

Commodity Strategist

Bitcoin's dirty little secrets

Thematic Investing

Bitcoin supply is artificially scarce, demand drives prices

Just like in other commodities, supply and demand drive Bitcoin prices. But there are twists. Bitcoin output is capped at 21mn coins and supply growth halves every 4 years. It is designed to become increasingly constrained. So demand swings are key to price moves. Indeed, we show major institutional announcements and miner reward cuts have been followed by upward Bitcoin moves. Similarly, flows into the Grayscale Bitcoin Trust (GBTC) appear to lead weekly Bitcoin returns. A while ago, we argued a surge in trading liquidity was a key feature of the asset. Yet Bitcoin remains limited by its complex settlement process (crypto mining), and can just handle 14k transactions per hour relative to Visa's stated 236mn.

No good reason to own BTC unless you see prices going up

Bitcoin has also become correlated to risk assets, it is not tied to inflation, and remains exceptionally volatile, making it impractical as a store of wealth or payments mechanism. As such, the main portfolio argument for holding Bitcoin is not diversification, stable returns, or inflation protection, but rather sheer price appreciation, a factor that depends on Bitcoin demand outpacing supply. Unlike other asset classes, our work shows liquidity bursts measured by the Amihud ratio caused positive Bitcoin returns. Average 10y Sharpe ratio for Bitcoin is about 1.3 despite stellar returns, compared to 1 for NDX. Plus Bitcoin returns are sensitive to increased dollar demand. A net inflow into Bitcoin of \$93mn may result in a 1% price rise, while the analogue for gold is more than 20 times higher.

Our Bitcoin ESG read: low on E, mixed on S and G

Few ESG providers factor Bitcoin exposure into ESG ratings. But its Environmental score is poor: the network emits today about 60mn tons of CO₂, the same as Greece. Plus a \$1bn fresh inflow into Bitcoin may cause CO₂ to rise by the equivalent of 1.2mn ICE cars. As hash power today is mostly in coal-fired Xinjiang, a link between prices, energy demand & CO₂ means Bitcoin is tied to Chinese coal. Should prices rise to \$1mn, Bitcoin may turn into the world's 5th largest emitter, surpassing Japan. On Social & Governance issues, democratization of money and anonymity of ownership can be positive, as it is helpful in territories with corrupt financial systems and lowers costs by eliminating intermediaries. But negatives outweigh. Anonymity aids nefarious activities. Reprisk, an ESG tracker, found 181 companies faced risks linked to Bitcoin around money laundering, corruption, bribery, fraud, and breaches of data privacy.

CBDCs are kryptonite for crypto, but DeFi is intriguing

A number of central banks (notably, the ECB) are talking about launching retail digital currencies that may use mainstream technology and operate on mainstream payment rails. Central Bank Digital Currencies (CBDCs) are aimed at protecting CBs against private sector stablecoins (such as Diem), as CBs view Bitcoin et al as (spec) assets, not currencies. Also, the growth of decentralized finance ("DeFi") shows the strength of Ethereum; its computational ability is vital to DeFi applications. Yet Ethereum has similar ESG issues as Bitcoin, even if it may have better tools to tackle them. DeFi is interesting, but small and faces challenges in going mainstream. We think it hasn't a compelling lending proposition at present, and its diversification makes it challenging for the mass market.

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Refer to important disclosures on page 48 to 49.

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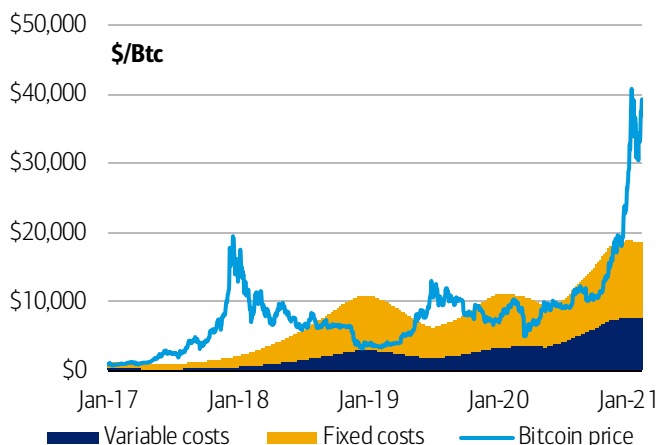
1. What drives Bitcoin prices?

Bitcoin supply is designed to become increasingly constrained

As it is the case in all other commodities, supply and demand drive Bitcoin prices. Thus, to understand why Bitcoin prices move today and how they could behave in the future, any analysis has to start with a deep look at the underlying supply and demand conditions of this commodity. For starters, it is worth noting that Bitcoin supply is capped and designed to become increasingly constrained. Also, by construction, the cost of Bitcoin mining features prominently (Exhibit 1) in price discovery, particularly energy. A quick look at the dramatic increase in prices in the past year quickly points to a major supply/demand imbalance. In fact, Bitcoin’s rise from late 2020 to now has made the previous run-up in 2017 look miniscule. Plus this time around the run up in Bitcoin prices has been joined by a surge in ether prices too (Exhibit 2).

Exhibit 1: Bitcoin cost of supply

Like other commodities, supply & demand drive Bitcoin prices, with costs featuring prominently over time

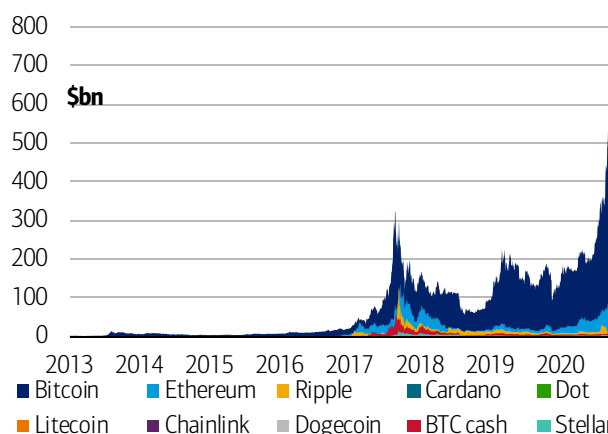


Source: Blockchain.com, asicminervalue.com, BofA Global Research estimates
Notes: Assume 5c/Kwh and annual mining hardware upgrades (20% resale value)

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Exhibit 2: Market capitalizations of cryptocurrencies

Bitcoin’s rise from late 2020 to now has more than doubled the previous run-up in 2017 and has been joined by Ethereum prices



Source: Coinmarketcap.com

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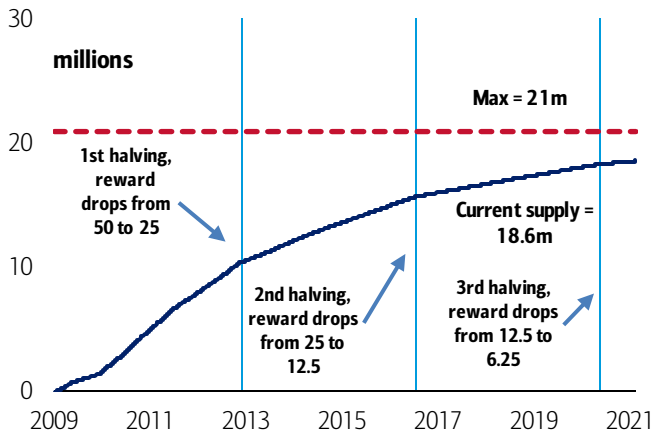
Miner rewards halve every 4 years and there is a 21 mn BTC cap

How is Bitcoin supply constrained? When Bitcoin was first launched in 2009, its supply was designed to be maxed out at 21mn coins. The view that unlimited money printing by central banks during the financial crisis would contribute to devalue fiat currencies featured prominently in the initial stage of Bitcoin. A similar view may have contributed to the recent hype too, as some investors argued that large scale monetary easing could lead to rising inflation. Yet, it is crucial to understand that Bitcoin is in fact “the fuel” that keeps the decentralized cryptocurrency system moving. New coins have to be issued constantly to “clear and settle” transactions on the blockchain. By design, the creators of Bitcoin allowed more than 100 years to get to this maximum level of 21mn coins (Exhibit 3). So given the hard cap, mining rewards have to halve every 4 years, a factor that has positively impacted prices in recent years by artificially reducing supply growth rates (Exhibit 4).



Exhibit 3: Total Bitcoin supply and halving dates

Bitcoin supply will be maxed out at 21mn coins, but it will take more than 100 years to get there...

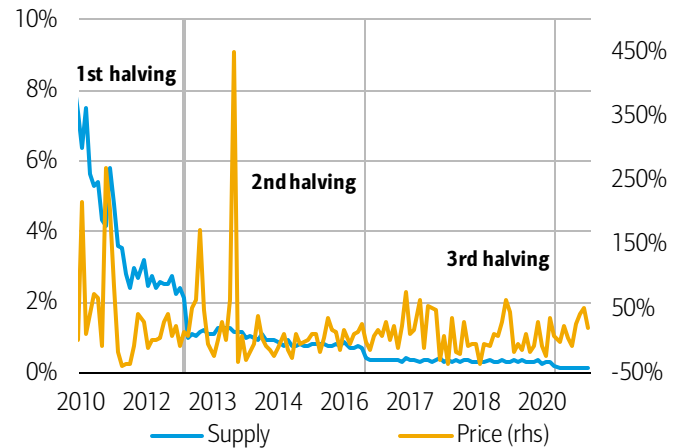


Source: Blockchain.com, Chainalysis.com

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Exhibit 4: Monthly Bitcoin supply and price growth

...as mining rewards are designed to halve every 4 years, a factor that has positively impacted prices in the past



Source: Blockchain.com, Bloomberg

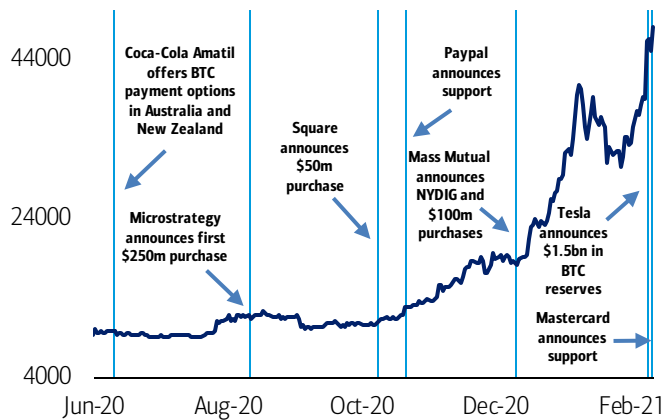
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Institutional demand has become more active in the past year...

With supply capped by design and supply growth built to halve every so often, the various swings in Bitcoin demand in recent years have been key to price changes. While there is no single way to split Bitcoin demand, we would differentiate between retail, whale/institutional, and illicit activity demand for crypto assets. For example, institutional announcements in the past year have led to major price increases (Exhibit 5), as a number of household names like Tesla, Square, and PayPal have incorporated Bitcoin into their businesses either as a treasury holding or as a means of payment. Still, reported institutional holdings generally comprise of a small portion of total Bitcoin supply, led by the Grayscale Bitcoin Trust (GBTC) (Exhibit 6).

Exhibit 5: Bitcoin price and adoption announcements

Institutional announcements in the past year have led to major price increases

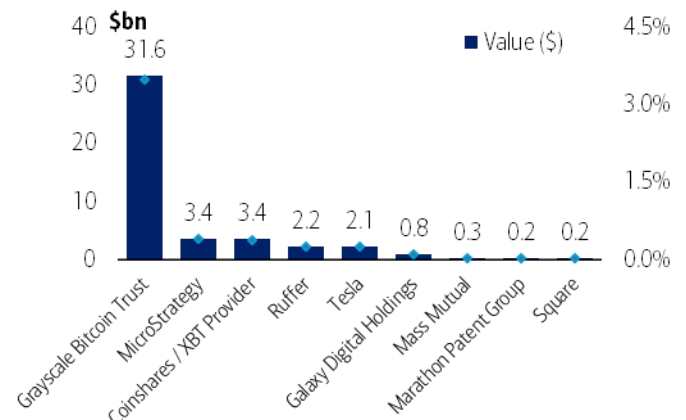


Source: BofA Global Research

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Exhibit 6: Large institutional Bitcoin holder positions

Reported institutional holdings generally comprise of a small portion of total Bitcoin supply, led by Grayscale with around \$30B



Source: Bitcoin treasuries.org, BofA Global Research estimates

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...in contrast to the retail flows that drove the 2017-18 run up

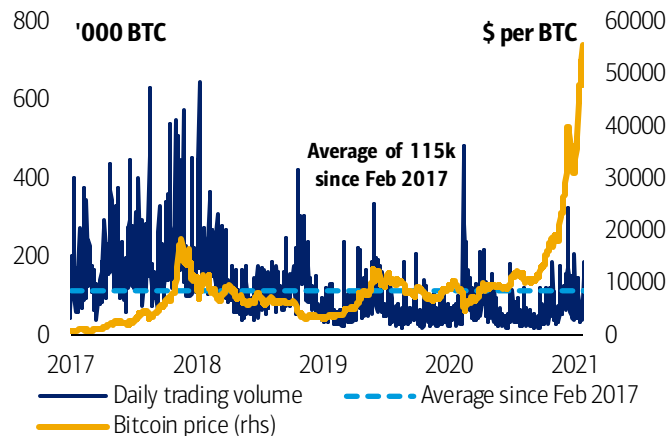
In section 2, we provide a detailed breakdown on whale/institutional demand for some of the largest accounts. We label it whale/institutional as it is unclear whether some of these billion dollar plus accounts are held by a single individual or by an institution. But it seems to us that, while a flurry of retail money to Coinbase and other crypto wallets drove prices higher in 2017 (Exhibit 7), the run up in Bitcoin prices in the past year has been more broadly driven by institutional money flows. In part, this is because



institutional scale Bitcoin purchases are hard to accommodate in such a supply constrained market. For instance, quarterly trading volume and change in ETF holdings relative to new Bitcoin supply show that institutional demand is overwhelming supply (Exhibit 8) at present, a factor that has surely contributed to rising prices. So who are the major institutional players entering the Bitcoin market?

Exhibit 7: Bitcoin aggregated daily trading volume from exchanges and price

Back in 2017, a flurry of retail money to Coinbase and other crypto wallets drove trading volumes to record levels and Bitcoin prices higher

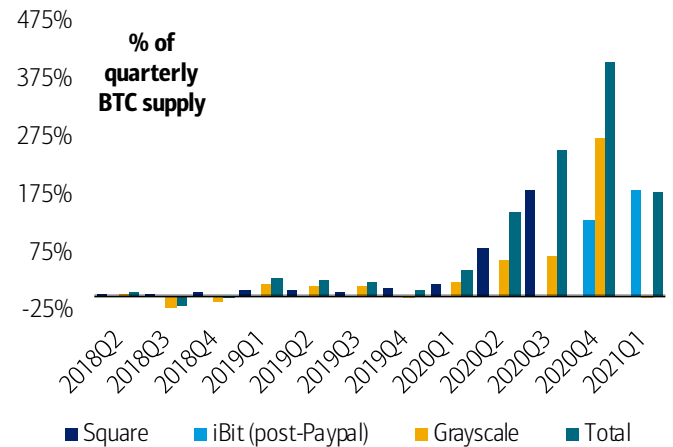


Source: Bitcoinity, Bloomberg

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Exhibit 8: Quarterly trading volume and change in ETF holdings relative to new Bitcoin supply

Now, quarterly trading volume and change in ETF holdings relative to new Bitcoin supply show that institutional demand is overwhelming supply



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

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Major institutional announcements and reward halving....

Microstrategy was probably the first billion+ dollar market cap corporation to announce Bitcoin holdings in August 2020 (Exhibit 9). The company is now holding over \$3.5bn in crypto, or about half its market cap, and plans on issuing a \$600m convertible senior note to purchase even more. Another notable transaction in the past year was Tesla's net purchase of \$1.5bn worth of Bitcoin in 4Q20. Separately, some financial companies have moved to add crypto services. For instance, Square has offered Bitcoin trading on their CashApp since 2018, and recently purchased \$50mn Bitcoin in October 2020 for their own balance sheet. On the other end, Paypal has not announced any purchases and only launched support for crypto transactions. While Paypal and Square may need to hold some crypto inventory, it's more probable they will operate like a broker dealer: a lot of the volume will likely be washed out. And last but not least, Mastercard recently announced support for crypto later in 2021, although nothing has been launched yet.

Exhibit 9: Notable recent Bitcoin adoption announcements

A wave of institutional Bitcoin adoption announcements e in Q3-2020

Date	Event	BTC amount	\$m amount
8/11/2020	MicroStrategy buys \$250m Bitcoins (21454 BTC)	21454	250
9/14/2020	MicroStrategy buys \$175m of Bitcoin (16796 BTC) to lead to an aggregate of \$425m (38250)	16796	175
10/8/2020	Square announces purchase of 4709 BTC at price of \$50m	4709	50
10/21/2020	Paypal announces service to buy/ hold, and sell crypto opening up for 346m users and 26m merchants worldwide		
12/4/2020	Microstrategy buys \$50m of Bitcoin (2574 BTC), 40284 total	2574	50
12/10/2020	Mass Mutual announces \$100m BTC purchase and \$5m equity investment in NYDIG	5405	100
12/21/2020	MicroStrategy purchases \$650m Bitcoin (29646) for aggregate of 70,470 for purchase price of \$1.125bn	29646	650
1/22/2021	Microstrategy purchases 314 BTC for (\$10m)	314	10
2/8/2021	Tesla announces in SEC filing that it holds \$1.5bn BTC	44079	1,500
2/10/2021	Mastercard announces support for cryptocurrency in 2021		
2/16/2021	Microstrategy to issue \$600m in convertible senior notes to buy BTC		

Source: BofA Global Research

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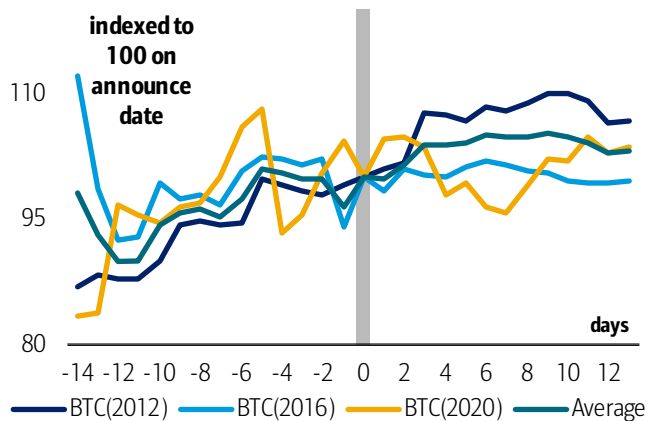


...have positively impacted Bitcoin prices, on average

A key point to note is that the steady purchases by some of these institutional buyers are a very sizeable share of the market. For instance, we calculate that the current position of Microstrategy amounts to about 0.40% of total Bitcoin supply. For Tesla, we estimate that the company purchased 44079 BTC, or about a quarter of a percent of total supply. Given the large scale of these purchase and the steady reduction in incremental supply, it is no surprise that Bitcoin prices have surged. In fact, when we look at the first three Bitcoin reward halvings, we note that each of these events led to price increases on average (Exhibit 10). Also, our work shows that Bitcoin prices have surged on average after major institutional adoption announcements (Exhibit 11).

Exhibit 10: Bitcoin prices after reward halving events

The first three Bitcoin reward halvings have led to price increases on average

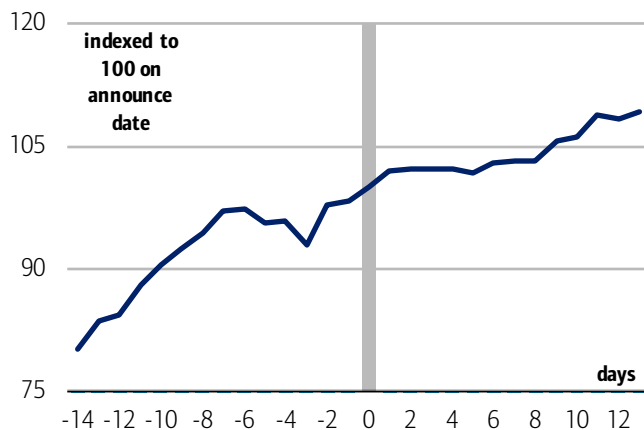


Source: BofA Global Research estimates

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Exhibit 11: Average Bitcoin price path after institutional adoption announcements

Bitcoin prices have surged on average after institutional adoption announcements



Source: BofA Global Research estimates

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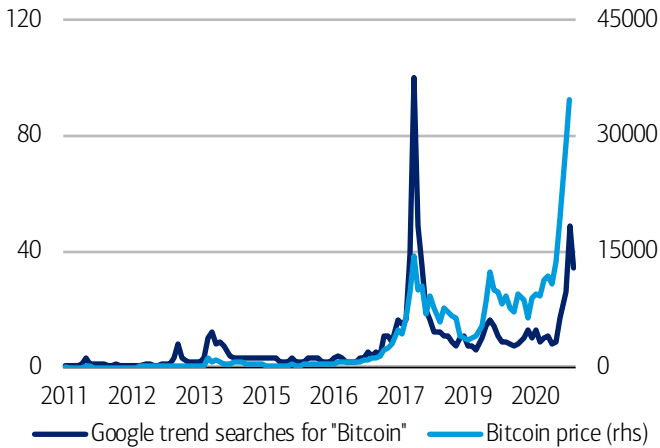
We find Bitcoin prices have been correlated to Google searches...

While it is clear that reductions in supply growth and increases in demand are behind the Bitcoin price increases of recent years, we also note that external signals seem to have provided some warning of impending movements in prices. In particular, some investors have pointed to internet searches as a potential leading indicator of crypto-currency moves. The last two large Bitcoin rallies have been accompanied by a large increase in on-line interest in crypto, as Google trends show (Exhibit 12). A similar pattern emerges with Ethereum and we show that interest has been even higher this time around than before (Exhibit 13).



Exhibit 12: Bitcoin price and Google trend searches

The last two large Bitcoin rallies have been accompanied by a large increase in interest as Google trends show...

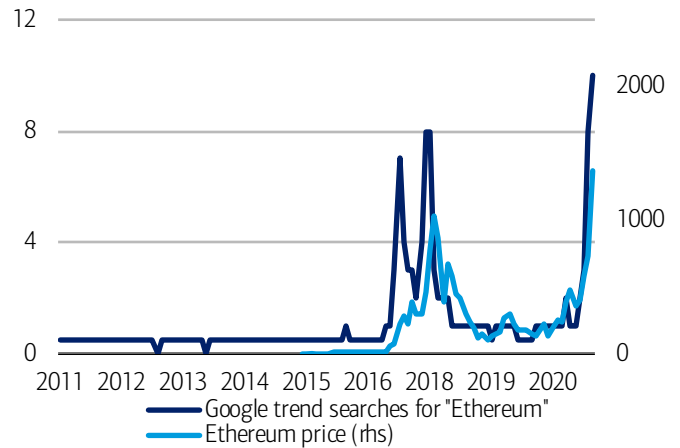


Source: Google Trends, Bloomberg

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Exhibit 13: Ethereum price and Google trend searches

... and a similar pattern emerges with Ethereum but Google interest is even higher this time around than before



Source: Google Trends, Bloomberg

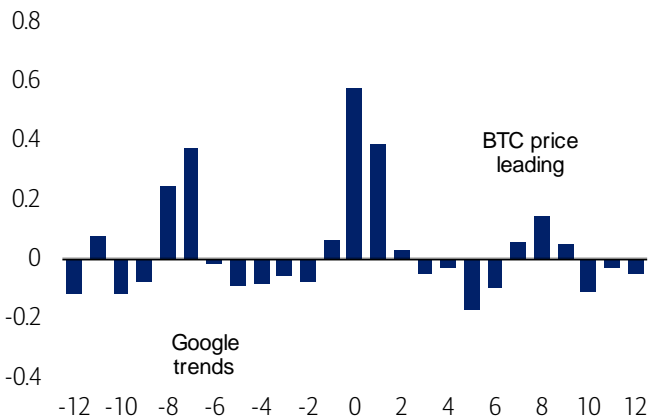
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...but our work also shows Google searches lagged Bitcoin prices

Yet correlation does not necessarily imply causation, and fortunately there are a few statistical tools that can help us establish the direction of this causality. For instance, the cross-correlations of Google trend searches and Bitcoin prices show that search trends lagged Bitcoin prices (Exhibit 14). Similarly, a Granger-causality test confirms the hypothesis that trends lagged Bitcoin prices (Exhibit 15), and not the other way around. Put differently, people do not generally search for Bitcoin and Ethereum on the internet to try to understand whether these crypto assets do or do not make good investments. Instead, statistical analysis shows people are looking for information on Bitcoin because they see prices going up.

Exhibit 14: Cross-correlations of Google trend searches and Bitcoin prices

The cross-correlations of Google trend searches and Bitcoin prices show that search trends lagged Bitcoin prices

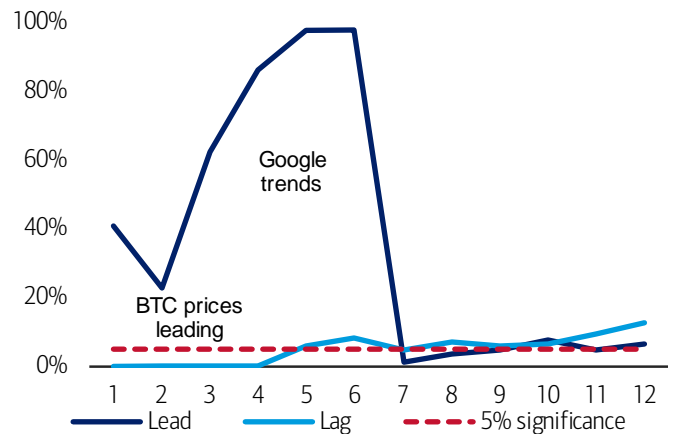


Source: Google Trends, BofA Global Research estimates

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Exhibit 15: P-values of Granger causality test of Google trends leading Bitcoin prices

A Granger-causality test confirms the hypothesis that search trends lagged Bitcoin prices



Source: Google Trends, BofA Global Research estimates

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Grayscale (GBTC) is now the largest public holder of Bitcoin

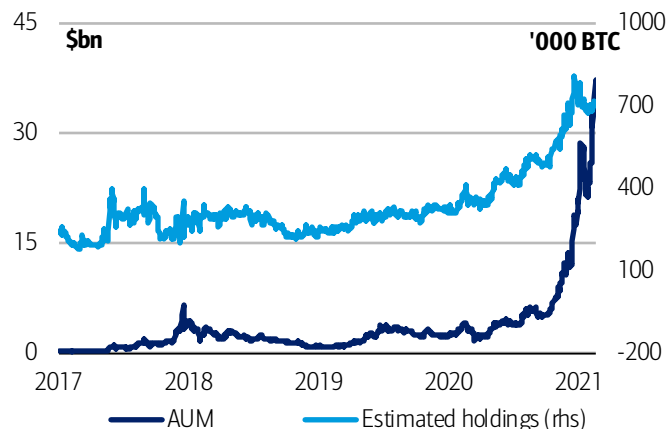
So what other public information can provide some clues regarding Bitcoin's price direction? Just like it is the case with other financial instruments, investor flows into publicly listed vehicles can also be of great use. For this reason, we looked at various financial instruments with direct exposure to crypto. We note that the market capitalization of Grayscale Bitcoin Trust has skyrocketed and the fund has accumulated



substantial BTC (Exhibit 16), with total assets now likely at 700k BTC or \$31bn or 3.5% of total supply. In that regard, we also show that the Trust has been steadily buying Bitcoin over 2020, especially in 4Q20 (Exhibit 17) and has become one of the 5 largest holders of the crypto-currency.

Exhibit 16: Grayscale Bitcoin Trust market capitalization and estimated holdings

The market capitalization of Grayscale Bitcoin Trust has risen sharply and the fund has accumulated substantial BTC

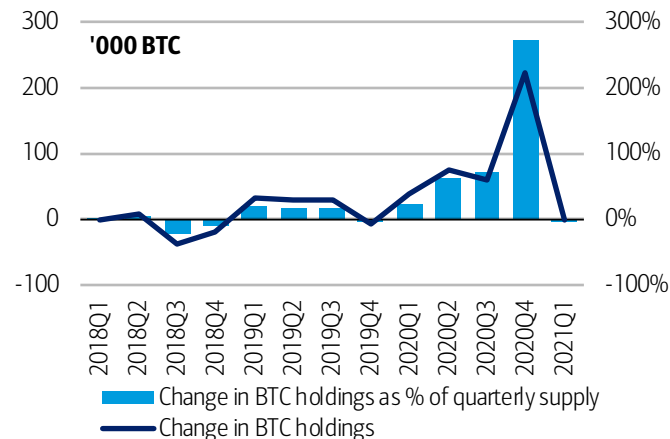


Source: Bloomberg, BofA Global Research estimates

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Exhibit 17: Grayscale Bitcoin Trust holdings The Trust was steadily buying Bitcoin over 2020, especially in Q4

The Trust has purchased over 200% of new supply in Q4 '20



Source: Bloomberg, BofA Global Research estimates

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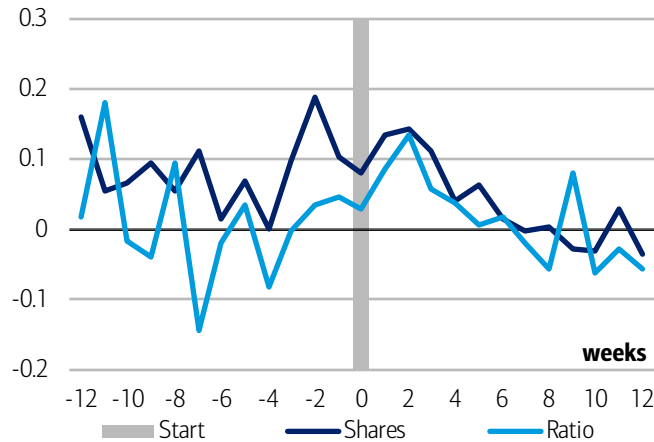
In contrast to searches, we do find GBTC flows lead Bitcoin returns?

While we have argued that Google searches provide little insight into the direction of Bitcoin prices, we do find instead that GBTC flows lead Bitcoin returns? To be precise, flows into Grayscale Bitcoin Trust as measured by changes in shares outstanding appear to have lead weekly Bitcoin returns (Exhibit 18). A similar pattern appears when analyzing cross-correlations in BTC and Granger causality tests (Exhibit 19). This is not an uncommon occurrence in the world of commodities, with physical gold and silver ETFs showing similar patterns. Inflows into GLD and SLV also lead prices of these precious metals. Unlike the price impact of money flows into futures markets, where every long position is matched by an exact short position, physically-backed ETFs reduce actual supply to the market. So as financial players mop up “physical” supply of gold, silver, copper, or even Bitcoin in this case, the spot market tightens and prices inevitably go up. In the next section, we provide a more detailed analysis of the GBTC and other crypto-financial instruments.



Exhibit 18: Cross-correlations of weekly Bitcoin returns and Grayscale Bitcoin Trust shares outstanding

Flows into GBTC measured by changes in shares outstanding seem to have lead weekly Bitcoin returns...

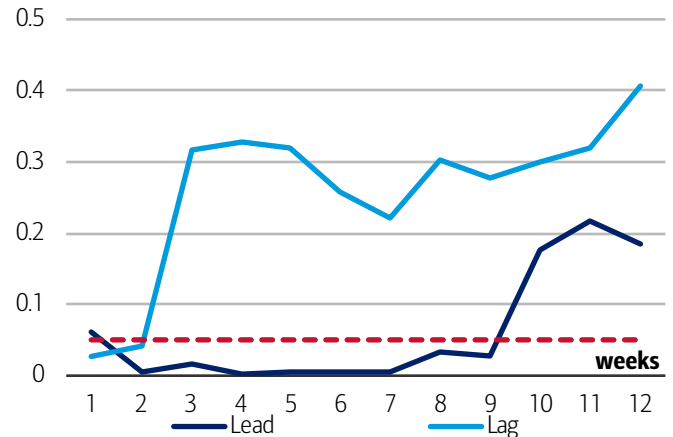


Source: Bloomberg, BofA Global Research estimates

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Exhibit 19: P-values of Granger causality tests of weekly Bitcoin returns on changes in Grayscale Bitcoin Trust shares

... as shown through cross-correlations in BTC and Granger causality tests



Source: Bloomberg, BofA Global Research estimates

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Greyscale Bitcoin Trust

Size, flows, liquidity, and comparison with global peers

Grayscale Bitcoin Trust (GBTC), is an open-ended trust that provides exposure to Bitcoin. The fund was launched in Sep-13 and started trading OTC in May-15. Currently AUM sits at \$37bn, having increased more than 10x last year, amid strong growth in demand (see Exhibit 20). Indeed, AUM increased by \$16bn in 2020 and a staggering \$20bn YTD. For context, at ~3.5%, its share of Bitcoin’s market cap has more than doubled since Bitcoin’s low of 16-Mar-20 (Exhibit 20).

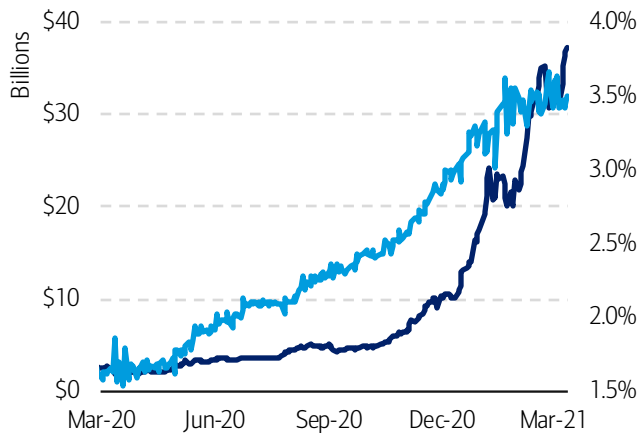
In terms of trading liquidity, GBTC dominates all other main global Bitcoin-focused funds/ETPs. For instance, the Bitcoin Tracker One (COINXBE SS), the first Bitcoin exchange-traded product, ranks fourth, with a trading value that is equal to 4% of that of GBTC (Exhibit 21). BTCE, which is the first ETP in a physically backed structure similarly to physically-backed gold and silver ETFs, ranks third, and its turnover is only 6% of that of GBTC.

Interestingly, until recently Bitcoin ETPs were only available in Europe -- in Switzerland, Sweden and Germany. On 11-Feb, the Ontario Securities Commission (OSC) approved the Purpose Investments’ BTCC (North America’s first Bitcoin ETF and the first Bitcoin product that’s officially labelled an exchange-traded fund). The Canadian ETF debuted on 18-Feb. Since then, investors have on average exchanged \$64 million worth of shares, slightly less than one-fifth of the GBTC average daily turnover (\$339mn). Lastly, the Canadian Bitcoin Fund (QBTC/U CN) is a closed-end fund with a structure similar to GBTC’s. As such, it too can trade at significant premium to NAV (see below section).



Exhibit 20: GBTC AUM in \$, and as a %-age of Bitcoin's market cap (rhs)

GBTC AUM has exploded over the past year, both in absolute terms and relative to Bitcoin's market cap

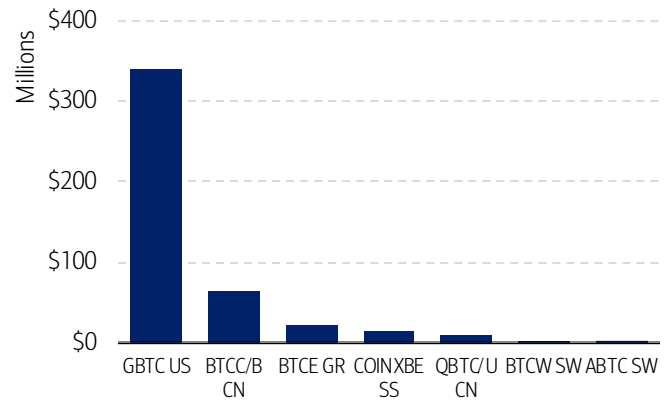


Source: Bloomberg

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Exhibit 21: 6m average of daily \$ turnover

GBTC dominates global volume among global Bitcoin funds/ETPs



Source: Bloomberg

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Deviations from NAV, creation/redemption, implications of a crypto ETF launch

GBTC trading started in May-15. Since then, GBTC has traded above NAV most of the time (see Exhibit 22). Indeed, while GBTC does not currently operate a redemption program, new shares can be created via private placements for accredited investors with a 6-month lockup on sales. Interestingly, the statutory holding period was halved on Jan-21 when Grayscale's Bitcoin Trust became officially registered as a SEC reporting company. The confluence of these factors makes supply of new shares relatively inelastic to every day changes in demand, such that increasing demand results in higher premiums in the short term. In other words, GBTC can behave as a quasi-closed-end fund.

Exhibit 22: GBTC daily deviations from NAV

Typically GBTC has traded at a premium to NAV; however, since 23-Feb-21 GBTC has traded below NAV in all except two trading days, with discounts as steep as 12%

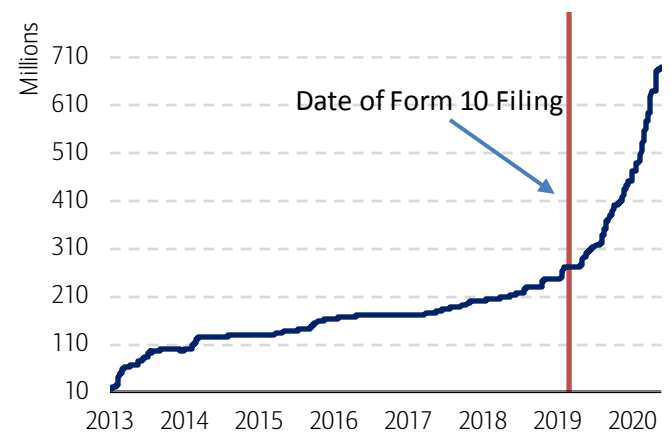


Source: Bloomberg

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Exhibit 23: GBTC number of shares outstanding

GBTC's Form 10 filing with the SEC in Nov-19 to become registered as a SEC reporting company catalysed a parabolic increase in news shares on the prospects of a shorter lockup period



Source: Bloomberg

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Exhibit 24: CME Bitcoin aggregate fut OI notional

Liquidity Bitcoin futures has improved substantially, with, for instance, CME futures surpassing the 3B dollars notional mark; futures provide a new hedging tool for private-placement investors in GBTC, which lacks options activity



Source: BofA Global Research

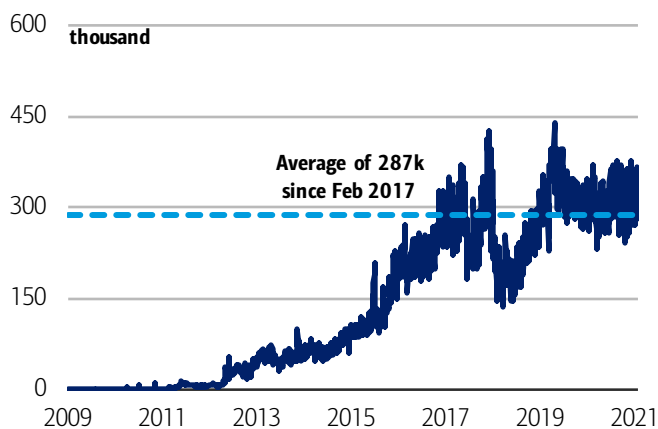
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Daily Bitcoin transactions have remained steady as prices rose

We first discussed the liquidity properties of Bitcoin three and a half years ago. Back then, we believed the surge in Bitcoin trading liquidity was perhaps one of the most important features of this emerging asset. Yet, much of the growth in crypto in recent years has not translated into increased Bitcoin liquidity. Rather, the number of daily Bitcoin transactions has averaged 287k in the past four years (Exhibit 25). While renewed interest is apparent, much of the increased institutional focus has translated into rising prices (and thus transactional values) and not into rising Bitcoin liquidity and not even in new Bitcoin addresses (Exhibit 26).

Exhibit 25: Number of daily Bitcoin transactions

The number of daily Bitcoin transactions has averaged 287k in the past four years and renewed interest is apparent...

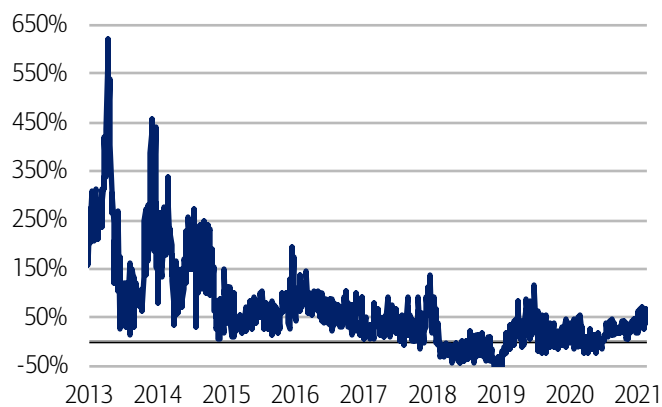


Source: Blockchain.com

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Exhibit 26: Year-on-year growth in Bitcoin addresses

... but the growth in accounts has been stable over last 3 years



Source: Blockchain.com

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Bitcoin transactions reflect higher fees and bigger players

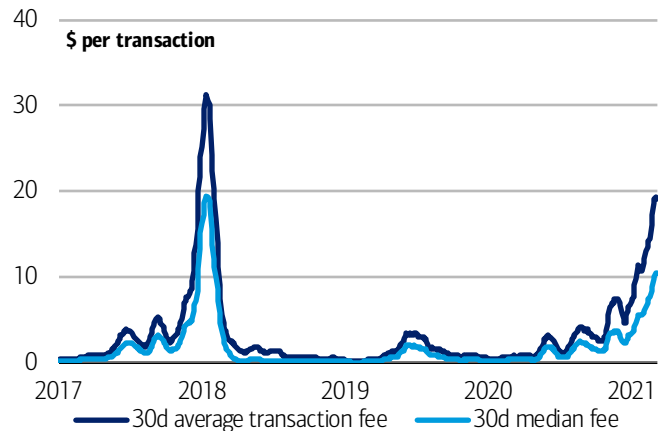
With the resurgence in Bitcoin interest, are there any features in transactions that are particularly striking? For starters, transaction fees have soared in 2021, with the 30-day average close to \$20 per transaction and median fees just north of \$10, and quickly closing in on peak levels seen in 2017-2018 (Exhibit 1). Taken as the ratio of total daily transaction fees to number of transactions, this suggests that even with more activity, participants are paying more to join the party. Furthermore we find that while the number of trades per account has dropped, total output (amount of transaction including



change) per transaction jumped late 2020 and has remained at high levels akin to 2017-2018 (Exhibit 2). Total output includes the amount of transactions and *change*, the amount of excess Bitcoin sent in a transaction above the transaction value that is returned following settlement¹. Parsing out *change*, estimated average transaction value (total output net of change) remains low, suggesting that average transactions have declined in size. However because average total output remains high, accounts making these transactions are likely facilitating them with larger positions, resulting in larger *change* and thus higher output despite estimated transaction values being low.

Exhibit 27: 30-day average of daily total transaction fees per number of transactions and median transaction fee

Transaction fees have been rising as of late and are approaching 2018-2018 levels

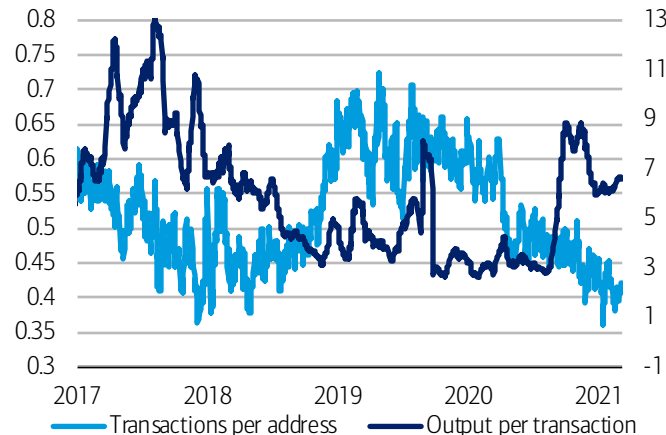


Source: Blockchain.com, Coinmetrics.op

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Exhibit 28: 30-day average of daily transactions per address and total output per transaction

Transactions per address have been dropping, but output per transactions jumped late in 2020



Source: Blockchain.com, BofA Global Research estimates

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Futures volumes have been growing at a relatively rapid pace

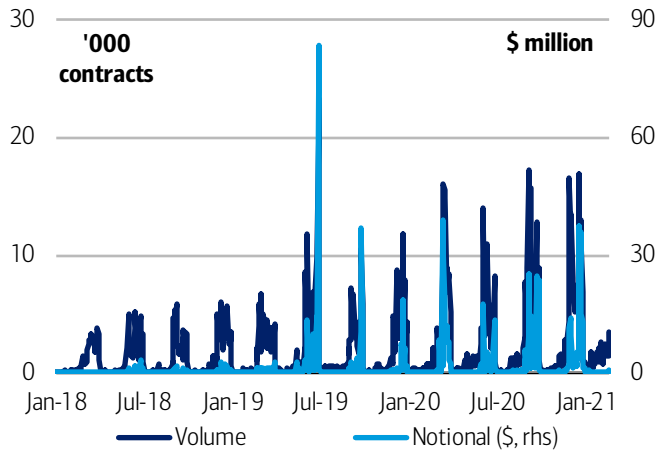
The same cannot be said of other financial instruments that support crypto assets. Bitcoin futures volume has been on the rise for several years now and we show that it tends to increase towards the end of the month as it approaches settlement. Even then, the notional amount of futures trading is still magnitudes below actual spot BTC volume (Exhibit 27). Note that in other commodity markets, the reverse is true. Daily futures and swaps liquidity in copper, gold, or oil is a multiple of the traded spot market value of these commodities. And as a side note, Bitcoin futures appear to be net short by the speculative community, suggesting that these instruments may in fact be used more for hedging than to establish fresh long Bitcoin positions (Exhibit 28).

¹ Bitcoin transactions can only be paid for in combinations of previous transactions or inflows, resulting in “change” in certain transactions. Every inflow into an account from a previous transaction can be viewed as a “bill”, analogous to bills in fiat currency. If a new transaction is made that is not the exact amount of one of the previous transactions or a combination of them, the owner initially sends a larger amount, namely the sum of previous transactions large enough to cover the desired transaction value. A change address is then created to send the difference between the initial amount sent and the actual desired transaction value, or the change, back to the sender.



Exhibit 29: CME front month Bitcoin futures trading volume

Bitcoin futures volume increases towards the end of the month, but the notional amount is still magnitudes below BTC volume

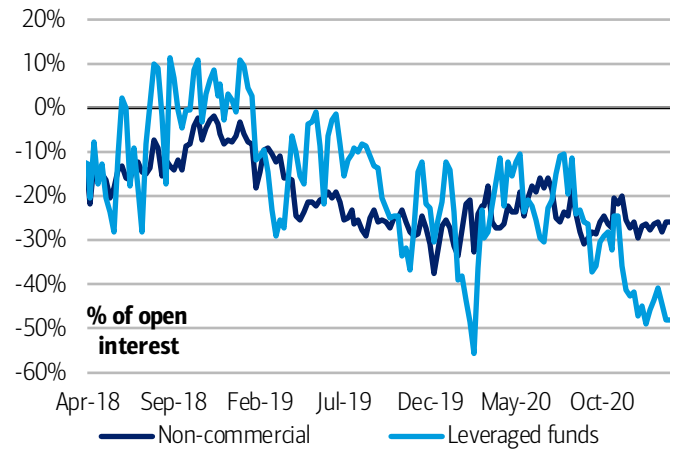


Source: CME

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Exhibit 30: CFTC CME Bitcoin futures positioning

Bitcoin futures appear to be net short by the speculative community, suggesting that they may in fact be used more for hedging



Source: CFTC

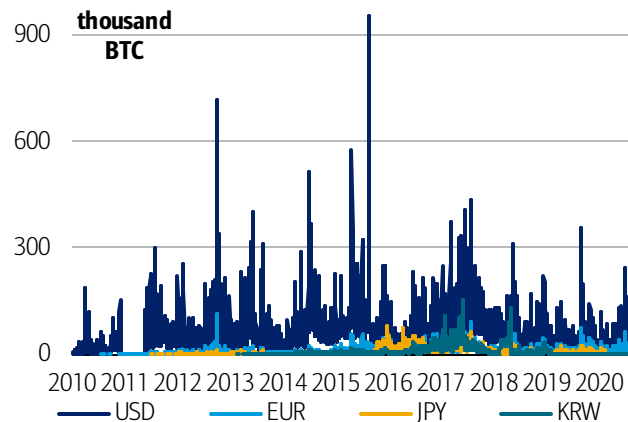
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Dollar crosses increasingly dominate Bitcoin transactions...

Another important aspect of price formation relates to the currency that Bitcoin is traded in. It is often said that a weaker USD helps gold prices rise and vice-versa. In the case of Bitcoin and Ethereum, dollar crosses increasingly dominate Bitcoin transactions. Nowadays, about 80% of Bitcoin is exchanged in dollars (Exhibit 29), while other currencies like the EUR, the JPY, and the KRW account for 19%, .01%, and .43% of Bitcoin trading, respectively. Another way to look at liquidity is to analyze the Amihud ratio, a key trading metric that represents the illiquidity of an asset as proxied by the absolute value of daily returns scaled by trading volume. For most assets, especially the most illiquid (high Amihud ratio), we expect higher illiquidity to translate to higher returns as buyers are compensated for an illiquidity premium. However with Bitcoin, we are finding that increased liquidity is actually supporting prices, with the largest impact coming from dollar and KRW liquidity, the opposite of traditional assets (Exhibit 30).

Exhibit 31: Daily Bitcoin trading volume by major currency of exchange, measured in thousand BTCs

The bulk of Bitcoin is transacted in dollars, with other important currencies including the euro, the yen and the won

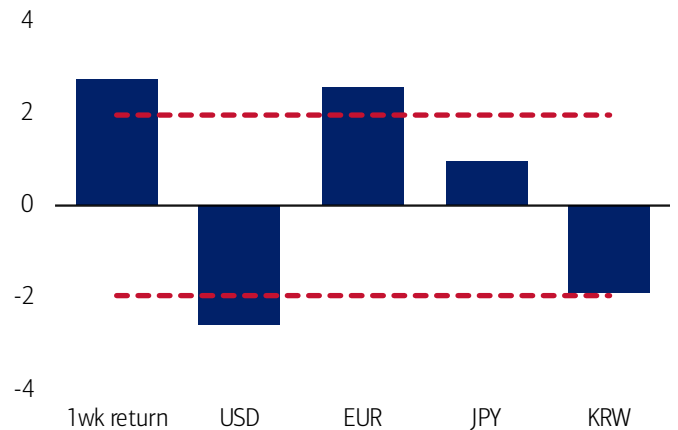


Source: data.Bitcoinity.org

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Exhibit 32: T-statistics for regression of 1 week Bitcoin returns on lagged returns and changes in Amihud liquidity by currency

With Bitcoin, we are finding that increased dollar and KRW liquidity are supporting prices



Source: Bitcoinity, BofA Global Research

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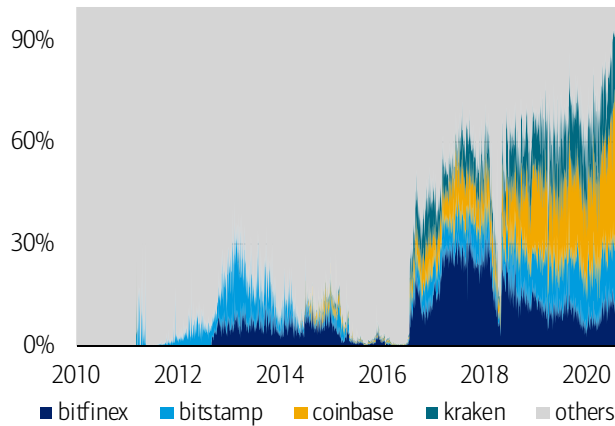


...with Coinbase market share increasing over other exchanges

One last point to note on our supply/demand analysis of Bitcoin is where it trades and where it is held. From that viewpoint, we show that the share of Coinbase as an exchange has increased to 40% in recent years (Exhibit 31) as the US company has become the leading wallet and exchange. Again, running a similar analysis using the Amihud ratio, we find that Coinbase volumes are now adding to Bitcoin liquidity and subsequently supporting prices (Exhibit 32).

Exhibit 33: Composition of Bitcoin trading volume by exchange

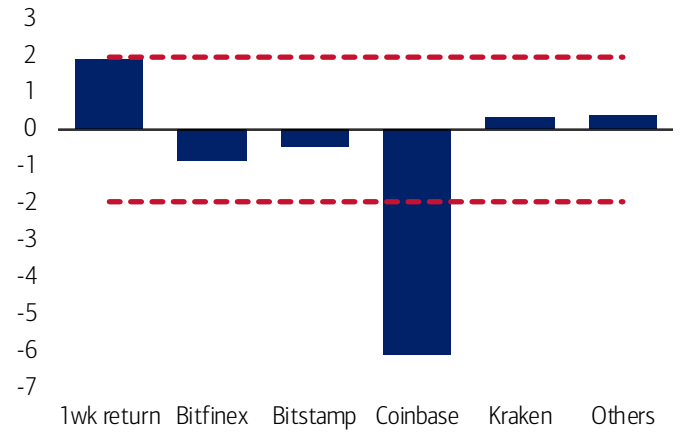
The share of Coinbase as an exchange has increased in recent years to more than 25% of the trading market...



Source: Bitcoinity
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Exhibit 34: T-statistics for regression of 1 week Bitcoin returns on lagged returns and changes in Amihud liquidity by exchange

...and now we find that Coinbase volumes are adding to Bitcoin liquidity



Source: Bitcoinity, BofA Global Research

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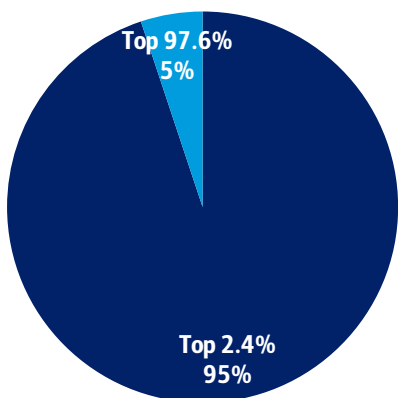
2. How does Bitcoin compare to traditional portfolio assets?

About 95% of Bitcoin is controlled by just 2.4% of the accounts...

In our view, one of the main challenges that Bitcoin faces to gain mainstream adoption going forward is its high concentration ownership ratio. As a reference point, we note that about 95% of total Bitcoin is owned by the top 2.4% of addresses with the largest balances (Exhibit 33). We also show that the distribution is heavily skewed towards the largest accounts (Exhibit 34). By comparison, the latest Fed data suggests that the top 1% of Americans control about 30.4% of all household wealth in the US. In our view, the fact that such a small percentage of Bitcoin accounts hold most of the BTC in circulation makes this instrument impractical as a payments mechanism or even as an investment vehicle. It can also create social and governance issues, as we will discuss in the section 3.

Exhibit 35: Distribution of Bitcoin value by fraction of addresses (accounts)

95% of total Bitcoin is owned by the top 2.4% of addresses with the largest balances...

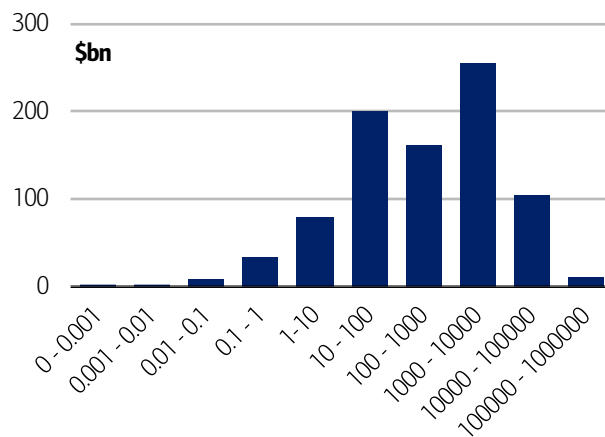


Source: Coinmarketcap.com

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Exhibit 36: Distribution of Bitcoin holdings by balance

... as the distribution is heavily skewed towards the largest accounts



Source: Coinmarketcap.com

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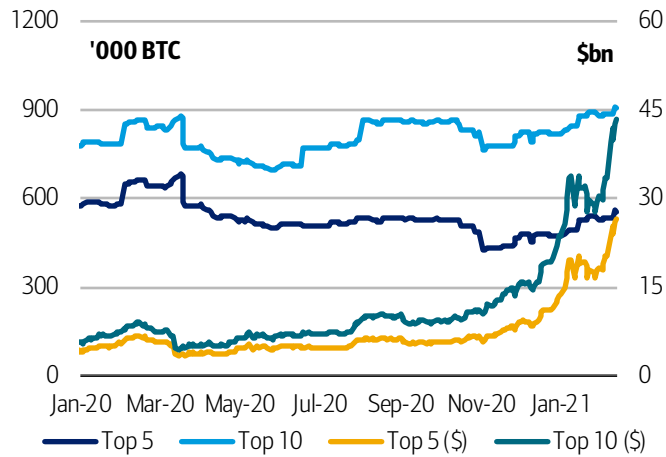
...and large holders have kept accumulating through the rally

An often misunderstood detail on Bitcoin is that many whale/institutional account holders are actually buying, rather selling BTC. Looking at detailed blockchain records, we find that the largest addresses have not been selling in aggregate (Exhibit 35) since the pandemic began. Also, we note that Bitcoin has a large number of dormant accounts, a factor that likely drains liquidity from the crypto-asset. For instance, the top 100 dormant Bitcoin addresses over the past year comprise of over 7% of total supply (Exhibit 36). Who are these dormant holders? It is hard to say, although recent news reports for example ([New York Times: Lost Passwords Lock Millionaires Out of Their Bitcoin Fortunes](#)) identified a holder of a lost a crypto key with \$220mn worth of Bitcoin. As much as 20% of existing Bitcoin appear to be in lost or in stranded wallets, according to crypto data firm Chainalysis.



Exhibit 37: Holdings of largest Bitcoin addresses by balance

The largest addresses have not been selling in aggregate...

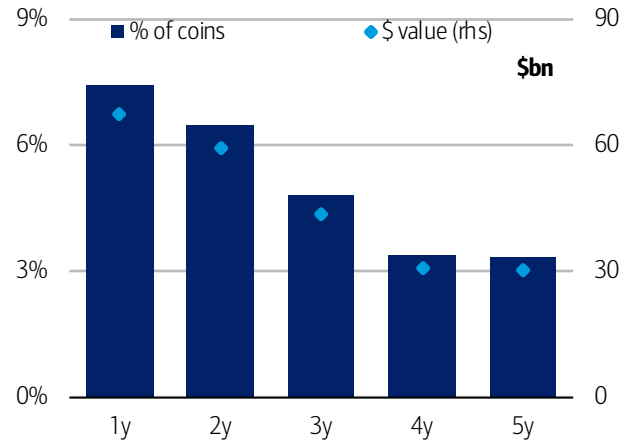


Source: BitInfoCharts.com

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Exhibit 38: Top 100 dormant Bitcoin addresses by time since last transaction

The top 100 dormant Bitcoin addresses over the past year comprise of over 7% of total supply



Source: BitInfoCharts.com

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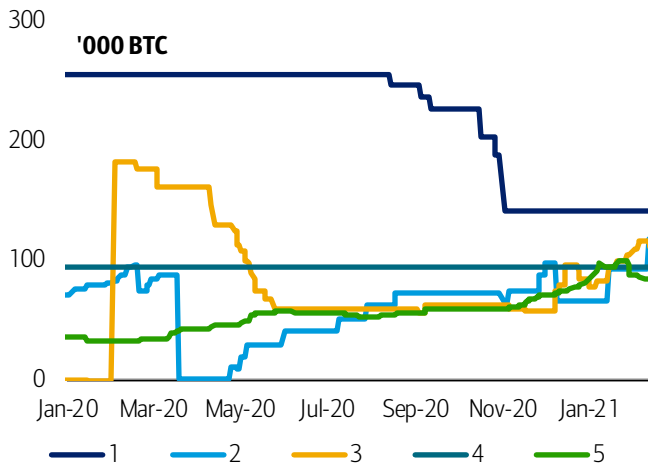
Tracking the largest Bitcoin addresses

The richest wallets have grown and a few appear new at first glance...

Given the concentrated nature of Bitcoin holdings at the top end of the spectrum, we take a detailed look into the individual activity for the top 10 Bitcoin addresses in search of any notable behavior. For starters, as with the aggregate, we find that the top 5 richest wallets outside of the largest wallet have been steadily accumulating Bitcoin over the past year, adding to their already sizeable positions (Exhibit 37). This holds true for the top 5-10 richest wallets as well and at first glance it appears that 3 of the richest wallets jumped into the market with sizeable positions starting last summer and extending into the fall (Exhibit 38).

Exhibit 41: Top 5 richest Bitcoin wallets

Top 5 richest wallets have been accumulating coins over the past year

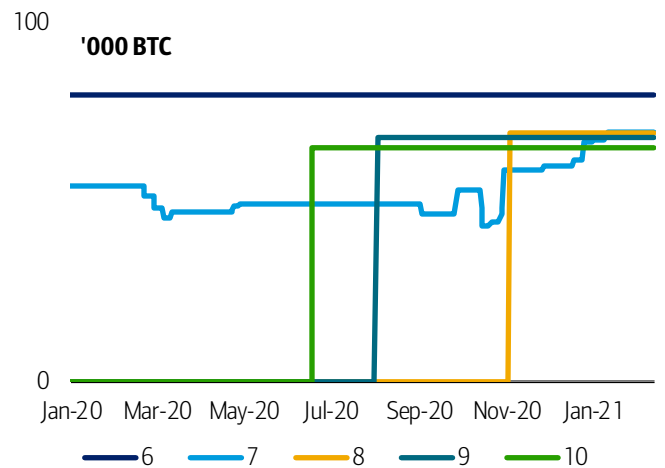


Source: BitInfoCharts.com

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Exhibit 40: Top 5-10 richest Bitcoin wallets

... and 3 of the top 10 richest wallets appear like completely new buyers who jumped into the market with sizeable positions at first glance...



Source: BitInfoCharts.com

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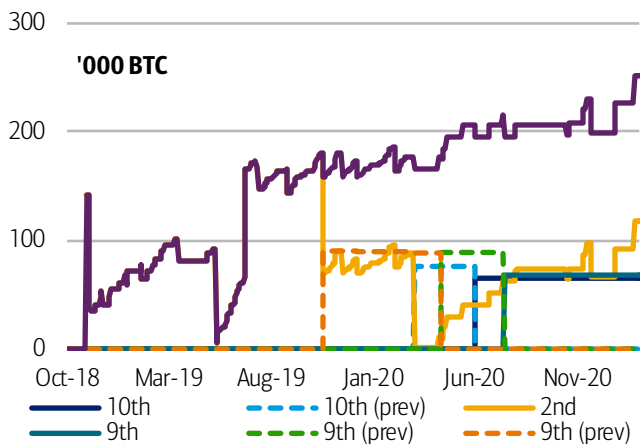


... but following transactions shows even higher concentration

Looking at account balances in isolation suggests that new institutional/whale money was introduced into the market last year. However upon deeper inspection, we find that this is in fact not the case as the money introduced into the top accounts has been circulating for some time. We tracked transactions across wallets and found that the 9th and 10th largest wallets, which appeared with size last summer are in fact offshoots of the second wallet (Exhibit 39). Following the funds backwards, we find that the 9th and 10th wallets were a result of transfers from intermediate accounts, all of which led back to the second wallet as sizeable drops in this wallet were matched by an influx of funds into the intermediate accounts. In other words, the 2nd wallet holder likely controls the 2nd, 9th, and 10th wallets and has been spreading out funds across rather than selling in size late 2019 and early 2020. Similarly, while the 8th largest account appears to be a new account, it was actually just a transfer from a previous account of similar size that was the result of a combination of two smaller accounts in 2013.

Exhibit 41: History of 2nd, 9th, and 10th richest Bitcoin addresses with intermediary accounts

The 2nd, 9th, and 10th largest accounts likely have the same owner as any sharp drops in balances are bulk transferred to the newer accounts

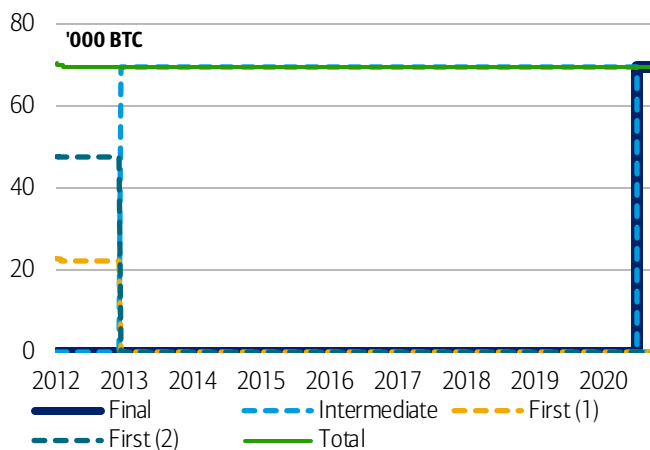


Source: BitInfoCharts.com

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Exhibit 42: History of 8th richest Bitcoin address with intermediary accounts

The 8th largest account is a legacy position that combined two accounts in 2013 and then transferred to the 8th largest address in November 2020



Source: BitInfoCharts.com

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There is simply no other major asset that shares Bitcoin's features

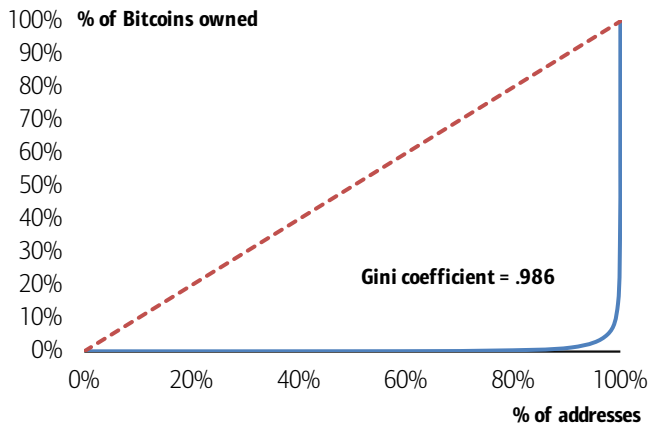
Bitcoin is clearly a unique asset class by way of its supply mechanics, ownership concentration, and even historical performance. Ownership concentration is particularly severe. A small set of total accounts owns a massive portion of Bitcoin, leaving the asset vulnerable to sharp price swings on account of movements in these “whale” accounts. Indeed looking at the income distribution, we find that Bitcoin inequality is unprecedented and easily eclipses countries plagued with the most income inequality as measured by its remarkably high Gini coefficient (Exhibit 41). However even with susceptibility to large movements on account of ownership concentration and limited



supply, the asset has produced relatively high risk-adjusted returns despite having one of the highest volatilities in the cross-asset space (Exhibit 42).

Exhibit 43: Percentage of Bitcoin owned relative to percentage of addresses

Bitcoin inequality is unprecedented and easily eclipses even countries plagued with the most income inequality

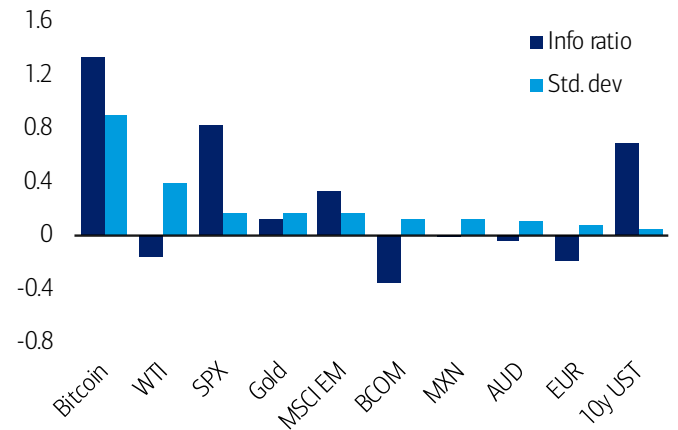


Source: Coinmarketcap.com, BofA Global Research estimates

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Exhibit 44: Bitcoin and cross asset daily return information ratios and standard deviations over past 10 years

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



Source: BofA Global Research estimates

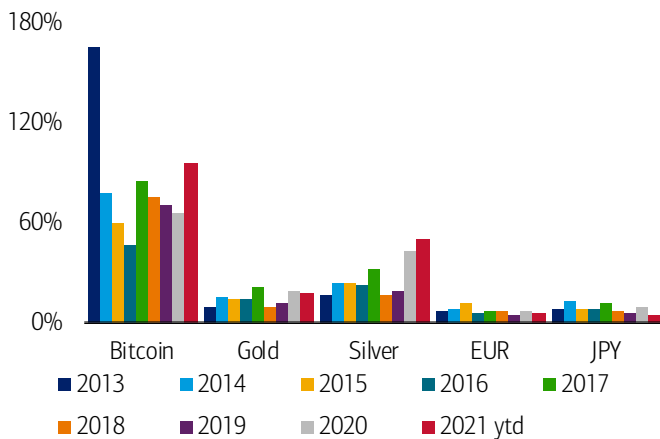
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Even after a decade of trading, Bitcoin remains very volatile...

Another feature that makes crypto-assets impractical as a payments or store of wealth mechanism is their persistently high volatility. As an example, Bitcoin volatility is well above that of FX, gold, and even silver. Bitcoin volatility in 2021 is already the second highest in history year-to-date (Exhibit 43). The persistently high volatility levels are a big concern, as they suggest that even after 10+ years of trading and major episodes of price appreciation, Bitcoin has failed to develop some price stability. If anything, Bitcoin volatility has been rising with prices during recent months. And if we had to make an observation on Bitcoin's realized volatility, it is that it appears to have had some cyclicity too (Exhibit 44).

Exhibit 45: Yearly annualized standard deviation of daily returns

Bitcoin volatility is well above that of FX, gold, and even silver, and is already the second highest in history year-to-date

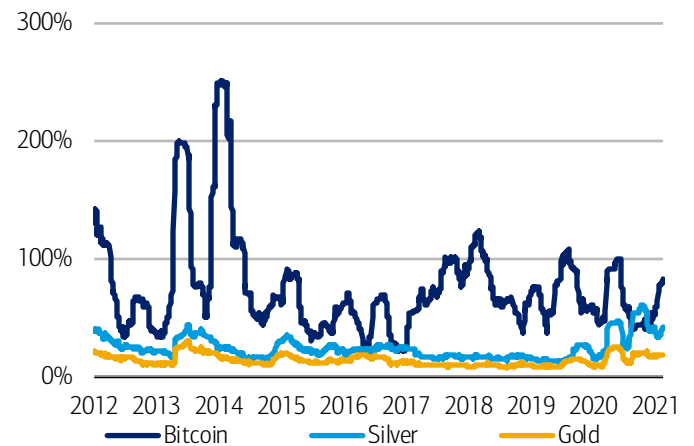


Source: BofA Global Research, Bloomberg

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Exhibit 46: 3-month rolling annual standard deviation of daily returns

Bitcoin volatility has been rising over recent months, and vol trends appear to have some cyclicity



Source: BofA Global Research, Bloomberg

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...and Bitcoin volatility still exceeds that of many EM FX...

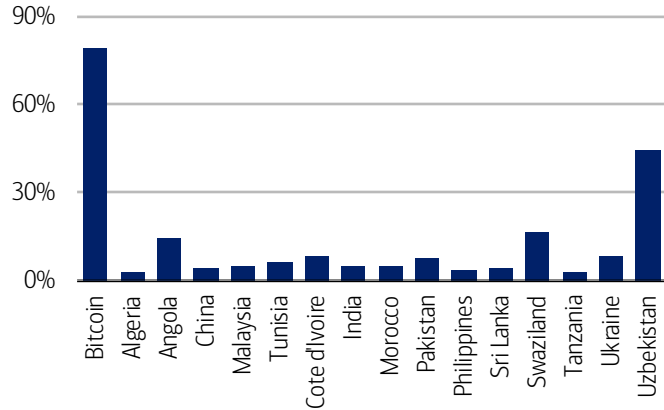
Just like Bitcoin volatility is multiples of the vol observed in other commodity markets, we also note that it vastly exceeds that of many Emerging Market FX. For instance, Bitcoin is more volatile than currencies with severe capital controls (Exhibit 45), which



tend to be EM countries with high inflation (Exhibit 46). Thus, we believe the claim that crypto could replace some volatile emerging market currencies sits on weak grounds and is only supported by the massive price appreciation observed in recent years-- appreciation which is a function of the major supply and demand imbalance discussed in section 1 of this note.

Exhibit 47: Annualized standard deviation of weekly returns

Bitcoin is more volatile than currencies with severe capital controls...

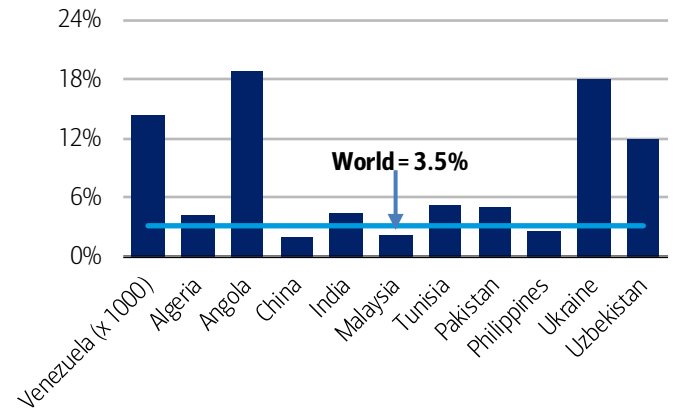


Source: BofA Global Research, Bloomberg

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Exhibit 48: Average inflation rates since 2014

... which tend to be EM countries with high inflation such as Venezuela or the Ukraine



Source: BofA Global Research, Haver

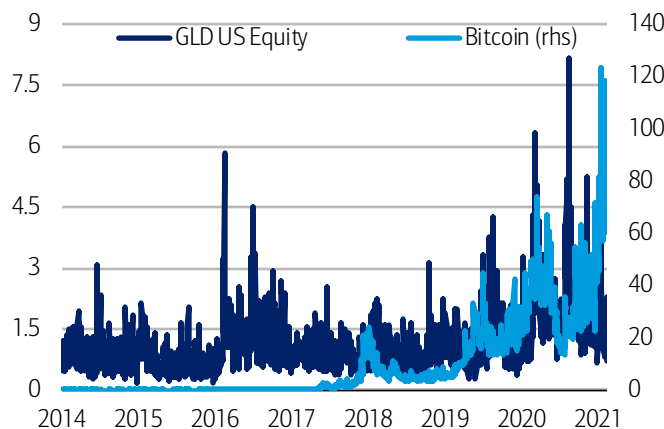
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... and rising \$ volumes are increasing vol and supporting prices

Having said all of that, there are some positive developments on the liquidity front when it comes to Bitcoin. For instance, the notional dollar value of Bitcoin trading volume has risen to over 10x that of GLD in the past 2 years (Exhibit 47), even if mostly driven by price appreciation. So large transactions are increasingly common in the crypto space. Also, a rolling Amihud liquidity analysis shows that Bitcoin liquidity is now helping speed up price gains as participants find the market more readily accessible and legitimate (Exhibit 48). Note that this same analysis provided similar conclusions during the retail-driven rally of 2017-18.

Exhibit 49: Daily trading volume for GLD and Bitcoin

The notional value of Bitcoin trading volume has exploded to over 10x that of gold in the past 2 years

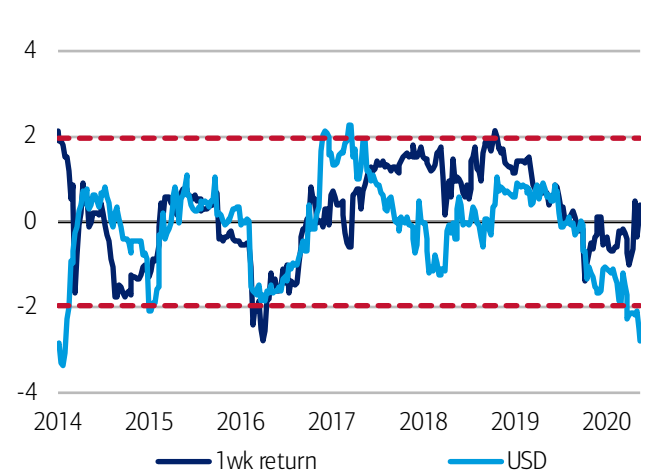


Source: Coinmarketcap.com

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Exhibit 50: Rolling 52-week t-statistics of regression of weekly Bitcoin returns on lagged returns and Amihud liquidity by FX

A rolling Amihud liquidity analysis shows that Bitcoin liquidity is now helping speed up, price gains



Source: Bitcoinity, BofA Global Research

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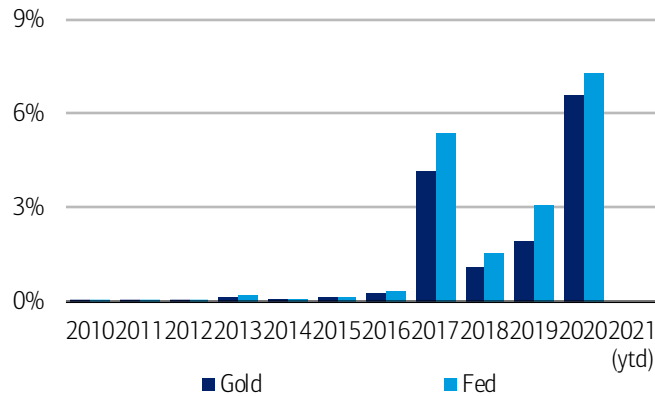


The market value of Bitcoin has been rising relative to gold

Another way to look at the importance and growth trajectory of Bitcoin is to compare it to the size of other major physical and financial assets. In particular, we believe assets like the Fed’s balance sheet or the price of gold are relatively good reference points for Bitcoin. In that regard, we note that Bitcoin market capitalization is still less than 10% of gold and the Fed’s balance sheet even after years of steady growth (Exhibit 49). Even then, the value of Bitcoin is enormous relative to the largest silver ETF (SLV) and the physical stock of silver in vaults (Exhibit 50), underscoring the diminishing importance of silver as a reserve asset.

Exhibit 52: Bitcoin market capitalization relative to gold, Fed balance sheet

Bitcoin market capitalization is still less than 10% that of gold and the Fed’s balance sheet...

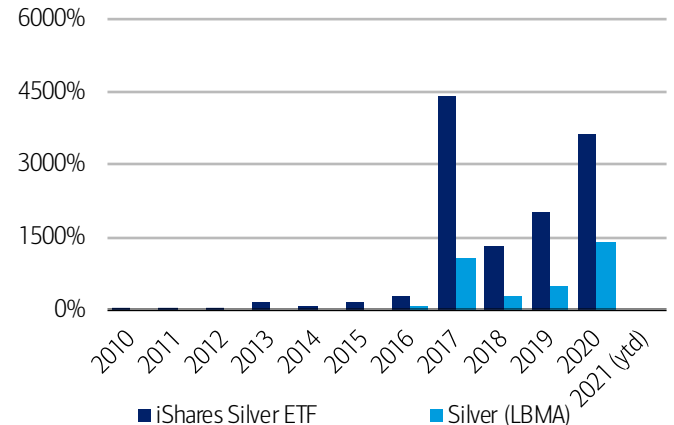


Source: BofA Global Research estimates, Bloomberg

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Exhibit 52: Bitcoin market capitalization relative to silver ETF SLV and the silver at the LBMA

... but is enormous relative to SLV and the physical stock of silver in vaults



Source: BofA Global Research estimates, Bloomberg

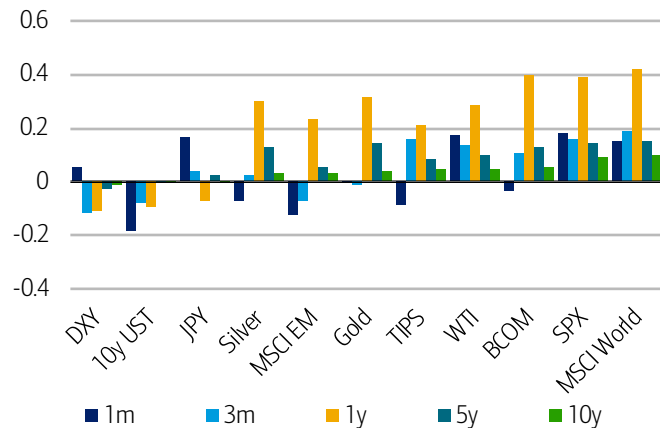
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Bitcoin no longer appears uncorrelated to other major risk assets...

Perhaps the biggest change in Bitcoin pricing dynamics since we last wrote about them in 2017 is the change in correlations to financial assets. For starters, Bitcoin no longer appears uncorrelated to other major risk assets. In fact, we find the crypto-currency more positively correlates with equities and commodities, while it is neutral/slightly negatively correlated to haven assets such as the dollar and US treasuries (Exhibit 51). And as a new development in the crypto space since the pandemic, Bitcoin correlations with risk assets have tended to move in lock step even across asset classes (Exhibit 52).

Exhibit 53: Bitcoin correlations with asset classes

Bitcoin more positively correlates with equities and commodities, while neutral/slightly correlated to haven assets such as the dollar and US treasuries

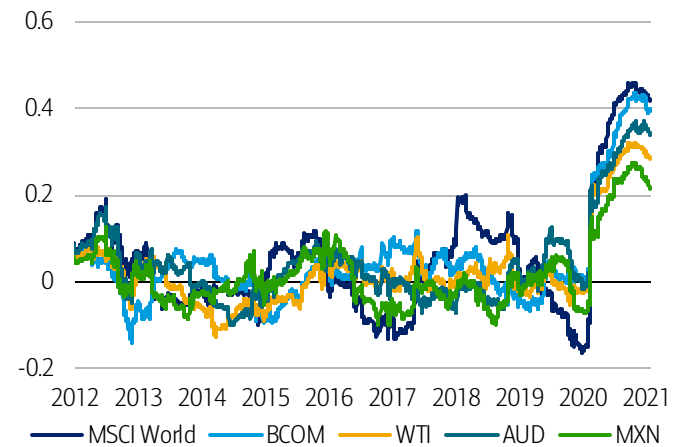


Source: BofA Global Research estimates

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Exhibit 54: Rolling 252-day Bitcoin correlations with risk assets

Bitcoin correlations with risk assets such as MSCI World tend to move in lock step even across asset classes



Source: BofA Global Research estimates

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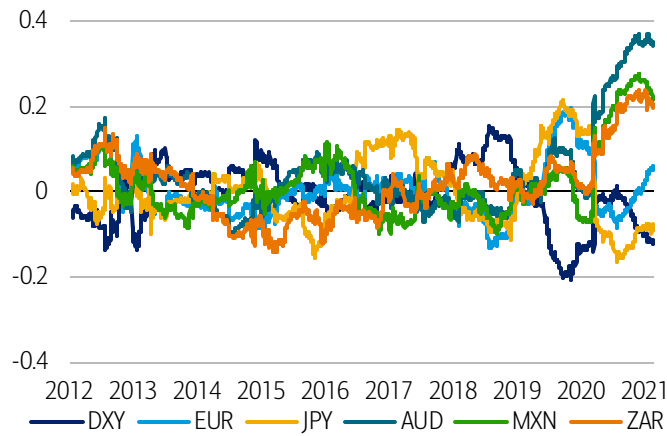


...although it is still highly correlated to other crypto assets...

Digging down a little deeper, we find that correlations are high with most risky FX, while have become negative with havens like the CHF and JPY (Exhibit 53). Note that this pattern is rather common for risk assets and ultimately subtracts from the diversification argument for owning Bitcoin and other cryptocurrencies. Importantly, Bitcoin has also started to correlate well with volatile and cyclical commodities as of late (Exhibit 54), again supporting the idea that Bitcoin diversification benefits are falling, not rising. Lastly, we would also note that Bitcoin correlations to other crypto assets remain relatively high, as they did years ago (Exhibit 55), suggesting once more that there may be limited benefits to owning a diversified basket of crypto in a portfolio.

Exhibit 55: Rolling 252-day Bitcoin and FX correlations

Correlations are high with most risky FX, while negative with havens DXY and JPY

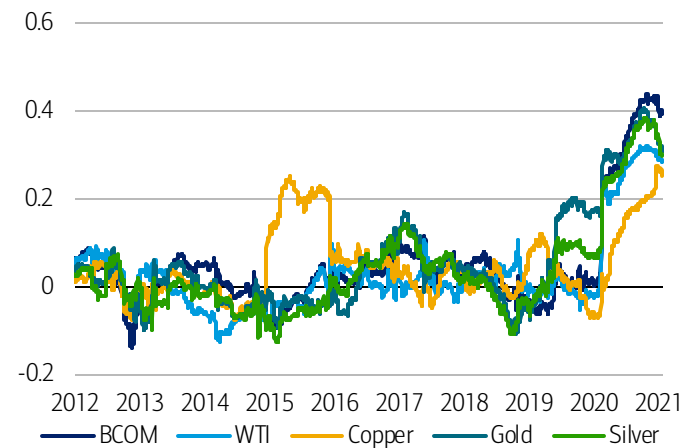


Source: BofA Global Research estimates

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Exhibit 56: Rolling 252-day Bitcoin and commodity correlations Bitcoin correlates well with commodities as of late

Bitcoin correlates well with commodities as of late



Source: BofA Global Research estimates

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Exhibit 58: Bitcoin correlations to other crypto assets

Bitcoin correlations to other cryptoassets remain relatively high, as they did years ago

	Bitcoin	Ethereum	Ripple	Cardano	Dot	Litecoin	Chainlink	Dogecoin	BTC cash	Stellar
Bitcoin		0.48	0.37	0.40	0.57	0.59	0.44	0.35	0.48	0.32
Ethereum			0.22	0.50	0.81	0.36	0.46	0.39	0.54	0.22
Ripple				0.53	0.26	0.63	0.33	0.28	0.46	0.64
Cardano					0.65	0.30	0.32	0.37	0.57	0.66
Dot						0.63	0.73	0.37	0.71	0.42
Litecoin							0.22	0.31	0.42	0.26
Chainlink								0.26	0.28	0.36
Dogecoin									0.32	0.33
BTC cash										0.30

Source: Coinmarketcap.com, BofA Global Research estimates

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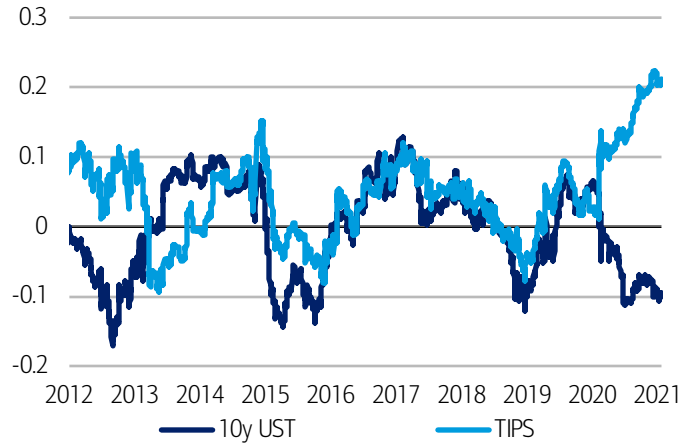
...so Bitcoin portfolio diversification benefits have come down...

A frequent argument advanced by investors in the past year is that Bitcoin could protect portfolios against inflation. In fact, we find that Bitcoin has been positively correlated with TIPS as of late. Meanwhile, higher rates have been associated with higher Bitcoin prices and we now are at multiyear troughs in this relationship (Exhibit 56). Broadly, we find that Bitcoin has not been particularly compelling as an inflation hedge as commodities and even equities provide better correlations to inflation (Exhibit 57). As such, we think the main portfolio argument for holding Bitcoin is not diversification, declining volatility, or inflation protection, but rather sheer price appreciation, a factor that depends exclusively on Bitcoin demand outpacing supply on a forward basis.



Exhibit 58: Bitcoin and US rates correlations

Bitcoin is positively correlated with TIPS as of late, while higher rates have been associated with higher Bitcoin but we are at multiyear troughs in this relationship

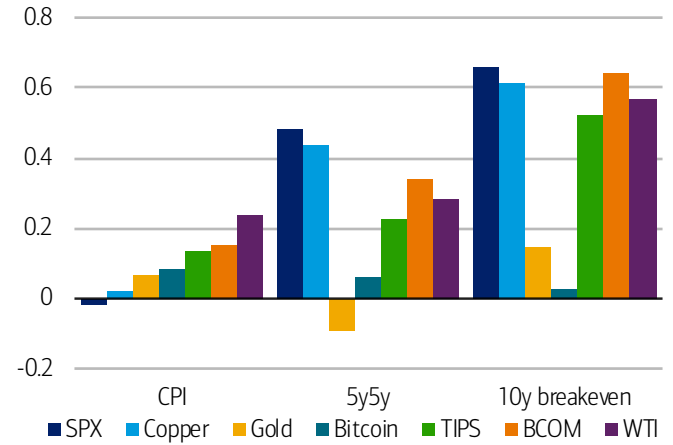


Source: BofA Global Research estimates

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Exhibit 59: Cross asset correlations with inflation measures

Bitcoin is not particularly compelling as an inflation hedge as commodities and even equities provide more connection to CPI, 5y5y or 10y breakeven inflation



Source: BofA Global Research estimates

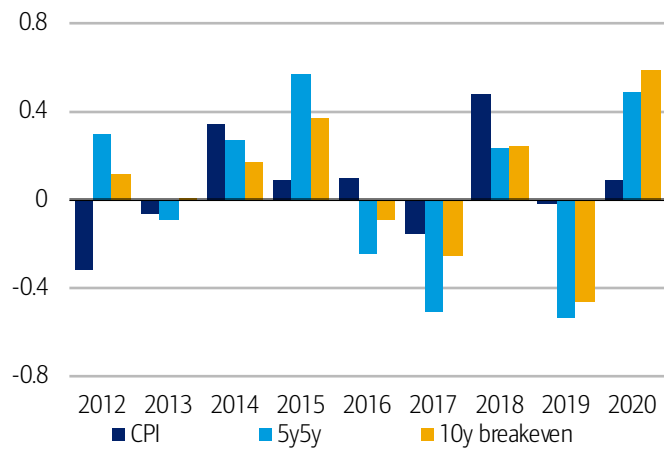
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... and inflation hedging benefits are not particularly apparent

Looking year by year, we find that Bitcoin has been positively correlated with CPI inflation in 5 out of the 9 past years, with the largest correlations in 2014 and 2018 (Exhibit 58). On the bright side, the 2018 performance is encouraging as this was the last time that US CPI inflation was above 2.5% for a sustained period of time. However when looking at correlations with inflation surprises since 2011, we find that Bitcoin has among the lowest co-movements, lagging most asset classes such as commodities, TIPS, and EM FX in particular (Exhibit 59).

Exhibit 60: Annual Bitcoin correlations to major US inflation measures such as CPI, 5y5y, and 10y breakevens

On the bright side, Bitcoin was highly correlated with inflation the last time it popped in 2018

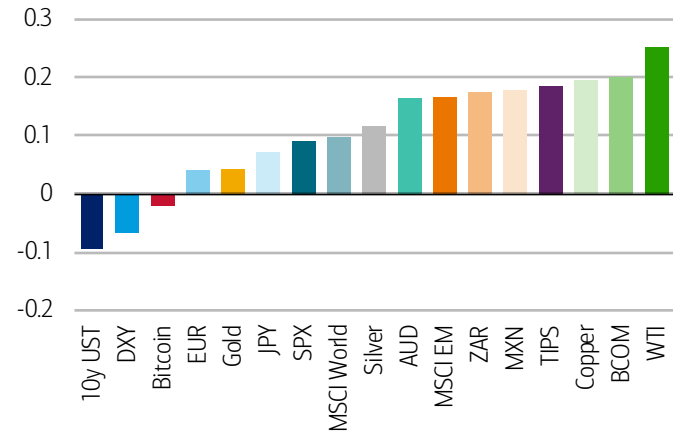


Source: BofA Global Research estimates

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Exhibit 61: Cross asset monthly correlations with Citi inflation surprise index

Bitcoin holds one of the lowest correlations to inflation surprises



Source: BofA Global Research estimates, Bloomberg

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Vol adjusted returns have been high compared to other assets

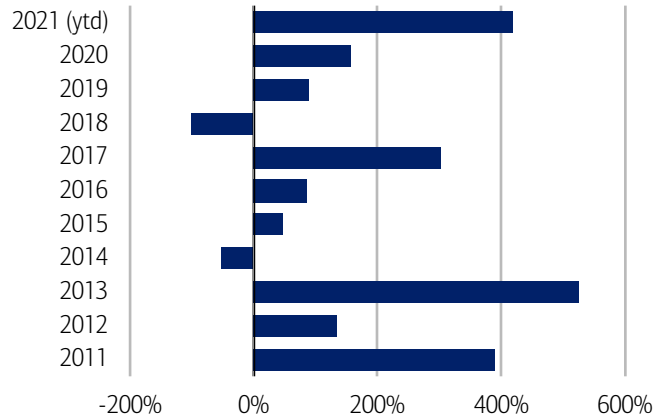
True, total Bitcoin returns this year are already among the highest in its short history (Exhibit 60) and investors have noticed. In 2020 Bitcoin returns neared 160%, while so far this year Bitcoin returns are up 420%. The lowest annualized return for Bitcoin in its nearly 13 year history is 101%, while the highest return was actually 525%, with the average annual return exceeding 180% when including 2021 year to date. Having said that, these high returns have also come with high volatility. So has Bitcoin delivered



good risk-adjusted returns? When adjusting Bitcoin returns for volatility and comparing them to other major asset classes, we still find that while Bitcoin risk-adjusted returns may look attractive from a historical perspective (Exhibit 61), they are not overwhelmingly larger than that of other risk assets.

Exhibit 62: Yearly annualized Bitcoin returns

Bitcoin returns this year are already among the highest in its short history...

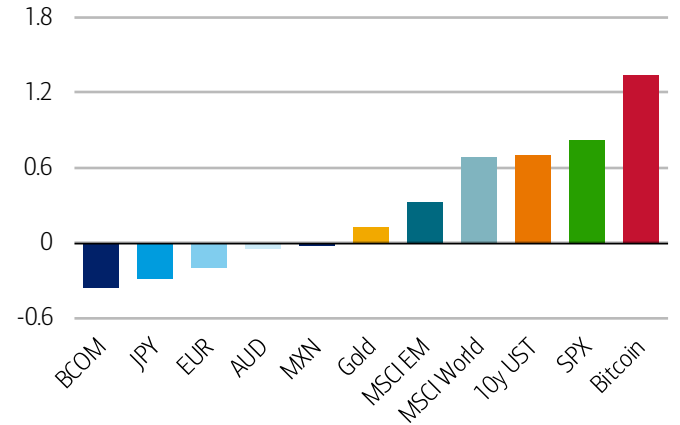


Source: Bloomberg

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Exhibit 63: Information ratios for daily returns over the past 10 years

... and when compared to other assets in vol-adjusted terms, they still look attractive historically



Source: BofA Global Research estimates

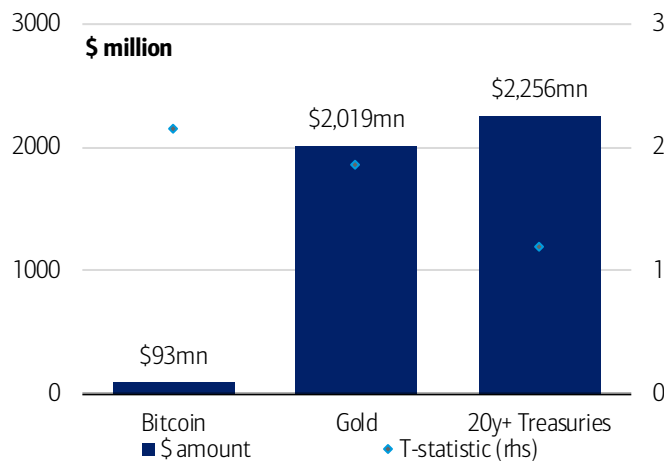
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Crucially, money inflows have a huge impact on Bitcoin prices

What has created the enormous upside pressure on Bitcoin prices in recent years and, particularly, in 2020? The simple answer: modest capital inflows. After a detailed analysis, we find that Bitcoin is extremely sensitive to increased dollar demand. For example, we estimate a net inflow into Bitcoin of just \$93mn would result in price appreciation of 1%, while the similar figure for gold would be closer to \$2bn or 20 times higher (Exhibit 62). In contrast, the same analysis for the 20y+ Treasuries shows that multi-billion money flows do not have a significant impact on price, pointing to the much larger and stable nature of the US Treasuries markets.

Exhibit 64: Dollar amount of purchases necessary for a 1% increase in price derived from ETF shares and underlying price

Bitcoin is particularly sensitive to increased demand, whereas gold requires significantly more pressure and 20y+ Treasuries is insignificant



Source: BofA Global Research estimates, Bloomberg. Bitcoin is based on a weekly Granger regression with two lags. Gold and 20y+ Treasury are based on monthly Granger regressions with one lag.

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3. How does Bitcoin score on ESG?

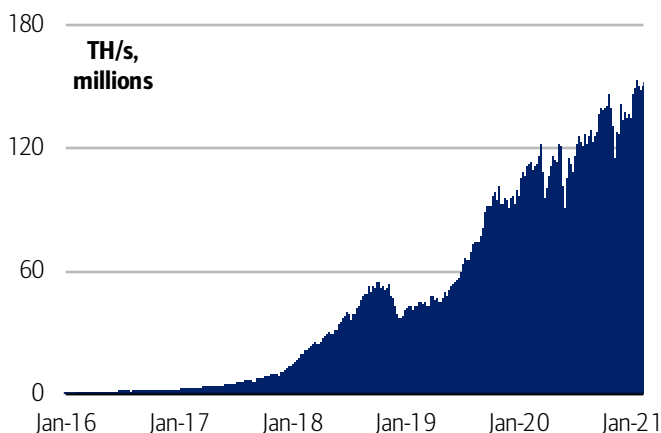
The E in Bitcoin: major environmental risks

Bitcoin prices are directly correlated to its energy consumption...

In contrast to the low carbon intensity of central bank digital currencies, we believe ESG-minded investors have to pay attention to the enormous environmental costs of Bitcoin, as well as its social and governance flaws. In some ways, the rising complexity that underpins Bitcoin is its biggest asset. In some others, rising complexity is the biggest flaw of the entire system. On the one hand, rising Bitcoin prices bring in rising miner profits and growing network complexity to capture them, essentially a mechanism aimed at preventing a hack. On the other, growing network complexity pushes up the hash rate and ultimately the energy consumption of the entire system. As such, the Bitcoin network hash rate continues to grow as the network adds mining hardware and improves efficiency (Exhibit 63). And even if the recent growth in Bitcoin's market value has outpaced the growth in its energy consumption (Exhibit 64), the skyrocketing prices have propelled Bitcoin's CO2 emissions higher.

Exhibit 65: Bitcoin network hash rate

Bitcoin network hash rate continues to grow as the network adds mining hardware and improves efficiency



Source: Blockchain.com

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Exhibit 66: Bitcoin energy consumption compared to market cap

Recent growth in Bitcoin's market cap has outpaced the growth in its energy consumption



Source: Blockchain.com, Coinmarketcap.com

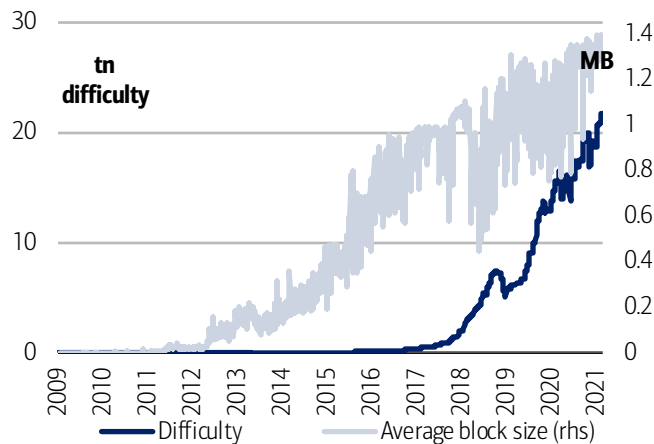
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...as the hash power required to solve blocks increases with price

Ultimately, new crypto miners keep joining the highly competitive crypto space in the hope of huge profits. With more miners around, the difficulty to solve each block goes up and, in turn, so does the hash rate. With renewed interest and volume in the past year, we can confidently say that Bitcoin's mining difficulty and blocksize are back to all-time highs (Exhibit 65). From an environmental standpoint, this development is not good news. Given the relatively linear relationship between Bitcoin prices and Bitcoin energy use, it is perhaps no surprise that Bitcoin's estimated energy consumption has grown over 200% in the past two years (Exhibit 66), creating large environmental risks.

Exhibit 67: Bitcoin mining difficulty and average block chain size

With renewed interest and volume, Bitcoin mining difficulty and blocksize are back to all-time highs



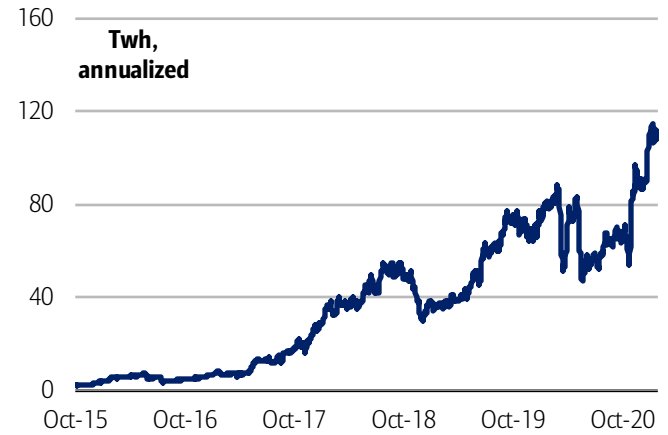
Source: Blockchain.com

Note: The difficulty is a unit of measurement designed to indicate how difficult it is to find a hash below the given target

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Exhibit 68: Bitcoin network estimated energy usage

Bitcoin energy consumption has grown over 200% in the last two years



Source: CBECI

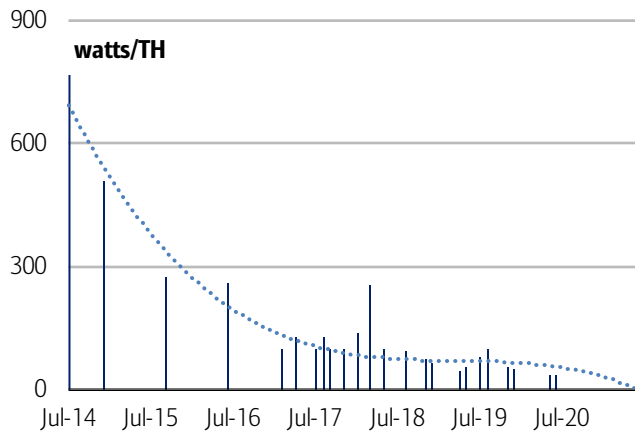
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Hardware becomes more efficient over time, but profits vanish

True, miners do not use old hardware or waste energy voluntarily, as this is a key input into Bitcoin mining costs and thus critical to profit margins. Bitmain Antminer, a leading hardware provider, has gotten more energy efficient with each release (Exhibit 67). Yet, Bitmain Antminer profit margins quickly decline as more efficient cards come to market (Exhibit 68), so the rising complexity of the system creates ultimately a vicious environmental cycle of rising prices, rising hashpower, rising energy consumption and, ultimately, rising CO2 emissions. And with limited amounts of capital pushing prices higher, as we discussed in section 2, rising Bitcoin prices can quickly lead to astronomical CO2 emissions.

Exhibit 69: Efficiency of Bitmain Antminer hardware by release year

Bitmain Antminer, a leading hardware provider, has gotten more energy efficient with each release

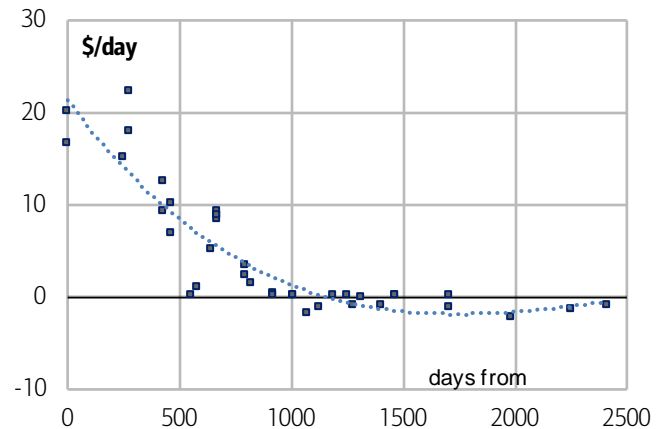


Source: ASICMINERVALUE.COM

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Exhibit 70: Profitability of Bitmain Antminer hardware over time

Bitmain Antminer profit margins quickly decline as more efficient cards come to market



Source: ASICMINERVALUE.COM

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Today Bitcoin consumes as much energy as a country like Greece...

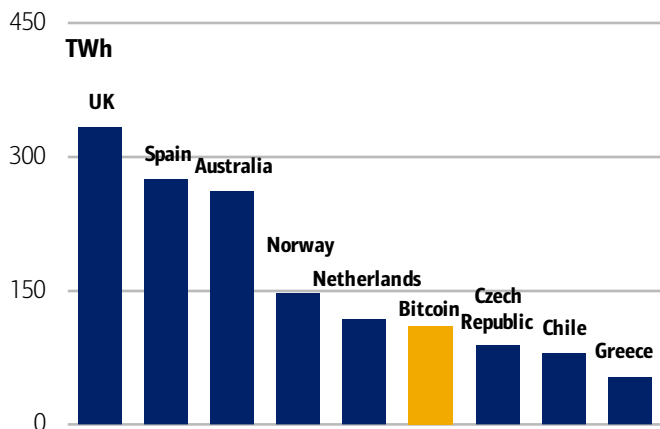
Our analysis shows that Bitcoin's annual energy consumption now rivals that of some small developed countries (Exhibit 69) like the Netherlands and Czech Republic. Of course, in each of these countries live 17 and 10 million people, respectively. And while Bitcoin may have some undetermined social value, it is hard to argue that it provides a



greater value to society than the lives of millions of people. From an institutional perspective, we find that Bitcoin’s energy consumption is comparable to that of major US corporations like American Airlines, the largest airline in the world that flies over 200mn people a year, or even the Federal US government (Exhibit 70), which employs more than 2mn people. The US military also emits about 60mn MT of CO₂.

Exhibit 71: Bitcoin energy consumption compared to select countries

Bitcoin’s annual energy consumption now rivals that of some small developed countries...

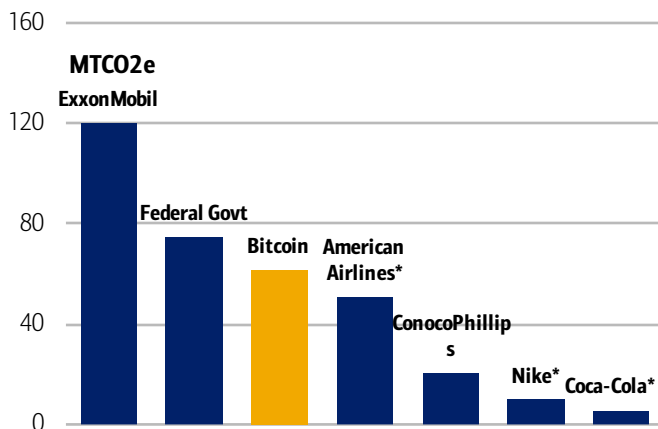


Source: CBECI, BP Statistical Review

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Exhibit 72: Annual Bitcoin emissions compared to select corporations

... and it is comparable to that of major US corporations like American Airlines or even the federal US government



Source: Company reports, CBECI, BofA Global Research estimates
Scope 1&2 emissions for all companies. *Scope 3 emissions provided.

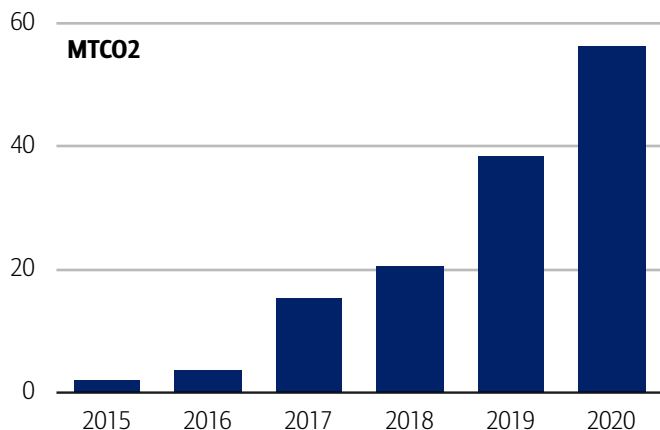
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...and, at \$50,000, it uses about 0.4% of global energy consumption

But as we noted at the start of this section, Bitcoin’s biggest energy design flaw is the same rising complexity that helps prevent a hack. One of the most concerning datapoints across the crypto space is that Bitcoin emissions have soared by over 40mn tons in the last two years (Exhibit 71), the equivalent of 8.9mn Internal Combustion Engine vehicles. With increasing Bitcoin prices, the carbon footprint of Bitcoin may rise further into the future. Again, that’s what the system is designed to do. Bitcoin supply is constrained, so any excess demand pushes prices higher. In turn, higher Bitcoin prices encourage more mining activity and would push CO₂ emissions to even higher levels (Exhibit 72).

Exhibit 73: Bitcoin carbon emissions

Bitcoin emissions have grown by over 40 million tons in the last two years

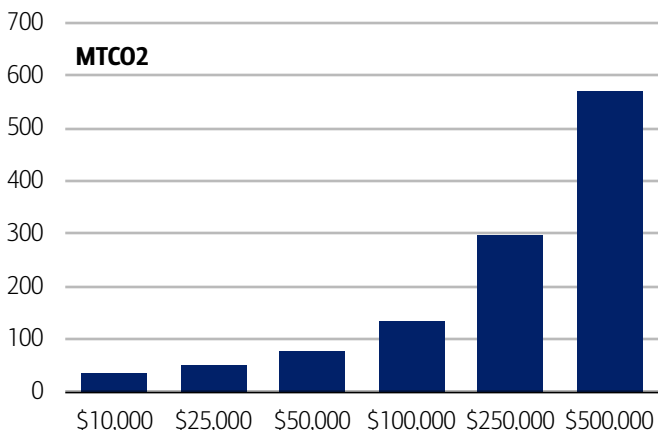


Source: CBECI, BofA Global Research estimates

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Exhibit 74: Bitcoin price scenarios and estimated CO₂ emissions

Higher Bitcoin prices will encourage increased mining activity and push CO₂ emissions higher



Source: CBECI, BofA Global Research estimates

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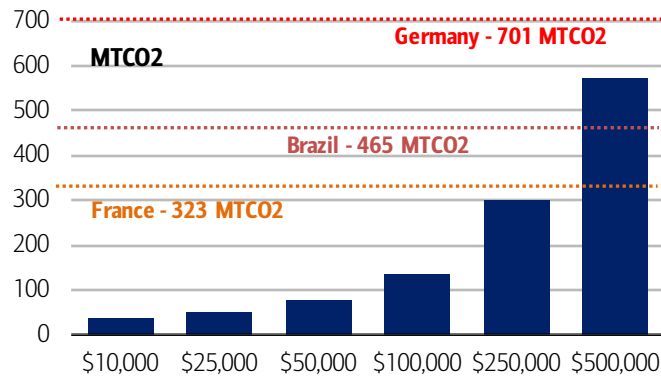


Yet, rising prices could push Bitcoin energy burn up dramatically

While the 40mn ton increase in CO2 emissions in the past two years is concerning, we find even more worrying the price sensitivity of Bitcoin to modest dollar capital inflows. In fact, a back-of-the-envelope calculation suggests that rising Bitcoin prices could push Bitcoin CO2 emissions to levels rivalling some of the largest economies in the world (Exhibit 73). Again, the network is operating exactly as it was designed to do. But this comes at an enormous environmental cost with arguably a limited social purpose. No surprise then that the network hash rate has continued to increase as miners have consistently been able to cover variable costs due to continued price appreciation (Exhibit 74).

Exhibit 75: Bitcoin price scenarios and estimated CO2 emissions

Rising Bitcoin prices could lead to and push CO2 emissions rivaling some of the largest countries in the world

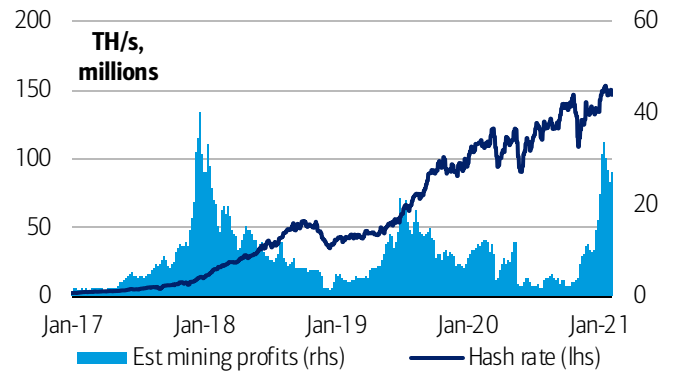


Source: CBECI, BofA Global Research estimates

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Exhibit 76: Bitcoin network hash rate and mining profitability

Network hash rate has continued to increase as miners have consistently been able to cover variable costs due to continued price appreciation



Source: CBECI, BofA Global Research estimates

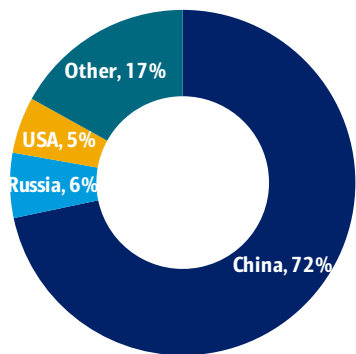
Notes: Assumes a six month delay in upgrading to latest Antminer equipment and 5c/KWh power
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Ultimately, three quarters of hash power is concentrated in China...

Perhaps the most environmentally concerning development of all when it comes to Bitcoin is where most of the world's hash power sits. Geo-location data from mining pools suggests that about three quarters of global Bitcoin mining occurs in China (Exhibit 75). So fresh capital into Bitcoin breeds increased use of Chinese electricity networks. And what source of energy does China use the most? Nearly 60% of Chinese electrical generation is from coal fired power plants, with less than 20% coming from natural gas or renewables (Exhibit 76). In other words, the main input into Bitcoin mining is coal, not exactly the cleanest source of energy on planet Earth.

Exhibit 77: Geographic distribution of global Bitcoin mining

Geo-location data from mining pools suggests the vast amount of Bitcoin mining occurs in China



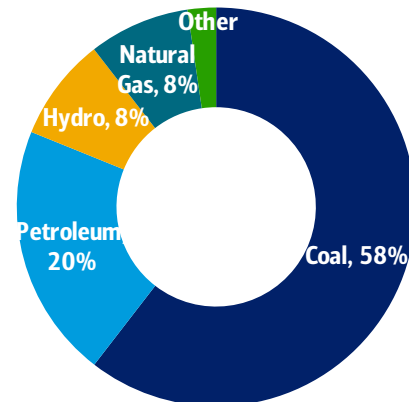
Source: CBECI

Notes: From geo-location data of hashers connecting to Bitcoin mining pools BTC.com, Poolin and ViaBTC. These pools collectively represent ~37% of Bitcoin total hashrate

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Exhibit 78: Source of electricity in China (2019)

Nearly 60% of Chinese electrical generation is from coal fired power plants, with less than 20% coming from natural gas or renewables



Source: EIA

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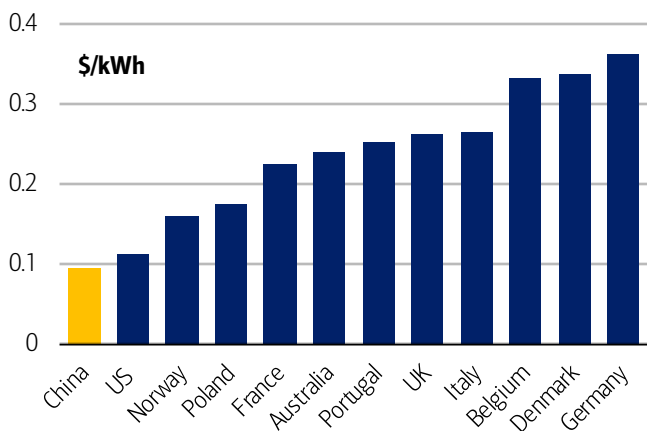


...largely because miners are looking for cheap electricity sources

Why are miners so concentrated in China? Perhaps it is because the Chinese government has encouraged Bitcoin mining to gain increased control to global crypto networks. Or perhaps it is because China has some of the lowest electricity costs in the world, an extremely attractive feature for Bitcoin miners (Exhibit 77). Or perhaps it is because China has overbuilt its electricity generation capacity over the years and needs to find a use for all those power plants. After all, most of the variable costs of Bitcoin mining comes from energy. Net, we find that Bitcoin’s cost of supply has risen to nearly \$20,000/BTC as supply became more limited and mining competition increased (Exhibit 78), with energy representing about 40% of that figure.

Exhibit 79: Global electricity prices

China has some of the lowest electricity costs in the world, an attractive feature for Bitcoin miners...

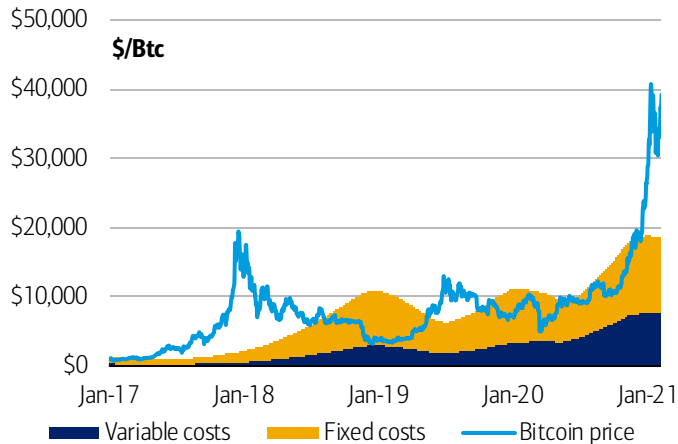


Source: CEIC, BofA Global Research estimates

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Exhibit 80: Bitcoin cost of supply

... as most of the variable costs of Bitcoin mining comes from energy



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

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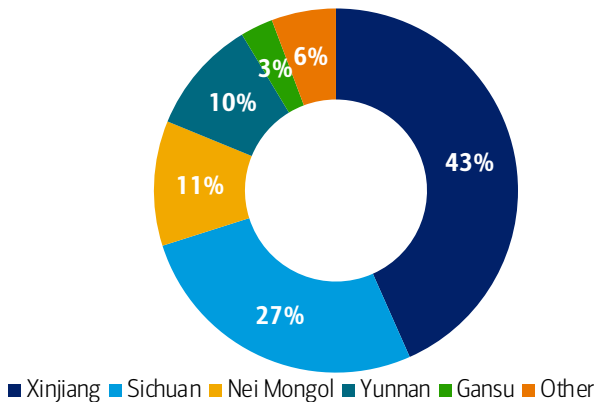
Half of China Bitcoin mining happens in coal-heavy Xinjiang province

For those that have followed the logic behind the our arguments, it should come as no surprise that China’s Bitcoin industry is not located around the Three Gorges Dam, the largest hydropower plant in the world, or around Qinghai Province, next to the second largest solar park on the planet. Rather, the Chinese province of Xinjiang is home to nearly half of all Bitcoin mining in China (Exhibit 79). In Xinjiang, more than 80% of the electricity is generated from thermal sources and it is mostly coal-based (Exhibit 80). Granted, Sichuan province, also an important Bitcoin mining center, does run along the Yangtze River and benefits from access to hydropower. But Bitcoin today is mostly a derivative of coal, with some of China’s hydropower being used seasonally in the summer months. While that may change in the future, and China has recently announced plans to be carbon neutral by 2060, the pace of appreciation of Bitcoin has been too fast to handle and comes with significant adverse environmental consequences.



Exhibit 81: Geographic distribution of Bitcoin mining in China

The Chinese province Xinjiang is home to nearly half of all Bitcoin mining in the country

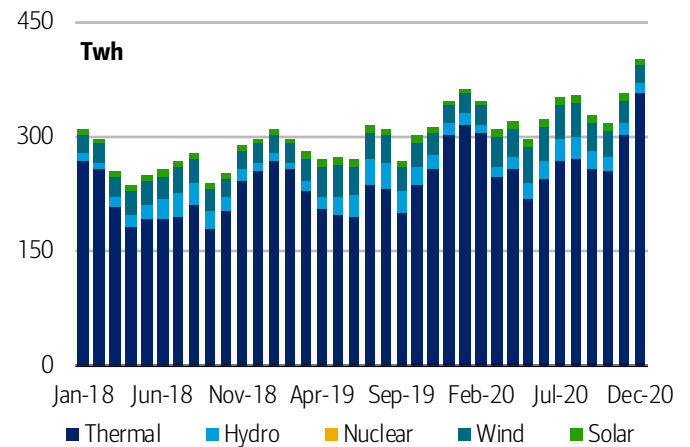


Source: CBECI

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Exhibit 82: Xinjiang province electricity generation

In Xinjiang, nearly 80% of the electricity is generated from thermal sources and it is mostly coal-based



Source: National Bureau of Statistics of China, BofA Global Research estimates

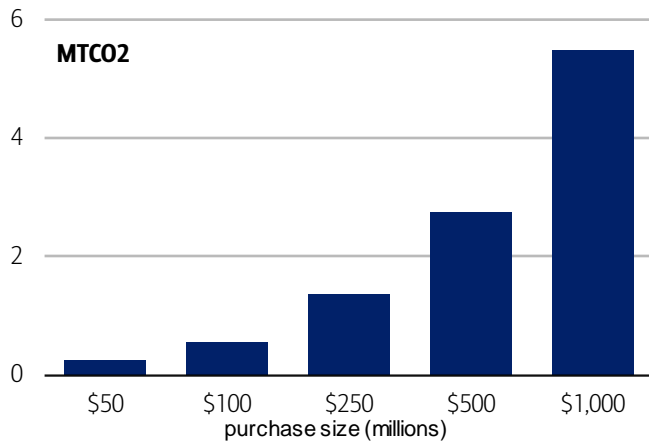
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A \$1bn Bitcoin purchase may have a CO2 footprint of 5.4mn tons

Investors looking into this asset class should keep in mind that modest amounts of capital inflows into Bitcoin can have an outsized environmental impact. We estimate that a \$1bn fresh inflow increases Bitcoin prices on average by 11%, which in turn results in a carbon footprint of 5.4mn tons (Exhibit 81). Comparatively, we do not find many other human activities that have a higher carbon footprint per dollar of inflow (Exhibit 82). As a reference point, we calculate that a \$1bn dollar inflow into Bitcoin is equal to 1.2mn cars driven over the course of a year or 12.7mn barrels of oil. Looked at differently, a single Bitcoin purchase at a price of ~\$50,000 has a carbon footprint of 270 tons, the equivalent of 60 ICE cars.

Exhibit 83: Impacts of purchasing Bitcoin on annual CO2 emissions

We estimate that a \$1bn fresh inflow into Bitcoin has a 11% price impact, resulting in a carbon footprint of 5.4mn tons

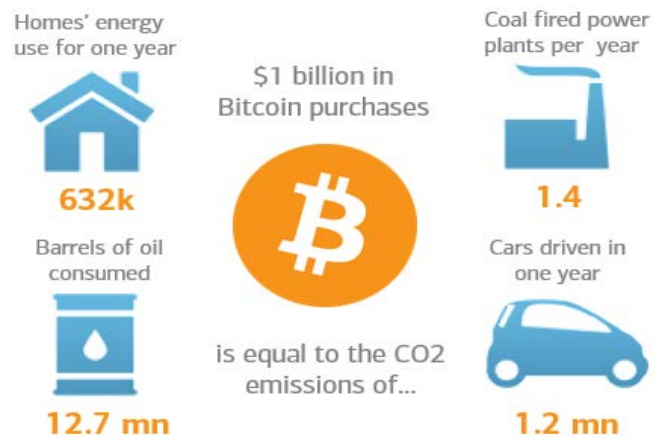


Source: CBECI, BofA Global Research estimates

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Exhibit 85: Bitcoin purchases CO2 equivalency

Comparatively, we do not find many other human activities that have a higher carbon footprint per dollar of inflow



Source: EPA, CBECI, BofA Global Research estimates

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Other cryptos like Ethereum also suffer from huge energy intensity

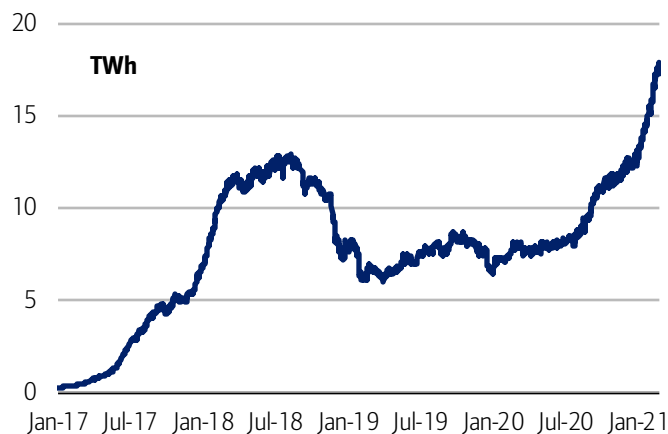
While Bitcoin's carbon footprint is concerning, other crypto assets are only slightly better. For instance, we estimate Ethereum's energy consumption doubled from 8 to 17 tera-watt hours in less than six months as prices jumped to nearly \$2,000 (Exhibit 83), pushing its carbon footprint from 4.4 to 9.5mn tons of CO2. At present, Ethereum's energy footprint appears comparable to that of a small economy like Cuba (Exhibit 84), home to 11 million people, but its rapid price appreciation presents meaningful



environmental risks down the line. True, the move away from proof-of-work to proof-of-stake could reduce Ether's carbon footprint. But in turn the new proof-of-stake model will increase both the social and governance risks of this crypto-currency. Is there a silver lining? As renewable energy production increases over the next 20 years, quantum computers reduce energy usage, and new, more efficient crypto assets continue to emerge, the cryptocurrency space could eventually find ways to reduce its carbon footprint. But a rapid surge in adoption of Bitcoin presents a major risk, and thus drives Bitcoin's low Environmental score.

Exhibit 85: Ethereum network estimated energy usage

Ethereum energy consumption doubled in less than six months as Ethereum prices jumped to nearly \$2000

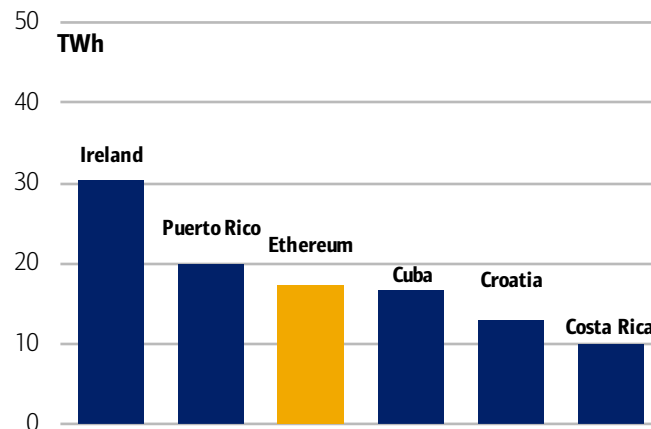


Source: Etherscan, BofA Global Research estimates

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Exhibit 86: Ethereum energy consumption compared to select countries

At present, Ethereum's energy footprint is comparable to that of a small economy



Source: Etherscan, BofA Global Research estimates

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The S in Bitcoin: anonymity can be good and bad

From a social perspective, the key negatives, including money laundering, tax evasion, terrorist financing, and cyber-attacks, could potentially be tackled through more stringent regulation.

On the positive side, Bitcoin, and particularly blockchain technology, has significant potential to contribute to long-term social sustainability vis a vis supply chain traceability, renewable energy distribution, proxy voting, and even prevention of some illicit activities.

- **The democratisation and decentralization of money:** A key premise of Bitcoin is that of democratizing the financial markets. As Satoshi Nakamoto wrote in his white paper from 2008: 'A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution'. Removing intermediaries presents some social advantages.
- **Furthering UN's Sustainable Development Goal target 17.3:** lower costs for remittances would benefit developing nations and more disadvantaged communities.
- **Small business benefit:** lower payment transaction costs would be helpful for small businesses (i.e. no card payment fees, which eat 1-5% of product value).
- **Anonymity** (also a negative, see below): helpful for individuals who live in oppressive societies, where Bitcoin can provide financial security independent of potentially corrupt domestic financial systems.

Negatives:

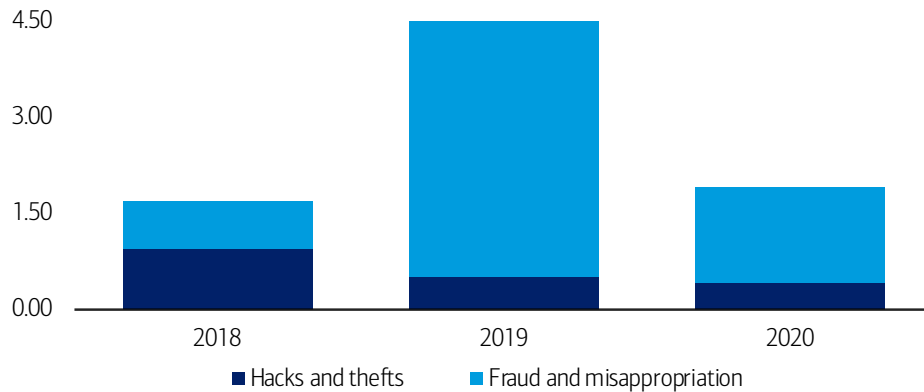
- **Technological requirements:** Bitcoin transactions presume access to computers and internet, which are particularly challenging for the developing countries. According to UN's International Telecommunication Union data, c.51% global population are using the Internet as of end-2019.
- **Currency volatility:** As discussed in the section on *How do cryptocurrencies compare to traditional portfolio assets?*, Bitcoin volatility is well above that of FX, gold, and even silver. But continued momentum in digitalisation, as well as wider adoption, could reduce volatility over time.
- **Anonymity:** the negative side of anonymity is the cover it provides for illicit activities including terrorism financing, money laundering, tax evasion, and even evasions of currency regimes.
 - Research from Copenhagen Business School and Collier School of Management uses forensic accounting and machine learning on millions of crypto transactions as a way to confirm a link between terrorism and cryptocurrency payments. The researchers find strong positive cumulative abnormal value responses in the week preceding attacks, followed by a reversal in the week after. This pattern is consistent with terrorist financing.
 - Researchers from the University of Sydney in 2019 estimated that around \$76bn of illegal activity per year involves Bitcoin, which is close to the scale of the US and European markets for illegal drugs².
 - A systematic literature review by researchers from the University of Ottawa (2020) points to a growing number of cyber-attacks through Bitcoin and other cryptocurrencies (most commonly Ethereum and monero). Some of the most common cyber-attacks are: high-yield investment programs, ransomware, pump and dump schemes, and crypto jacking. Furthermore, CipherTrace's 2020 Cryptocurrency Crime and Anti-Money Laundering Report reveals that in 2020, major crypto thefts, hacks, and frauds totalled \$1.9 billion.
- **More regulatory oversight needed:** concerns about Bitcoin point to increased need for regulation and, more importantly, compliance, which is costly and onerous. Illicit activities remain a challenge for both crypto and non-crypto channels of payments.

² These numbers are independent estimates from academic research rather than actual numbers based on all prospective activities. Illicit activities are difficult to quantify for transactions with cryptocurrencies and hard cash alike.



Exhibit 87: Blockchain illicit activities in 2020 totalled 1.9bn USD, according to CipherTrace’s 2020 Cryptocurrency Crime and Anti-Money Laundering Report

Blockchain fraud exceeds hacks and theft



Source: CipherTrace Cryptocurrency Intelligence., BofA Global Research

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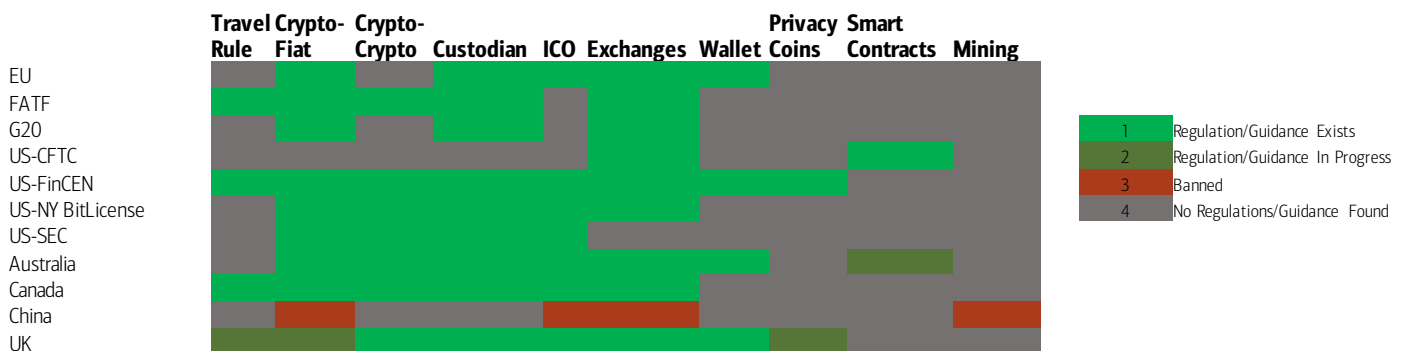
Mixed reviews on G

Bitcoin presents mostly negative G consequences from the perspective of decentralised finance, where key stakeholders (particularly the exchanges) remain relatively concentrated and lack regulatory oversight. This concern resonates strongly with the centralised ownership structure discussed in the previous sections (i.e. about 95% of Bitcoin is controlled by just 2.4% of the accounts).

With wider adoption of Bitcoin, there is scope and necessity for more robust governance / regulatory mechanisms to protect customers. An additional regulatory issue is a lack of international cooperation and heterogeneous AML (anti money laundering) /CTF (counter terrorist financing) regimes globally.

Exhibit 89: Implementation of crypto regulation in major jurisdictions

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



Source: CipherTrace Cryptocurrency Intelligence., BofA Global Research

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Unregulated exchanges

Bitcoin has highly concentrated control over the mining process (by a small number of mining pools), transactions / payments (through cryptocurrency exchanges), and maintenance of the code (the ‘Bitcoin Core’ group). For prospective investors / users who would invest in or transact with Bitcoin, the most problematic aspect is exchanges.

Crypto exchanges provide liquidity and facilitate price discovery, just like traditional exchanges. Furthermore, many crypto exchanges have expanded their business models



into upstream activities (i.e. mining) and downstream (i.e. payment). This, in turn, allows them to play a larger role that would normally be shared among trading platforms, custodians, banks, and clearinghouses.

The concentration of power is not necessarily negative per se (the economic literature would support some benefits from centralisation), but the modus operandi of some exchanges is concerning. According to researchers from Cornell, Newcastle, and Tsinghua universities, unregulated exchanges are active in market manipulations. Based on the sample of 29 exchanges and millions of transactions from 2019, the researchers concluded that the wash trading volume on average is as high as 77.5% of the total trading volume on the unregulated exchanges analysed. Currently, a majority of exchanges are unregulated.

Bitcoin trading can be done well: There are notable examples of good practices. For example the Swiss exchanges where all cryptocurrency transactions comply with regulations such as customer protection and anti-money laundering.

Institutional adoption of Bitcoin

The current cryptocurrency regulatory framework is insufficient, as reflected in European Central Bank President Christine Lagarde's call for regulation to address 'funny business' associated with cryptocurrencies. However, regulation is ever-evolving and is likely to speed up with more institutional adoption of Bitcoin.

According to research by our US banking analysts, 21% of US banks under coverage already have blockchain technology in use: JPM, C, WFC, UBS (an early investor in R3), PNC, FITB, and SBNY. Of the regionals not currently using blockchain technology, MTB and CFG appeared to be the most open to engaging third parties at some point to provide the technology (for more details see [here](#)).

ESG analytics mostly fail to capture Bitcoin risks

Most ESG data providers do not provide a comprehensive framework for how to assess large Bitcoin / cryptocurrency portfolio holdings or exposure. This theme is likely to become more salient if corporates begin to purchase large amounts of Bitcoin (most recently, Tesla). Such purchases could gain more traction through the existing ESG metrics of materiality or controversies.

Reprisk, a leading data provider on risk scores related to environmental, social and governance related issues, found 181 companies that have an association between ESG risks and crypto-currency, 60 of these incidents occurring in 2020 – a demonstrable acceleration in crypto-currency related risks. The "S" and "G" issues most frequently associated with Bitcoin are money laundering, corruption, bribery, fraud, and breaches of data privacy, with US, UK and Japan as the top 3 countries by incident.

Case study: A peek under the hood of Tesla

Favored by passive ESG, not by active ESG: Tesla currently holds the top weighting in the MSCI USA SRI index, one of the largest ETFs that we track, and generally carries a 60% overweight in the average passive ESG fund. But active ESG managers are less bullish, and only one in ten funds own the stock (versus one in three passive funds) and the average active ESG manager is ~60% **underweight** the stock. Why the difference? [TSLA scores Low](#) in our ESGMeter scoring system, with Low scores on all components of E S and G. The low scores were impacted by lack of disclosure (more below) as well as incentive compensation structure, lack of proxy access, and board characteristics (staggered, negative votes on directors).



Most data providers rank Tesla as above average on environmental aspects – after all, the company produces electric cars. But TSLA fails to disclose Scope 1, 2 or 3 emissions, where peers like General Motors (GM) do disclose this information. A lack of emissions disclosure currently carries a median 3 point P/E multiple discount by for companies within Consumer Discretionary.

Furthermore, by applying our Bitcoin emissions analysis to TSLA's recent investment of \$1.5bn of reserves in Bitcoin, the indirect carbon intensity of the company if disclosed would jump by a significant amount.

From a Social and Governance perspective, the diversity of thought leadership and workforce statistics at Tesla are sparse, but we do note that average age of board members is considerably younger at 53 than Consumer Discretionary peers (60yo average age) indicating perhaps greater comfort with new asset classes like Bitcoin, but also perhaps shorter experience with boom/bust cycles for speculative themes.

4. Are CBDCs Kryptonite for crypto?³

Central bank digital currencies (“CBDC”) would represent a major break with the status quo; in this, they are like cryptocurrencies. However, we think they are likely to differ technologically from cryptos, and are in part motivated by central banks’ wanting to defend their territory from cryptos and their relatives.

Giving retail access to central bank assets

At the moment, when retail users (you and I) use any electronic money, be it via phone, card or direct payment, we use some form of commercial bank money. Our credit risk is the risk of the bank. Typically, when banks settle between each other, they do so using central bank money, that is, money backed by the central bank of where they are settling. In Europe, securities trades are also settled in central bank money, via T2S. When we use cash, though, we use central bank money.

A lot of the structure of modern finance derives from this structure. For example, we maintain bank accounts with commercial banks in part because central banks don’t provide current account services. If they did, they would probably be highly valued for their credit quality. Commercial banks, in turn, typically use retail deposits to fund lending activity.

The idea behind a CBDC is that, in some form, it would give retail users access to a central bank asset. This is a highly radical decision, we think. The authors of this section (Philip Middleton, Alastair Ryan and Adithya Metuku) have explored the consequences of this in the “Digital Money” series.

Digital Money – deep dives into CBDC

Digital Money #1: [“How did we get here”](#) (Middleton and Ryan, 8th December 2020) looks at why central bankers, including the ECB, seem to be growing more positive about launching retail digital currencies.

Digital Money #2: [“If the ECB becomes your current account”](#), (Ryan, 8th December 2020) sets out the implications for incumbents of a retail CBDC. In particular, it could hollow out the incumbents’ deposit franchises.

Digital money #3: [“How will it work?”](#) (25th January 2021 Middleton, Metuku, Ryan), looks at how a CBDC could be implemented and what it could mean for the payments and banking industries.

Digital money #4: [“Innovation, arbitrage and reward”](#) (25th January 2021 Ryan, Middleton, Metuku), examines how the different capital treatments of banks and others drives regulatory arbitrage away from the banks, and points out that the ECB may look to regulate payment companies who use the mooted “digital Euro”.

Digital money #5, [“Duration, duration, duration”](#) (Ryan, 10 March 2021) shows how a digital euro, d€, centres activity ever more at ECB – by design, not side effect.

It’s important to understand why central bankers have decided to move towards a CBDC. The clearest presentation here is the ECB’s.

What’s the ECB doing?

The ECB is currently reviewing the replies to a consultative exercise about CBDC. It has said it will announce whether or not it will proceed to a trial of a CBDC by the middle of the year. We think it is likely that they do. The decision whether or not to proceed to a production version will, we presume, depend on the experience of the trial as well as other macro developments.

³ This section was largely written by Philip Middleton and Alastair Ryan.

Why CBDC?

A good starting point here is a speech by ECB Executive Board member Fabio Panetta⁴. Mr Panetta writes that:

We are working to safeguard the role of sovereign money in the digital era: we want to be ready to introduce a digital euro, if needed. A digital euro would combine the efficiency of a digital payment instrument with the safety of central bank money. It would complement cash, not replace it. Together, these two types of money would be available to all, offering greater choice and access to simple, costless ways of paying.

This represents a positive agenda for CBDC. However, Mr Panetta also sets out a number of concerns which may weigh on central bankers.

Big tech, China

He talks about the potential for big techs to become major players in payment – he appears to be against this. “If not properly regulated, big techs may pose considerable risks from an economic and social perspective and they may restrict, rather than expand, consumer choice.” Also, “Monetary sovereignty could be threatened if foreign central bank digital currencies became widely used in the euro area”.

Eurocentric approach

He also points out that cards used across Europe rely on “agreements with international card schemes. As a result, people mostly use international schemes for cross-border card payments, and the European market for card payments is dominated by non-European schemes.” Presumably, this includes MasterCard and Visa.

This suggests that major reasons for the ECB being interested in a digital Euro include the worry that the Facebook-led “Diem” digital currency might become a dominant currency, and that Europeans might progressively adopt another central bank’s digital currency (such as the Chinese Yuan).

What about crypto?

Mr Panetta’s commentary on CBDC doesn’t explicitly engage with cryptocurrencies. ECB President Christine Lagarde has made a range of comments which touch on cryptos, though. For example, she said recently in an interview on BFMTV⁵:

“Ce n'est pas une monnaie. Les cryptoactifs, ce n'est pas une monnaie. C'est un actif hautement spéculatif”. Bitcoin is not a currency but a “highly speculative asset”.

This is an important distinction. The ECB is here placing Bitcoin in a totally separate category to currencies, suggesting it is an investment (a “speculative” one, to boot) rather than a mode of transaction.

There is a clear contrast here with Diem, the renamed Libra currency proposed by Facebook, which is explicitly positioned as a private sector currency.

This ties in with a section of the ECB’s recent thinkpiece on the digital Euro. This argues that a CBDC is “not a crypto-asset or ‘stablecoin’”⁶. It argues that:

The digital euro would be a risk-free form of central bank money (i.e. a digital representation of cash), which means that it is issued by the central bank and remains its liability at all times. ...

Commercial bank money and electronic money are by contrast liabilities of supervised private entities. Private money issuance needs to comply with the regulations and the

⁴ Fabio Panetta, “Future of Payments in Europe”, 27.11.20, ECB website.

⁵ “CHRISTINE LAGARDE : “LE BITCOIN, CE N’EST PAS UNE MONNAIE”” Thomas Leroy, BFMTV.com, 7.2.21.

⁶ “Report on a digital euro”, ECB, Oct 20, P51

issuing private institution is subject to supervision or oversight by public authorities. While such entities might in theory default and become unable to satisfy the claims of their customers to, for example, convert their holdings into central bank money, their customers are protected by a legally binding regulatory framework that obliges the supervised private issuer to take measures to protect the value of their liabilities. The central bank, beside its supervisory function, acts as a lender of last resort to avoid default by the commercial banks in exceptional situations. Moreover, deposits with commercial banks are protected in the euro area by deposit insurance schemes.

Crypto-assets, in contrast, are not a liability of any entity, thus there is no reliable framework to sustain their value and to protect their direct holders. These assets are mostly unregulated, which poses high risks to the users. Their price is highly volatile because crypto-assets lack any intrinsic value, which means that they trade like a speculative commodity. ... Regardless of the technology used for a digital euro, its nature – i.e. the fact that it is a risk-free liability of the central bank – makes it fundamentally different from crypto-assets.

In other words, this makes the same distinction which Mme Lagarde did, albeit in less colourful language. Cryptocurrencies are assets which trade like a “speculative commodity”.

The division the ECB is making here is between cryptocurrencies, which have no backing, commercial bank money, which has some backing from the regulators, central bank money, which is an obligation of the central bank, and stablecoins. On these, it says:

In spite of the fact that [stablecoins] are all recorded by means of distributed ledger technology, their characteristics differ according to the type of claim they represent, which could make them similar to commercial bank money, electronic money, investment funds or crypto-assets. All forms of “stablecoins”, aim at keeping their value stable over time, but this can only be guaranteed by a digital euro⁷.

The argument here is that an initiative like Diem is less attractive than a digital Euro because although this would “aim” to keep its value stable (by backing Diem one for one with high quality Euro assets for its Euro coin), this would not be “guaranteed”, as it’s not an ECB liability. This is true. No private sector currency, be it Diem or commercial bank money, can provide the same type of guarantee as a central bank can.

So, the ECB’s argument is that a digital Euro would dominate private sector money in terms of credit quality, and that Bitcoin and its peers aren’t currencies anyway. These all seem persuasive arguments, and we think that a big part of the ECB’s CBDC agenda is to use them to fend off what it sees as unwanted competition with its currency. That said, we think that private sector money, be it from a commercial bank or Diem, may have a number of things going for it,

- The ECB is keen not to allow the digital Euro to become an investment asset – it is intended as a transaction-oriented cash substitute. The bank is floating a cap of €3,000 for zero interest rate digital Euro, with higher amounts being charged a negative interest rate.
- We don’t know how the digital Euro would improve cross-border transactions. This is currently an area where the incumbent services seem a bit expensive to us; something like Diem may be a viable alternative here, although there are already a range of [disruptive FX businesses](#) which provide alternatives to the status quo.
- A lot of new digital businesses aim to compete on the quality of the user experience. Who knows if this would be a strong point for a central bank?

⁷ Ibid, P52

Not just the ECB

The ECB has been unusually explicit in its intentions, but other central banks are also expressing a lot of interest in CBDC. According to the BIS⁸, which conducts a regular survey of central banks' approaches to CBDC:

Over the last four years, the share of central banks actively engaging in some form of CBDC work grew by about one third and now stands at 86%. ... The central banks not currently involved in any CBDC work are primarily in smaller jurisdictions. This finding is consistent with the results of the previous two surveys. Research also suggests that CBDCs are more likely to be under research and development in jurisdictions with high mobile phone use, innovation capacity and internet search interest for CBDCs.... About 60% of central banks (up from 42% in 2019) are conducting experiments or proofs-of-concept, while 14% are moving forward to development and pilot arrangements.

Fed – “right not first”

One central bank which has historically not seemed particularly enthusiastic about a CBDC is the US Federal Reserve. Fed Chair Jerome Powell recently commented on CBDC before the Senate Banking Committee⁹. Here are some edited highlights of his comments:

We are looking ... very carefully at the question of whether we could issue a digital dollar... there are significant both technical and policy questions to do with how we would go about doing that. I would say that we're committed to solving the technology problems, and to consulting very broadly with the public, and very transparently with all interested constituencies as to whether we should do this.

We don't need to be the first, we need to get it right.

At the same time you want to avoid creating things that ... might draw funds away from the banking system. We have a banking system which intermediates between savers and borrowers.

This strikes us as a relatively balanced presentation of the policy trade-offs which a CBDC entails.

How will it work?

There's a lot we don't know about CBDC. In particular, there are a range of architectural decisions which need to be taken. Our view is that, at least initially, banks won't choose disruptive options. We don't think they will necessarily opt for distributed ledger technology. We think the most likely approach will be to work with the existing infrastructure, as this looks the easiest way to achieve a viable product. We strongly don't believe that the ECB would want to run accounts for all European citizens. There are two reasons for this:

- It would be a major task in terms of technology, which would materially increase the risk of the project failing.
- It would also involve the bank in having to take responsibility for AML and KYC monitoring of all these accounts. This would be a highly complex task.

Our assumption is that a digital Euro would look very much like digital commercial bank money, and move through the same rails via the same intermediaries. The only difference would be that the ECB would stand behind the currency, which is the point of the whole thing.

⁸ “Ready, steady, go? – Results of the third BIS survey on central bank digital currency”, BIS papers 114, Jan 21.

⁹ “SENATE BANKING, HOUSING, AND URBAN AFFAIRS COMMITTEE HEARING ON THE SEMIANNUAL MONETARY POLICY REPORT TO THE CONGRESS” 23.2.21 Source: Bloomberg Government. Mr Powell's comments came in response to a question from Senator Hagerty,

We wouldn't be surprised if the bank sought to apply a bit of price pressure to the intermediaries it uses. We would be very surprised if it didn't seek to use a CBDC to bring more entities within its regulatory ambit. A digital Euro would initially be very innovative in terms of market structure, we think, but not technology.

Environmental impact

From an environmental perspective, a CBDC would be no different to the current settlement and payments rails. We do not expect any central bank to use a distributed ledger for its CBDC, not least because the central banks are highly confident in their ability to offer reliability and finality in settlement. Indeed, that would be the point, from their perspective. Therefore, CBDC should not have the significant power consumption drawbacks of crypto assets. It is possible that through shortening payment chains and replacing cash, the environmental footprint of payments may even be somewhat reduced. This is not a key goal of the projects, but would be a welcome side effect.

Longer term

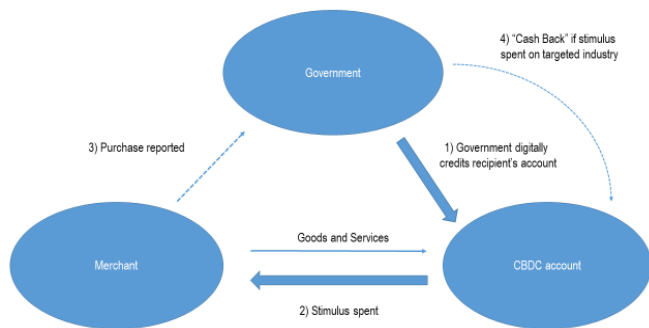
Global central banks pulled out all the stops in 2020 to counter the COVID-19 crash, delivering 190 rate cuts and \$8tn in stimulus, equal to \$1.4bn spent every hour. In our view, the big investment trends of the 2020s are bigger government, smaller world, US dollar debasement, fiscal excess and more accommodative central banks. The pursuit of a sustained rise in inflation expectations over the next decade should drive central banks to continue to expand their footprint in markets.

The adoption of CBDCs could facilitate the operational issues associated with a more activist policy agenda and represent the next frontier in the central bank revolution. Depending on how a digital currency is designed, governments could credit funds to a broad set of recipients, or potentially, credit accounts which transact in targeted industries. In principle, the stimulus can be tailored to provide additional 'cash back' if funds are spent on targeted businesses, allowing government to design more carefully tailored stimulus than currently possible (Exhibit 90).

Accounts holding digital currencies at central banks can also be designed as interest-bearing accounts. This innovation could have important implications for monetary policy; via CBDC accounts, central banks could directly impact money market rates rather than relying on commercial bank intermediation as they current do. While European authorities have so far said they aim to keep an element of any CBDC at zero interest rates, in principle, a shift towards digital currencies could allow central banks to pass negative interest rates more directly to the population (Exhibit 91).

Exhibit 90: Central bank digital currency role in directed stimulus

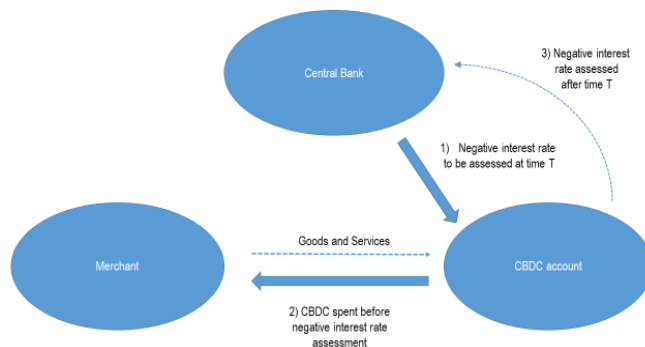
Stimulus could be tailored to provide additional 'cash back', allowing government to design more carefully tailored stimulus



Source: CELO, <https://celo.org/papers/cbdc-velocity>, BofA Global Investment Strategy
BofA GLOBAL RESEARCH

Exhibit 91: Negative interest rates using central bank digital currencies

A shift towards digital currencies could allow central banks to pass negative interest rates more directly to the population



Source: CELO, <https://celo.org/papers/cbdc-velocity>, BofA Global Investment Strategy
BofA GLOBAL RESEARCH



CBDCs offer other policy benefits, such as the potential to increase speed and decrease costs in existing payment systems, facilitate international capital flows, and promote financial inclusion. The current global payment systems is fragmented and costly with layers of intermediation and supervision. Digital currencies could boost international capital flows by reducing intermediation and costs associated with transfers between payment systems. States and municipalities could benefit from having grey market activities drawn into taxable sphere, while CBDCs can facilitate a more effective enforcement of value-added taxes by national governments.

There are potential drawbacks as well (Table 1). Central bank digital currencies could compete with banks and money funds, providing another option to store value. Banks could see cheap deposit funding curtailed and money funds could see their margins further reduced, even as the near-zero rate environment have squeezed margins to the limits. During times of financial stress, there could also be a 'flight to quality', potentially creating new run risks for banks. Depending on how CBDCs are designed, nearly all transactions could be visible to authorities, raising concerns over loss of privacy.

Table 1: CBDC role in directed stimulus

CBDC's hold a variety of benefits and costs

Benefits	Costs
Increased speed/Decreased cost in payments and settlement	Interest-bearing CBDCs can compete with money funds and bank deposits
Facilitates international capital flows	May create run risks during periods of financial stress
Promotes Financial Inclusion	Loss of privacy / larger role for government
Enhances transmission of monetary/fiscal stimulus	Increased operational/reputational risk to central banks
Can reduce illicit transactions/ enhance ability of govts to raise revenue	

Source: BofA Global Research

BofA GLOBAL RESEARCH

5. Is DeFi potentially more disruptive than Bitcoin?

Bitcoin is the most talked about cryptocurrency but Ethereum has more features, including being more flexible than Bitcoin. As we wrote in our 2017 note on [cryptocurrencies](#),

Ethereum sees itself as an environment in which users can create a range of applications using blockchain and smart contracts. Ether is the currency needed to pay for smart contract functionality, and also for a range of Initial Coin Offerings (“ICOs”) also hosted on the Ethereum platform. On this reading, ether is more like a season ticket for the underground than a currency.¹⁰

The founder of Ethereum, Vitalik Buterin, built the system so that the “Ethereum virtual machine is Turing-complete; this means that EVM code can encode any computation that can be conceivably carried out”¹¹. When we last wrote, ICOs were arguably the most notable applications built on Ethereum. More recently, so-called Decentralised Finance (“DeFi” to its friends) has taken over. A number of theoreticians, including Buterin himself, have designed ways of replicating various functions of modern finance in a decentralised way using Ethereum code. The challenge here is not so much programming (the benefit of Turing completeness), as deciding what to program.

A radical challenge to mainstream finance

DeFi is, we think, the most fundamental challenge to modern finance that we’ve encountered. Modern finance works on the basis of there being trusted entities acting as central points for providing various services and filling various functions. For example, banks take deposits, insurers pool various risks, exchanges pool liquidity, CCPs and CSDs pool settlement and ownership activity and so on. This places a huge amount of weight on these centralised, usually private sector, entities to behave both fairly and prudently. Recognising this, states place guardrails around these businesses. So, banks have to maintain pre-set levels of capital and abide by minimum standards of how they treat their customers. Exchanges abide by a relatively prescriptive set of rules about how they handle the orders they receive.

DeFi is different. Just as Bitcoin seems to replace a centralised issuing authority who imbues a currency with its own trustworthiness, so DeFi seeks to replace a range of centralised, regulated institutions with decentralised systems, typically based on the Ethereum blockchain. Ethereum is a logical choice for this, as it has been explicitly set up as a “world computer”. Many of the building blocks for DeFi applications are based on ideas set out by Buterin himself, in particular, the notion of “atomic swaps” where what typically could be viewed as DVP transactions¹² are executed via smart contracts.

How does Ethereum work?

Ethereum is in many ways similar to Bitcoin, in that it is based on a blockchain (please see our writings on [cryptocurrency](#) for an explanation of this, along with mining, proof of work and proof of stake). It is currently validated by a proof of work algorithm, although it is in the midst of an ambitious programme to move to “proof of stake”. This is part of the upgrade to “Ethereum 2.0”, which is intended to improve operational performance as well as move to a more environmentally friendly validation process.

¹⁰ “Introducing cryptocurrencies – what are they good for?”, Middleton, Blanch, Iaralov, Metuku and Lam, 16.10.17, P 28

¹¹ “Ethereum Whitepaper”, Buterin, 2013

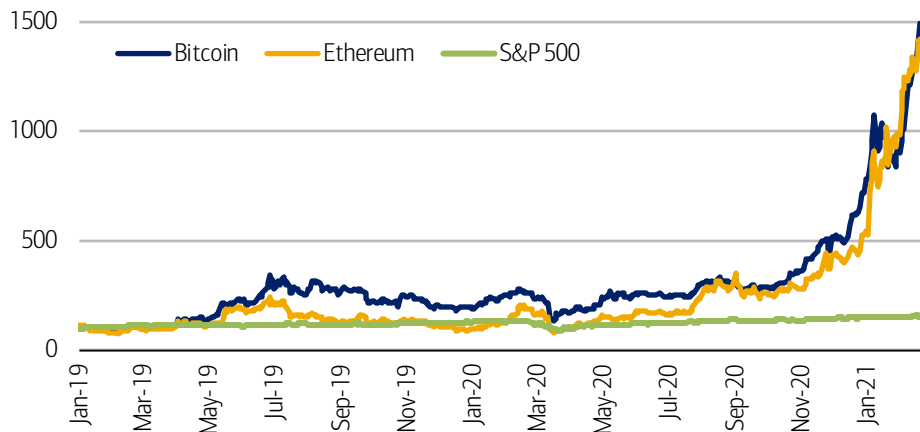
¹² delivery versus payment

The core difference is that the Ethereum blockchain is made up of accounts and “contracts”, which contain code and/or states. These can contain so-called “smart contracts”. Executing contracts comes at a cost, quantified in “gas”, the amount of Ether, Ethereum’s currency required for execution. Both account and contracts typically include gas.

Although Ethereum is very different to Bitcoin, the two have performed in a roughly similar way, as the chart below suggests. As a comparison, we’ve shown the S&P 500, which to equity investors feels like it has been a good performer.

Exhibit 91: Ethereum in USD

Strong performer, correlates to BTC



Source: Bloomberg

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The computational ability of Ethereum is usually seen as the defining difference between the two coins. Ethereum basically allows you to program anything, but usually its most talked-about feature is “smart contracts”, which can solve a wide range of issues.

Smart contracts

In our view, smart contracts are neither smart, nor contracts. They are, typically “if...then” statements, a staple of computer programming. They can be used to replicate financial products. “If the price of gold is over \$1,300, pay the owner the difference” would represent a call option on gold. “If the date is either 30/6 or 31/12, pay the bearer \$5” would represent a fixed income security. As a result, smart contracts are often seen as having applicability to finance. However, they have many other applications, too.

They aren’t smart because they are simply an exercise in following orders, however daft the orders might be. This provided a clear example of the “I was only obeying orders” nature of smart contracts delivering unwelcome outcomes. And they aren’t contracts, as in themselves they have no particular legal status; they can of course derive legal status if people agree to be bound by the outcome of smart contracts.

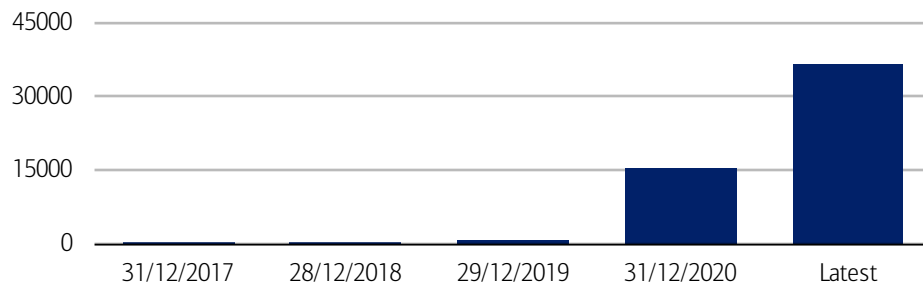
From ICOs to DeFi

An early use case for Ethereum was the ICOs¹³. At the same time, though, there was a lot of talk about how Ethereum and smart contracts implemented in Ethereum could replicate traditional finance products. This has led to the overall DeFi movement. Although this remains small compared to the total collection of cryptos (which currently has a market cap of \$1.5tr, according to CoinMarketCap), DeFi has grown significantly since the start of 2020.

¹³ Initial Coin Offering

Exhibit 92: Value locked in DeFi universe (\$000)

Rapid recent growth



Source: DeFi Pulse

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“Value locked” is a measure often used to assess the DeFi universe. It represents the quantity of Ethereum and other coins posted with the smart contracts which make up a particular service. Crudely, it’s a bit like the assets under custody for a custodian. Crudely, most current DeFi projects mainly break down into five buckets.¹⁴

Asset tokenisations

This means establishing tokens which represent assets. The assets can be either generic (the USD, for example) or specific – such as a particular diamond, or the house where we live.

Once you’ve tokenised assets, it becomes much easier to move these around using DLT¹⁵. One of the most interesting DeFi constructs is the on-chain collateralised stablecoin. Stablecoins are supposed to represent a fixed exchange rate with a fiat currency. Arguably the best known is Tether, which is supposed to track the USD, and to be backed by dollars held on deposit¹⁶. This places a lot of weight on the integrity of the external entity or entities validating the assets on deposit. The DeFi alternative is on-chain collateralisation, where a chain-native token is “locked” via a smart contract to provide collateral. Dai, a well-known DeFi stablecoin, works like this, with 1USD being collateralised by Ether worth USD 1.50. A smart contract would liquidate the collateralised position, selling Ether and redeeming Dai, should the collateral fall below this level. Clearly, given the performance of Ethereum over the past couple of years, this would overall have worked well, but faces a mixture of gap risk and wrong-way risk. The more Ethereum falls, the more it has to be sold.

Why Dai matters

Dai is an important part of the DeFi landscape because it provides a way of settling contracts in USD. Many financial products require a low volatility asset, and Dai provides this. Dai currently has around a \$2.3bn market cap, according to CoinMarketCap. Tether is an order of magnitude larger, possibly in part reflecting the present difference in scale between the DeFi universe and the broader crypto world. We think Tether fulfils a similar role to Dai for the broader Crypto world.

Lending

A range of DeFi applications allow owners of crypto to use their holdings either to collateralise borrowing or to earn interest via lending. There are two broad approaches¹⁷.

¹⁴ A lot of this account is based on “Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets”, Schär, Federal Reserve Bank of St. Louis Review, Early Edition 2021

¹⁵ Distributed Ledger Technology – Blockchains are an example of DLT, but there are other approaches to distributed ledgers.

¹⁶ Here, we note Tether’s recent settlement with the New York Attorney General (23.2.21).

¹⁷ We’re here ignoring so-called “flash loans”, which are an even newer product which wrap up receiving and repaying the loan into the same transaction.



Creating new coins

This is how Dai are created, for instance. People deposit Ether, and receive Dai. They can then use Dai, or lend it, earning interest. MakerDAO is the obvious example of this.

Lending existing coins

In this paradigm, participants lend and borrow coins, and pay and receive interest, with once again collateral being locked inside a smart contract to protect the lender. The largest lender of this sort appears to be Compound, which pools coins and pays lenders a composite interest rate which reflects, in part, how much of the pool has been borrowed. The other approach matches lenders and borrowers.

Exchanges

DeFi has also seen a lot of innovation among exchanges. The key factor here is that with distributed ledger, many of the functions which are separate in fiat trading are conducted on chain. DVP takes place via a so-called “atomic swap”, with ownership of two different assets occurring at the same time. Transaction and settlement are the same thing. Given that custody also occurs on chain, at least three functions of a traditional exchange are merged into one.

Schär has broken DeFi exchanges into four categories:

- Decentralized Order Book Exchanges, which typically have a centralised price discovery system off chain, but use the chain for execution and settlement. Ox is, according to Schär, the leading proponent of this approach.
- Constant Function Market Maker – this is a less familiar sounding model where transactions within a marketmaker cause the marketmaker to move its price. This is in turn pulled back to the prevailing market price by arbitrage. Curve, UniSwap and Balancer are some of the larger exchanges using this approach.
- Smart Contract-Based Reserve Aggregation – which sounds quite a lot like a marketmaker-driven model. Liquidity providers submit prices to a smart contract. Liquidity takers then approach the smart contract, which executes against the best price. Kyber is an example of this.
- Peer-to-Peer Protocols. This is a RFQ-type model, whereby participants identify potential counterparties then negotiate pricing bilaterally, once again executing and settling on chain. AirSwap is the best known example of this approach.

We are not aware of this approach being taken to trading conventional assets, but if you were to tokenise a conventional equity, you could use similar approaches.

Is there more?

There are also a range of other DeFi services.

Derivatives

There are platforms which allow you to deposit collateral and trade various forms of derivatives. Synthetics, for example, allows people to trade tokenised forms of fiat currencies, cryptocurrencies (long and short) and commodities. Others allow people to trade on the outcome of real world events – Auger is a well known example of this.

Asset management

There are a range of entities exploring on-chain asset management products. These are interesting in that custody occurs on chain (DLT may be a sensible option for mainstream custody, though it's not one which has been widely embraced yet), with assets being locked in smart contracts. This provides investors which a lot more transparency than mainstream management, and typically investors also can withdraw funds as they choose.

Potential issues

We see a number of potential issues.

It's not very big

Firstly, the scale of DeFi products thusfar has clearly grown sharply, but at around \$35bn at present, is still miniscule compared to mainstream finance. This seems an opportune moment to recycle something like “mighty oaks from little accords grow”; however, nobody reasonably could claim that DeFi has at present been fully stress-tested.

How hack-proof would DeFi be if the numbers involved were larger? We simply don't know.

Scalability

On the other hand, you could legitimately worry about how well DeFi would cope with a major influx of funds. Ethereum may be more scalable than Bitcoin, but it, too, faces constraints in terms of speed, block size, the price of Ether and so on. Solutions to scalability typically involve moving activity off chain, with the chain being used for settlement finality. This tends to undermine some of the core characteristics of DeFi, including transparency, decentralisation and the lack of dependencies on third party entities.

It's not really creating credit

Credit creation is one of the key motors of modern finance. As yet, DeFi doesn't do anything like this. The various loan products there are typically are simply reworkings of the traditional margin loan concept, except that rather than turning an asset into cash, they turn one kind of coin into another, whilst locking up more of the first coin. We haven't seen anything like fractional reserve banking. This would seem hard to replicate in a DeFi environment, precisely because it relies on the kind of structure (trusted, highly regulated entity) that DeFi is trying to get away from.

The code is the law?

The core argument of DeFi is that its products are safe because the code which the various smart contracts implement is transparent. Everyone can see exactly what's going on underneath the bonnet.

However, we see two problems with this argument.

Most people aren't experts

Confronted with a piece of DeFi code, we would have no confidence at all in our ability to predict that it would do. A system which requires its users to be PhD level programmers is not going to find widespread adoption, we'd assume.

Even experts make mistakes

In fact, it's worse than that. Even experts make mistakes. If they didn't, no piece of buggy software would ever be issued. We often point to the DAO as an example of what can go wrong – evidently, plenty of people did NOT expect the DAO to work the way it did – but you have no need of such an extreme example to make the point that glitches are pretty ubiquitous.

Mainstream finance takes the tech risk itself

Of course, mainstream finance gets tech wrong, too. However, if a tech glitch caused my bank to send £1,000 to a random third party, they would not reply to my complaint with “that's on you – you should have realised that our software would do that”, as a DeFi application might. Instead, they would give me the money back.



The point simply is that if you decentralise finance, you do away with a clear legal entity to complain about, regulate and sue. This is the point of it. But you also give up the ability to seek redress against such an entity.

Will trust re-enter the system?

An obvious way round this would be to say “although we don’t precisely understand how contract X works, expert Y or trusted entity Z says it’s fine, so I’ll go with that”. The issue here is that this brings trust back in via the back door.

Mining concentration worries us

Any mined currency is vulnerable to a so-called “51% attack”, where a malevolent actor amasses just over 50% of hashing power, and can use this to write their version of truth. Although the original idea behind Bitcoin was that validation would be distributed among thousands of idealistic computer aficionados, mining has become a commercial enterprise. The four largest mining pools typically account for around a half the total hashpower, according to Blockchain.com.

If DeFi began to replace mainstream finance, would you be happy with four unregulated entities having such a material influence on the system?

But proof of stake

Ethereum is moving towards a proof of stake system. This has its benefits (in particular, proof of stake does not require the same energy use as Argentina) but once again, it ends up with an oligopolistic collection of entities having a large influence over how the system works. We have not seen that many people worrying about this, but it worries us.

Exchanges – speed an issue

In addition, given we cover the exchanges, we have to point out that apart from the constant function marketmaker, the other three approaches mirror existing execution practices. We think it’s sensible to use a distributed ledger as a custody solution, and think that a distributed ledger central bank rail would make settlement much more straightforward than it is at present. However, we think there are clear benefits of a centralised, regulated exchange, in terms of speed (we think distributed ledgers are too slow to trade mainstream assets) and information security.

Overall – a lot of innovation, a long way to go

It’s hard not to be impressed with the degree of innovation on display in DeFi. At present, we think that there is nothing which is likely to provide a material challenge to mainstream finance. The core issue which DeFi faces is that the absence of a centralised, regulated entity leaves users very dependent on their ability to understand code. DeFi does, however, show the opportunity which DLT offers to finance. We believe that one of the best defences against being disintermediated by DeFi would be mainstream finance grasping these opportunities.

In sum, the growth of DeFi speaks to the flexibility of Ethereum, which we see as more than Bitcoin’s smaller sibling.

What we said about the DAO in our earlier note on cryptocurrencies

This was a major incident in the world of coins, but it is also arguably contributed mightily to Ethereum’s development. The DAO (“Decentralised autonomous organization”) was intended as a community directed venture capital fund. It was crowdfunded via a token sale in May 2016. The idea was that individual investors would vote on proposed investments chosen by a nominated manager. This

whole process was to be executed via smart contracts, taking advantage of Ethereum's capabilities.

Sadly, in June 2016, some malefactors moved a third of the DAO's funds into a subsidiary account. This was clearly contrary to the intentions of the DAO's promoters, but it was in keeping with the DAO's coding. This set off a vigorous debate about how to respond. Some argued that "the code is the law" and therefore although the action was evidently abusive, it was nonetheless valid. Others took the contrary view; Vitalik Buterin, the moving spirit behind Ethereum, fell into the latter camp, and he prevailed on the community to deploy a hard fork restoring the state of the Ethereum chain to how it was before the DAO hack.

This was not universally supported; some coin owners rejected this fork, and instead opted to move into "Ethereum Classic", a system with in essence the same code as Ethereum, but without the hard fork. Both versions of Ethereum implemented software patches which would stop future attacks such as the one suffered by the DAO.

Although this was not a glowing endorsement of Ethereum, the leadership the community showed seemed to have been reassuring, and certainly it has not damped enthusiasm for subsequent ICOs. However, this does show that code can do odd things, and that, in our view, the code isn't the law; the law is the law, and the code is at best a useful way of automating certain processes.

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