Bitcoin investor guide

- **We present our framework for valuing Bitcoin**
- **Structurally, we 'value' Bitcoin in a USD 50,000-175,000 range**
- **Cyclically, we expect a peak around USD 100,000 in late 2021 or early 2022**
- **Beyond that, institutional flows should limit downside before the next halving of new supply in late 2024**

A pragmatic approach

Bitcoin (BTC), the world's leading crypto asset, is the subject of heated debate over its valuation – estimates range from zero to USD 600,000. In this report, our first on crypto assets, we look at various attributes of Bitcoin through both a structural and cyclical lens to generate metrics for BTC valuation. Defining BTC is also a subject of debate – which type of asset is it? We take a pragmatic approach to this question, as we believe BTC shares characteristics with currencies, commodities and equities (specifically early-stage tech companies).

As a medium of exchange, BTC may become the dominant peer-to-peer payment method for the global unbanked in a future cashless world. Based on the estimated size of that market (USD 20tn), and using credit-card companies' transactions and market valuations as a reference point, we arrive at an initial medium-of-exchange BTC valuation of USD 50,000 – which happens to be close to its recent trading level.

As a store of value, BTC enjoys a potential premium given the slow pace of increase in supply (currently 1.8% y/y and set to decelerate over time). In real terms, applying 'normal' US M2 growth rates to known BTC supply, USD 50,000 of BTC today would be USD 120,000 in 2040.

Portfolio optimisation is an alternate valuation measure. Starting the optimisation from the previous BTC peak (around USD 20,000 in late 2017) gives an optimal allocation to cryptocurrencies of around 2% of global portfolios. That would put BTC at USD 175,000 if, as we expect, Ethereum (ETH) market cap catches up to BTC's.

These three approaches put BTC's value in the range of USD 50,000-175,000.

Cyclically, it is periodic cuts in new BTC supply that matter; the growth rate of new supply is cut in half roughly every 4.5 years. Since the latest such cut in May 2020, BTC has risen around 6x – a very conservative multiple compared to 28x following the 2016 halving of new supply growth, and 93x following the 2012 one. Previously, BTC prices have peaked around 1.5 years after the new supply reductions. That would be late 2021 or early 2022 for this cycle, and it would take 'only' a cyclical 12x increase for the peak to be above USD 100,000.

Beyond this expected peak, for BTC to gain longer-term acceptance, its decline from early 2022 to late 2024 – when the rate of new supply will next be cut by half – will have to be significantly shallower than the 83-84% peak-to-trough drops seen during the latter halves of the previous two halving cycles. The emergence since 2020 of institutional flows during this halving period (a first for crypto assets) suggests that this will be the case. We will watch other cyclical metrics, such as transaction numbers and fees, as well as 'eyeball' measures like Google searches and Twitter mentions, for confirmation of this.

Finally, we consider challenges and opportunities for BTC market development in the coming years.

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Structural considerations

The economic case for Bitcoin?

A peer-to-peer electronic cash system

Bitcoin (BTC) was created in 2008 by an individual or group referred to as Satoshi Nakamoto. In the original paper outlining their work, BTC was referred to as a "peer-to-peer electronic cash system" that would facilitate decentralisation, i.e., "allow online payments to be sent directly from one party to another without going through a financial institution".

To address privacy and security concerns associated with mining, storing and transacting, BTC uses complex cryptographic methods. The more fundamental challenges with such a system are lack of trust and the potential for 'double spending', whereby digital tokens in use could be spent more than once. For existing currencies, financial institutions hold the ledger (and central banks hold the master ledger); this form of intermediation is absent from a decentralised peer-to-peer system, where the ledger is instead distributed among all users (or 'nodes') on the system.

To overcome this problem, Nakamoto used the proof-of-work (PoW) concept, whereby 'miners' compete to solve computationally difficult problems in order to win the right to create the next block of transactions. In return, they receive a portion of the native currency (BTC) within the system, as well as transaction fees. Each block of transactions is added to the previous one, creating a 'blockchain' record – the equivalent of a historic financial ledger held by a bank or central bank, which is both immutable and visible to all. The reward system – along with the time and energy costs associated with mining – acts as a disincentive to fraud. In turn, confidence in the integrity of the native currency improves, underpinning its value case.

While there have been several previous attempts to create an electronic peer-to-peer payment system, Nakamoto's built-in solutions to privacy, security, trust and fraud issues suggest that he created something more akin to a currency. Historically, the key economic attributes of a currency have been the following:

1. Medium of exchange
2. Store of value
3. Unit of account

BTC has the potential to become a currency

Before we delve into each of these components for Bitcoin and attempt to value its currency unit (XBT), it is worth noting that we think BTC has the potential to meet each of these definitions over time, but does not yet do so. As such, we would classify ourselves as crypto pragmatists, as opposed to crypto minimalists (like Nouriel Roubini, Joseph Stiglitz and Paul Krugman) or crypto maximalists (such as hedge fund managers).

However, given the tendency of markets to price an 'end game' for financial assets we do not think it matters that BTC does not yet fulfil each of these definitions. Rather, its potential to do so at some point in the future is what matters in driving XBT prices today.

Bitcoin as a medium of exchange

The 'medium of exchange' component of money allows it to achieve efficiencies relative to a barter economy. An important aspect of this component is the ease with which the asset can be used to make payments.

Transaction costs are a current obstacle to BTC being a 'medium of exchange'

The aspects of medium of exchange that are relevant for BTC are:

1. Societal acceptance – economic actors trust and accept the currency as the medium of exchange
2. It is divisible/fungible
3. Transaction costs are extremely low

Again, while BTC has not yet achieved any of these parameters (while transaction costs have fallen back to c.USD 2, they were as high as USD 50 in late April), it is reasonable to assume it could get there. Transaction costs for future versions of BTC could collapse.

The development of supporting financial infrastructure for BTC – including brokers, trading platforms, exchanges, wallet providers and payment service providers – is leading to greater ease of transacting in BTC. However, scalability and liquidity issues remain major headwinds. Given the limit on the size of each block of transactions (1MB) and the time interval between the creation of blocks (10 minutes), the theoretical upper bound for transactions per second is seven. This is significantly less than for other crypto assets like Ripple (XRP), which reportedly manages around 1,500 per second but can manage up to 50,000; and for the Visa electronic payment network, which averages 1,700 but has the capacity to manage up to 24,000 (ETH 2.0 is expected to handle 100,000 per second – see Figure 1).

Liquidity is also a concern

Liquidity is also a key consideration; a large number of BTC holders do not use bitcoins to transact with, resulting in a limited number of buyers and sellers in the market at any given time; hence the high degree of volatility. BTC's speculative nature is likely preventing users from viewing it as a medium of exchange and not just as a store of value; in theory, this speculative nature could be suppressing BTC's long-term value. However, while scalability issues arise from blockchain technology in general and from capacity constraints specific to BTC, there are a variety of ways to overcome these problems (see the *Caveats, challenges and opportunities* section below).

Assuming BTC can overcome these practical constraints on its widespread use, the next question is, what is the scale of the market?
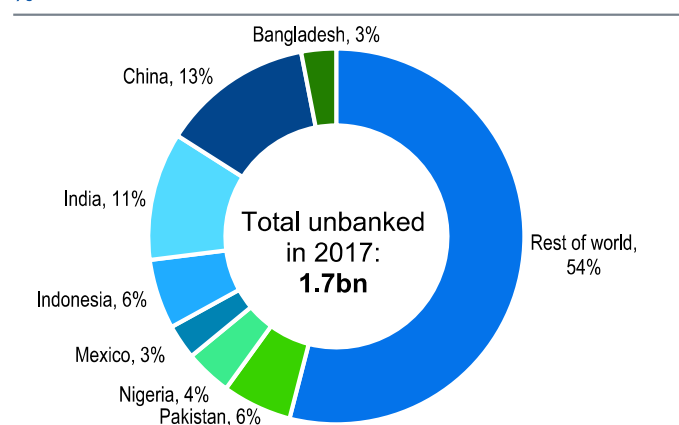
Figure 1: Average transactions per second
Number
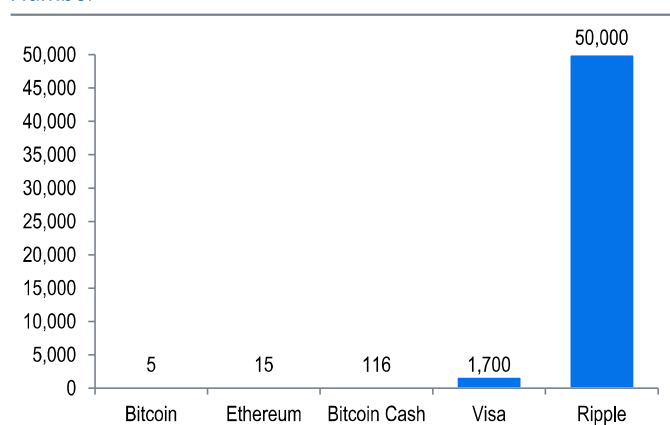
Figure 2: Unbanked population
%

Total unbanked in 2017: **1.7bn**

BTC can solve the unbanked population issue

One way to define this is through the size of the current unbanked population. This is the sector where rapid gains are achievable given the lack of competition with established payment services. In 2017, the unbanked population was estimated at around 1.7bn people globally (Figure 2) and could account for c.USD 20tn worth of annual transactions, according to the World Bank. Roughly half of the unbanked population already has access to mobile phones, which could provide the required platform for storing and transacting in BTC. Kenya's M-Pesa service is a successful example of mobile phones being used to facilitate peer-to-peer transactions. Some 70% of households in Kenya use the service, which was designed to enable micro loan payments but is widely used for peer-to-peer transfers between individuals.

Using the major credit-card companies as a guide, BTC's total market cap could reach USD 1tn, assuming that BTC captures all of the USD 20tn of transactions in the unbanked sector (this does not seem entirely unrealistic in a future cashless economy, where a 'winner-takes-all' outcome is possible). Visa has USD 8.8tn of annual transactions (and a market cap of USD 503bn); Mastercard has USD 6.3tn (USD 342bn), and American Express has USD 1tn (USD 132bn); see Figure 3. Applying these ratios to BTC's USD 20tn of transactions would arrive at a BTC market cap of c. USD 1tn. Divided by the 18.8mn bitcoins mined to date, that equates to an XBT-USD rate of 53,191 – or USD 47,619 if divided by the eventual 21mn supply of bitcoins. The midpoint between those values is c.USD 50,000.

Bitcoin as a store of value

New supply rates are cut by half every 4.5 years

The supply of BTC can be measured on a stock basis (total bitcoins minted so far are c.18.8mn) or on a flow basis (newly minted bitcoins per day are currently c.900). The BTC algorithm dictates a finite supply of 21mn over the long run. To ensure this target is reached, the rate of supply of new BTC is adjusted over time; this is achieved via a halving mechanism, whereby every 210,000 blocks produced (or roughly every 4.5 years), the growth rate of new BTC supply is cut in half. This supply inelasticity helps to explain the high volatility in BTC prices (XBT), as economic theory shows that demand shifts naturally result in larger price swings the more inelastic supply is.

The latest halving of the rate of new supply took place in May 2020, when the supply of newly minted BTC per block fell from 12.5 to 6.25. The next halving (due around

Figure 3: Annual transactions
USD tn
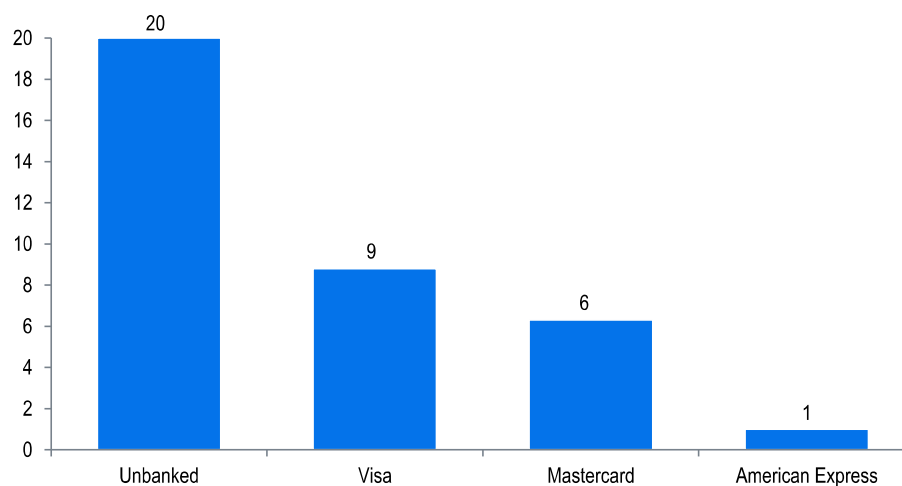
end-2024) will reduce the supply rate to 3.125, and so on. A separate part of the algorithm adjusts the computational difficulty to ensure that each new block is created roughly every 10 minutes; this means the 21mn target should be met around the year 2140. Together, the asymptotic limit and the halving mechanism mean that almost 90% of all BTC that will ever exist already do so.

Finite supply serves as an inflation hedge

Advocates of BTC point to its finite supply as underpinning this store of value – similar in nature to most commodities, where short-term supply can be elastic but long-term supply is fixed. By serving as a store of value, BTC may also provide a hedge against inflation compared to other assets. This argument has strengthened since BTC's creation in 2008 as central banks have expanded money supply of fiat currencies in order to return to compliance with national inflation targets (Figure 4). This was true after the global financial crisis, when QE programmes were initially introduced, and has since been magnified by much larger increases in money supply in response to the economic impact of COVID-19 restrictions.

While the growth rate of BTC supply was high during its first few years of existence, it has fallen consistently as rewards for mining have been cut in line with the algorithm's halving process. After the reward per block was most recently cut to 6.25 BTC in May 2020, the effective inflation rate for BTC now stands at around 1.8%.

In Figure 5 we demonstrate the effect of low rates of BTC supply growth. Here, we conservatively assume that US M2 returns to 'normal' growth of 5% a year, closer to trend nominal GDP growth. In that scenario, an XBT value of USD 50,000 today is equal in real terms to USD 120,000 in 2040.

However, BTC detractors argue that given its high price volatility, the store of value over a shorter time horizon cannot be assumed; this volatility also impedes BTC's practical use as a means of exchange. The standard deviation (measure of volatility) of XBT compared to XAU, the S&P 500 and the TRY (a high-beta currency) shows that BTC's monthly swings are still 5-10 times higher on average, despite a significant decline in volatility from the 2013 peaks (Figure 6). Over the longer term, however, volatility should have less impact on BTC's function as a store of value given the general uptrend in XBT-USD since 2008. Volatility should also subside as liquidity in the BTC ecosystem improves.

Figure 4: BTC growth vs US M2 growth
% y/y
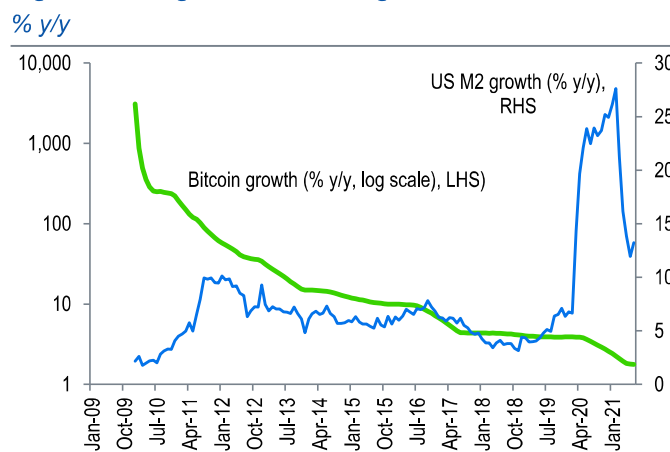
Figure 5: Real vs nominal XBT price
Assumes value of USD 50,000 at end-2020
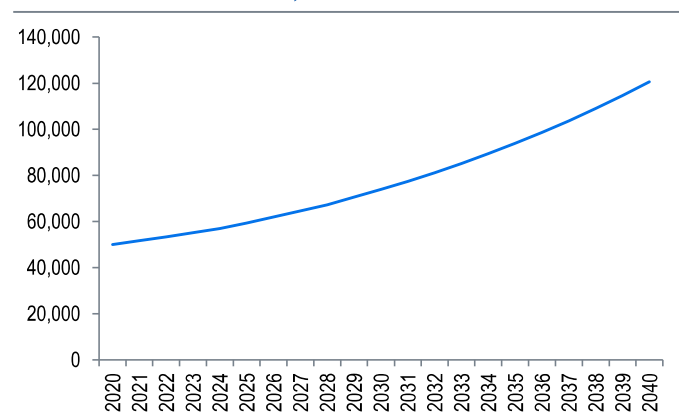
A disadvantage of BTC's slowing rate of new supply growth (and its finite supply over the long term) is the inability to adjust money supply in response to economic shocks. In other words, its monetary policy is built into the system, or endogenous. In the early years, BTC was clearly characterised by monetary inflation – a high growth rate in its money supply.

More recently, BTC has been characterised by steady monetary disinflation as the growth rate has fallen – and will continue to fall – over time. Once the rate of supply growth falls sufficiently, BTC could eventually be characterised by monetary deflation if bitcoins are being lost at a greater rate than they are being produced, but we are not there yet. Nonetheless, the falling supply rate, the rapid increase in value since its creation, and high volatility in XBT-USD impede BTC's ability to serve as a means of exchange; expectations of continued rapid gains in BTC's value limit the number of users who will actively use it for day-to-day transactions.

First-mover advantage

Network effects create a huge first-mover advantage

Adding to BTC's 'store of value' appeal is the fact that it was the first major crypto asset to gain public exposure. Despite a multitude of other crypto assets having been created since – many of which have more compelling value cases or have sought to correct deficiencies in BTC's architecture – BTC's share of the crypto market has increased in recent years, from around 30% in early 2018 to over 40% today (although it was as high as 60% in March). This is likely the result of BTC's exposure and the network effect – i.e., the more users on the BTC network, the more the network's value increases (Metcalfe's law suggests that the impact on the value of network can be a square function of the number of users).

BTC's ecosystem – including brokers, merchants and wallet providers – and its media and investor profile position it well to remain the top crypto asset in terms of market share, despite its drawbacks (see the *Caveats, challenges and opportunities* section below). BTC is also arguably the only completely leaderless and decentralised crypto asset, which means changes to the architecture occur only through consensus. This, along with the inherent anonymity of BTC users, is very appealing to a large number of investors.

Figure 6: Monthly standard deviations

%
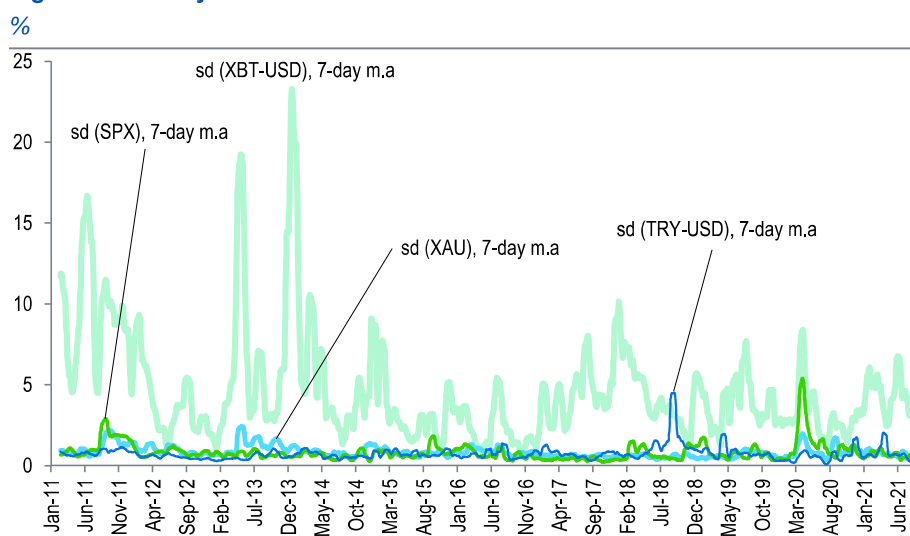
Bitcoin as a unit of account

BTC volatility is too high for it to function as a 'unit of account'

Often considered the most important characteristic of money, its function as a unit of account relates to whether the asset can be used to measure the value of a specific good or service. As the Bank of England notes, "Money's second role is to be a unit of account – the thing that goods and services are priced in terms of." There is limited evidence that this is the case for BTC. While many individuals and companies accept payment in BTC, its price volatility means it is rarely (if ever) used to price items or to carry out a company's accounts.

One area where BTC is likely to form a unit of account is within the crypto market itself. BTC currently accounts for over 40% of the global crypto assets market (Figure 7), making it a 'standard bearer' for the market. We explore this in our *Ethereum investor guide*, where we compare XBT drivers to Ethereum (XET) drivers.

Portfolio flows and optimisation

Institutional money has started to enter the crypto market in reasonable size. For example, the AUM of the Grayscale Bitcoin Trust reached around USD 30bn recently (Figure 9). While this is still only a small percentage of BTC's overall market cap, institutional flows have finally begun. Given this ongoing shift, we discuss flows here as a structural consideration, even though they can also be viewed as a cyclical driver.

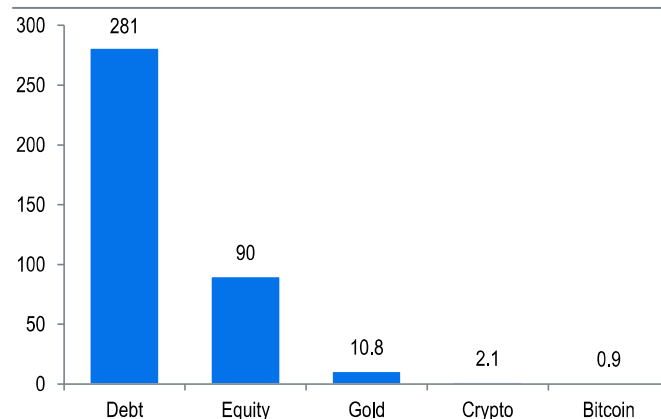*Portfolio optimisation may lead BTC to USD 175,000*

As BTC attracts institutional flows, portfolio optimisation can be used to determine its value. Even if BTC fails to gain traction as a means of exchange (or, by extension, a unit of account), it could build on its early establishment as a store of value to challenge existing stores of value such as gold. At current market prices, outstanding BTC has a value of c.USD 900bn. The same calculation for gold gives a value of USD 10tn, while global equities stand at USD 90tn and global fixed income at USD 280tn (Figure 8). As a percentage of total financial assets, the current market share of BTC (as well as the broader crypto asset market) does not look excessive if it can continue to eat into the existing market share of established stores of value like gold. BTC's value case is strengthened if it can provide portfolio diversification to existing asset allocations via uncorrelated returns.

Traditional portfolio optimisation tools use either a pre-set starting point or rolling time windows for the optimisation. A pre-set starting point has the advantage of starting an analysis from previous tops/bottoms of risk asset markets in order to optimise over a cycle. Rolling time windows have the advantage of achieving more robust output, as a pre-set starting point can determine the optimal mix.

Figure 7: Crypto assets market breakdown
USD bn

Crypto market capitalisation: **$2.09tn**

Other, 471
Dogecoin, 39
Ripple, 55
Cardano, 87
Tether, 65
Binance Coin, 81
Ethereum, 380
Bitcoin, 912
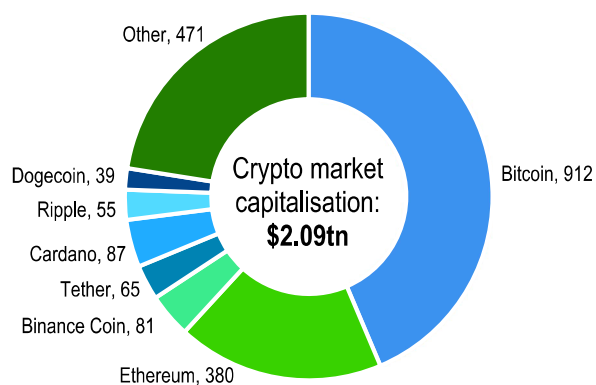
Figure 8: Market cap
USD tn

Debt	Equity	Gold	Crypto	Bitcoin
281	90	10.8	2.1	0.9

For crypto assets, there are two additional challenges to portfolio optimisation: data (time series are short) and lack of market maturity. Data limitations mean that portfolios are optimised over short horizons, and the lack of market maturity means that the exponential price growth (returns) of crypto assets overwhelm any volatility and correlation points – which are what portfolio optimisation is ultimately trying to solve for.

To address these concerns, we think a reasonable starting point for the optimisation is the previous XBT peak on 19 December 2017. Using this starting point, XBT has multiplied by 'only' 2.5x during the sample period; in comparison, the MSCI World Index (equities) is up around 40% over the same period. We then optimise a portfolio of global equities, global bonds, global commodities and a 'crypto 10' index.

The optimal weights are 82% bonds, 15% equities, 1% commodities and 2% (2.27%) crypto. Given that total global AUM of all financial assets is around USD 400tn, 2.27% would translate to crypto AUM of USD 9tn. That is a 5x increase from crypto's current market cap, and would value XBT at around USD 250,000 (assuming Bitcoin's current 40% share of crypto market cap). However, we think there is a reasonable case to be made that XET's market cap will increase over time, perhaps equalling XBT's (see *Ethereum investor guide*). That would give XBT and XET each around one-third of the total crypto market cap. At that rate, XBT would be valued at around USD 175,000.

Cyclical considerations

Supply of BTC

Bull and bear markets are common during the periods between new-supply 'halving' exercises

The main 'store of value' argument for BTC is that supply is limited. Specifically, the BTC algorithm ensures a finite supply of 21mn bitcoins over the long run, with the rate of supply of new BTC adjusted over time via the halving mechanism.

XBT has seen major bull runs after each halving exercise, as shown in Figures 11 and 12. After the first one in November 2012, the price increased 93x by November 2013, then fell 84%. The increase was more gradual after the second halving in July 2016, but XBT had increased 28x by December 2017, when the next bear market kicked in (prices again fell by 83%). Since the third halving in May 2020, XBT has increased 6x so far (even taking into account that XBT is 25% off its recent price peak).
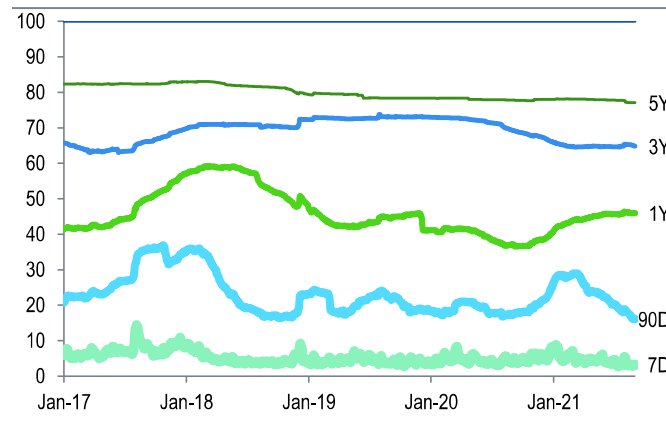
Figure 9: Grayscale Bitcoin Trust
USD (LHS), USD bn (RHS)
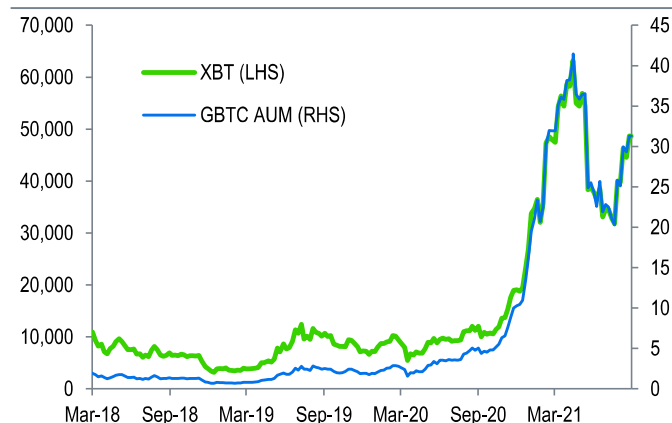
Figure 10: Active supply by age distribution
%

*Previous halving cycles would suggest a peak XBT price in late 2021/early 2022*

In order to establish XBT's institutional credibility, the next bear market – which will presumably come before the next halving of new supply in late 2024 – will have to be much shallower than the previous declines of more than 80%. This may already be the case given the c.50% price correction between April and July, although a further price correction could yet be in the offing. Indeed, previous price peaks were achieved roughly one year and 1.5 years after the 2012 and 2016 new supply halvings, respectively. Assuming a similar timeframe for this cycle, the next peak would be in late 2021 or early 2022.

Supply can deviate from the pre-set growth rate in the short term, but this will eventually be corrected. The cost of processing power incurred by bitcoin miners – which stems primarily from the electricity costs to run their computers – is a key determinant of supply in the short run. For instance, if electricity prices were to rise, this would raise miners' operational costs; assuming XBT's price is constant, some miners would no longer view mining as a profitable exercise and would stop their activities, reducing the overall amount of computational power on the network, or the 'hash rate' (see the appendix for further details on mining).

Assuming existing miners would still need to process the same number of transactions as before, miners would take longer to form each block, meaning the supply of newly minted BTC would also fall. However, every two weeks (or every 2,016 blocks), the BTC algorithm adjusts the difficulty of required computations to verify new blocks, in order to ensure that the average processing time for each block remains approximately 10 minutes. As a result, if the block time exceeded 10 minutes, the algorithm would lower the difficulty of computation at the next review period, in turn reducing the amount of processing power (and, by extension, electricity costs) required to produce each block. This could encourage miners to return to the system until balance was restored.

The opposite would be true if computing power increased; processing time for each block would likely fall below 10 minutes, and at the subsequent review period the algorithm would simply increase the difficulty of the required computations. Lower operating costs could initially incentivise new miners, but they would be disincentivised once operating costs re-adjusted higher. As computing power has increased over the past 12 years, the difficulty of computations has increased, in line with XBT (Figure 13).

Figure 11: BTC supply vs XBT price
mn (LHS), log scale (RHS)
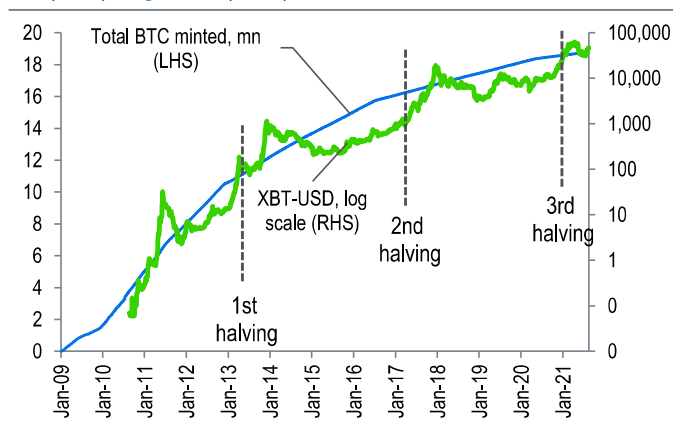
Figure 12: XBT price after each halving of new supply
USD
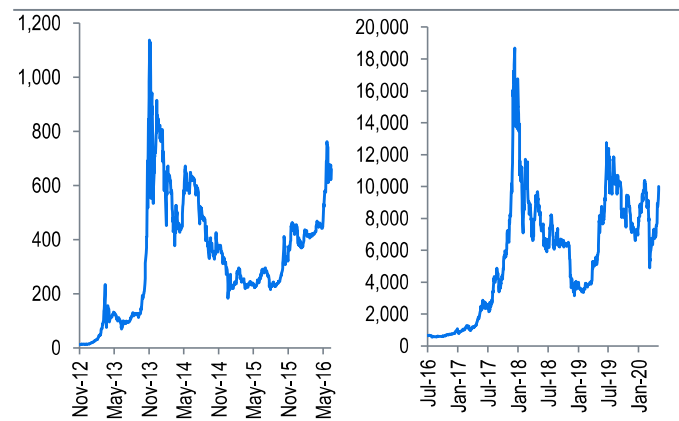
Circulation is another supply-side factor affecting BTC value. Some estimates suggest that around 20% of existing bitcoins have been lost due to forgotten passwords or wallets. If tracing and recovery software improves in the future, this could provide a boost to circulation. However, it is also estimated that over 60% of bitcoins have not left their wallets in the past 12 months (source: theblockcrypto.com; see Figure 10). This suggests that only a small quantity of the 18.8mn outstanding bitcoins are actually being used for transactions, the rest being either lost or held for long-term value gains; this helps to explain the high degree of XBT volatility. If BTC began to show signs of greater price stability in the future, this could facilitate its use as a means of exchange, which would help to boost overall circulation.

Demand for BTC

Transaction data helps to measure demand

Measuring demand for BTC is difficult, but one metric we have is the number of transactions carried out on the network. This was rising significantly until April 2021, when the most recent price correction occurred. As the logged scale in Figure 14 shows, the number of transactions per day had risen from c.100 in early 2009 to c.300,000 In March (about 3.5 per second) before falling back by almost one-third to 200,000 per day in July; the number of transactions has since started rising again, reaching 230,000 per day in mid-August. However, the relationship – and any causality – between the number of transactions and BTC's price is not straightforward, with correlations flipping during some historical periods.

A related demand metric is the number of active BTC addresses on the network. This recovered to its late-2017 high in early 2021, after having declined sharply in the 2018 bear market; it has pulled back more recently (Figure 15). Another demand consideration is the cost of using BTC, as measured by transaction fees; this serves as both a measure of demand on the network and a determinant of future demand. Average transaction fees rise when there is high demand or congestion on the network (demand to create more transactions), or if the transaction size itself is bigger. Individuals wishing to transact can decide on an appropriate transaction fee – the higher the fee, the more likely their transaction will be included in the next block and thus settled faster. Increasingly, though, dynamic fees (where intermediaries set the appropriate fee) are being used.

As we have noted, a decrease in the supply rate should lead to an increase in demand (due to scarcity), which should in turn push XBT-USD higher. This is necessary to keep the system in balance – on the one hand, miners will be
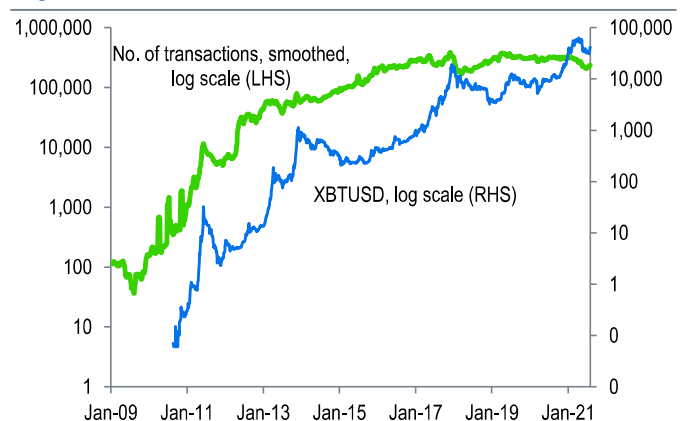
Figure 13: XBT vs computational difficulty
Log scale
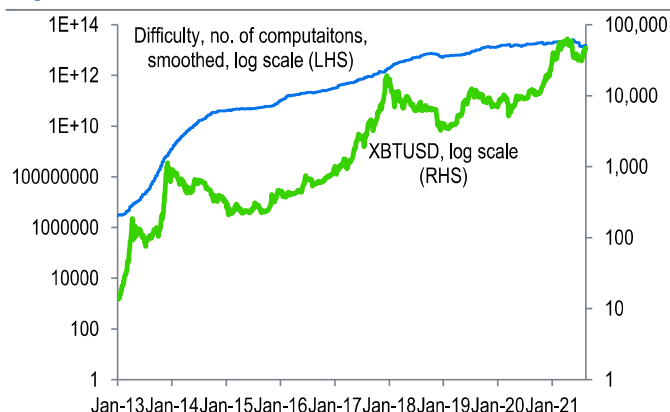
Figure 14: XBT vs number of transactions
Log scale

disincentivised from mining due to the reduced rewards on offer, but on the other, they will be incentivised to keep mining as XBT-USD goes up.

What demand changes mean for transaction fees is less obvious; if miners step back from the system, the overall computational power available – or the 'hash rate' – falls. This increases pressure on remaining miners (as they still have to process the same number of transactions) and lengthens the time taken to generate each new block. Transaction fees should rise, as congestion on the network will have increased.

Data on 'eyeballs' also helps gauge public investor interest

However, as the algorithm adjusts the difficultly of required computations every two weeks to ensure that the average time remains approximately 10 minutes between blocks, the required processing power for existing miners to verify each new block should fall, lowering operating costs and increasing profit. This will draw new miners back in. As a result, the most recent halving in May 2020 likely put upward pressure on fees in the immediate period afterwards, but this should have been corrected over time. The fact that BTC transaction fees continued to rise beyond the adjustment period following the halving in 2020 (although they have fallen back since the latest price correction) suggests that this was driven by higher demand on the network more than anything else.

Other indicators of interest in crypto assets are akin to the 'eyeballs' measure used to value tech stocks in the 1990s. Today, the best and most timely of these are Google and Twitter mentions. The Google series is longer, so we show it in Figure 16.

Caveats, challenges and opportunities

We address key challenges and opportunities for Bitcoin, which also apply to crypto assets more broadly. We believe they fall into the following categories:

1. Computational
2. Security
3. Regulatory
4. Environmental
5. Competitive landscape

Figure 15: XBT vs active BTC addresses
USD (LHS), number (RHS)
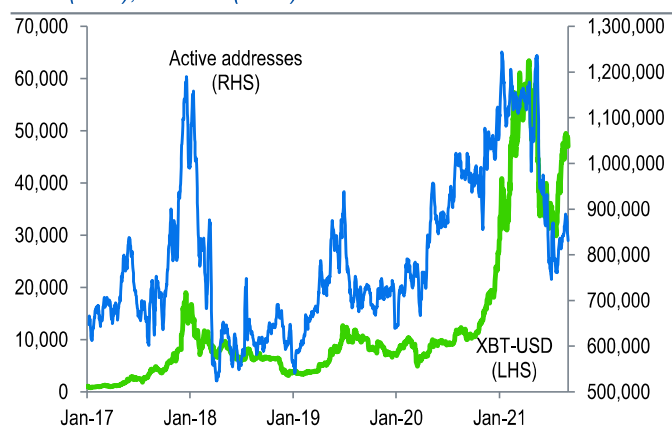
Figure 16: XBT vs Google searches
USD (LHS), index where max. is 100 (RHS)
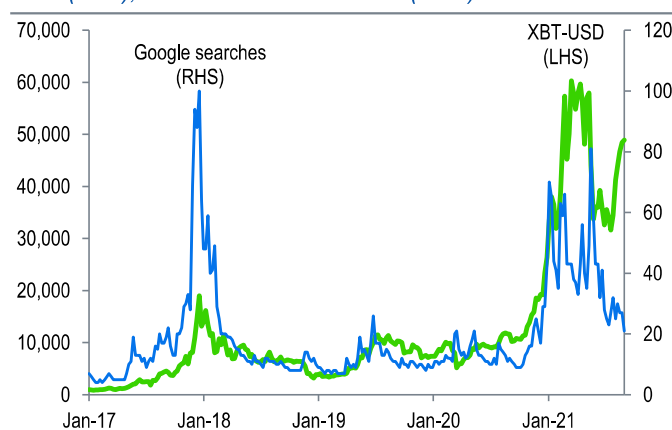
Computational

A key constraint for BTC is scalability, which in turn affects liquidity. Given limitations on the size of each subsequent block of transactions and time intervals between the creation of blocks, the theoretical upper bound for transactions per second is seven – nowhere near high enough to be globally competitive in financial transactions (compared to existing electronic payment systems). Ethereum founder Vitalik Buterin highlights this in his 'scalability trilemma', whereby crypto assets cannot be simultaneously secure, scalable and decentralised; there will always be a trade-off, with only two of these criteria met at any given time.

BTC's consensus protocol may incorporate changes to the architecture in order to compete in the long run and widen the potential uses of BTC. This could improve scalability, even if it leads to slightly less decentralisation and security. A few alternatives have already been proposed, including 'batch payments', where transaction sizes are reduced to allow more transactions to be included in each block; or the 'lightning network', a payment protocol that could sit on top of BTC and enable faster transactions. The architecture could also be changed if smart contracts or decentralised apps (dApps) continue to grow as an industry; these could theoretically be added as a new layer on top of BTC's existing architecture.

Security

Given BTC's consensus protocol, a 51% attack is possible. In such a scenario, a majority of the miners on the network would take control of the proof-of-work system and reverse previous transactions, double-spend existing BTC, or cancel entire blocks of the blockchain. The likelihood of such an attack is very low given the scale of computing power (and electricity cost) required to take control of 51% of miners. While such attacks have happened on smaller crypto asset networks, they have not happened on the BTC network. However, the fact that BTC miners are centralised in large mining pools suggests there is a risk of this occurring.

A separate concern is a potential rapid shift in computer power – for example via a breakthrough in quantum computing – potentially enabling either a single miner or a group/pool of miners to gain a 51% majority of the network hash rate, or even attack the security of the existing BTC architecture. There is a concern within the cybersecurity field that quantum computing could be used to break elliptic curve cryptography (which is used to ensure that bitcoins can only be used by their rightful owners), although the consensus is that this is still at least a decade away. Any breakthrough in this technology would pose a significant threat to encryption more generally, so we can expect significant efforts across various industries to build resilience against this threat.

Regulatory

The rise of crypto assets has raised a variety of public policy concerns. The larger the sector becomes, the more likely governments or international bodies will be to respond. Regulation is likely to focus on three broad areas: countering illicit activities, ensuring financial stability, and protecting the investing public.

With respect to illicit activities, estimates vary as to how much activity on the BTC network they account for, but user anonymity is a clear incentive. Governments are likely to mandate that any financial intermediaries involved in the BTC architecture adhere to strict know-your-client (KYC), anti-money laundering (AML), combating the financing of terrorism (CFT) and customer due diligence (CDD) rules. Over time, this

could weaken the anonymity advantage of BTC. With respect to financial stability, the larger the sector becomes (and the more users on the network), the greater the likelihood that a price shock could have knock-on effects on other markets.

The current SEC has a strong understanding of crypto assets

The SEC's main focus is likely to be on protecting the investing public, particularly as it applies to how crypto assets are classified (for example, as commodities, currencies or securities, each of which have their own SEC rules). Interestingly, the new SEC chairman, Gary Gensler, previously taught a course at MIT called 'blockchain and money' (we found it very educational; it can be found on YouTube). So it is reasonable to assume that the current SEC has good knowledge of crypto assets. This in itself increases regulatory risks, but also opportunities. For example, the SEC may at some point allow ETFs that track crypto assets. This could significantly increase the potential investor pool by enabling mass retail participation.

For now, the crypto asset market is still too small to have a significant effect on broader financial markets and financial stability. However, governments with capital controls could face near-term risks.

Beyond these three areas, governments may also see crypto assets as a growing threat to fiat currencies and their sovereignty over monetary policy. Such concerns could grow if BTC is increasingly used as a means of exchange. Outright bans – while incentivising some groups to continue to use BTC – could halt its move to mass usage. Rather than blanket regulation covering all crypto assets, governments might seek more targeted regulations based on the characteristics of each asset (as the UK already does with e-money tokens, security tokens, and unregulated utility or exchange tokens).

Ultimately, countries could go one of two ways. In 2021, China has initiated a crackdown on Bitcoin mining activities and trading (see below), while El Salvador announced that Bitcoin would be adopted as legal tender alongside the US dollar in early September; how this experiment plays out will likely dictate whether other countries shift towards adoption of virtual currencies in the future.

Environmental
BTC's environmental impact is under increasing scrutiny given the heavy energy consumption involved in mining it (Figure 17). This raises the question not only of whether governments should take BTC's carbon footprint into account when considering its regulatory and tax framework, but also whether the BTC architecture is fit for purpose

Figure 17: XBT vs global energy consumption
TWh (LHS), USD (RHS)
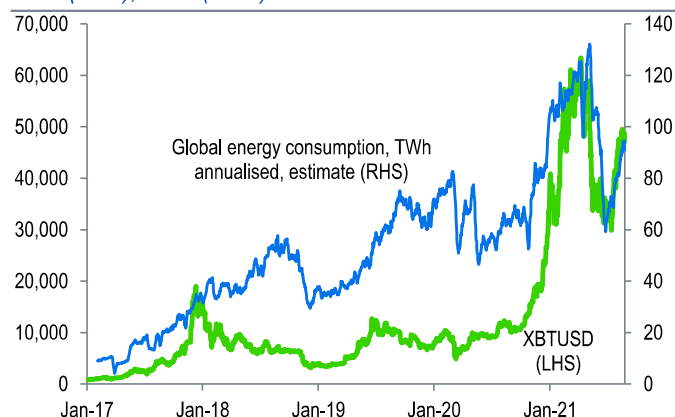
Figure 18: Hash rate shares of different mining pools
%
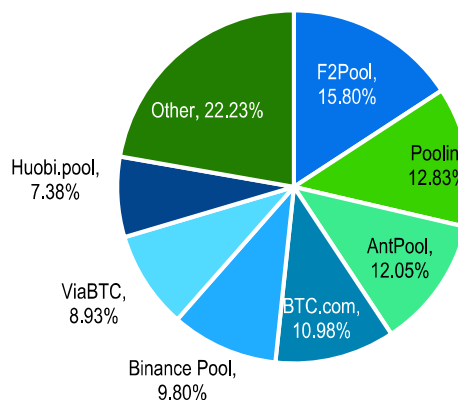
over the long run. Indeed, the more successful BTC is over time and the higher its price goes, the greater the competition among miners – and, by extension, computational 'difficulty'. This, in turn, increases the energy consumption required for mining.

Environmental concerns around 'mining' are becoming a problem

Tesla CEO Elon Musk announced in early May – only a few weeks after announcing that Tesla had purchased USD 1.5bn of XBT and would begin accepting it as payment for vehicles – that the company would no longer accept it due to energy concerns related to mining of Bitcoin. This was accompanied by an intraday fall of more than 10% in XBT's price.

One way around this issue would be to shift from a proof-of-work consensus mechanism to a proof-of-stake mechanism (see *Ethereum investor guide*). This could significantly cut the annual global energy consumption associated with BTC, which is currently equivalent to that of Argentina. A separate issue arises from the concentration of mining pools, although the environment appears to be changing rapidly on this front. Most mining pools had been operating in China until earlier this year owing to the availability of low-cost electricity generation; but according to data collected by Cambridge University, China's share of the global hash rate fell to 46% in April 2021 from over 75% in late 2019. It has likely fallen even further in recent months after China announced a crackdown on Bitcoin mining activities in late May – a development that also resulted in a large correction in Bitcoin's price at the time.

The full effects of this regulatory change by China's government are likely still being felt in the BTC ecosystem, as mining pools (Figure 18) must relocate to new locations and – in many cases – absorb higher energy costs. On the other hand, less concentration of the global hash rate in any particular country could be viewed as a positive development over the long run.

While BTC's 'cost per transaction' is significantly higher than Visa's, we think this is a misleading comparison, as Visa handles only one step in the global payment system, while BTC's transaction cost includes all of the steps through settlement (including clearing and security). Even so, the BTC landscape uses a significant amount of energy, which will only grow if its use becomes more widespread. This could be the avenue governments pursue for regulatory intervention.

Competitive landscape

While BTC has a first-mover advantage, other crypto assets face minimal barriers to entry. A new asset could quickly erode BTC's market share if it offers the benefits of BTC (i.e., it is decentralised, secure and finite) plus additional benefits of other crypto assets (i.e., the inclusion of smart contracts and dApps), and is also supported by a global user footprint such as Amazon or Facebook. New assets could also emerge via 'forks' in BTC, whereby new features are added to the existing blockchain and the consensus breakdown is not resolved. The fork (e.g., a change in transaction speed) could then be adopted by nodes that deem the new protocols desirable.

BTC's first-mover advantage is strong, but barriers to entry are low

This has already happened with BTC before, with the creation of Bitcoin Cash in August 2017, Bitcoin SV in November 2018 and Bitcoin Gold in October 2017 (these are the largest and best-known of many). If 51% of nodes agree, then the changes are simply incorporated into the existing BTC architecture. But forks still have the potential to syphon off significant demand into a separate crypto asset, diminishing BTC's network effect.

A separate – and potentially larger – challenge could come from the creation of central bank digital currencies (CBDCs). Many are already discussing how this would work in practice, and a recent report by the Bank for International Settlements

explored the "foundational principles necessary…to help central banks meet their public policy objectives". CBDCs certainly have the ability to create more flexible payment systems for users, which could serve the unbanked population. However, without a return to the gold standard or some limitation on monetary policy (which central banks are highly unlikely to accept), BTC will always have the advantage of being decentralised and having a finite supply.

BTC in decentralised finance (DeFi)

DeFi holds huge potential for crypto assets

Decentralised finance (DeFi) took off in a big way in 2020. The total value of crypto assets locked into DeFi has grown 150-fold, to USD 92bn today from just USD 660mn at the start of 2020 (source: Defi Pulse).

DeFi refers to the use of blockchain technology to remove intermediaries between parties in financial transactions (such as lending, borrowing, derivatives and exchange). By lending out crypto assets to others via lending pools on DeFi platforms, crypto owners can earn fees in the form of crypto. Alternatively, crypto owners can enhance returns by moving their crypto assets between different DeFi lending marketplaces, also known as yield-farming. Some DeFi platforms further incentivise lending and borrowing on their platform by allowing both lenders and borrowers to accrue the liquidity provider's tokens. The process of earning a secondary token in addition to interest is referred to as liquidity mining.

Tokenisation of BTC

Tokenisation of BTC has grown more ubiquitous amid the DeFi boom. Previously, BTC holders used BTC primarily for payment transactions on the BTC blockchain or held it as a store of value. Now, BTC holders can generate a return on their holdings on DeFi platforms. However, most DeFi platforms are built on the Etherum blockchain (see *Ethereum investor guide*) due to its ability to execute smart contracts that govern the loan, repayment, and liquidation processes. In order to participate on DeFi platforms, BTC holders can tokenise their BTC for Ethereum-compatible ERC-20[1] tokens such as Wrapped Bitcoin (wBTC) or Huobi Bitcoin (HBTC) at a 1:1 asset-backed peg. To wrap a token, a user typically 'locks' the original token into a smart contract, which then mints an equivalent amount of wrapped tokens issued by a DeFi robot – similar to a traditional structured note.

Figure 19: Bitcoin on Ethereum
'000
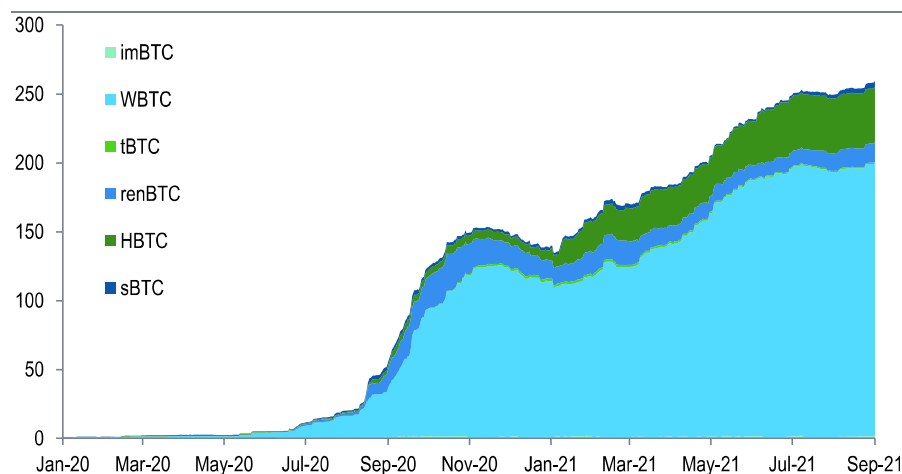
Source: theblockcrypto.com, Standard Chartered Research

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[1] ERC-20 is the common set of criteria outlining the rules and technical standards that an Ethereum token must follow to function optimally and interoperably on the Ethereum blockchain. It ensures that the rules of smart contracts remain compatible with applications like decentralised

Another method for tokenising BTC that has recently gained popularity is synthetic Bitcoin, where holders lock their BTC into a smart contract and receive a synthetic asset with equal value. The synthetic token functions like a derivative, as it replicates the returns of BTC but is not backed by BTC.

There are around 100 (and growing) versions of tokenised Bitcoin; wBTC and HBTC are currently the largest by market capitalisation (Figure 19). Around 250,000 bitcoins worth USD 12.5bn had been tokenised as of end-August 2021, up from 80,000 12 months prior; around 75% of this amount was tokenised into wBTC. In other words, more tokenised bitcoins are created on a daily basis than bitcoins are mined per day (currently around 900/day).

Implications for BTC

DeFi platforms rely heavily on over-collateralisation to mitigate the risk associated with the price volatility of crypto assets, and to compensate for borrower default risk given their lack of a universal identity protocol. Hence, the amount that can be borrowed is limited by the value of collateral in the system. As the largest crypto asset by market capitalisation, BTC offers valuable liquidity and collateral to expand the scope and strength of the DeFi ecosystem. In return, BTC holders can now access a variety of financial services built on the Ethereum blockchain, which were previously inaccessible to them.

Tokenisation can add much-needed speed to BTC settlement

In addition, tokenised Bitcoin transactions also clear more quickly because they are settled on the Ethereum blockchain, which adds a new block every 15 seconds (versus every 10 minutes on the Bitcoin blockchain). Because of this functionality, tokenised BTC can move between Ethereum wallets, exchanges and services much more rapidly than BTC.

The development and use of tokenised BTC is a sign that interoperability between Bitcoin and Ethereum is facilitating DeFi's growth, and has the potential to add value for users in the rapidly maturing crypto ecosystem.

Appendix – Bitcoin primer

The below primer covers the essentials of Bitcoin's architecture and explains the processes of mining and transacting in BTC. It is based largely on Satoshi Nakamoto's original white paper, as well as various online resources.

What is Bitcoin?

As is widely noted in the literature, Bitcoin defies simple definition. It can be understood in a variety of ways: as a currency, an asset, a payment network, or software. We use the term asset over currency when considering its use cases, but for the purpose of explaining how it works, we prefer to categorise BTC as a ledger or database that compiles all of the transactions ever recorded using BTC. Before discussing how the ledger works in practice, it is worth considering Bitcoin's origins.

Why was Bitcoin created?

There were attempts to produce digital currencies before Bitcoin, including 'Bit Gold' and 'Hashcash'. However, Satoshi Nakamoto's white paper from 2008 was focused on solving a very particular problem: how to overcome the 'trust' problem associated with the creation of a decentralised, peer-to-peer, electronic payment system. Let's unpack that.

- **Decentralised:** In the Bitcoin context, this means that the ledger or database is held on each user's system, and each user must update the ledger accordingly.
- **Peer-to-peer (p2p):** This refers to a network where files or 'Bitcoin' can be shared directly between users rather than via an intermediary.
- **Electronic:** Transactions happen through a digital medium (i.e., paperless).
- **Payment system:** The intent is for Bitcoin to be used to transfer value.

From the above attributes, it is clear where the 'trust' problem comes from: without a central authority, and given the relative ease of replicating digital copies, how can such a payment system ensure no double spending, i.e., one party pledging the same online token to two or more transactions? It achieves this via the use of cryptography, which renders the system 'trustless' – in theory, individuals do not need to trust each other for the system to work as it is supposed to.

Before we explore how transactions and mining draw on cryptography, it is worth noting that Bitcoin's success can also be attributed to its timing. Interest in digital currencies was growing throughout the 1990s and 2000s, and Bitcoin provided the desirable addition of decentralisation. Given the simultaneous development of blockchain technology over the same period, when Bitcoin was launched, it was leveraging on a technology that ostensibly mitigated many of the security concerns associated with other electronic payment systems.

The launch of Bitcoin in 2008 also coincided with central banks expanding money supply of fiat currencies in order to return to compliance with national inflation targets. QE programmes were initially introduced in response to the global financial crisis; money supply increases have since become much larger in response to the economic impact of COVID-19. As a result, Bitcoin's disinflationary characteristic (via algorithms ensuring that the supply rate falls over time and that there is a finite future supply) attracted growing interest from economists and investors concerned about fiat currencies' store of value.

How do transactions work?

To prevent false transactions on the network, each transaction must be accompanied by a digital signature; as Nakamoto notes, these "provide part of the solution" in creating a digital currency. This signature includes both a public and a private key, the latter of which should always be kept secret. Crucial to addressing security concerns is that a digital signature is produced as a result of the message (or transaction) being sent alongside the private key. Therefore, any change – however small – to a future transaction sent by the same individual would produce a different digital signature.

The public key (which is anonymous) allows the recipient to determine whether the transaction is true or not. To provide security against hacking, unless the private key is known, an attacker would be unable to determine the digital signature without relying on brute force attacks; given that a private key is 256 digits long (made up of 1s and 0s), such an attack would take an unfathomable amount of time, based on current computing power. Both the sender and the recipient of the transaction can therefore trust that the transaction is genuine. Furthermore, to rule out the risk of an attacker simply replicating previous transactions precisely, a unique transaction ID is also included.

How does the ledger work?

To prevent double spending by individuals, or individuals spending what they do not have, the full history of transactions on the network needs to be known. This is where the ledger comes in. Because there is no central authority or holding place for the ledger, everyone on the system holds a copy of it (or can at least view one), which means they can always access the full history of transactions. To explain how the network works in practice, we use the steps outlined in Nakamoto's paper as a guide:

1. "*New transactions are broadcast to all nodes*": While everyone can see all transactions on the network, individuals would have no way of knowing which new transactions broadcast to the network are valid (and therefore which ones to accept or reject). To establish this would require everyone to complete a substantial amount of work on a consistent basis, which is impractical. Instead, designated 'nodes' perform the task of updating the ledger while following all of the rules of the network. But how do individuals who encounter two different ledgers know which one to trust?
2. "*Each node collects new transactions into a block*". A key principle of Bitcoin is that individuals accept the ledger with the largest amount of work put into it (hence the 'proof-of-work', or PoW, concept). The ledger of transactions is broken into a chain of blocks ('blockchain'), which are produced on average every 10 minutes – i.e., nodes consolidate all of the transactions made in the previous 10 minutes into blocks.
3. "*Each node works on finding a difficult proof-of-work for its block*". In the words of Nakamoto, nodes will then scan "for a value that when hashed, such as with SHA-256, the hash begins with a number of zero bits". Essentially, nodes are trying to find a number starting with a certain number of 0s by using cryptographic hash functions like SHA-256 (algorithms that turn any amount of data into a fixed-size numerical output). The more 0s at the start of the number, the longer it takes to find, or the more computing power is required to find it in a specific time. Nodes can either attempt to find this number themselves or pool their computing power to complete the task. Finding the number required involves guesswork. There is therefore no guarantee that more computing power

will ensure that a node (or group of nodes) wins the right to broadcast the next block; it will simply increase their chance of success.

4. *"When a node finds a proof-of-work, it broadcasts the block to all nodes":* The block can be considered valid once the number has been found, i.e., once PoW has been demonstrated. Not only does the 'work' carried out raise the cost of trying to attack the system, but the node that is successful also receives a fixed amount of the native currency (used within the system) as a reward for constructing the block and carrying out the PoW, as well as any transaction fees individuals have attached to their own transactions to get them processed as quickly as possible. There is therefore both a cost to cheating and a reward for following the rules. Given that the creation of a block leads to the introduction of a new amount of native currency, nodes that perform this work are referred to as 'miners'. When miners pool their resources, they are referred to as 'mining pools'. Miners may achieve the PoW requirement around the same time as others, and due to time delays multiple valid blocks could be produced concurrently. In this case, the block with the greater share of PoW will be treated as valid, and the others will be classed as 'orphaned blocks', to which no new blocks will be attached; any valid transactions that were not included in the winning block can be transferred to the next block in the chain.

5. *"Nodes accept the block only if all transactions in it are valid and not already spent":* A majority of nodes must accept that transactions are valid in order for the newly broadcast block to be added to the blockchain. In order to attack the system and create blocks with erroneous transactions within them (enabling double spending, for example), a miner or mining pool would need to achieve the PoW solution first and broadcast the invalid block to the system. While this block may initially be assumed by some miners to be valid, other miners would continue to broadcast their own valid blocks. The attacker would therefore need to ensure that they could continue to generate new blocks faster than the rest of the mining community; this would likely be unsustainable over time unless the attacker had control over a significant proportion of the computing power (or 'hash rate') on the system. Eventually, once the attacker's blockchain was overtaken by other chains, it would no longer be the longest ledger, and would be considered invalid.

6. "Nodes express their acceptance of the block by working on creating the next block in the chain, using the hash of the accepted block as the previous hash": Finally, to ensure that previous blocks cannot be rewritten with alternative transactions included (to reverse previous transactions, for example), each new block created in the chain includes the information from all previous blocks (created via a hash). This means that any attempt to change an earlier block – even by changing a single transaction – would have a cascading effect through the blockchain, as each subsequent hash included in future blocks would change accordingly. To achieve this, all blocks would have to have new PoW solutions generated for them, which would require an enormous amount of time and computing power.

Based on the above steps involved in creating a transaction and maintaining the ledger, it becomes clear that the Bitcoin network aims to provide the following properties: transparency, immutability, decentralisation, consensus-driven, security and privacy. In the main section of this investor guide, we explore the questions of whether these aims are fully realised, which other characteristics (such as speed) are sacrificed as a result, and whether these characteristics are sufficient to generate valid use cases for Bitcoin.

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