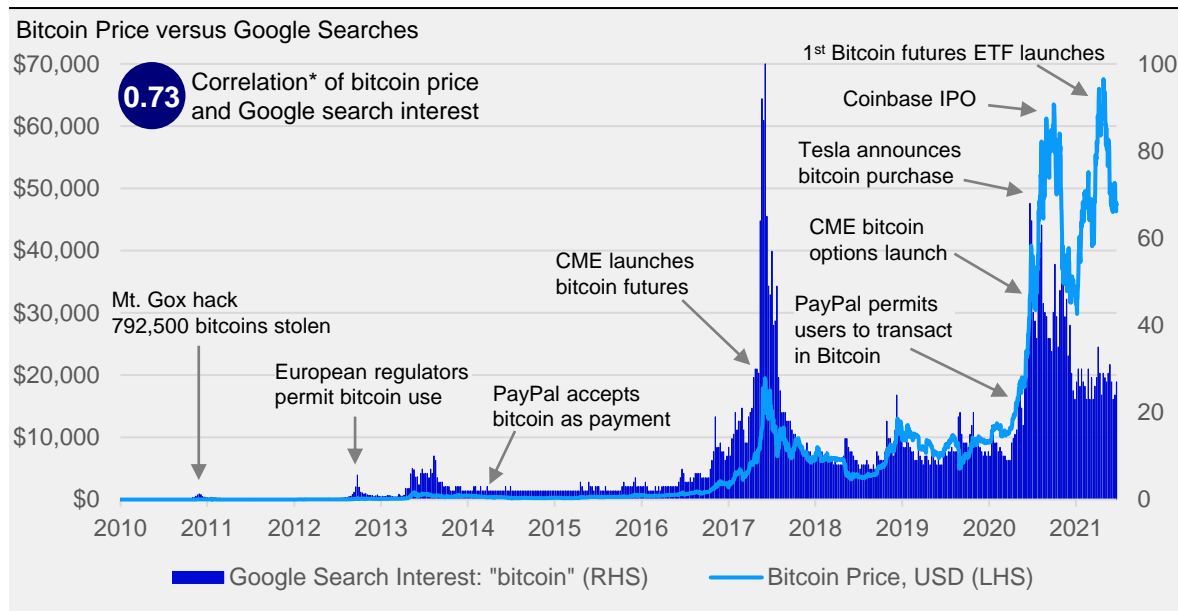
Why Is Everyone Paying Attention?

“A bubble is only a trade that someone missed.” –Anonymous

Since March 2020, Bitcoin has increased from \$8,500 to \$46,000, a remarkable 565% cumulative gain. While the potential applications of the underlying blockchain technology are interesting and may be vast, we argue that for most crypto-investors, that these applications are an afterthought and focus most on Bitcoin’s rapid price appreciation. Others insist that its scarcity alone justifies its price.

Cryptocurrencies are unique and deserve review. Finding assets that grow at exponential rates and have little correlation to traditional assets like stocks, bonds, and commodities is the Holy Grail for portfolio construction (but only if future returns are expected to be positive). At first glance, Bitcoin seems to fit this description. But this is changing.

In the very recent past, many price fluctuations could be explained simply by retail interest. Yet as cryptos have become more mainstream, their price behavior has also fallen more into line with traditional markets. When viewed as a cyclical, risk-on asset, we can explain some of Bitcoin’s recent moves.



* Correlation coefficient uses the average of weekly prices compared against average Google search interest over the same period.

Sources: Google, Macrobond, and Invesco. As of 31 December 2021. Past performance does not guarantee future results.

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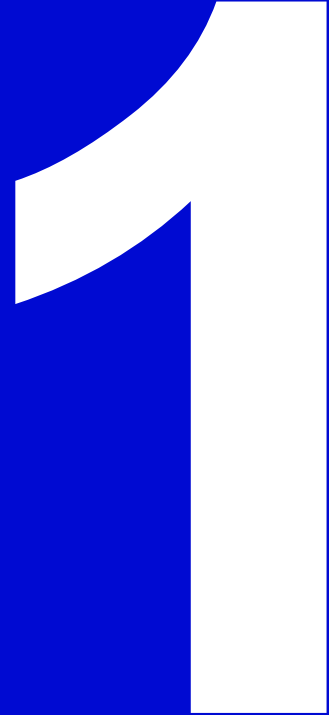
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Bitcoin and Blockchain... How Does It Work?

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The Crypto Believer Manifesto

A dash of distrust of institutions and a pinch of cryptographic tech...

Cryptocurrencies were born in the depths of deep financial crisis. They quickly became emblematic of widespread fears of traditional banking institutions and Wall Street financial products, made worse by fears of rampant inflation spurred by central bank asset purchases. Many of these points were captured in Satoshi Nakamoto's seminal paper, *Bitcoin: A Peer-to-Peer Electronic Cash System*, which is widely recognized as the birth of cryptocurrencies.

Bitcoin best captures these primary characteristics shown here, though cryptocurrencies developed since then have taken various spins on the original premise. Still, these common themes tend to re-emerge throughout various cryptocurrencies. This includes a distrust of institutions and fiat currencies, often in pursuit of a decentralized financial system (popularly referred to as "DeFi"). However, some cryptocurrencies appear far more cozy with the traditional financial system than others.

Source: Invesco. For illustrative purposes only.



Decentralization

The lack of a central authority controlling the currency is an attractive trait in a world distrustful of traditional financial institutions.



Democratization

Cryptocurrencies are designed to operate with consensus. Majority decisions are required for structural changes to most coins or tokens.



Cross-Border Payment Facilitation

Existing in cyberspace, cryptocurrencies trade outside the realm of government borders on often unregulated exchanges.



Blockchain Immutability

Cryptocurrencies rely on cryptography to preserve anonymity while preventing on-blockchain double-spend and ensuring settlement.



Finite Supply

With certain cryptocurrencies designed to have a finite supply, there is virtually no risk within such coins for a central authority diluting the value of assets.



Peer-to-Peer (Disintermediated)

Trades occur without intermediating authorities, such as banks or bookkeepers, which allows settlement to take place in real-time.

How Does One Get a Bitcoin?

The circle of Bitcoin's life

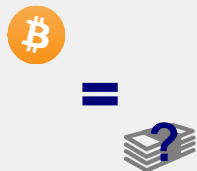
Like gold, bitcoins are mined and the supply of them is finite. New Bitcoins are minted and given to those “miners” who allocate their computing power to the blockchain network where they verify that transactions are accurate in the system, thus creating more “blocks” in the chain, and thus forming a “distributed ledger” where everyone has record of every Bitcoin transaction. Over time, fewer bitcoins are awarded to each successfully verified block of transactions according to a predefined release schedule.

Participants can trade their bitcoin for other currencies or goods and services from a limited number of participating vendors. Price per coin versus any currency is determined by inter-exchange trading.

Within this framework, one can get Bitcoin by either trading for it—on an exchange or via a blockchain transaction—or by mining it.

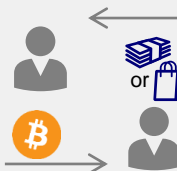
A Cryptocurrency in Motion

1) Market Determines Exchange Rate



Similar to a market for a commodity or currency, the market determines the price in fiat currency of a bitcoin by supply and demand dynamics, expressed through cryptocurrency exchanges.

2) User Transacts in Bitcoin



A user trades a bitcoin for a product, service or currency. Users can access their balance from their digital “wallets”, where they hold single-use codes representing bitcoin and generate one-time use codes for receiving coins.

4) Miners Are Rewarded

Computing Power



Mining Reward

For the computing power required to verify the ledger of transactions, those contributing their computing power (“miners”) are awarded with bitcoins, an amount which gradually decreases over time to zero.

3) Blockchain Network Verifies Transaction



A network of computers verifies the transaction(s) in a digital ledger and appends the transaction(s) into the latest block, preserving a digital “paper trail”. This represents trade settlement.

Sources: Satoshi Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System*, 30 October 2008. Please refer to glossary for further definitions.

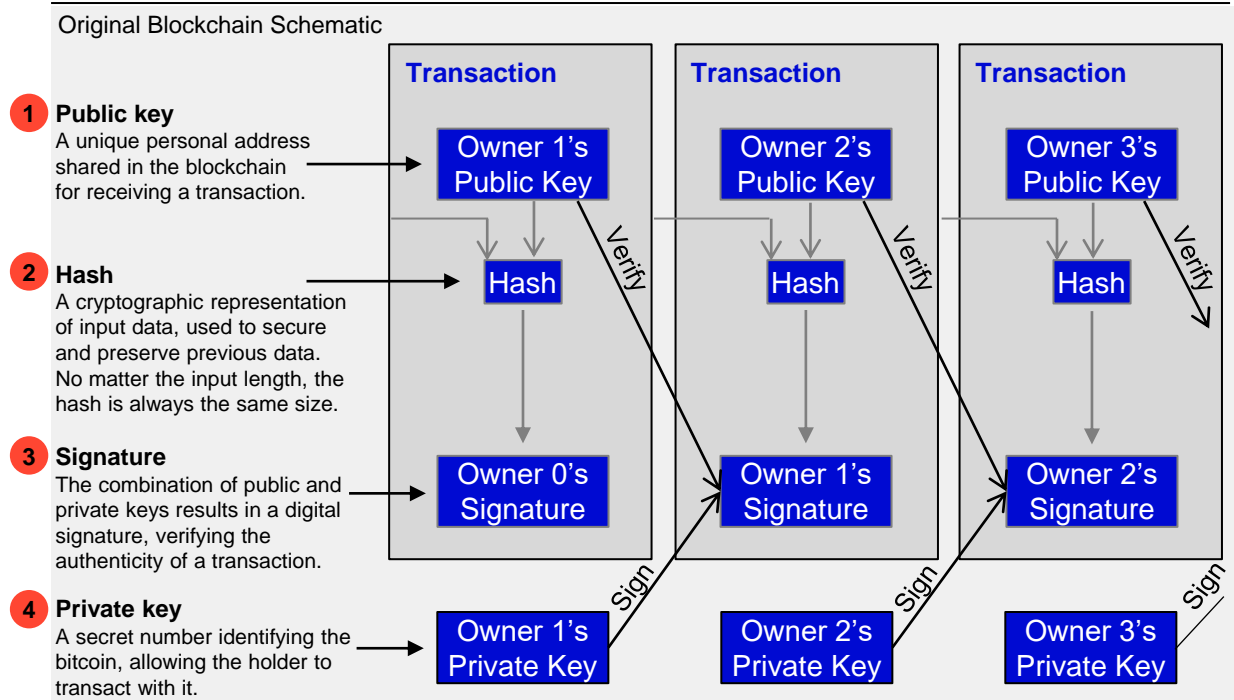
Understanding Blockchain Technology

A decentralized ledger powered by cryptography

Blockchain technology has been the darling of the cryptocurrency phenomenon. In the original paper, Satoshi drew out the schematic of a blockchain transaction, reproduced on the right (with some added notes). The idea was to create a ledger of transactions as private as the banking system and as public as the internet. Each transaction is appended to a decentralized ledger, which is held by miners participating in the blockchain that volunteer to do so.

A few key terms here are useful for understanding the security underlying blockchains. First, a public key is merely the identity of a user participating on the blockchain, much like an account number. A private key, on the other hand, represents ownership of unspent bitcoin. When combined with a public key, one can spend the bitcoin balance associated with it. But can someone guess your private key? To illustrate the security behind this, a supercomputer of today running since the Big Bang would still not have guessed a private key.

The security of one's Bitcoins, therefore, are a matter of how well kept one's private keys are.



Source: Satoshi Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System*, 30 October 2008. Icons and notes are added. Please refer to glossary for further definitions.

Understanding Blockchain Technology

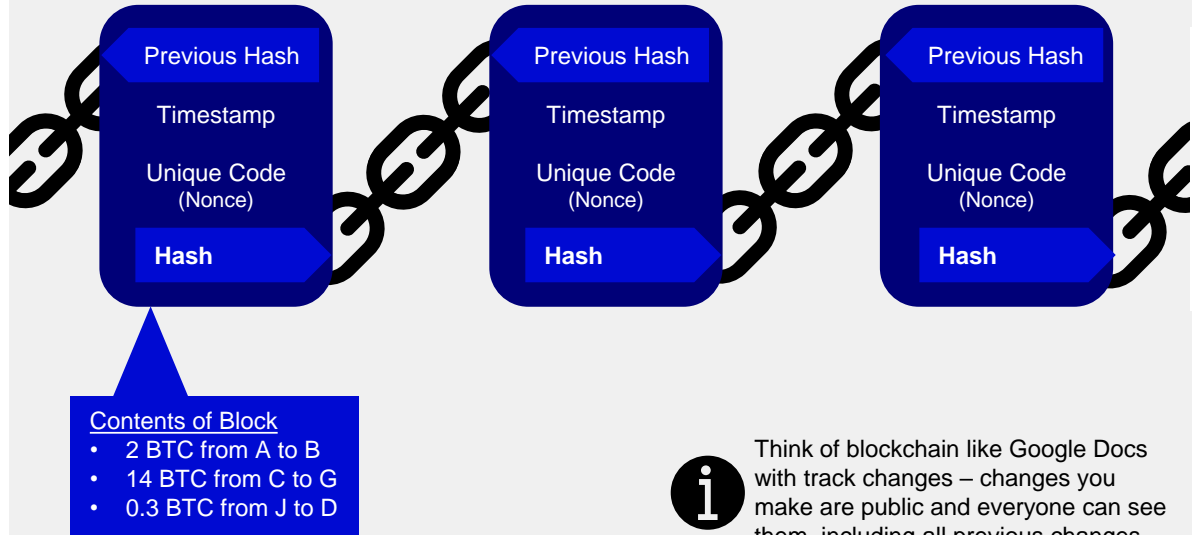
A blockchain is a linear log of records to which we append parcels of data

A blockchain is simply a growing list of records, or “blocks”, linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, a nonce – or a unique identifier – and the transaction data contained within that block. These components together allow one to identify each unique block and the data contained within it.

As time passes, new blocks are added to the blockchain, resulting in a linear log of data to which we append through time. This is the core of what blockchain is.

For Bitcoin, the data stored in each block is transaction data, with a block containing around 2,000 transactions each. By design, a new block is created roughly once every 10 minutes.

Visualizing A Blockchain and Its Contents









Think of blockchain like Google Docs with track changes – changes you make are public and everyone can see them, including all previous changes.

*This statement applies to Proof-of-Work blockchains. The Proof-of-Stake consensus mechanism is more computationally efficient. We define these terms in the Glossary. Source: Satoshi Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System*, 30 October 2008. For illustrative purposes only. Please refer to glossary for further definitions.

Weighing the Benefits and Drawbacks of Blockchain

Blockchain appears innovative, but there are tradeoffs to consider

	 Fast Settlement	 Distributed	 Immutable	 Openness
Strengths 	<p>Contrary to the banking system in which transactions take days to verify, blockchain allows rapid trade settlement, confirmed by a network of participants.</p>	<p>Cryptocurrencies were designed to be decentralized such that there is no issuing authority and no centralized transaction processor, an advantage where there is no trusted central party.</p>	<p>Bitcoin is theoretically impossible to counterfeit. All transactions are irreversible and unable to be changed. To override the ledger, an attacker would need to obtain a majority of computing power used in maintaining the ledger, a tremendously arduous task given the scale of mining participation*.</p>	<p>Since cryptocurrencies are transacted on a public ledger, all transactions can be publicly tracked and verified. It is also possible to analyze how much each address contains using this same data.</p>
Weaknesses 	<p>Rapid settlement comes at the expense of irreversible transactions – after the blockchain has confirmed a transaction, it cannot be reversed. Moreover, some blockchains have relatively limited network throughput, leading to delays in transaction settlement at times of heavy blockchain activity.</p>	<p>A distributed ledger is not necessarily an efficient one. On the infrastructure side, changes to the protocol that govern the system can be slow to implement, even if they are considered beneficial. In terms of scalability, distributed systems tend to be slower than otherwise equivalent centralized systems.</p>	<p>The immutability of blockchain comes at great cost in terms of computing power, sinking both capital equipment (miners) and electricity to carry out the cryptographic problems that power the blockchain*.</p>	<p>Note that just because you can see the contents of an address does not mean you can identify its owner. And to the extent that users do have visibility, there are concerns about privacy.</p>

*Note: The above points on electricity use refer specifically to the Proof of Work blockchain model. Other consensus mechanisms exist.

Source: Invesco.

Putting Bitcoin into Perspective

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Bitcoin Is A Truly Deflationary Asset

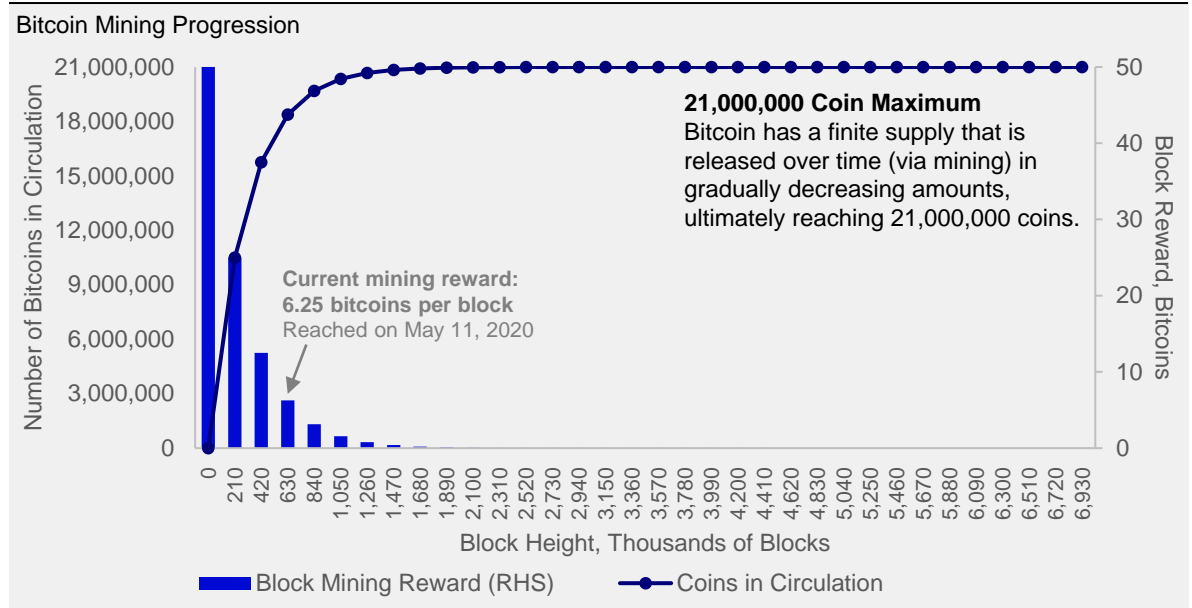
Estimates indicate that all bitcoin will be mined by around the year 2140

Bitcoin is a truly deflationary asset, with a total supply of 21,000,000 coins, due to be fully mined by around the year 2140. Today, the current supply is about 18.9 million, with additional bitcoins mined at a predetermined rate. As the network reaches certain numbers of blocks, the mining reward decreases in what is called a “halving.” Views about bitcoin are often centered around this idea of finite supply.

Of the 18.9 million coins existing today, it is estimated that 3.7 million of those are lost forever due to users forgetting their unique keys or losing access to their wallets.

While the supply of bitcoins is fixed, they are highly divisible. A single bitcoin is divisible to as many as eight decimal places. This smallest measure of a bitcoin is referred to as a Satoshi.

As new bitcoins are the incentive for miners to participate, one might wonder what incentive would power Bitcoin once all coins are mined. This can be remedied simply with a different incentive, such as transaction costs – which would make the chain more bank-like than originally envisioned.



Source: Blockchain.com, as of 31 December 2021. Chart reproduced from bitcoin.it. For illustrative purposes only.

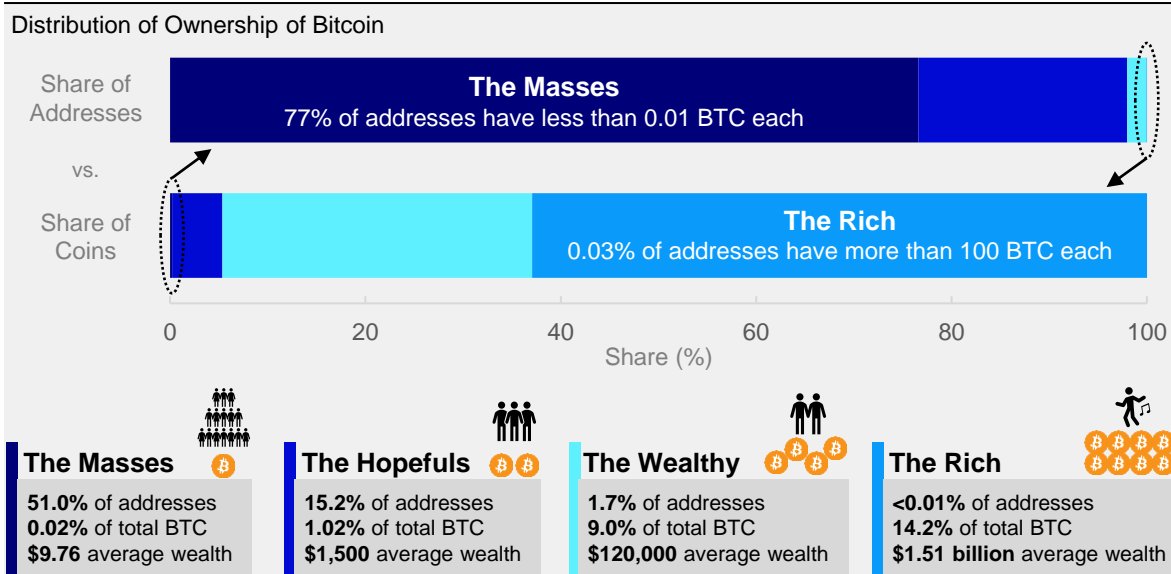
Bitcoin Is Concentrated Among Few Wallets

Billionaires have been minted, but not many

Unlike the traditional banking system, the transparent nature of the Bitcoin blockchain shows exactly how many bitcoins are in the average wallet. From this data, we can see that early adopters have become rich but few others have. Some striking data we have found include the following:

- Satoshi owns roughly 5% of the wealth
- 51% of addresses own less than 0.001 BTC, or an average of \$9.76
- Only 0.4% of addresses have more than 10 BTC and yet hold 86% of all bitcoin

We provide the interesting caveat to this data that wallet data is inherently flawed due to the existence of centralized exchanges. Such exchanges typically hold cryptocurrencies on behalf of clients within their own wallets.



Sources: <https://bitinfocharts.com/top-100-richest-bitcoin-addresses.html> and Invesco, as of 21 January 2022. Figures are based on a spot price of \$37,000 USD per bitcoin. Numbers of coins, wallets, and US dollar values are rounded amounts. Note: Here, we use “wallets” and “addresses” interchangeably as a simplification.

Bitcoin: Who's Mining?

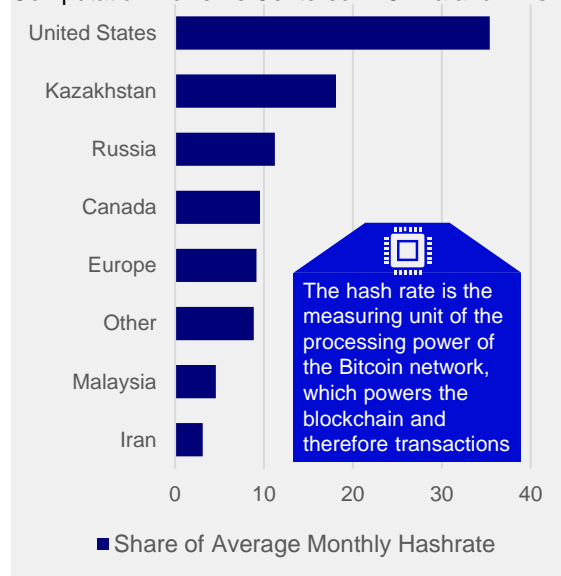
Mining has shifted from emerging markets to more developed economies

Bitcoin's blockchain is powered by "miners," or those users who contribute computational power to verify and maintain the blockchain ledger. By tracing the internet addresses of participating miners, it is possible to estimate the geographical shares of computational power. Based on an analysis of the Cambridge Centre for Alternative Finance's data, more than 45% of the bitcoin hash rate today originates from emerging markets, down from its 70% high before China cracked down on cryptocurrency mining.

Why is this? We believe that lower capital costs, cheap electricity, and the desire to capture mining revenue creates the appropriate incentives for miners to focus on a particular locality. Increasingly, miners are moving into developed markets where they can capitalize on cheap renewable energies.

Ultimately, the location of mining power is of little consequence for the Bitcoin network.

Computation Power Is Centered in China and EMs



What drives the location of miners?



Lower Capital Costs



Cheap Electricity



Lower Fixed Costs (e.g. land)

What happens when mining power is turned off?



As mining power goes offline, the amount of computing power necessary to mine (confirm) a block decreases automatically. However, blocks may be mined more slowly for a brief period until this mechanism takes effect, meaning temporarily slower transaction speeds.

Sources: Bitcoin Mining Map from the Cambridge Centre for Alternative Finance, and Invesco, latest available as of 31 December 2021. Past performance does not guarantee future results.

The Anti-ESG Asset? Electricity Consumption Poses Risk

Energy costs of computing power present a key issue

Bitcoin holds a precarious position as one of the most discussed assets in a time of increasing prioritization of ESG factors in investing. If the Bitcoin network were a country, it would be the 27th largest electricity consumer in the world. This is equivalent to the annual needs of Ukraine or Egypt.

The debate here is nuanced. Some state that comparisons against traditional payments processors are unfair as the electricity intensity cited (as on the right) fails to account for ATMs, physical location costs, and other facets of traditional financial services that consume resources. Others claim that renewables power a large portion of crypto mining.

Whatever one's view, it is worth noting that the amount of electricity used by a cryptocurrency is dependent on the consensus mechanism used. For Bitcoin, this is the mining process described earlier. Other cryptocurrencies are able to accomplish decentralized ledgers with far less energy inputs.

Mapping Transaction Speeds and Costs

Medium	Transactions per Second	KWh per Transaction	Electricity Cost Per Transaction*
Cash†	Unlimited	0.08 KWh	< \$0.01
Visa	56,000	0.0008	< \$0.001
Mastercard	45,000	0.0008	< \$0.001
Ripple (XRP)	1,500	0.0079	< \$0.001
Bitcoin Cash	300	18.96	\$2.13
PayPal	193	–	–
Litecoin	56	18.52	\$2.08
Ethereum	25	87.29	\$9.79
Bitcoin	7	1173	\$131.49

Striving for efficiency Ethereum 2.0 as an example

To illustrate how electricity use can vary across crypto designs, the Ethereum Foundation is seeking to transition Ethereum to a new consensus mechanism that would increase transactions per second while significantly cutting electricity consumption.

They claim the below will be achieved in Ethereum 2.0:

- **2,000** transactions per second (vs. 25 today)
- **99.9% less** energy consumption (vs. today)

*Prices in USD, assuming 11.21 cents per KWh as of November 2021 based on the US Energy Information Administration (US EIA). Prices are estimates and for illustrative purposes only.

†Electricity intensity of printing a single bill. Sources: Deutsche Bank study, "Future of Payments: When digital currencies become mainstream", MoneySuperMarket.com, Ripple, Coinanalysis.io, Blockchain.com and Cambridge University Centre for Alternative Finance. Past performance does not guarantee future results.

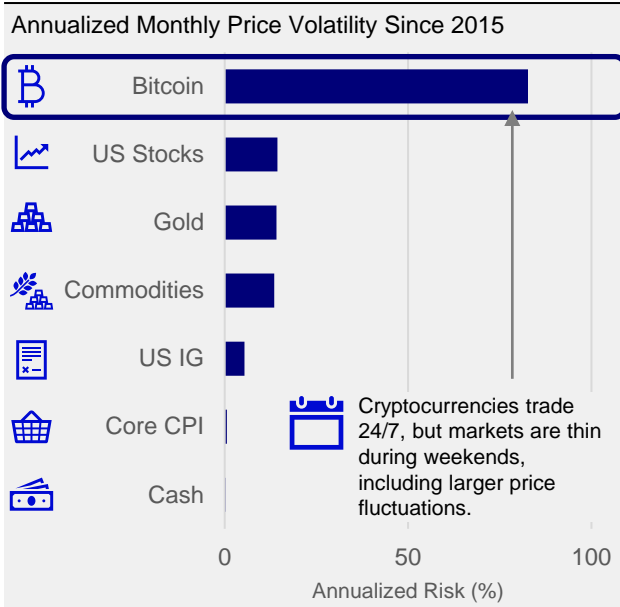
Bitcoin: Is It a Currency? We Don't Think So

"I can't buy a latte with bitcoin"

In viewing Bitcoin as a financial instrument, it is necessary to decide how to categorize it. We take two perspectives in assessing whether Bitcoin – and other cryptocurrencies – is feasible as a currency: (1) an economic test, as on the right, and (2) its potential for scale as a means of transacting.

On the first point, we take the view that money is typically thought of in economics as satisfying three functions: a store of value, a unit of account, and a medium of exchange. Here, on all three accounts, we are left wanting, pointing us more to look at Bitcoin and similar cryptocurrencies as commodities.

On the second point, most cryptocurrencies fall victim to a specific scalability limitation. Cryptocurrencies are limited within their respective blockchains by the combination of block size and the average block creation time, which combine to yield a limited transaction throughput. In other words, each crypto is constrained to a certain maximum pace of transactions – which is often quite limited.



- Store of Value**
 - Bitcoin is far too volatile to be considered a reliable store of value
 - Price behavior is erratic with 83% annualized volatility
- Unit of Account**
 - Product prices are not quoted in bitcoin amounts. Instead, pricing is based on a fiat currency amount converted using bitcoin's spot rate
- Medium of Exchange**
 - While some platforms permit the use of Bitcoin for payment, there is little evidence to suggest that this is what makes it attractive

Sources: Bloomberg, as of 31 December 2021, and *Bitcoin – Currency of the Future or Speculative Asset*, John Greenwood and Adam Burton. Please see page 38 for index definitions. Note that "Core CPI" refers to the United States consumer price index, less the effects of food and energy. Past performance does not guarantee future results.



Bitcoin: Is It Digital Gold? Maybe, Maybe Not

Investors like Bitcoin's fixed supply, but ultimately the asset remains untested

Bitcoin is often equated to a digital version of gold, especially in light of its fixed supply limit. But is this the right comparison?

Crypto investors tend to assign the various cryptocurrencies into buckets based on their designed functionalities. Bitcoin is usually thought of as "digital gold" due to the asset's strong security protocols, its limited supply, and claims of low correlations with traditional assets. This "digital gold" description also seems convenient given that Bitcoin is perhaps the least scalable cryptocurrency in existence due to its limited transaction speed and electricity intensity.

We assess some of the qualities of Bitcoin versus gold in the table on the right. Ultimately, we are left wanting. Bitcoin does not appear to share the key qualities of gold. Instead, we are left wondering what kind of equivalency to draw to analyze Bitcoin.

	Gold 	Bitcoin 
Finite Supply	Supply increases about 2% per year ✓	Supply increases less over time, with terminal limit of 21,000,000 coins ✓
Liquid Markets	Gold has a highly liquid market with a huge variety of participants and contracts ✓	Bitcoin, like gold, appears to have highly liquid markets, including futures contracts* ✓
Uncorrelated	Correlations with other assets are typically low, especially in times of economic distress ✓	Price behavior is still evolving, with correlations with other asset classes increasing more recently ?
Inflation Hedge	Past inflationary episodes have shown gold tends to perform well in such environments ✓	Finite supply is attractive, but the asset remains untested given its limited history ?
Global Acceptance	Gold is a globally recognized store of value, held as reserve assets by most central banks ✓	Bitcoin is banned in a number of countries and is widely regarded with scepticism by authorities ✗
Use in Goods	Gold is commonly used in high-tech manufacturing and jewellery ✓	Bitcoin has no uses outside its value as an asset ✗

*Bitcoin trades 24/7, resulting in periods of relative illiquidity. This appears to be especially true on Sundays, resulting in greater price volatility on these days.

Sources: Bloomberg and Invesco, latest data available as of 31 December 2021.

How Do You Value a Cryptocurrency?

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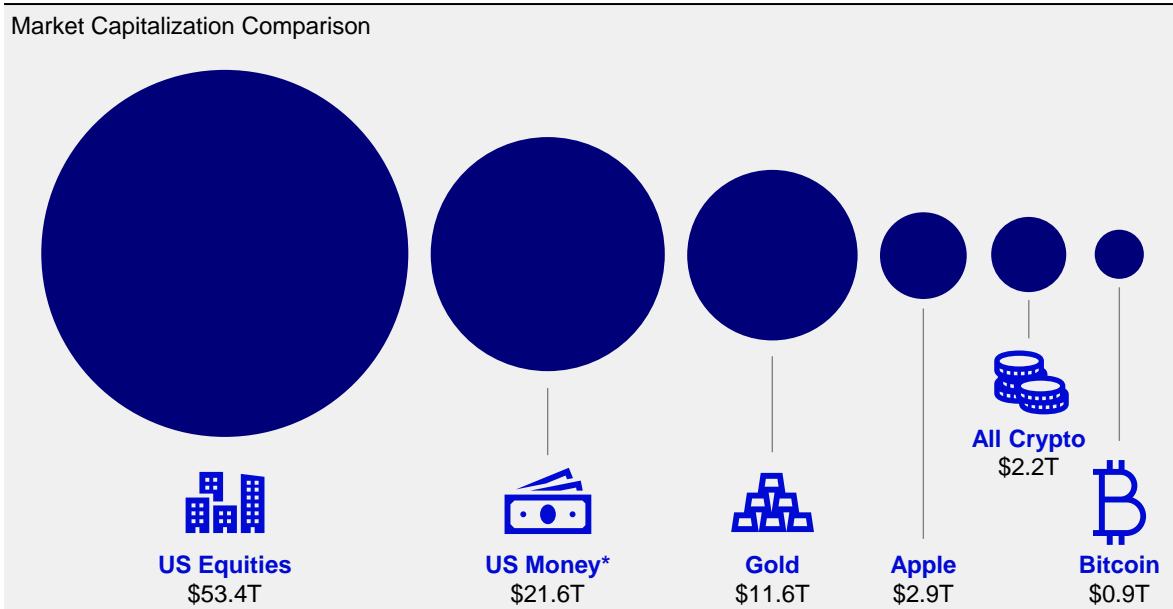
Cryptocurrency Market Capitalization Is Small, but Rising

As an emerging asset class, cryptos appear to be climbing into the big leagues

Whatever cryptocurrencies “are,” they are without a doubt growing in market capitalization and trading volumes. As we show in the chart on the right, cryptocurrency market cap at \$2.2 trillion is relatively small compared to other asset classes, such as US equities where the total market capitalization is around \$53.4 trillion. However, there is potential for this to grow.

However, as market capitalization of cryptocurrencies increases, we suspect that major cryptos will behave more in line with traditional market drivers rather than mostly idiosyncratic factors. Maturity, in other words, may make crypto less of a diversifier than once thought.

With this in mind, we turn our attention here to methods of valuation in the cryptocurrency space.



*US Money is represented by M2 for the United States, which measures highly liquid dollar deposits and select small-denomination time deposits and money market fund deposits.

Sources: Bloomberg, CoinMarketCap.com, and US Federal Reserve, as of 31 December 2021.

What Is the Value Proposition of Cryptocurrencies?

Every buyer has a thesis – which may include speculation

Digital means of transacting?

Cryptocurrencies can be spent and received by anyone, anywhere, and at any time without the need for an intermediating institution. Some assert that cryptos have value for this reason.

Others counter that Bitcoin is an inefficient mechanism of exchange due to its inability to scale. We note that other cryptocurrencies offer significantly faster network throughput.

Decentralized finance?

Cryptocurrencies are emblematic of distrust in the traditional financial services industry. Some envision a new financial system in which the nature of fees and intermediaries is reconceived. Others counter, however, that decentralized finance is already centralizing around key players, in essence recreating a paradigm similar to today's financial system.

New format of trust?

Some argue that Bitcoin and other cryptocurrencies have value because they present a new method of establishing trust. The backstop of such systems is trust in the underlying cryptography. In fiat currencies, trust in the issuing government is the ultimate backstop.

This mechanism of trust may be appealing in a variety of use cases not limited to payments.

A store of value?

Bitcoin has exhibited substantial price movements that have made it difficult to consider it as a store of value. Other cryptocurrencies also fluctuate dramatically in value, often moving in tandem with Bitcoin.

Interestingly, some digital assets resolve this issue by tying their value to an underlying asset, such as is the case with Tether.



Avoiding Government Institutions?

Those desiring a financial system devoid of government and central bank involvement value the decentralized, internet-based nature of cryptocurrencies. For some, avoidance of government reach, including borders, regulation and taxation, is an attractive feature.

However, regulators are increasingly stepping into the space and imposing controls.

... or just speculation?

Source: Invesco. For illustrative purposes only.

Principles of Valuation in the Crypto World

“Not everything can be valued, but almost everything can be priced.” *

While typical financial valuation models rely on assumptions about expected cash flows and discount rates, crypto investors instead pay attention to supply and demand dynamics, not dissimilar to commodity valuation. In addition, investors evaluate crypto-specific factors, including security features and blockchain design. This may involve an evaluation of how changes to the protocol are introduced and how malicious actors may be able to exploit design vulnerabilities.

There are also cryptos, notably Ethereum and Solana, which run decentralized applications – or “dapps” – that can automatically execute small programs to complete a specified task. In the process, some of the crypto is destroyed to act as a transaction cost. This capability allows “smart contracts” to be designed and automatically executed without a clearinghouse, escrow, or other 3rd party actor. These capabilities can justify use cases for these cryptos and contribute to their valuation, especially in the context of decentralized finance. (We provide greater depth on this later.)

Considerations and Questions to Ask of Each Cryptocurrency

Supply Dynamics



- How many coins are available?
- How often are new coins minted?
- How difficult is it to mine new coins?
- Is there an issuing authority or company?
- Are coins ever destroyed?

Demand Drivers



- Is there significant reputation and/or press coverage (as is the case for Bitcoin)?
- How scalable is the crypto? Does it suffer from limited network throughput?
- Is demand driven by speculation or for use?
- Do similar or undifferentiated coins exist?

Security Features



- Is the blockchain design secure and resistant to tampering?
- Is ownership concentrated?
- What consensus mechanism is used?
- Is the design of the crypto transparent?

Use Case Considerations



- Does the crypto support decentralized applications? If so, is there an active development community?
- Does the crypto serve a specific use case (e.g. payments facilitation, or value pegged to an asset like gold or the dollar)?

*Quote attributed to Aswath Damodaran, 24 October 2017.

Source: Invesco. Past performance does not guarantee future results.

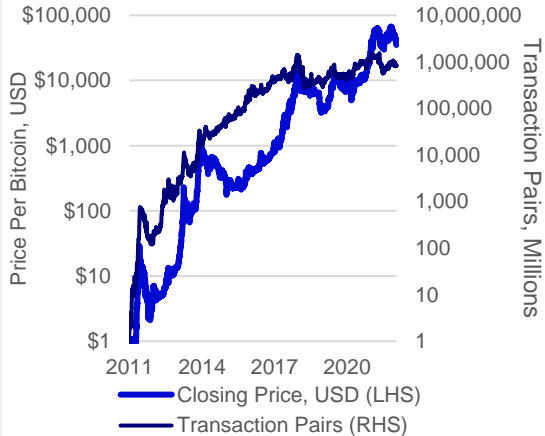
Principles of Valuation in a Formulaic Approach

Can empirical models describe Bitcoin's price behavior? Not likely

Network Effects: Metcalfe's Law

Metcalfe's law argues that value originates from network effects. As adoption increases, the value of the network – in this case, Bitcoin – also rises as the number of possible connections increases exponentially.

This approach is interesting but flawed as value is not defined.



$$\text{Value of a Network} = \# \text{ of Nodes}^2$$



Embodied Costs of Production



A theory put forward by Adam Hayes argues for the value of Bitcoin having a floor of *at least* its costs of production – in other words, the marginal cost of mining each bitcoin.

We are skeptical of this approach – just because costs went into producing something does not mean it has value.*

$$\text{Cost of Production} = \frac{\text{Electricity Cost of Hash Rate}}{\text{ Bitcoins Mined Per Day}}$$

*From *Bitcoin – Currency of the Future or Speculative Asset*, John Greenwood and Adam Burton.

Sources: *Bitcoin price and its marginal cost of production: support for a fundamental value* by Adam S. Hayes, CFA, and *Metcalfe's Law as a Model for Bitcoin's Value* by Timothy F. Peterson, CFA, CAIA. Model recreated using estimates from Cambridge University Centre for Alternative Finance and data from Coinmetrics. Values on the right-hand chart are seven-day moving averages. Data as of 31 December 2021. Past performance does not guarantee future results.



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The Many Meanings of Currency

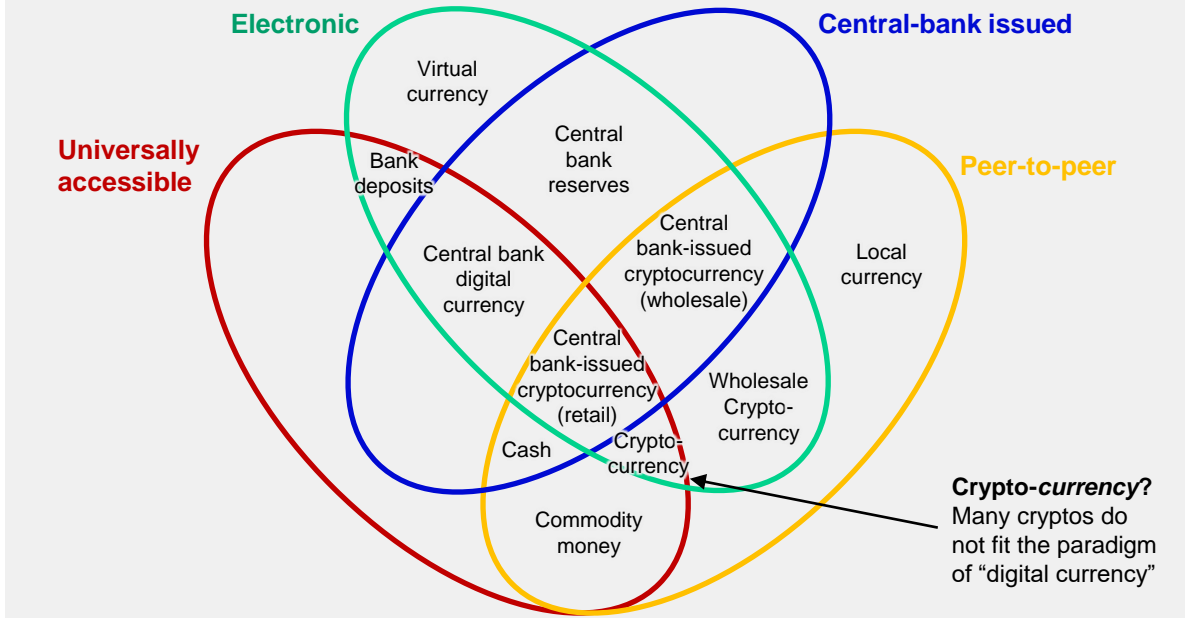
Contrary to their name, cryptocurrencies are not always digital currencies

While Bitcoin is ostensibly a “currency,” it lacks key features to be valid as a currency in the traditional economic sense, as we explored earlier. But other forms of cryptocurrency may very well play this role with better transaction throughput and greater supply. There is also much talk about central bank digital currencies, which may or may not use blockchain technology.

Ultimately, “cryptocurrency” may be a misnomer as many cryptocurrencies were designed with intentions beyond a currency-like instrument.

Thinking about different cryptocurrencies (Bitcoin, Ethereum, etc.) like different fiat currencies (USD, EUR, GBP, etc.) is misleading. Instead, cryptocurrencies are united by the technology that underlies them, but each is seeking to accomplish a different objective. In this way, it may be helpful to think of each crypto like a software company rather than a currency. Keeping this in mind is helpful in considering other so-called cryptocurrencies.

“The Money Flower” – Categorizing the Kinds of Money



Sources: Bank for International Settlements, Wikipedia. Adapted and reproduced from *Central bank cryptocurrencies* by Morten Linnemann Bech and Rodney Garratt.

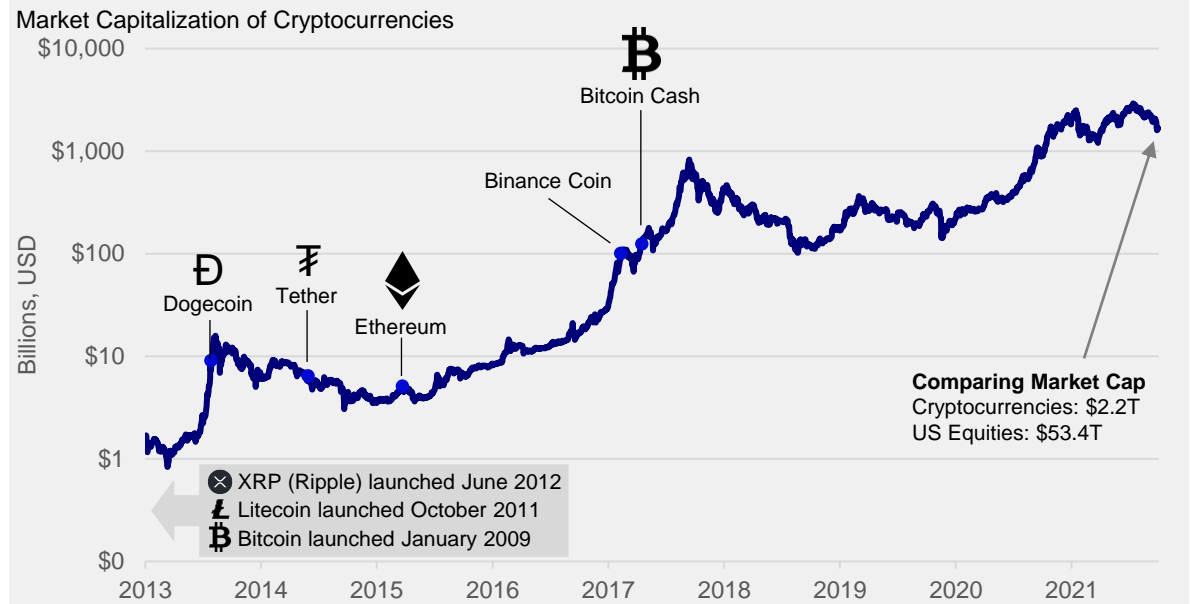
Not Just Bitcoin: Cryptocurrencies Are Numerous and Varied

Since Bitcoin's launch in 2009, more than 17,000 "altcoins" have appeared

There are more than 17,000 cryptocurrencies out there* in various sizes and uses, and many more go unaccounted for or abandoned. In total, the market capitalization of all cryptocurrencies is \$2.2T USD.

Why so many? Each crypto is differentiated from every other by a number of factors, including...

- the way in which their blockchain works, including the speed and scalability of the platform
- total supply cap (capped, like Bitcoin, or uncapped, like Dogecoin)
- mining difficulty (and whether coins are mined or distributed by an entity) and release pattern of new coins
- whether the coin is tied to a business, such as XRP (Ripple) or Binance Coin (Binance)
- The ability to embed miniature, decentralized applications (called "dapps"), such as is the case with Ethereum



*The market capitalization above includes the data of 17,198 cryptocurrencies that CoinMarketCap tracks. Additional coins exist, but their market capitalization is likely to be tiny.

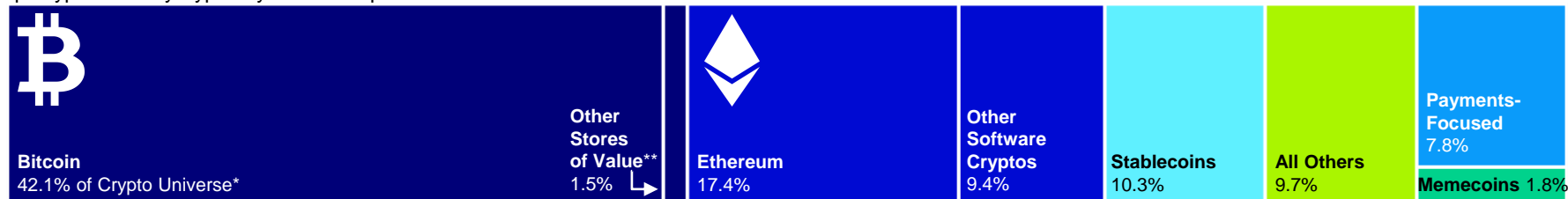
Survivorship bias may be present as the methodology of coin tracking may shift and reconstitute the available coin history.

Sources: CoinMarketCap.com and Macrobond, as of 31 December 2021. Past performance does not guarantee future results.

Not All Cryptos Are Made Equal

Cryptocurrencies are varied by design, use, and value propositions

Top Cryptocurrency Types by Market Capitalization



Stores of Value**

These cryptos seek to offer methods of storing value securely through a crypto, yet their values are quite volatile.

Top Contenders:

1. Bitcoin (42%)
2. Litecoin (0.5%)

Software Platforms

Such “software” cryptos act like a decentralized computer, with programs stored on and executed via blockchains.

Top Contenders:

1. Ethereum (17%)
2. Cardano (2%)
3. Solana (2%)

Stablecoins

Stablecoins sidestep the store of value debate by pegging their value to an underlying, such as the US dollar.

Top Contenders:

1. Tether (5%)
2. USD Coin (3%)
3. Binance USD (>1%)

Payments-Focused

These cryptos focus on scalability for the sake of rapid payments and are often run or created by a business.

Top Contenders:

1. Binance Coin (4%)
2. XRP (2%)

Memecoins

Born out of their namesake, memecoins are perhaps the easiest to criticize for lacking a key value proposition.

Top Contenders:

1. Dogecoin (1%)
2. Shiba Inu (>1%)

*Market Share indicates the relative share of the market capitalization of the cryptocurrency universe, including both coins and tokens.

**As we discussed earlier in this deck, the claim that any of these cryptos is a store of value is a dubious one with numerous considerations.

Sources: CoinDesk, CoinGecko, CoinMarketCap.com, Coin.Dance and Invesco as of 27 January 2022. Cryptocurrency count is sourced from CoinMarketCap and CoinGecko.

Cryptos as a “Software Platform”?

About 20% of crypto market cap is in decentralized software

While throughout this deck we have focused on Bitcoin, other developments in the digital assets space seek goals beyond a digital store of value or payments solution. Here we lay out those cryptocurrencies whose underlying blockchains act as a platform for software.

The idea here appears complex at first but is ultimately simple: Rather than a central server fetching information and executing tasks, we have instead a network of computers that carry out those same functions in exchange for a small fee.

This is the same technology that powers a lot of the buzzwords we hear today, such as parts of decentralized finance (“DeFi”), Web 3.0, and non-fungible tokens (NFTs). We explore briefly how this works on the right.

Exploring “Software Platform” Cryptos

How can a blockchain power software?

The blockchain hosts applications and their data via participating computers. To run your application, you must have the right to expend computing resources within the protocol.

Where does the crypto come in?

The protocol prices computing power in terms of its native token (e.g. for Ethereum, this is Ether) based on the level of demand for computing resources. The price of this computing power is commonly called **gas fees** and are paid to the computers that carry out such computations.

So what gives it value?

The market price of a blockchain’s native token (e.g. Ether) is based ultimately on demand for it, whether for the token for application execution or speculation.

Examples of Applications Built on Blockchains

- **Decentralized automated exchanges:** Automatically match buyers and sellers.
- **Non-fungible tokens (NFTs):** Represent ownership of an asset via a bearer-form token.
- **Lending platforms:** Provide credit via crypto.
- **Video games:** Execute in-game events, rules and transactions.

Top “Software Platform” Cryptos by Market Cap

Ethereum ETH <i>Market Cap: \$322 billion</i> First-mover and most popular software crypto.	Solana SOL <i>Market Cap: \$3 billion</i> Relatively centralized but ultra-fast and efficient.
Cardano ADA <i>Market Cap: \$35 billion</i> Prioritizes speed and interoperability of projects.	Polkadot DOT <i>Market Cap: \$1.1 billion</i> Focuses on interoperability of blockchains.

Sources: Invesco and CoinMarketCap.com. As of 2 February 2022.



5

Is Bitcoin A Diversifier? At First Glance, Maybe...

Crypto assets are often viewed as a portfolio diversifier

Bitcoin is often viewed as “digital gold” with enormous return potential and as a safety from the tribulations of inflation. And for asset allocators, it is often viewed as a portfolio diversifier. Indeed, if one reviews bitcoin performance on a monthly basis versus other asset classes, it does appear to offer uncorrelated returns.

That said, as Bitcoin and other cryptocurrencies have grown in popularity, their behavior has transformed into more of a traditional risk-on asset.

Monthly Asset Return Correlations, Since 2011

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Cash	1.00															
2 DXY	-0.04	1.00														
3 S&P 500	-0.13	-0.37	1.00													
4 Int'l Stocks	-0.11	-0.57	0.87	1.00												
5 EM Stocks	-0.06	-0.60	0.72	0.82	1.00											
6 Global Gov Bonds	0.06	-0.74	0.20	0.34	0.46	1.00										
7 Tsy Bonds (7-10)	0.15	0.11	-0.37	-0.35	-0.24	0.41	1.00									
8 US IG	-0.02	-0.19	0.35	0.38	0.44	0.58	0.49	1.00								
9 US HY	-0.15	-0.40	0.76	0.79	0.75	0.37	-0.19	0.65	1.00							
10 Gold	0.09	-0.46	0.09	0.16	0.31	0.63	0.36	0.38	0.21	1.00						
11 TIPS	0.01	-0.22	0.15	0.20	0.29	0.59	0.67	0.74	0.37	0.54	1.00					
12 Commodities	-0.07	-0.56	0.51	0.59	0.61	0.34	-0.29	0.20	0.61	0.39	0.19	1.00				
13 Oil	-0.12	-0.34	0.47	0.52	0.41	0.15	-0.33	0.19	0.60	0.09	0.05	0.65	1.00			
14 US REITs	-0.11	-0.25	0.70	0.64	0.55	0.35	0.07	0.60	0.68	0.19	0.46	0.37	0.28	1.00		
15 REITs ex. US	-0.09	-0.55	0.74	0.87	0.80	0.51	-0.09	0.57	0.78	0.26	0.42	0.55	0.41	0.77	1.00	
16 Bitcoin	-0.11	-0.07	0.15	0.14	0.06	0.07	0.00	0.11	0.13	-0.02	0.05	0.05	0.00	0.05	0.11	1.00

Sources: Bloomberg and Invesco, as of 31 December 2021. See page 38 for index definitions. Past performance does not guarantee future results.

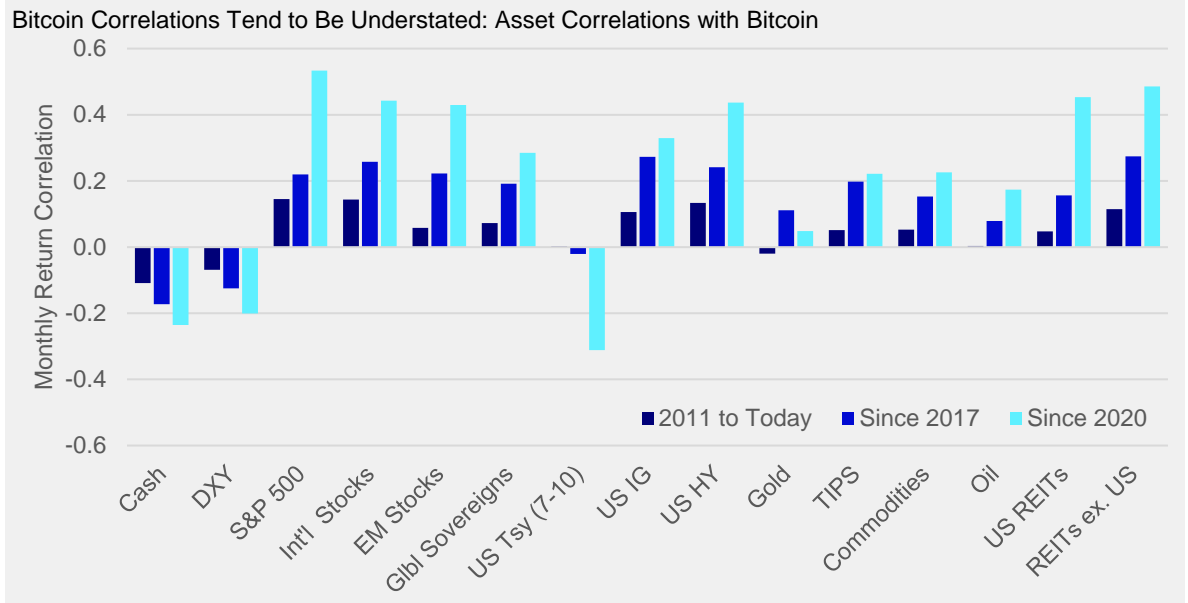
Beware the Correlations of Bitcoin

Drawing correlations since Bitcoin's inception can be misleading

Bitcoin bulls tend to praise the virtues of the asset's uncorrelated returns since its launch in 2009.

However, over this timeframe Bitcoin had a market cap less than the net worth of many individuals. For example, in 2011 (when many correlation studies begin for Bitcoin), its market cap was just \$1.4 million at the start of the year. In 2013, the market cap started the year at \$142 million and reached as high as \$11.9 billion, a level not reached again until the end of 2016.

As bitcoin has grown, it has become more correlated with traditional asset classes. We caution against measuring correlations for Bitcoin and any young crypto. Indeed, with Bitcoin's inception in 2009 – and its market cap only becoming significant in 2017 – we have only a few years of data with which to draw conclusions.



Note: We chose 2011 to start as Bitcoin became transacted more regularly on exchanges. It is possible, however, to go all the way back to the very first transaction on 12 January 2009.

Sources: Bloomberg and Invesco, as of 31 December 2021. Past performance does not guarantee future results.

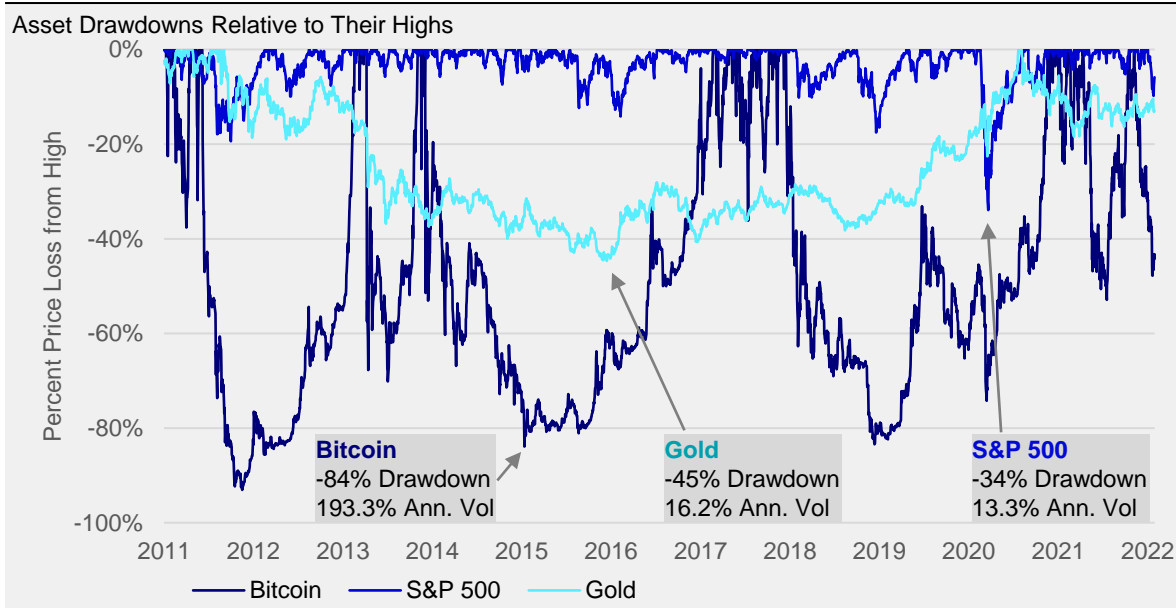
Bitcoin: A Store of Value?

The volatility of bitcoin may understate the severity of drawdowns

Is Bitcoin a viable store of value? To answer this question, we look to price volatility and, in this case, how frequently and at what magnitude it loses value.

First, we ask how often prices change. Since 2011, Bitcoin has spent 94.4% of days trading beneath its highs. This compares favorably to gold over the same period, which spent 98.5% of days trading beneath its highs. But for the S&P 500, this statistic was just 85.5%. In other words, US equities notched new price peaks far more often than Bitcoin or gold.

We also consider how far prices fall when they're not registering new highs. When Bitcoin has traded beneath its highs, it was trading on average -50.4% below its highs. For gold, the same measure was -24.5%. For the S&P 500, this was just -3.6%. In other words, when Bitcoin prices fall, they tend to fall hard, making equities – an asset class known to be volatile – appear far less risky in comparison.



Note: We chose 2011 to start as Bitcoin became transacted more regularly on exchanges. It is possible, however, to go all the way back to the very first transaction on 12 January 2009. Annualized volatility is based on monthly returns.

Sources: Bloomberg and Invesco, as of 31 December 2021. Past performance does not guarantee future results.

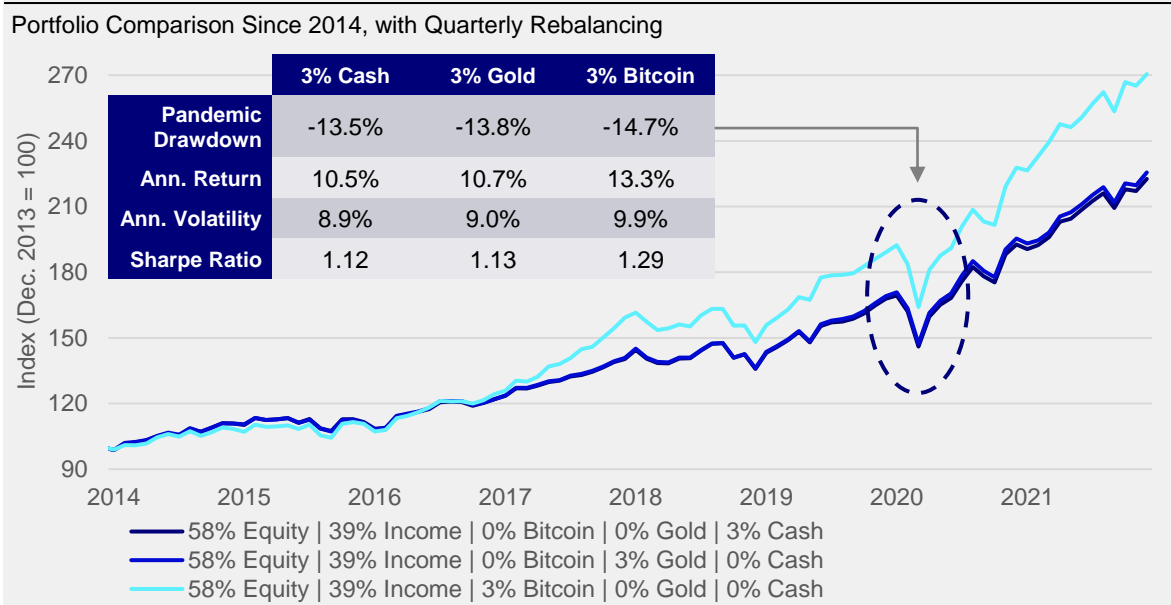
The Bitcoin Portfolio Perspective: Rebalancing Is Essential

Bitcoin introduces volatility, but regular profit-taking can lock-in gains

In reviewing Bitcoin's performance in a portfolio context, we compared a hypothetical portfolio of US Treasury bills (3% of total), a diversified portfolio of US bonds (39%), and US stocks (58%) against a portfolio of the same composition but with the Treasury bills swapped out for a 3% allocation to bitcoin.

We found that this allocation to bitcoin contributed a percentage point of annualized risk relative to the baseline portfolio. In the current run-up in cryptocurrency prices, we find that this is extra risk is compensated with an additional 2.8 percent-age points of annualized return. However, we do caution that, given the volatility of bitcoin prices, this metric can quickly be reversed.

Therefore, we view regular profit-taking as essential for capitalizing run-ups in bitcoin prices. Indeed, our example on the right uses quarterly rebalancing.



"Equity" is represented by the S&P 500 Index. "Income" is represented by the Bloomberg Barclays Aggregate Bond Index. "Cash" is represented by the Bloomberg Barclays 1-3 Month US Treasury Bill Index. Returns displayed are total returns with quarterly rebalancing. No transaction fees are considered. For illustrative purposes only. Sources: Bloomberg and Invesco, as of 31 December 2021. Past performance does not guarantee future results.

Bitcoin – What the Bulls Think

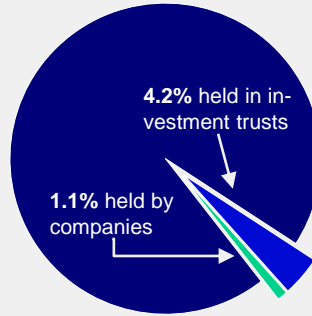
Decentralized finance triumphs, with Bitcoin as the digital store of value

Our bull case for Bitcoin supposes increasing adoption of the cryptocurrency. With Bitcoin's limited supply, it is straightforward to draw sky-high price targets after assuming a level of demand.

As an often-cited report from JP Morgan points out, if the private investment exposure to bitcoin were equal to that of gold, the price per bitcoin would reach about \$140,000. Meanwhile, in ARK Investment Management's 2021 Big Ideas report, they show that bitcoin's price can increase dramatically if S&P 500 companies allocated their cash to the asset. As they show, 1% of cash would grow the price by \$40,000 per bitcoin, and 10% would bring the price up to nearly \$460,000.

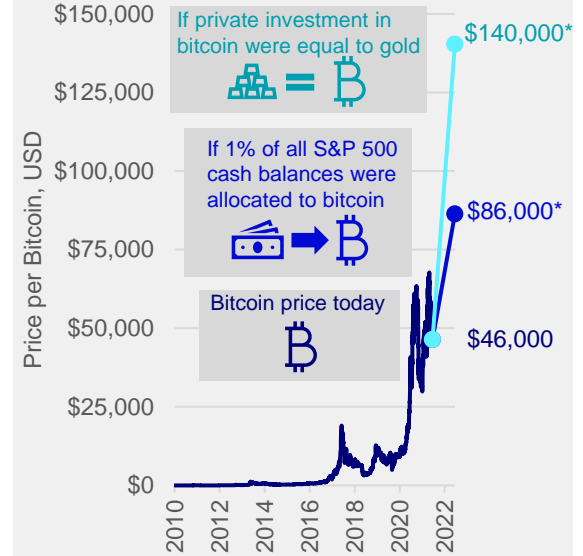
These lofty figures can be tempting for even the most disciplined investor, and word of these targets appears to contribute to price upswings. With all of the attention on cryptocurrencies in recent years, the excitement about its future adoption almost seems palatable.

Distribution of Bitcoin Ownership



Private companies, investors, and even governments are increasingly exposed to Bitcoin, with an estimated **1.5 million BTC** held by institutional investors—equivalent to **\$55 billion USD**.

Bitcoin Price Projections, Selected Studies



*Prices shown are simple projections only. **Returns are estimated based on available filings.

Sources: Bloomberg, JP Morgan, ARK Investment Management Big Ideas 2021, CoinGecko, BitcoinTreasuries.org, and public filings. As of 31 December 2021. For illustrative purposes only. Past performance does not guarantee future results.

Bitcoin – What the Bears Think

Regulations loom, and the long-term outlook is uncertain

No discussion of cryptocurrency is complete without reviewing the regulatory outlook. “[Bitcoin] is not a stable store of value and it doesn’t constitute legal tender,” says Janet Yellen in the US. The UK’s Financial Conduct Authority warned investors “should be prepared to lose all their money”. In the EU, the European Securities and Markets Authority noted some cryptos are “highly risky and speculative.” China recently cracked down on mining, and regulators already closed crypto exchanges back in 2017. Clearly regulators are taking a hard look at crypto assets.

In addition, there are other reasons to be hesitant on cryptocurrencies, including but not limited to:

- Rising correlations with traditional assets.
- The long-term outlook is uncertain and rapidly evolving. Each coin is not special and can be replaced by a better-executed version.
- Bitcoin is massively energy intensive. How will ESG focuses affect it?

The Regulatory Landscape Is Shifting, Especially as Interest Grows



United States



- Mining revenues are taxed as income; capital gains also taxed when cryptos sold/ exchanged
- Exchanges are permitted
- AML reporting applies to high value transactions & mining
- No restrictions on mining



Eurozone



- Member states have varying rules & treatments for cryptos
- EU law requires AML & counter-terrorist financing reporting for crypto transactions across member states
- Bitcoin exempt from VAT



United Kingdom



- Mining revenues are taxed as income; capital gains also taxed when cryptos sold/ exchanged
- Derivatives and exchange-traded notes (ETNs) are banned for retail investors
- No restrictions on mining



China



- Trading on exchanges banned
- ICOs are banned
- Mining is banned, with enforcement increasing



Global Outlook

- **8** have banned cryptocurrencies.
- **8** have not addressed cryptocurrencies.
- **132** currently permit cryptocurrencies with specific guidance for their treatment.



Sources: United States Internal Revenue Service, United Kingdom Financial Conduct Authority and Her Majesty’s Revenue and Customs, European Parliamentary Research Service, and various government agencies. The above is for illustrative purposes only and does not constitute legal or tax advice and is by no means a full summary of the existing regulatory structure. The cryptocurrency regulatory environment is subject to rapid change. Please see the glossary in the Appendix for definitions of terms. Data as of 31 December 2021.

Accessing Exposure to Digital Assets

Degree of exposure varies with different entry points

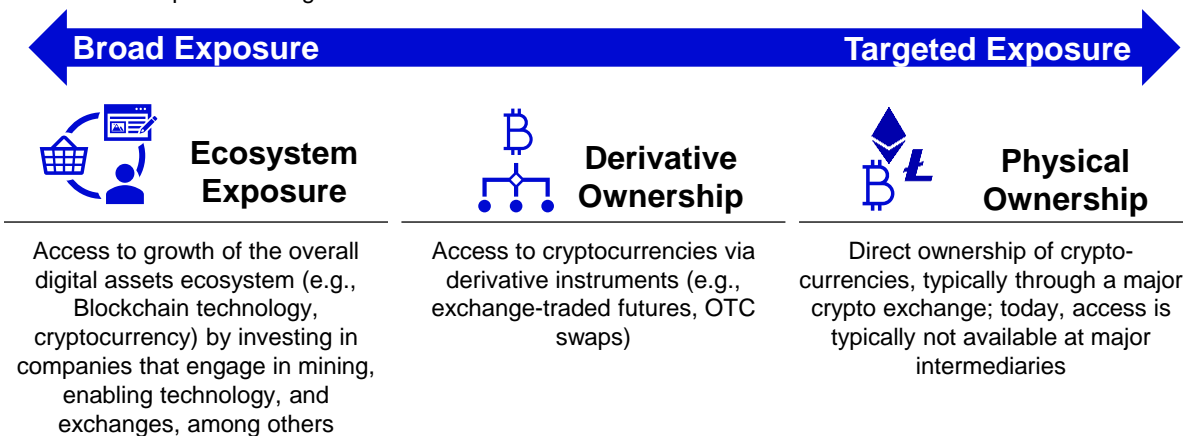
Exposure to cryptocurrencies and the ecosystem being developed around them may be an attractive opportunity. The range of exposure methods—from direct ownership of particular cryptocurrencies to broader market approaches—involves varying considerations and tradeoffs.

Physical ownership typically provides the most direct exposure to movements in crypto prices at the expense of greater concentration and volatility. Fears of theft, proper custodianship, and liquidity tend to dominate physical ownership considerations.

Derivative products traded on financial markets whose underlying are based on cryptocurrencies tend to fall under existing regulatory frameworks, yet their return structure adds a layer of complexity to accessing crypto market exposure.

Finally, the broadest exposure approach is in accessing cash flows resulting from the crypto ecosystem. This is a vast area but one that is perhaps more diversified and accountable. The so-called “picks and shovels” approach typically falls under this bucket.

Overview of Exposure to Digital Assets



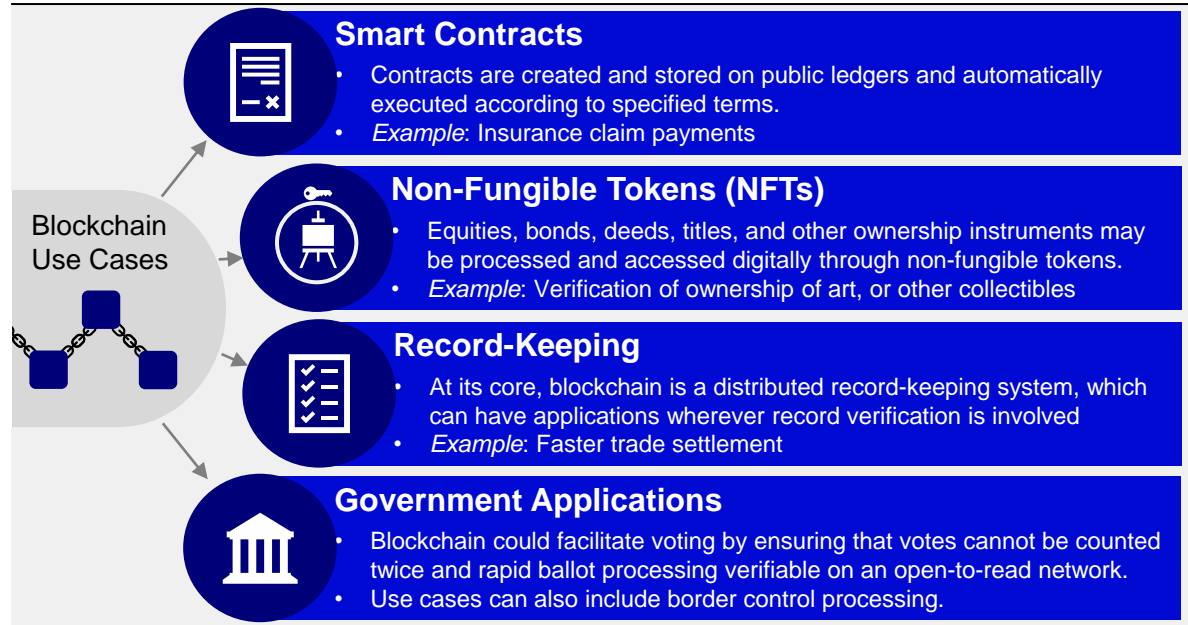
Source: Invesco. For illustrative purposes only. The risk and return considerations here capture only a selection of factors and do not constitute investment advice.

Food for Thought: Blockchain May Be a Longer Play

Digital currency is just one application of blockchain technology

If we take a step back from cryptocurrencies for a moment, we can appreciate blockchain for what it is: a decentralized authority of data, capable of exchanging and passing along data in a secure fashion and only with the permission of the data's owner. The applications of this technology may be manifold and disruptive.

We view this as an exciting space, as we briefly explore on the right. While blockchain technology suffers some flaws as we have discussed, there are nevertheless a growing number of businesses that are building products using distributed ledger technology. If you are skeptical on the ups-and-downs of cryptocurrencies, it is still worthwhile to consider the applications of blockchain technology and the ways in which it may disrupt industries.



Source: Invesco. For illustrative purposes only.



Common Terms Used in the Cryptocurrency World

Cryptocurrency	A non-traditional, digital form of currency that is a medium of exchange that uses cryptography to validate and secure transactions, typically through a blockchain. Importantly, some digital cryptocurrencies vary on this definition.
Bitcoin	The first and most popular cryptocurrency that is a reward for participating in the Bitcoin blockchain network.
Altcoin	Any cryptocurrency other than Bitcoin.
Token	A token is a crypto asset whose underlying value is based on another asset (e.g. gold or a title). This is different from a coin in that a coin's value is not directly related to the value of an underlying asset. "Token" and "coin" are often used interchangeably, perhaps improperly.
Stablecoin	A stablecoin is a cryptocurrency in which its market value is intended to be pegged to another asset, such as US dollars.
Blockchain	A digital ledger maintained by computers worldwide in a decentralized manner, where each "block" is a packet of data.
Mining	Users can participate in a blockchain network by verifying ever harder transactions and are rewarded with a particular cryptocurrency in a specified amount.
Wallet	Where Bitcoin and other cryptocurrencies are, in essence, held for use. Note that <i>wallets</i> facilitate holding cryptocurrencies, whereas an <i>address</i> is specific to each blockchain and is used in transactions, serving as an identity.
Exchanges	Where cryptocurrencies can be transacted with other people or currencies for a fee. <ul style="list-style-type: none"> • Decentralized Exchange – Users are matched with buyers/sellers algorithmically. Such exchanges tend to be less liquid and operate more slowly compared to centralized exchanges, but are more secure and involve lower fees. • Centralized Exchange – Users create an account with an exchange which typically holds their cryptoassets. These are considered more liquid and regulated, but less secure as the exchange acts as your custodian and can be hacked.

Source: Invesco.

Common Terms Used in the Cryptocurrency World (continued)

1 “Satoshi”	A unit of measurement equal to one hundred millionth of a single bitcoin (0.00000001 BTC).
Initial Coin Offering	An Initial Coin Offering (or ICO) is like an IPO but with digital coins. They are the object of regulatory scrutiny as they require no formal filings but serve a similar purpose to equity securities.
Hash	The hash rate is the measuring unit of the processing power of a blockchain network operating with a Proof-of-Work consensus mechanism.
Proof-of-Work (PoW)	A consensus mechanism that powers blockchains without a central party. Miners solve increasingly complex cryptographic problems and are rewarded with an amount of cryptocurrency for finding the correct solution. This process acts as a verification of the blockchain’s integrity. To compensate for the costs involved in this computation, miners sell their earned cryptocurrency. The PoW model is notorious for being massively energy intensive and is most often associated with Bitcoin.
Proof-of-Stake (PoS)	An alternative to PoW, PoS requires that participating miners hold an amount of the cryptocurrency—their “stake”—in order to qualify for the ability to verify blockchain transactions. PoS is significantly less energy intensive than PoW and is regarded as a safer approach than PoW.
Consensus mechanism	A consensus mechanism is required for every implementation of distributed ledger technology. It is the process by which state changes of the ledger are verified and validated by involved parties.

Source: Invesco.

Common Terms Used in the Cryptocurrency World

Web 1.0	The first iteration of the Internet. Here, web applications were simply read-only displays of information, such as a business webpage. Generally, users could not interact with such websites beyond searching for and reading information.
Web 2.0	The second generation of web experiences, commonly referred to as Web 2, was a revolution in the way in which users could interact with a website and web servers. In this case, users could participate and generate content, such as is the case with social media platforms, blogs, wiki pages, and more. It is commonly criticized for the centralization of data structures, where companies with large repositories of data could benefit by keeping such data for its own use and sale.
Web 3.0	Definitions of Web 3 are often nebulous and variable. However, the commonality across definitions and uses of the phrase is an idea of disintermediation of data structures, where decentralization is key. Cryptocurrencies are one expression of this, where no central party or actor governs the use and distribution of data.
Decentralized Finance (DeFi)	As with Web 3, definitions may vary. The general idea of DeFi is to change financial markets and products operated by transparent crypto-based protocols rather than by financial institutions.

Source: Invesco.

Index Definitions

Cash is represented by the Bloomberg Barclays 1-3 Month U.S. T Bill Index, which is designed to track the market for US Treasury bills with 1 to 3 months to maturity.

DXY is an index designed to capture the general international value of the US dollar by averaging exchange rates between the USD and major world currencies.

The S&P 500 Index is a market capitalization weighted index of the 500 largest domestic U.S. stocks.

Int'l (International) Stocks is represented by the MSCI World exluding US Index, which is designed to measure large and mid market capitalization stocks in developed markets, excluding the United States.

EM (Emerging Market) Stocks is represented by the MSCI Emerging Markets Index, which is designed to measure large and mid market capitalization stocks in emerging markets.

Global Gov Bonds is represented by the FTSE World Government Bond Index (ex-USD) index, which is designed to measure the performance of international developed bonds excluding US dollar denominated bonds.

Tsy (Treasury) Bonds (7-10) is represented by the Bloomberg Barclays US Treasury: 7-10 Year Index, which is designed to measure the US dollar-denominated, fixed-rate, nominal debt issued by the US Treasury with 7-10 years to maturity.

US IG (Investment Grade) is represented by the Bloomberg Barclays US Aggregate Bond Index, which is designed to measure the performance of investment grade bonds in the United States.

US HY (High Yield) is represented by the Bloomberg Barclays US High Yield Bond Index, which is designed to measure the performance of US corporate high yield bonds.

Gold is measured by the gold spot price quoted as US Dollars per Troy Ounce.

TIPS is represented by the Bloomberg Barclays US Treasury Inflation Notes Index, which is designed to measure the performance of the US Treasury Inflation Protected Securities (TIPS) market, excluding Federal Reserve holdings.

Commodities are represented by the Bloomberg Commodity Index, which uses futures contracts to reflect the returns on a basket of diversified commodities investments.

Oil is represented by the West Texas Intermediate spot price in US dollar terms.

US REITs (Real Estate Investment Trusts) are represented by the FTSE NAREIT All Equity REITS Total Return Index, which seeks to measure all tax qualified REITs listed in the NYSE, AMEX, and NASDAQ National Market.

REITs ex. US are measured by the FTSE EPRA/NAREIT Developed ex US Index, which is a market capitalization weighted index designed to measure the performance of real estate investment trusts in developed markets, excluding the United States.

Indices are unmanaged and cannot be purchased directly by investors. Index performance is shown for illustrative purposes only and does not predict or depict the performance of any investment. **Past performance does not guarantee future results.**

Disclosures

In researching this piece, the author Ashley Oerth acquired Bitcoin, Bitcoin Cash, Litecoin, Cardano, and Ethereum whose combined value is less than £150 GBP as of 31 January 2021.

“ETH diamond (glyph)” by the Ethereum Foundation is licensed under Creative Commons attribution 3.0. Original source: <https://ethereum.org/en/assets/#brand>. The image color was adjusted to white on pages 1 and 25, and to blue on pages 14 and 34. The use of the ETH diamond (glyph) logo is not intended to convey endorsement by the Ethereum Foundation.

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