The Halving
Trends & Implications of Bitcoin's Inflation Mechanism

February 2020

EXECUTIVE SUMMARY

Bitcoin is hailed as the soundest form of non-sovereign digital money. Much of this reputation stems from a strictly regulated rate of inflation, which unambiguously and mathematically limits total supply to 21 million bitcoins. Less known, the reason bitcoin supply is so predictably scarce is the byproduct of a hard-coded event casually referred to as the halving (or "halvening").

The halving occurs every 210,000 blocks, or roughly every four years, and reduces Bitcoin's block reward by -50%. The next bitcoin halving - the third in the network's existence - will occur at block 630,000, which is expected to take place on May 12, 2020. This halving will reduce the block reward, or "coinbase transaction," from 12.5 bitcoins per block to 6.25 bitcoins per block, and supply inflation from 3.72% to 1.79%. For the first time ever, Bitcoin's inflation rate will fall below the 2% inflation target used by most central banks for their respective fiat currencies. As of January 31, 2020, 18.19M bitcoins have been minted, representing approximately 87% of the total supply.

Historically, the halving of block rewards is regularly cited as a bullish trigger, but will history repeat itself? This report discusses trends around previous halving events, bitcoin in the context of other commodities, and the relevant impact on the mining community.

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I. Introduction

Bitcoin is the first digital currency to combine censorship-resistance, transaction immutability, and pseudonymity on a distributed settlement layer. Sounds great in theory, but how can we feel confident the bitcoin network enforces these standards? The answer is found in the process of "mining," where network participants - miners - contribute computational resources to validate transactions. Validated transaction data is aggregated into containers, called blocks, which are recorded on an immutable, distributed ledger called a blockchain. Each block is cryptographically "chained" to the network, containing: metadata from the previous block, a timestamp, and transaction data.

Blocks are added to the bitcoin blockchain every 10 minutes, on average, and each block emits a reward of newly-minted bitcoin to miners who successfully validate a block. Currently, each block yields a reward of 12.5 bitcoins. At an average rate of 144 blocks per day, 1,800 new bitcoins (~3.9% annual inflation) are added to the circulating supply each day. As prescribed by the code behind the bitcoin network, bitcoin's monetary policy exhibits a down-trending inflation rate until total supply approaches 21 million bitcoins in the year 2140; however, 99% of bitcoin's supply will be minted by 2032.

Referred to as the "bitcoin halving," the number of bitcoins created in each block algorithmically decreases by -50% every 210,000 blocks, or roughly every four years. It's important to note that block rewards aren't gradually diminished, but rather they are immediately halved as soon as the 210,000th block is mined. In other words, block 629,999 will yield 12.5 bitcoins while block 630,000 will yield 6.25 bitcoins.

Figure 1: Bitcoin Block Halving Schedule

Era	Start Date	Block Height	BTC/block	Starting Supply	% of total supply	Inflation (4-yr avg)	
1	1-3-2009	0 - 209,999	50 BTC	0	0%	61.11%	
2	11-28-2012	210,000 - 419,999	25 BTC	10,500,000	50.00%	10.68%	
3	7-9-2016	420,000 - 629,999	12.5 BTC	15,750,000	75.00%	3.93%	Current Era
4	~5-12-2020	630,000 - 839,999	6.25 BTC	18,375,000	87.50%	1.74%	

Source: Kraken Intelligence

Note: Inflation from era 1 is a 3-year average because annualized inflation for 2009 was infinite.

There have been two prior bitcoin halvings, the first occurring on November 28, 2012, and the second on July 8, 2016. The last satoshi[1] will be mined on block 6,929,999, the block before the 33rd halving, when the mining reward will drop to 0 bitcoin, with a technical supply cap of 20,999,999.9769 bitcoins. Based on the block height of 615,350 as of January 31, 2020, the last bitcoin is expected to be mined in March 2140.
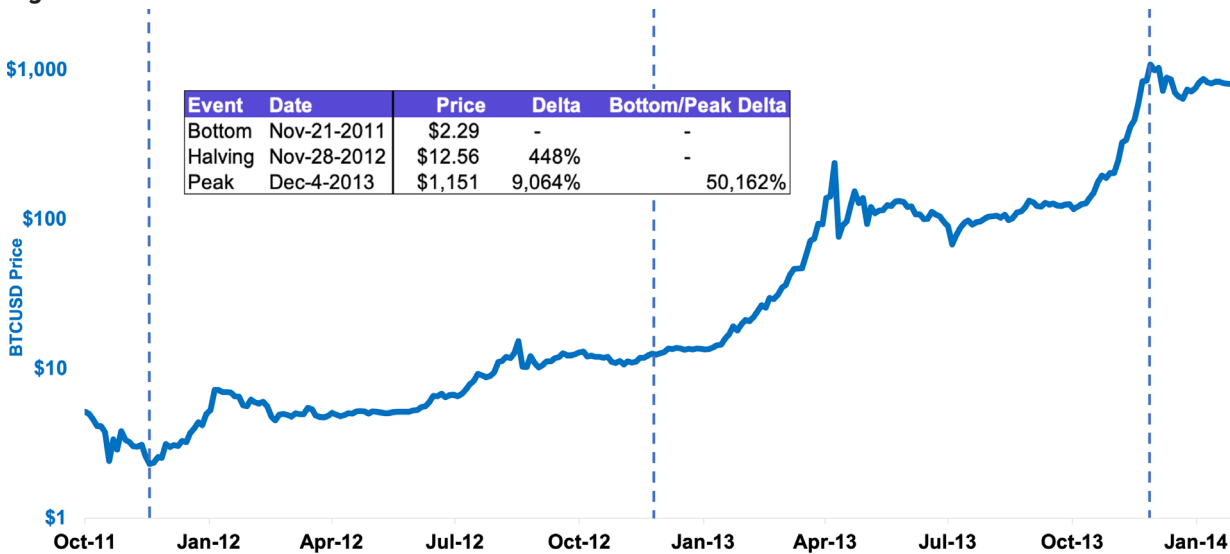

II. Historical Analysis

Analyzing the past two halvings in the network's history reveals a trend of bull runs taking place around reward reduction events. Because prior bull runs began 12-18 months before the halving and ended 12-18 months following the halving, we found it useful to analyze these timeframes and label the "relative bottom" or "relative peak" when referring to price changes around the time of halving.

1st Halving

Bitcoin's first halving took place on November 28, 2012 at block 210,000, reducing the block reward from 50 bitcoins to 25 bitcoins. Assuming 144 blocks are mined per day, this event caused daily rewards to decline from 7,200 to 3,600 bitcoins.

Looking to figure 2, a local bull market began in November 2011, one year prior to the halving, and ended in December, 2013, one year later. This period is marked by a +50,162% trough-to-peak increase in bitcoin's price. The uptrend later reversed in late-December 2013, descending into a multi-year bear market for bitcoin, marked by a drawdown of -80%.

Figure 2: BTCUSD Price Nov. 2011 - Dec. 2013

Event	Date	Price	Delta	Bottom/Peak Delta
Bottom	Nov-21-2011	$2.29	-	-
Halving	Nov-28-2012	$12.56	448%	-
Peak	Dec-4-2013	$1,151	9,064%	50,162%

Source: Kraken Intelligence, Blockchain.com
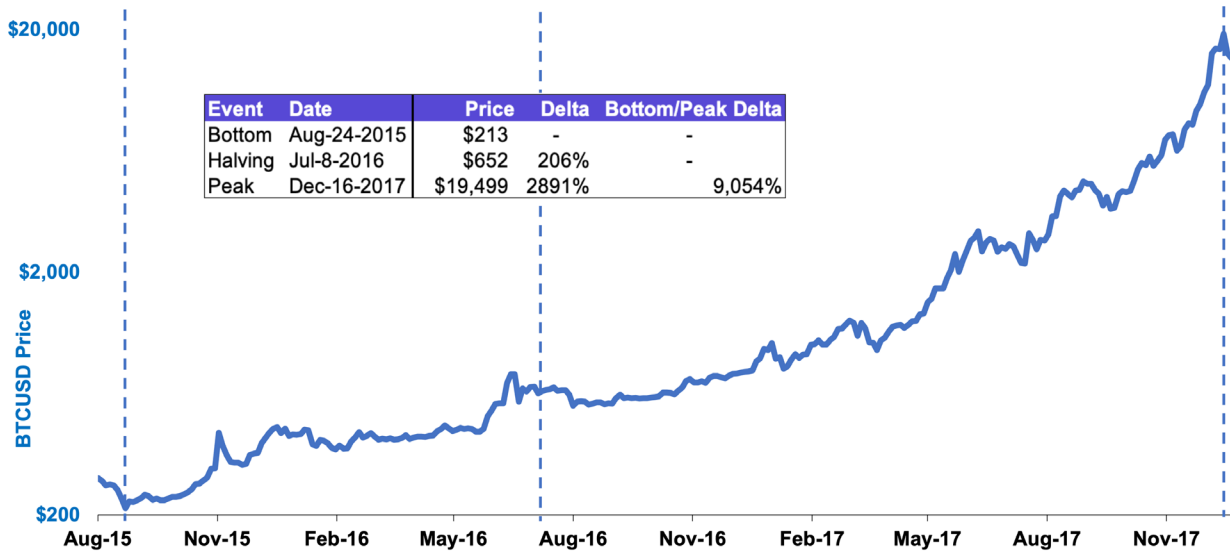
2nd Halving

The second halving event took place on July 9, 2016 at block 420,000, decreasing the block reward from 25 bitcoins to the current 12.5 bitcoins. On a daily basis, minting fell from 3,600 bitcoins to the current rate of 1,800 bitcoins per day.

Notably, the time between the first and second halving was only 1,316 days (3.6 years), falling nearly 150 days short of the widely expected 1,460 days (4 years). This anomaly can be attributed to mining growth outpacing the network's mining difficulty adjustment since application-specific integrated circuits (ASICs), the fourth-generation bitcoin mining equipment, were introduced in February 2013 and supplanted both field-programmable gate arrays (FPGAs) and GPUs. Although the mining difficulty feature is automatically adjusted every 2,016 blocks, or approximately every two weeks, to accommodate mining growth while sustaining an average block discovery time of 10 minutes, the algorithm did not account for unusually rapid technological advancements such as the leap from GPU and FPGA mining to ASIC mining. Even the first iterations of these mining rigs were able to generate 20-50x more bitcoins per dollar invested than GPUs, which in turn drove immense miner demand.[2]

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2   "The Evolution of Bitcoin Hardware," Michael Bedford Taylor. (https://cseweb.ucsd.edu/~mbtaylor/papers/Taylor_Bitcoin_IEEE_Computer_2017.pdf)

Unlike the first halving, where a local bull trend began one year prior to the event, bitcoin experienced a second bull run, this time beginning nine months prior. This event ostensibly straddles the infamous bull run of 2017, when bitcoin prices flirted with a price of $20,000. This bull run saw a +9,054% appreciation in price between the relative price bottom of $213 on September 21st, 2015 and the relative price peak of $19,499 on December 16th 2017, 18 months after the second halving. Similar to the first halving, this parabolic bull run resulted in a drawdown of -80%, bottoming out in December 2018.

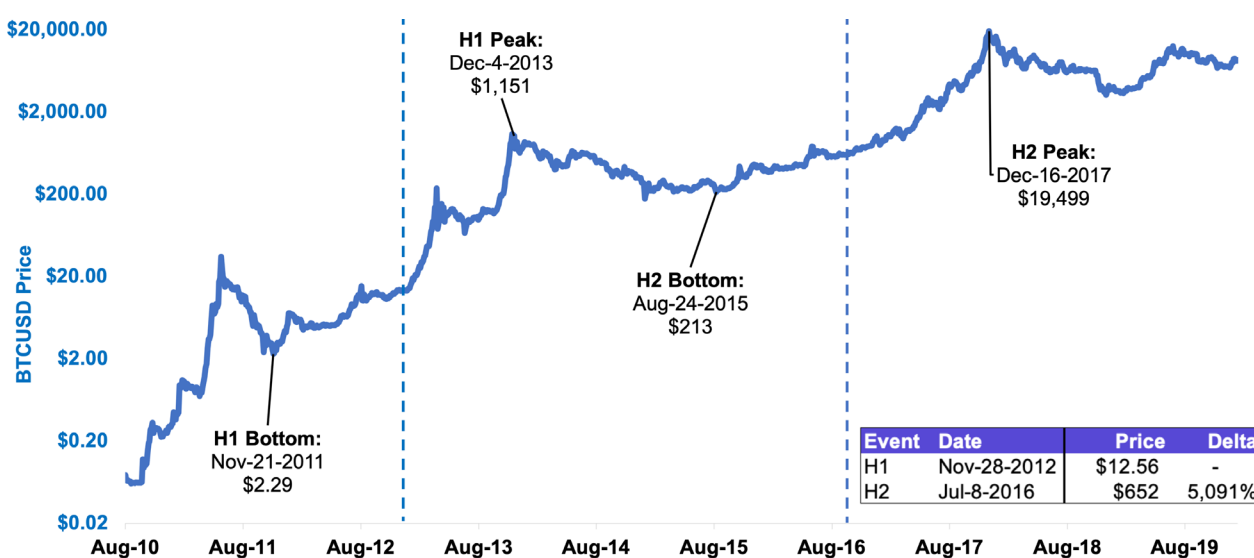**Figure 3: BTCUSD Price Sept. 2015 - Dec. 2017**

Event	Date	Price	Delta	Bottom/Peak Delta
Bottom	Aug-24-2015	$213	-	-
Halving	Jul-8-2016	$652	206%	-
Peak	Dec-16-2017	$19,499	2891%	9,054%

Source: Kraken Intelligence, Blockchain.com

Macro Perspective

Taking a step back, commonality between both halving events indicate a 2-year uptrend in bitcoin price around halving events followed by a 12-18 month, roughly -80% peak-to-trough downtrend. The relative price peak surrounding the first halving in November 2012 reached $1,151 in December 2013 almost exactly one year after the halving event. Nearly two years later, bitcoin's price retraced -81.5% to $213 in August 2015 before the second halving's bull-market cycle began. The second halving's local bull market ended nearly two and a half years later in December 2017 as price topped out at $19,499. Similarly to the first halving, price retraced -83% and ostensibly bottomed out at $3,225 in late-December 2018, one year later. Price has since partially recovered to $9,300 as of January 31st, 2020, representing an increase of +188% YoY.

Figure 4: BTCUSD Price Jan. 2009 - Jan. 2020

H1 Peak:
Dec-4-2013
$1,151

H2 Peak:
Dec-16-2017
$19,499

H2 Bottom:
Aug-24-2015
$213

H1 Bottom:
Nov-21-2011
$2.29

Event	Date	Price	Delta
H1	Nov-28-2012	$12.56	-
H2	Jul-8-2016	$652	5,091%

Source: Kraken Intelligence, Blockchain.com

III. Event Significance

"It's more typical of a precious metal. Instead of the supply changing to keep the value the same, the supply is predetermined and the value changes. As the number of users grows, the value per coin increases. It has the potential for a positive feedback loop; as users increase, the value goes up, which could attract more users to take advantage of the increasing value."[3]
- Satoshi Nakamoto

The halving is critical to helping bitcoin satisfy the definition of sound money. Because the minting process is subject to 50% reductions, bitcoin supply follows a disinflationary curve. The upcoming halving will reduce annual supply inflation from a rate of 3.7% to 1.8%. This marks the first time in history that Bitcoin's inflation rate will fall below the 2% inflation target used by most central banks for their respective fiat currencies.

Disinflationary assets such as gold have proven to be a better store of value than inflationary assets (e.g., fiat currency). Serving as an anecdote, the British pound sterling, the longest standing fiat currency at 317 years, has lost more than 99.5% of its value since inception.[4] Notably, this price decline does not account for the price depreciation of silver, as the pound was originally defined as 12 ounces of silver. In other words, arguably the most successful currency in history is worth less than 0.5% of its value due to its inflationary nature. On the other hand, since the U.S. officially ended its adherence to the gold standard in 1973, the value of gold has appreciated by +1,760% while the U.S. dollar experienced a cumulative inflation rate of 472.53% within the same timeframe; namely, $1 in 1973 had the same purchasing power as $5.73 does today.

Figure 5: Real Purchasing Power (Inflation-adjusted)

Year	EUR	GBP	USD	BTCUSD (12/31)
2010	€1.00	£ 1.00	$1.00	$0.30
2011	€0.98	£ 0.97	$0.97	$4.85
2012	€0.95	£ 0.95	$0.95	$12.97
2013	€0.93	£ 0.93	$0.94	$698.82
2014	€0.92	£ 0.91	$0.93	$296.16
2015	€0.93	£ 0.88	$0.93	$398.59
2016	€0.92	£ 0.85	$0.91	$871.12
2017	€0.91	£ 0.82	$0.89	$12,591.24
2018	€0.90	£ 0.80	$0.87	$3,307.33
2019	€0.89	£ 0.79	$0.85	$6,123.45

Source: Kraken Intelligence, Blockchain.com, Inflationtool.com

3   "Bitcoin open source implementation of P2P currency," Satoshi Nakamoto (http://p2pfoundation.ning.com/forum/topics/bitcoin-open-source?commentId=2003008%3AComment%3A9562)
4   "Pound Sterling," Wikipedia (https://en.wikipedia.org/wiki/Pound_sterling)"What's with this odd generation?" Satoshi Nakamoto (https://bitcointalk.org/index.php?topic=48.msg329#msg329)

Scarcity & Stock-to-Flow

"As a thought experiment, imagine there was a base metal as scarce as gold but with the following properties: boring grey in colour, not a good conductor of electricity, not particularly strong, but not ductile or easily malleable either, not useful for any practical or ornamental purpose, and one special, magical property: can be transported over a communications channel"[5]
- Satoshi Nakamoto

Satoshi's infamous 2008 bitcoin whitepaper envisioned how provably scarce data could serve as a form of electronic cash. Often, bitcoin is likened to a commodity more akin to gold or silver. Bitcoin, commonly referred to as "digital gold," currently struggles to compete with widely-adopted payment systems due to price volatility, scaling limitations, and a complex user experience. That said, many bitcoin adopters maintain unwavering confidence in bitcoin's attractiveness as a store of value. The incumbent store of value that we all recognize - gold - shares similar limitations as a modern payment mechanism: few merchants accept gold for payments; gold exhibits price volatility, albeit lower; and the ability to transport or modify transaction sizes is limited to melting and shaving bullion.

Though gold is not an ideal modern medium of exchange, it has built a reputation as one of mankind's oldest and most trusted stores of value. In large part, gold's value holds well over time due to its scarcity, commonly measured by the stock-to-flow (SF) ratio. The SF ratio quantifies the scarcity of an asset, measured by dividing an asset's total circulating supply (stock) by the amount produced annually (flow).

$$Stock\ to\ Flow\ = \frac{Stock\ (Circulating\ Supply)}{Flow\ (Annual\ Production)}$$

Stock-to-flow recognizes that economic utility of a consumable good is realized when the good is used, but the utility of investment assets with high SF ratios lie in their storage and eventual resale. For reference, an asset with a SF ratio of 50 will take 50 years of the current production rate to double current stock levels.

Figure 6: SF of metal commodities vs. BTC

January 2020 (Pre-halving)

Asset	Stock	Flow	SF	Inflation
Gold	209,483	3,300	63.48	1.58%
₿	18,100,000	657,000	27.55	3.63%
Palladium	283	193	1.47	68.20%
Platinum	251	176	1.43	70.12%
Silver	31,375	26,750	1.17	85.26%

May 2020 (Post-halving)

Stock	Flow	SF	Inflation
209,483	3,300	63.48	1.58%
18,375,000	328,500	55.94	1.79%
283	193	1.47	68.20%
251	176	1.43	70.12%
31,375	26,750	1.17	85.26%

Source: Kraken Intelligence, Gold.org, Mining.com, Statista.com, Silverinstitute.org, Blockchain.com

Note: Stock and Flow are both measured in US tons with the exception of BTC

Assets with higher SF ratios exhibit lower annual inflation rates. While gold currently has the highest SF of popular metal commodities, bitcoin's SF is expected to take the lead immediately following fourth halving in May 2024. Bitcoin isn't itself a metal commodity, but we found this to be an impactful comparison since it is commonly seen as "digital gold" due to its similar properties (e.g., store of value, rare, currency functionality, production via "mining"). Importantly, the SF ratio may prove unpredictable for certain commodities, including gold, if major resource discoveries are made or technology advances allow for cheaper resource extraction. For example, the discovery of a large gold mine or new techniques to extract gold that was otherwise too difficult to source economically can both result in higher-than-expected flows. Bitcoin uniquely benefits from mathematical certainty of known and extractable supply based on current network parameters.

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5   "Bitcoin does NOT violate Mises' Regression Theorem" Satoshi Nakamoto (https://bitcointalk.org/index.php?topic=583.msg11405#msg11405)

Additionally, bitcoin's scarcity may be understated due to a potentially large amount of bitcoin's supply being inaccessible, lost, or encumbered in unspendable wallets, which some estimates claim to be 7% - 29% (1.5-6M bitcoins) of total supply.[6,7,8,9]

Impact on Miners

> *"In a few decades when the reward gets too small, the transaction fee will become the main compensation for [mining] nodes. I'm sure that in 20 years there will either be very large transaction volume or no volume."[10]*
> *– Satoshi Nakamoto*

Still, the halving does not simply impact the numerical supply of new bitcoins generated. Market participants should note, too, that mining businesses will be affected, as their fiat-denominated earnings and ability to pay real-world costs adjust to the change.

At the time of halving, miners will immediately undergo a ~50% reduction in revenue as the reward for providing new valid blocks declines. This could be complicated, however, by the regular change to bitcoin's mining difficulty, the measure of how challenging the protocol makes solving the calculations required to produce valid blocks and which adjusts programmatically every two weeks.

It's worth noting that the network will experience a mining difficulty adjustment at block 631,008, just over 1,000 blocks after the third halving, meaning miners will have to exert the same amount of work for half the revenue until the network's difficulty adjusts one week later (i.e., less competition correlates with lower difficulty and vice-versa). As a result, block validators must act accordingly prior to the difficulty adjustment in an effort to avoid associated financial risks.

As the halving approaches, bitcoin participants should consider the following implications:
- Miners will experience an estimated 45% - 50% decrease in nominal bitcoin rewards as the block reward, 92% - 96% of total mining rewards, falls -50%;
- Mining profitability may come under significant pressure depending on bitcoin price performance going into the halving as operating costs, including facilities and electricity, remain largely fixed;
- Assuming a price of $9,300, gross annual mining revenue will drop from $6.1 billion per year to $3.1B billion following the May 2020 halving;
- Expect transaction fees to become a more salient topic for debate as network participants begin to digest a subdued block subsidy environment; and
- If miners choose to exit the market, the network may experience a reduction in hash rate and security, albeit the security of the bitcoin network is very high today and price remains much higher than best-in-class marginal production cost.

Because transaction fees only represent 4 - 8% of the total block rewards, we must consider whether *greater adoption and transaction volume will result in transaction fees sufficient to cover block reward subsidies. Further, is the four-year interval between halvings enough for adoption to flourish?*

Transaction fees are determined at the discretion of the bitcoin user, and higher fees incentivize miners to process a transaction. Thus, transaction fees are more closely correlated with a fundamental increase in demand than the bitcoin halving itself. While transaction fees aren't seemingly increasing in direct response to the halving, they have on average been increasing over time.

6   "5 Million Bitcoin May Have Been Lost Forever" (https://www.trustnodes.com/2019/05/14/5-million-bitcoin-may-have-been-lost-forever)
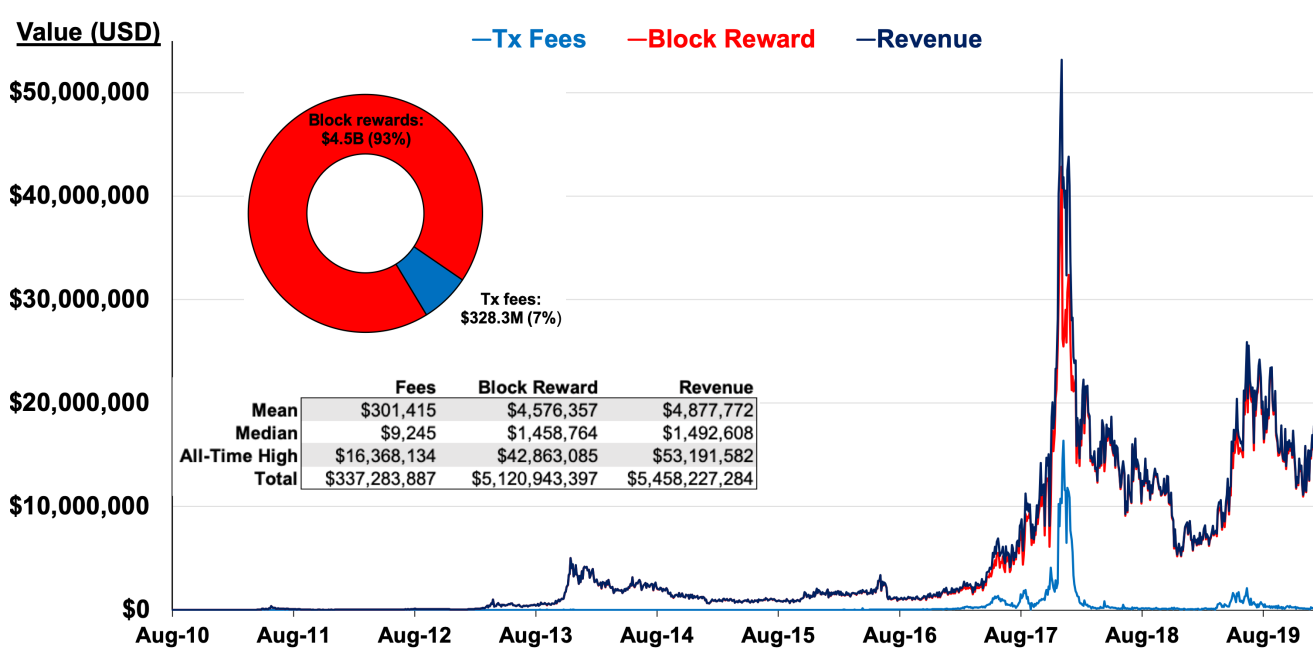7   "6 Million Bitcoin is Lost or Stolen, Should the Real Value of BTC Higher?" (https://www.ccn.com/6-million-bitcoin-is-lost-or-stolen-should-the-real-value-of-btc-higher/)
8   "Exclusive: Nearly 4 Million Bitcoins Lost Forever, New Study Says" (https://fortune.com/2017/11/25/lost-bitcoins/)
9   Coin Metrics' State of the Network: Issue 26 (https://coinmetrics.substack.com/p/coin-metrics-state-of-the-network-d2e)
10   "What's with this odd generation?" Satoshi Nakamoto (https://bitcointalk.org/index.php?topic=48.msg329#msg329)

Figure 7: Tx Fees vs. Coinbase vs. Revenue

	Fees	Block Reward	Revenue
Mean	$301,415	$4,576,357	$4,877,772
Median	$9,245	$1,458,764	$1,492,608
All-Time High	$16,368,134	$42,863,085	$53,191,582
Total	$337,283,887	$5,120,943,397	$5,458,227,284

Source: Kraken Intelligence, Blockchain.com

In the network's current state, Bitcoin does not have the required transaction volumes or fees to compensate for the reduction in block reward subsidies, although that may change in the future.

Figure 8: May-2020 reward adjustment estimation

Block #629,999	BTC	FX Rate	Total
Mining subsidy	12.5	$9,300	$116,250
Tx Fees	0.32	$9,300	$2,951
Revenue	**12.82**		**$119,201**

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Block #630,000	BTC	FX Rate	Total
Mining subsidy	6.25	$9,300	$58,125
Tx Fees	0.32	$9,300	$2,951
Revenue	**6.57**		**$61,076**

Source: Kraken Intelligence, Blockchain.com
Note: Transaction fees are estimated based on the 2019 average

As seen above in figure 8, total miner revenue will be reduced by -$58,125 (assuming a BTCUSD FX rate of $9,300) at block 630,000 later this year. In order for miners to be fully compensated for the loss in revenue, transaction fees would need to grow by a factor of 19.7x. This means that, assuming an average of 330,000 transactions per day amounting to a total $425,000 in fees (based on 2019 averages), either transactions per day would have to increase by +1,970% to an average of 6.83M or fees by +1,869% to $25.40 per transaction to make up for the revenue loss (see figure 9).

Figure 9: Current average Tx fee & daily volume vs. Required average Tx fee & daily volume for compensation

Source: Kraken Intelligence, Blockchain.com

This is a topic that we expect will come under more scrutiny around the time of the 2020 halving and beyond, but for the time being, the only metric that has the power to fully compensate miners for the reduction in revenue is a proportionate increase in the value of bitcoin.

IV. Summary & Conclusion

The two previous halvings demonstrated a 2-year uptrend in bitcoin price beginning 12-18 months prior to halving, followed by a roughly -80% peak-to-trough downtrend. The most recent halving's bull run lasted nearly two-and-a-half years and ended in December 2017 as price topped out at $19,499. Price gradually retraced -83% and ostensibly bottomed out at $3,225 in late-December 2018, one year later. Bitcoin has since partially recovered to $9,300 as of January 31st, 2020, representing an increase of +188% YoY.

The halving is critical to helping bitcoin meet the definition of sound money. Because the minting process undergoes -50% reductions, bitcoin supply follows a disinflationary curve. Other assets that follow a disinflationary curve, such as gold, have proven to be a better store of value than inflationary assets (e.g., fiat currency). The third halving - expected to occur on May 12, 2020 - will reduce annual supply inflation from a rate of 3.7% to 1.8%, marking the first time in history that Bitcoin's inflation rate will fall below the 2% inflation target used by most central banks. Bitcoin's code prescribes a down-trending inflation rate until total supply approaches 21 million bitcoins in the year 2140; however, 99% of bitcoin's supply will be minted by 2032.

Assets with higher stock-to-flow ratios, such as gold, exhibit lower annual inflation rates. While gold currently has the highest SF of popular metal commodities, bitcoin's SF is expected to take the lead at the time of the fourth halving in May 2024. Bitcoin isn't a metal commodity, but we found this to be a meaningful comparison since the digital asset is commonly seen as "digital gold" due to its similar properties.

At the time of halving, mining profitability may come under significant pressure depending on bitcoin price performance as miners will experience an estimated 45% - 50% decrease in nominal bitcoin rewards while operating costs, including facilities and electricity, remain largely fixed.

Bitcoin does not currently have the required transaction volumes or fees to compensate for the reduction in block reward subsidies, although that may change in the distant future. Transaction fees will likely become a trending topic for debate as network participants begin to digest a subdued block subsidy environment. For the time being, the only metric that has the power to fully compensate miners for the reduction in revenue is a proportionate increase in the value of bitcoin.

In conclusion, Bitcoin currently struggles to contend with mass-adopted payment systems due to price volatility, scaling limitations, and a complex user experience. That being said, many bitcoin users maintain resolute confidence in bitcoin's attractiveness as a store of value thanks to the halving.

Disclosure appendix

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