Impact of 2020 Bitcoin Halving: A Mathematical, Social, and Econometric Analysis

Jered Masters, November 2019

DRAFT #3
27/11/2019

Abstract

Bitcoin [1] is a decentralised crypto currency where transactions are made by broadcasting the intention to transact to volunteer "miners" around the world. These miners then compete to create a cryptographic signature that proves the transaction is valid and was initiated by a party in control of the funds. These miners are rewarded for creating this signature in a fixed amount of bitcoin, the amount of which halves approximately every four years.

The next halving is predicted to occur in May 2020. This will result in the block reward for every miner halving from 12.5 BTC per block to 6.25 BTC. This could have significant impact on mining profitability, the price of Bitcoin, liquidity and global transaction volume.

This "Halving" or "Halvening" event is predicted to have significant impact on Bitcoin price and mining profitability. At the time of writing this event will reduce the global revenue of Mining by $7.3M USD (equivalent) per day. However, some experts and analysts are speculating there will be significant increase in the price of Bitcoin, possibly more than doubling it over 12 months resulting in an extra $146.6B USD on the current Bitcoin market capitalization.

Table of Contents

1.0 Introduction

1.1 Purpose

This document is intended to inform about the general industry opinion, statistical historic analysis, and the prediction of available mathematical models.

1.2 Scope

This will review existing literature, apply proven models to the latest data and present the mathematical findings. Where possible making predictions is avoided, excluding where simply showing the results existing models are applied to publicly available data. This in no way should be interpreted as investment or financial advice. Please conduct your own due diligence before making any investment decision.

1.3 Audience

This document is intended to be read by stake holders such as miners and traders. However, the concepts should be readily accessible to others with a casual understanding of crypto currencies and trading.

1.4 Summary of Results

2.0 Literature Review

Given the significant impact of the halving on mining rates and profitability there has much online speculation and casual analysis, but few papers written. However, there are many papers on Bitcoin itself, concerning the price and volatility.

2.1 Fundamental Value of Bitcoin

Placing a fundamental value on Bitcoin has been a highly controversial topic with Jamie Dimon, the CEO of investment bank JPMorgan Chase, saying in 2018 that the value of bitcoin is zero and the entire pursuit is at best fools errand, and at worst a fraud. Dimons' views are echoed by Cheah and Fry in [2]. In their 2015 paper they laid out an empirical investigation and mathematical observations using formulas and from Johansen at al (1998) [3] and concepts from Shiller (2000) [4] who have both done extensive work on understanding market bubbles and crashes from mathematical views and social views respectively.

There have also been several attempts to establish a fundamental value for Bitcoin [5], or at least lower and/or upper bounds [6]. Hayes in 2015 proposed a model looking at the cost of production to evaluate the price of Bitcoin [7] and in 2018 Hayes back tested the model on recent data [5]:

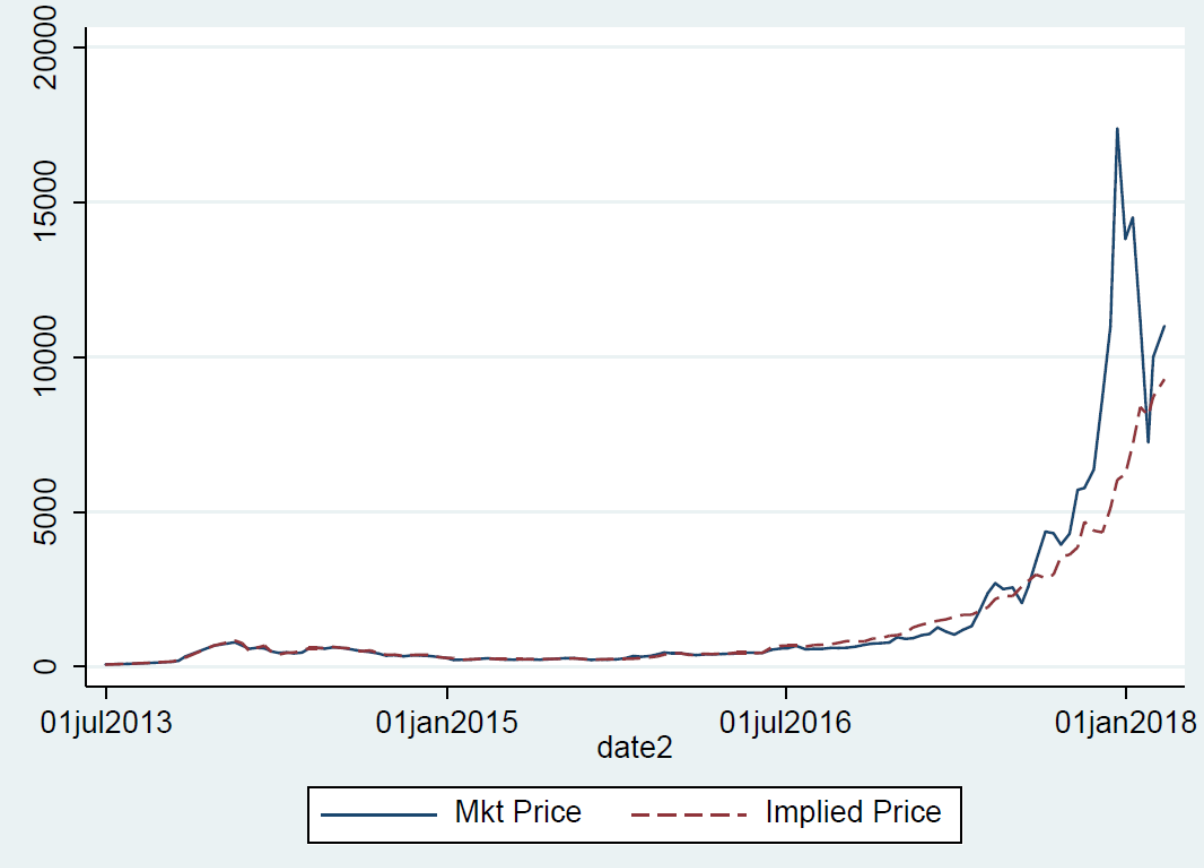

Figure 1 - Price of Bitcoin vs Production Cost Implied Price [5]

Although these findings have been informally disputed [8], but without a specific correction. It is also possible that this finding merely proves that the investment in mining has an equilibrium with the value of Bitcoin but is slow to react; as opposed to the value returning to the fundamental value.

2.2 Bitcoin Price Factors

An article in Risk and Financial Management journal by Frode Kjærland et al [6] finds the (global) Hashrate to be irrelevant in modelling Bitcoin price dynamics. This is in stark contrast to Hayes in 2015 [7] who found the Hashrate to be a significant factor of Bitcoin price. Kjærland counters that the underlying protocol requiring adjustments in the mining difficulty to effect a consistent and deterministic supply of Bitcoins, and therefore has no market impact and goes on to prove this via statistical correlation.

Other market factors have been closely studied and have been found to have a significant impact [9] [10]. This makes intuitive sense from a supply and demand point of view. These factors include exchange-trade, equity market indices, currency exchange rates, commodity prices, and transaction volume.

2.3 Mining Cost and Energy Efficiency

In his 2015 paper, Hayes evaluated the average energy cost of mining [7]. This evaluation sheds light on the significant performance increases given by the different technologies applied to mining.

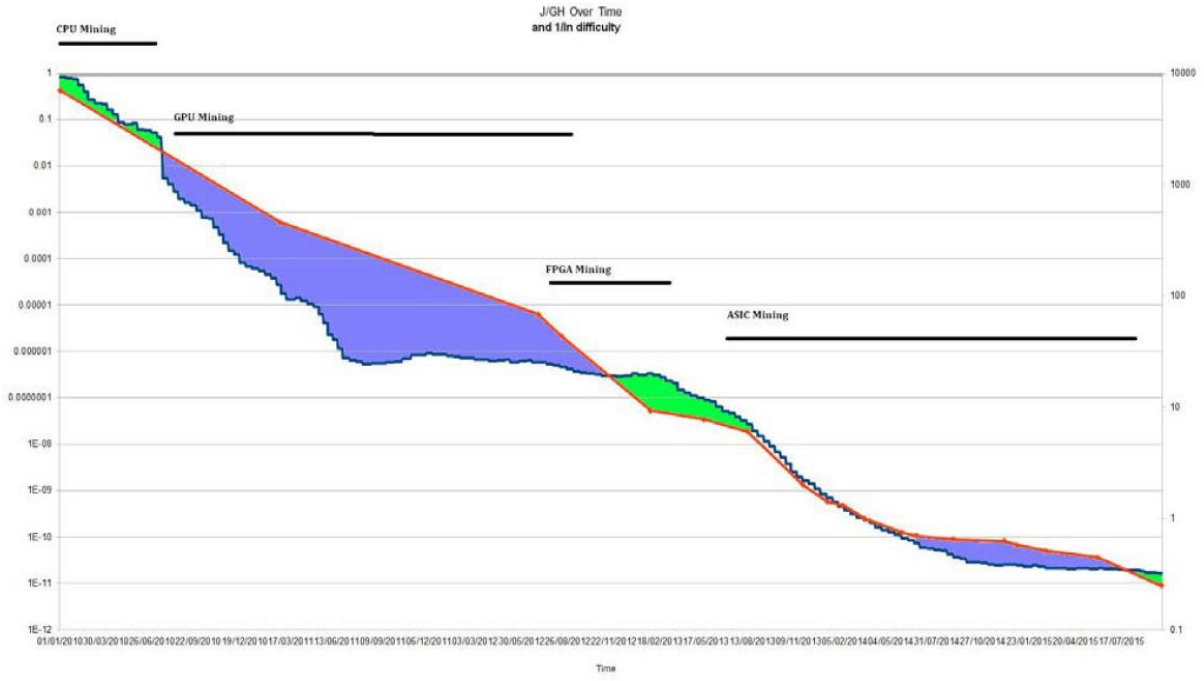

Figure 2 - Bitcoin mining difficulty vs mining energy efficiency over time [7]

2.4 Global Mining Efforts

Historically, the returns in Bitcoin mining was determined by capital expenditure, the ability to purchase the latest and greatest hardware [11]. The specialised mining hardware industry was in it's infancy until recently. In a few months the latest best practice in mining hardware development should change and having the latest hardware could provide a significant edge. However, it has recently become the general case that progress has slowed to a point where the largest miners no longer compete on hardware (thereby CAPEX) and instead on decreasing operating costs [11] [12].

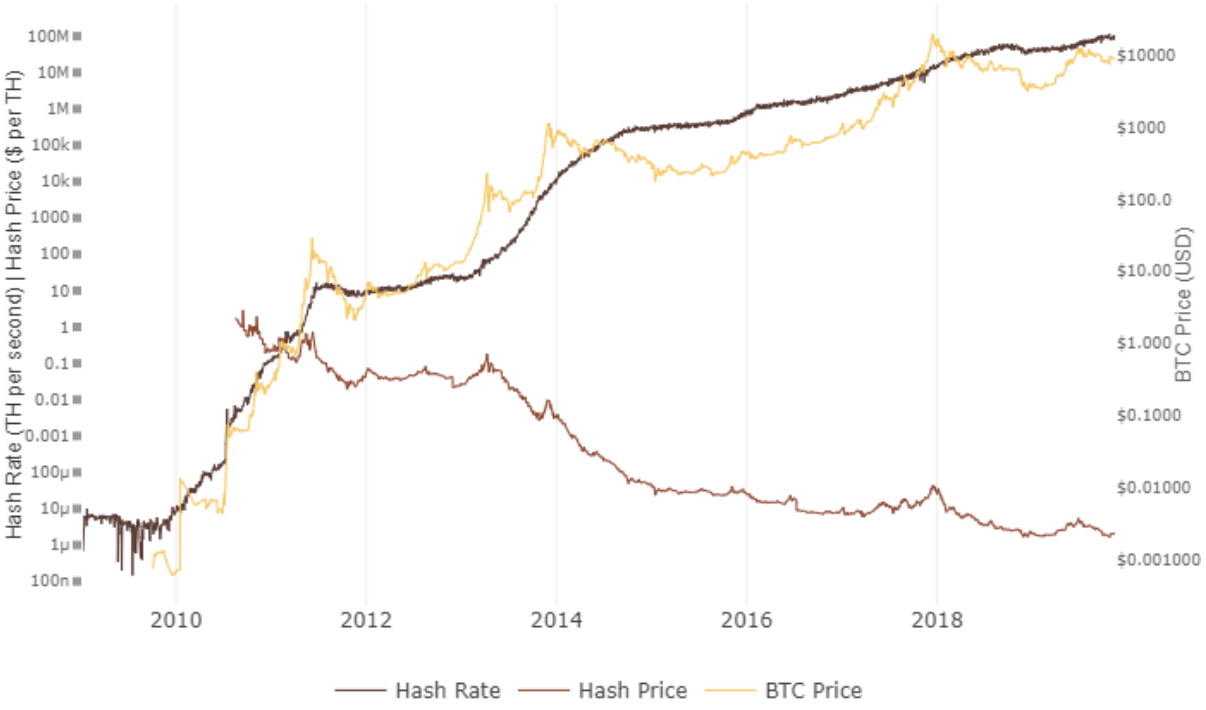

Figure 3 - Hash rate, Hash cost and Bitcoin Price [13]

2.5 Non-Economic Trade Volume on Exchanges

In a presentation to U.S. Securities and Exchange Commission in 2019, Bitwise CEO Teddy Fusaro and Global Head of Research Matt Hougan reports that up to 95% of all reported trade volume is fake or non-economic in nature [14]. Another study by Alameda Research reports that up to 86% of trading volume is either fake or loss trading [15].

2.6 Altcoin Value Correlation to Bitcoin Value

In his 2015 paper, Hayes finds and equation for BTC denominated price of the top 66 altcoins (by trading volume).

$$ln(CoinPrice) = \beta 1 + \beta 2 ln(GH/s) + \beta 3 ln(CoinsPerMin) + \beta 4(\%CoinsMined) + \beta 5(Algo) + \beta 6(DaysSince) + e$$

where:

PRICE	:	is the bitcoin-denominated market price
GH/s	:	is the computational power in GigaHashes per second
COINS_PER_MIN	:	average number of coins mined per minute
%COINS_MINED	:	Percentage of coins mined thus far
ALGO	:	0 when using SHA256 and 1 when using scrypt
DAYS_SINCE	:	the number of calendar days since the altcoin inception

Equation 1 - Least Squares multiple regression for price correlation [7]

The beta coefficients were found to be as follows:

- β1 = -9.68
- β2 = 0.67
- β3 = -0.98
- β4 = -0.57
- β5 = 7.43
- β6 = 6.7 x 10^{-4}

This results in a historic correlation (for data up to September 18, 2014) of R^2=0.844. This suggest that approximately 84.4% of the variation in BTC equivalent value is caused by the variables described above.

2.7 Previous Halvings

It has been speculated that previous halvings have resulted in short price boom, then a smaller correction [16]. We can learn from previous halvings what might happen, but also the effect that making predictions might have as well.

Figure 4 - Bitcoin Price Over Time with Halvings. Source: [17]

2.7.1 Halving 2012, 50 BTC to 25 BTC

The first halving occurred on 28/Nov/2012, where the block reward dropped from 50 BTC (~$612.5USD then, ~$423,920 USD now) [18].

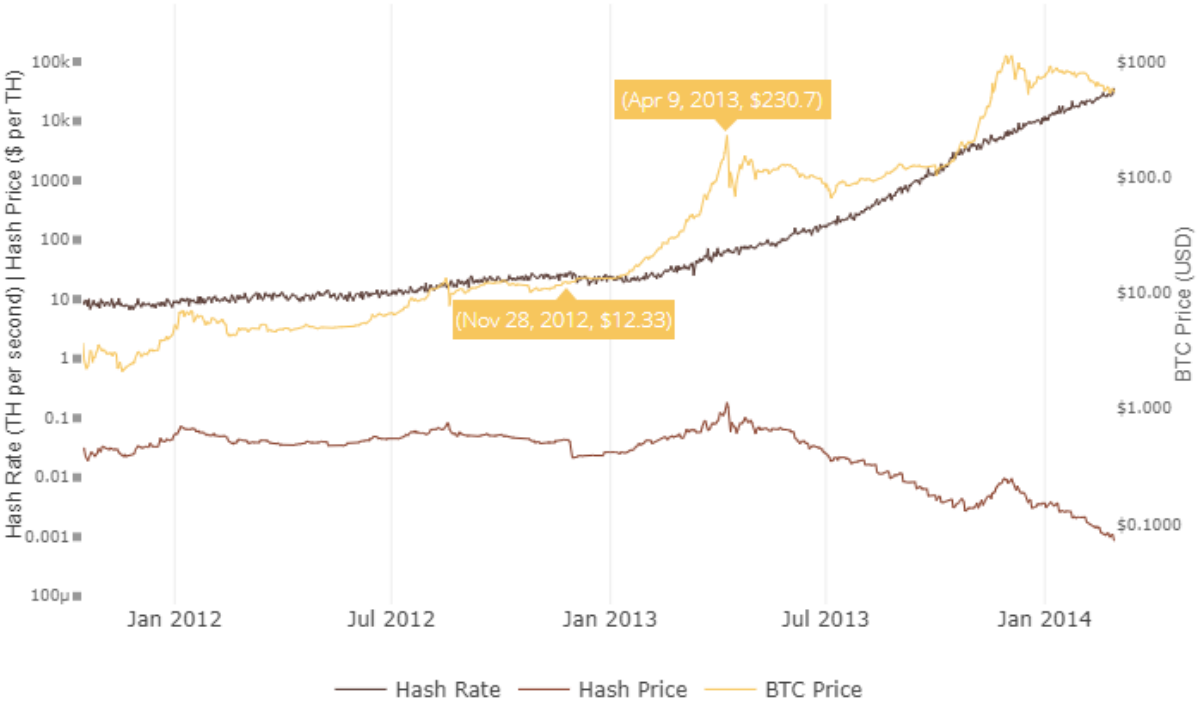

Figure 5 - Bitcoin Hashrate, Hash Price, and BTC Brice over 2012 Halving. Image Source: [13]

In the 2012 halving, the industry observed a significant increase in the value of Bitcoin, on the order of ~20x, within 6 months. After a not insignificant correction it retained about half of the value it gained.

2.7.2 Halving 2016, 25 BTC to 12.5 BTC

The second halving occurred on 9/Jul/2016, where the block reward dropped from 25 BTC to 12.5 BTC.

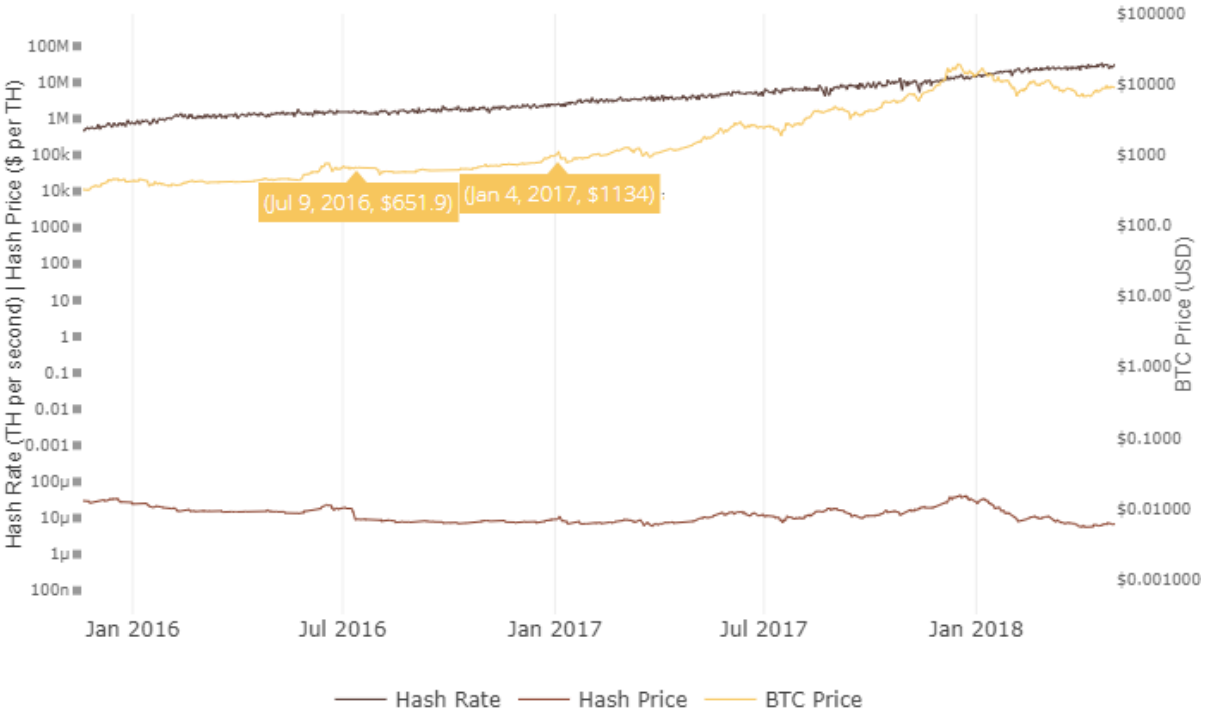

Figure 6- Bitcoin Hashrate, Hash Price, and BTC Brice over 2016 Halving. Image Source: [13]

The second halving shows less of an impact on the price within the first six months, however still very significant compared to other assets in the finance industry.

It should be noted that approximately 12 months after the 2016 halving Bitcoin saw its biggest surge in value, and 18 months after the halving it's highest price to date. Some experts have argued that this surge was due to factors other than the halving [19] [20].

3.0 Analysis of Previous Halvings

3.1 Block/Hash Reward and Difficulty

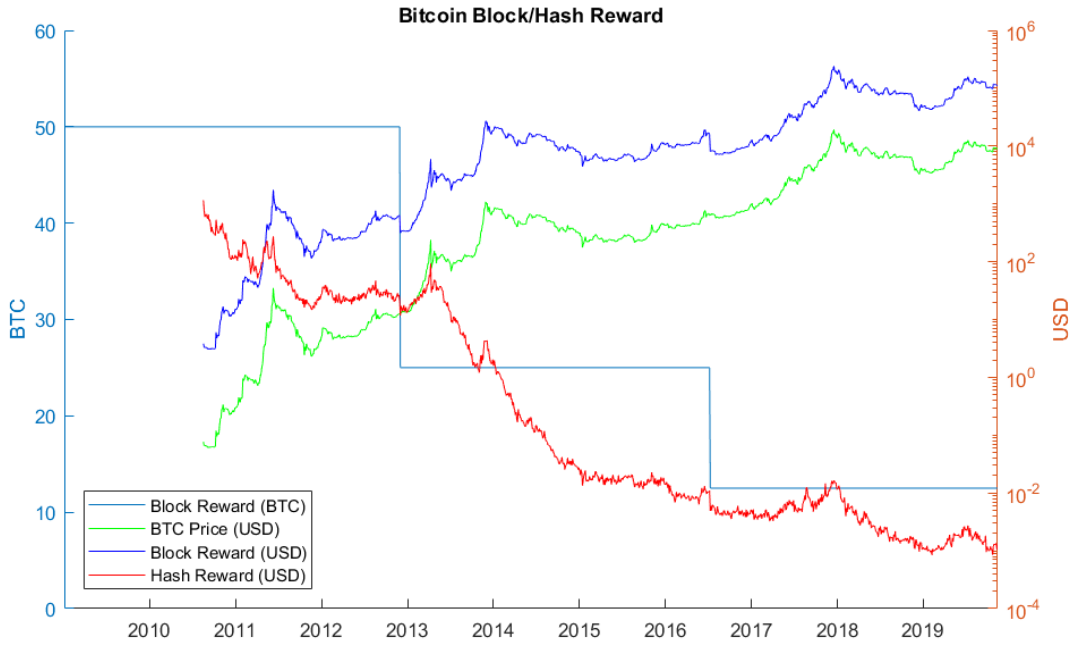

Figure 7 - Bitcoin Block/Hash Reward. Data source: [13] [18]

Small dips during the two previous halving's are visible in the USD equivalent block yield, however the price of bitcoin increases to the point where revenue per block continues to increase.

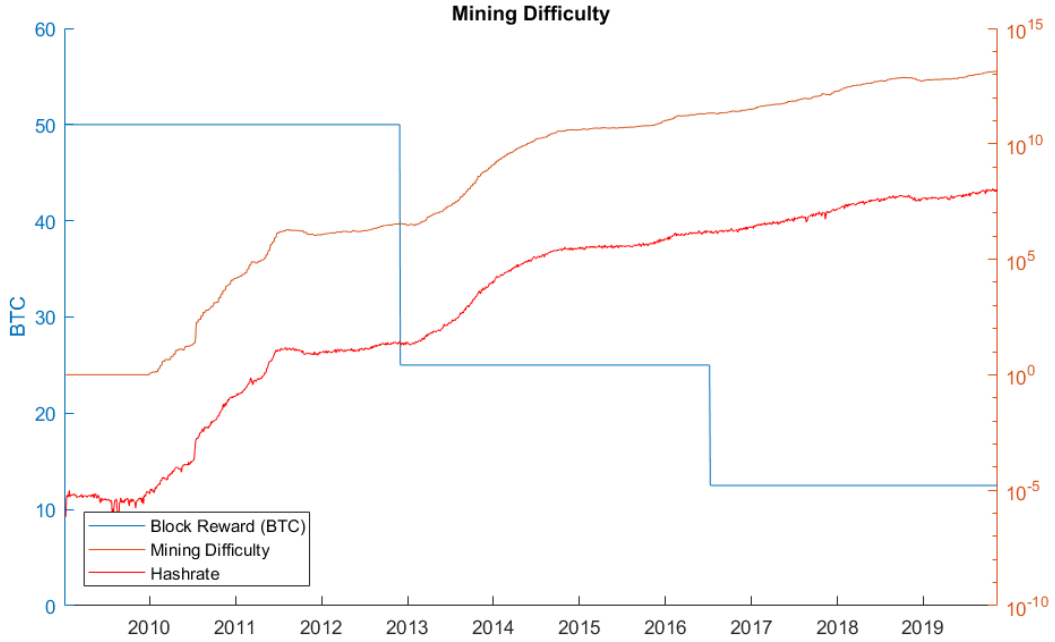

Figure 8 - Bitcoin Mining Difficulty. Data source: [13] [18]

3.2 Mining Power Consumption

Mining power consumption is an estimation based on currently available mining hardware and the publicly announced sales figures (where available) [21]. This has resulted in a best guess of the power per TH, and estimates upper and lower bounds [22]. These figures only produce reliable estimations after late 2014.

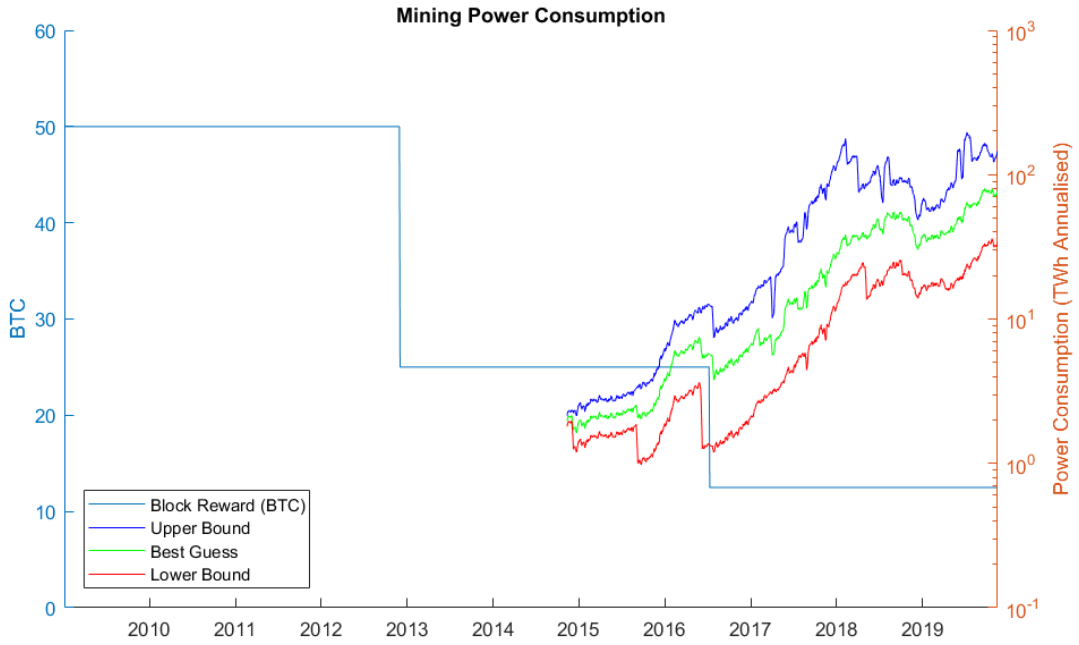

Figure 9 - Bitcoin Network Power Consumption. Data source: [22]

This data shows an expected increase over time in the amount of power consumed by the Bitcoin network overtime. Most notable is in the sudden drop in consumption around the second halving (data not available for the first halving)

3.3 Mining Estimated Global Cost/Revenue

Below is the estimated cost of mining based on the three estimation above (upper/lower/best guess). Power cost is simply the USD/KWh used in the calculation. The other factor taken into account is the Power Utilization Efficiency (PUE). This is a measure ratio of how much power an entire mining operation uses, vs the power applied only to the mining instruments (losses due to PSU and cooling). PUE is a value either equal to 1 (perfectly efficient) or greater.

The values used for these variables are different for the three levels used below:

	Power Cost (USD/KWh)	**PUE**
Upper Bound	0.02	1.01
Best Guess	0.05	1.03
Lower Bound	0.12	1.1

$$MiningCost = PowerConsumption \times PowerCost \times PUE$$

where: MiningCost : Mining cost per block in USD

PowerConsumption : KWh consumed in 10 min

PowerCost : Estimated cost of electricity

PUE : Power Usage Effectiveness

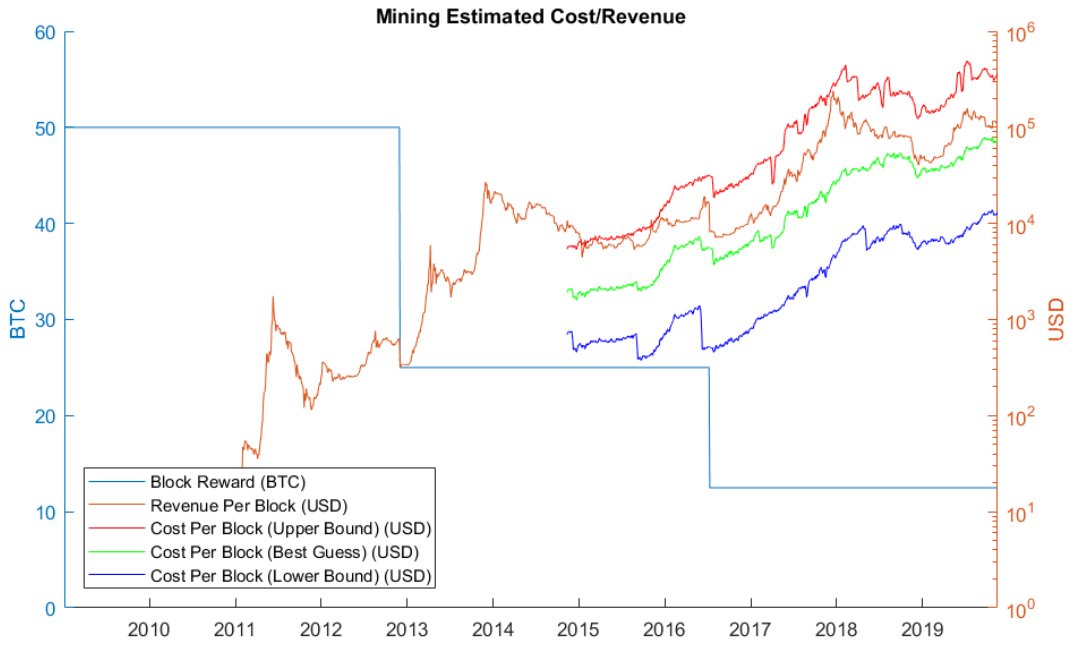

Figure 10 - Mining Estimated Cost/Revenue. Data source: [21] [18]

3.4 Mining Estimated Profitability

Profitability is calculated by subtracting the estimated cost from the revenue.

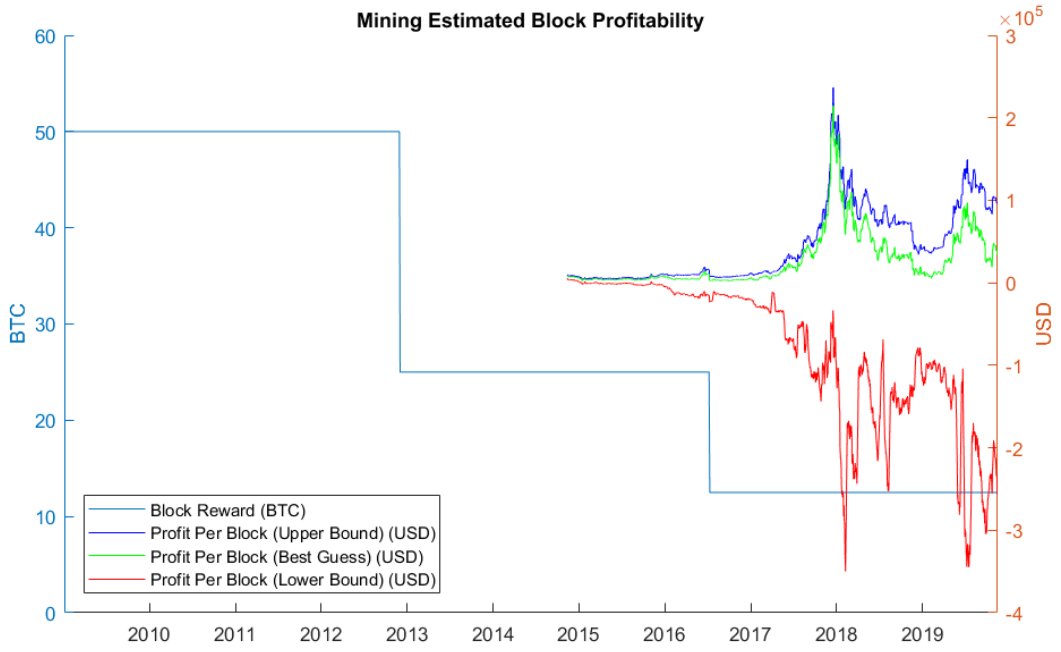

Figure 11 - Mining Estimated Block Profitability. Data source: [21] [18]

The most pessimistic mining cost estimations have been losing money for the majority of Bitcoin history. The profitability per block is misleading as the work required to mine a single block has increased significantly over time.

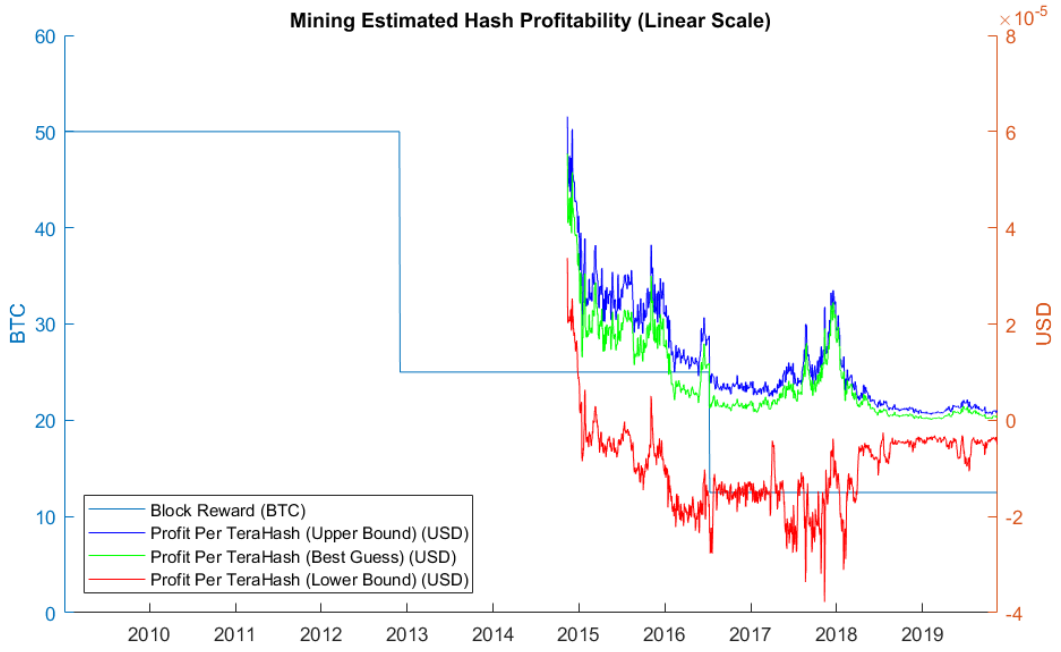

Figure 12 - Mining Estimated Hash Profitability (Linear Scale). Data source: [21] [18]

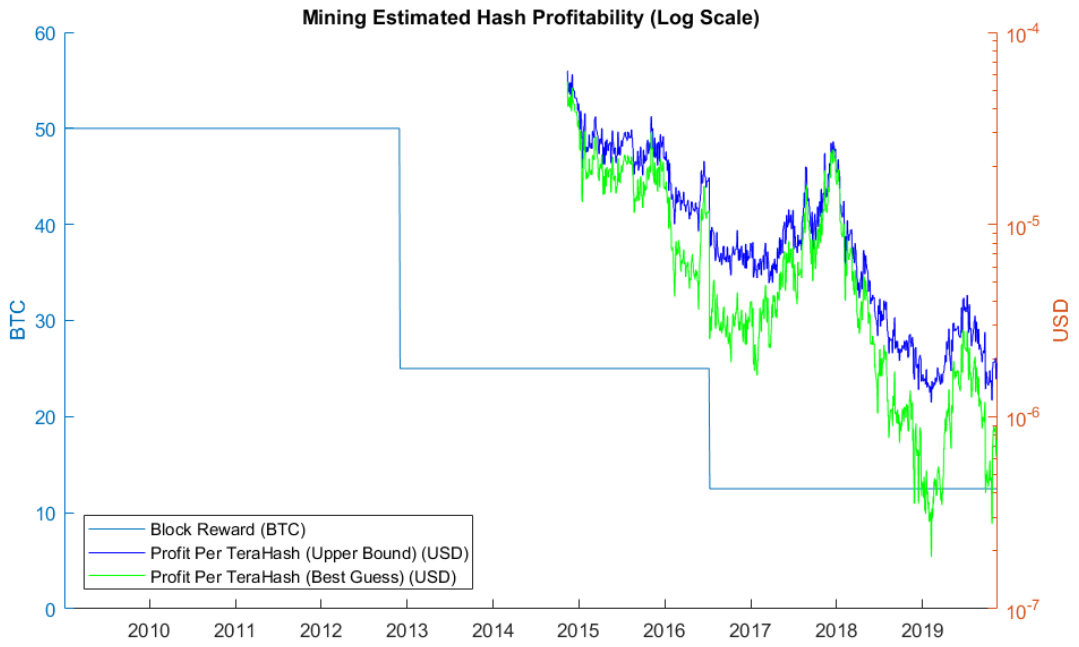

Figure 13 - Mining Estimated Hash Profitability (Log Scale). Data source: [21] [18]

Here the best guess and most optimistic estimation for cost of mining shows profits of less than $\$1x10^{-6}$ USD.

4.0 2020 Halving – First Order Consequences

4.1 Market and Mining Reaction (Current)

By taking the most recent values for cost per hash (best guess) and carrying it forward it is possible to estimate the projected profit for different variations in global Hashrate and Bitcoin price [22] [7]. The effect of hashrate is to influence the mining difficulty and can be used to model the profit as a competitive pressure [23] [7]. Using these concepts, the profit per TH for a variable hashrate and Bitcoin price have been modelled below for both before and after the 2020 halving (assuming other factors such as price of electricity remain stable [24]).

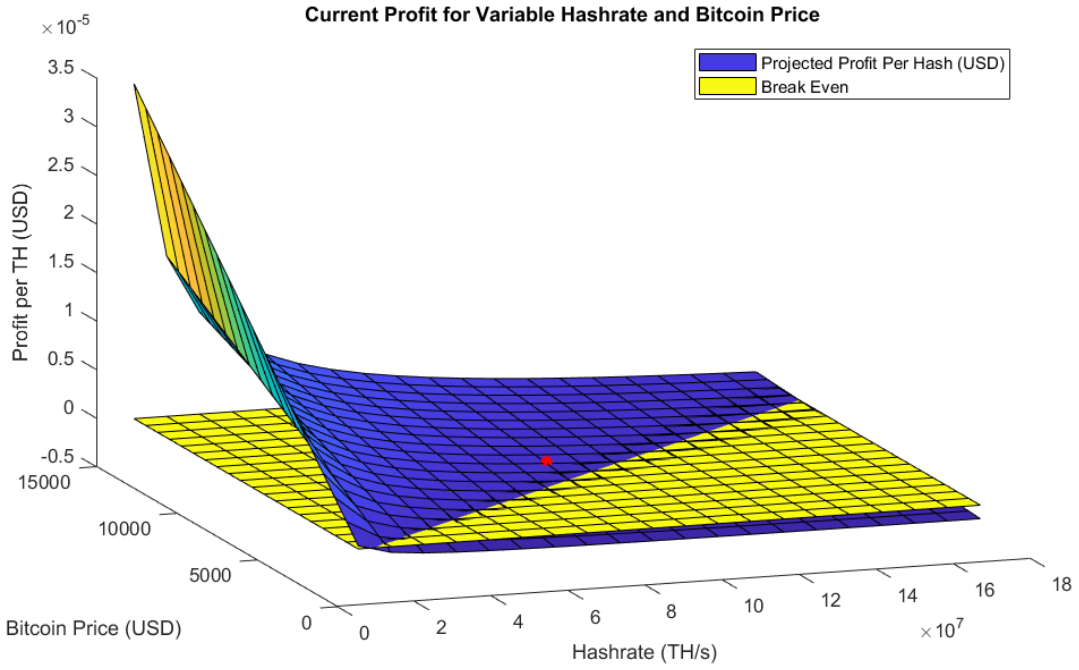

Figure 14 - Current Profitability of Bitcoin Mining for Variable Hashrate and Bitcoin price. Data source: [13] [18] [21]

This provides a surface of profitability, where returns below zero are making a loss and above zero are making a profit. To make this easier to interpret a second surface (in yellow) has been added on the z=0 plane. An increasing hashrate can be seen to decrease in the profitability as the same number of Bitcoins are spread between more miners.

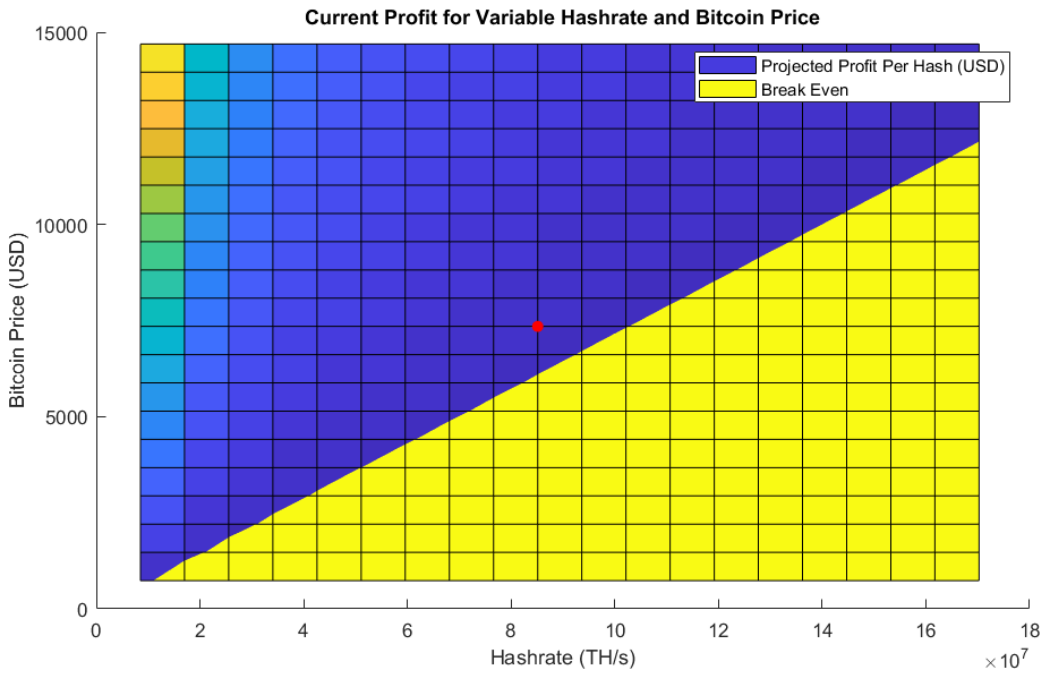

Figure 15 - Current Profitability with Current Variables Marked. Data source: [13] [18] [21]

This is the same surface as shown in Figure 15 above, but looking straight down from above. The current values (as of 25/November/2019) [18] have been marked with a red dot. This mark lies in the profitable region of the graph.

Below is a similar surface plot calculated for 6.25 BTC per block.

4.2 Market and Mining Reaction (Projection)

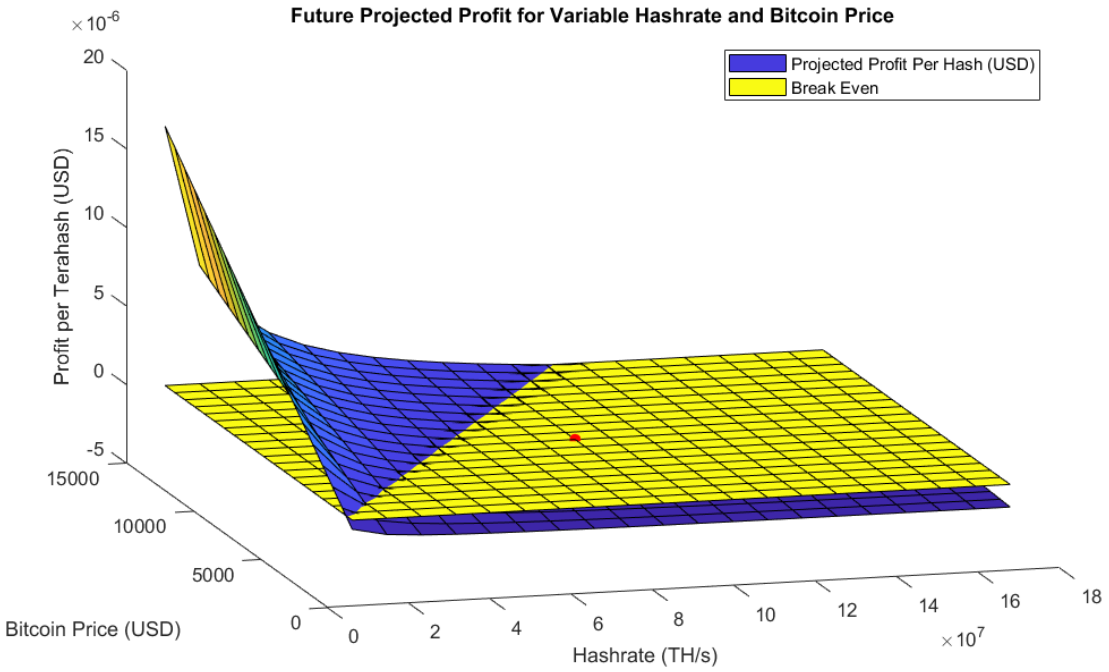

Figure 16 - Future Profit Projections for Variable Hashrate and Bitcoin Price. Data source: [13] [18] [21]

In this plot, the profitability is significantly lower as expected. The size of the profitability region here should not be considered as the bound of the graph have been arbitrarily chosen at double the current price and double the current hashrate.

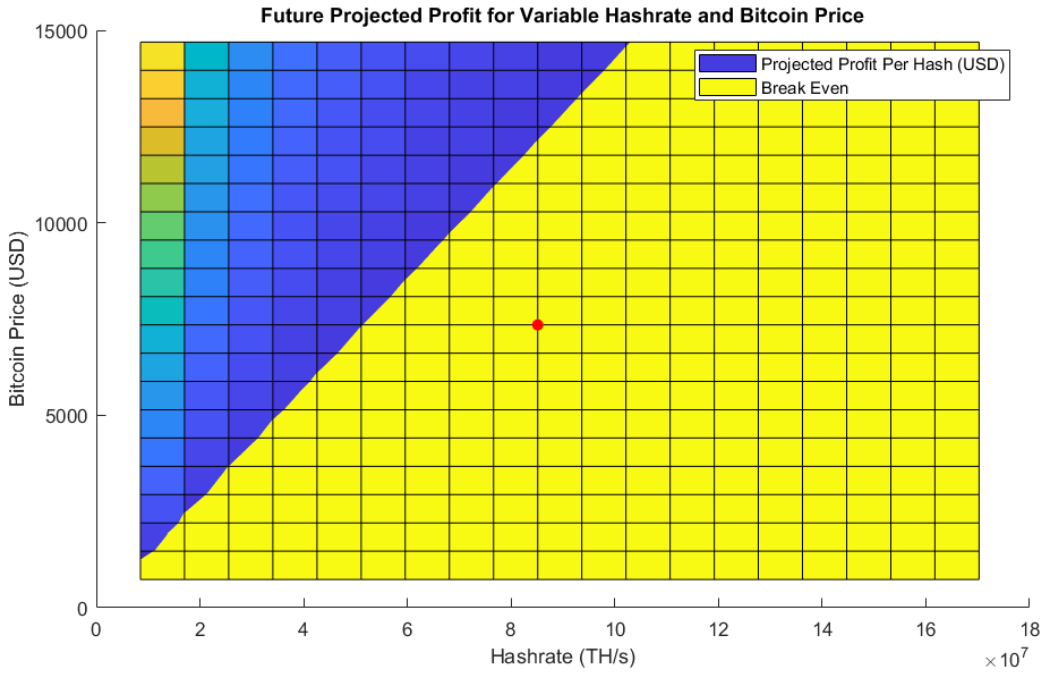

Figure 17 - Projected Profitability with Current Variables Marked. Data source: [13] [18] [21]

Here is can be seen that for mining to be break even after the halving (for the best guess of cost of production [22]) either the price of Bitcoin will need to increase to ~$12,500 USD or the competitive landscape of mining decreases to ~$5x10^7$ TH/s (~50 EH/s) (~41%). If both variables change so cover the shortest distance to profitability this would result in a price of approximately $11,000 USD or ~$6.8x10^7$ TH/s.

What is not included in these diagrams is the transaction fees. This is because they are a second order consequence and will be covered in the next section. However, transaction fees do affect the estimation above, where the range of possibilities could possibly be narrower. If the transaction fees increase, then the value of Bitcoin does not need to increase as much, or the hashrate does not need to reduce as much.

4.2 Restricting Supply

Before the halving, while all blocks yield a 12.5 BTC reward and a block is approximately every 10 minutes, the global production of bitcoin is approximately 1,800 BTC per day. This figure will reduce to 6.25 BTC per block and approximately 900 BTC per day.

5.0 2020 Halving – Second Order Consequences

5.1 Mempool Congestion

As analysed in 4.2 Market and Mining Reaction (Projection)(p19), if the price of Bitcoin doesn't change, the global hashrate will drop by approximately 41%. If the happens the mining difficulty will take 2 weeks adjust, resulting in a period of significantly reduced block mining rate. At this rate, each block will take approximately 24 minutes (instead of the usual 10 minutes). This will likely result in a significant increase in mempool size as users of the network continue to submit transaction at the same rate.

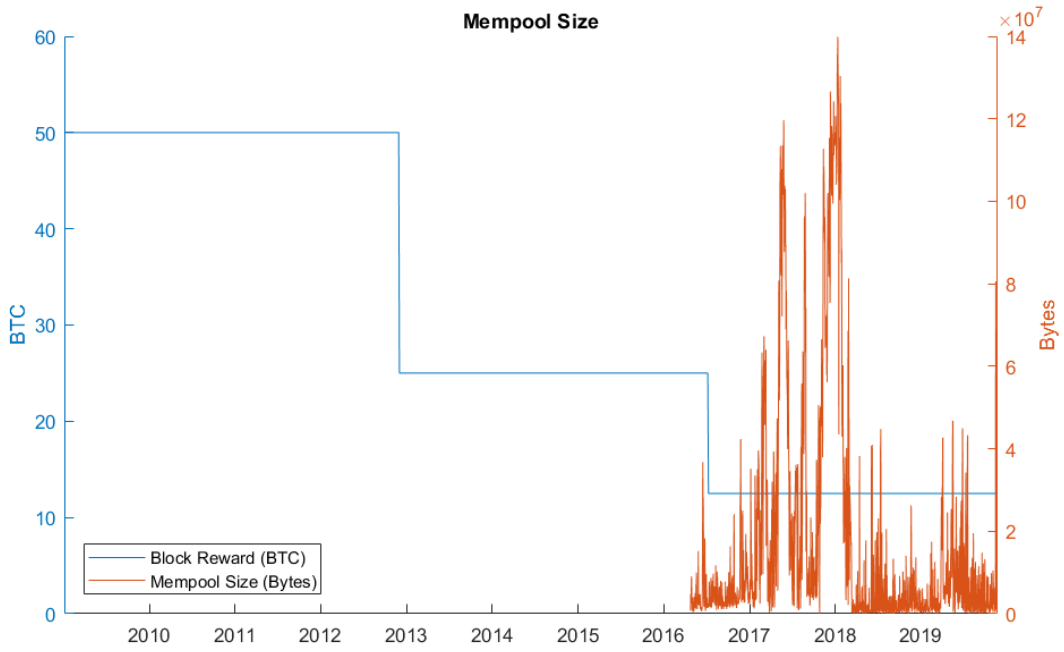

Figure 18 - Mempool Size. Data source [13]

Unfortunately, mempool size data is a "per miner" metric as mempools are assembled as miners and nodes see the broadcasted transactions. Many of miners and nodes don't publish this data historically. However, this data shows there was no sudden increase in mempool size at the point of the previous halving.

This graph does show there was an increase during the media frenzy late 2017, early 2018. This spike in mempool size means that transaction get delayed in processing and. To get transactions processed in a timely fashion during this period, users had to increase in the transaction fee they were offering.

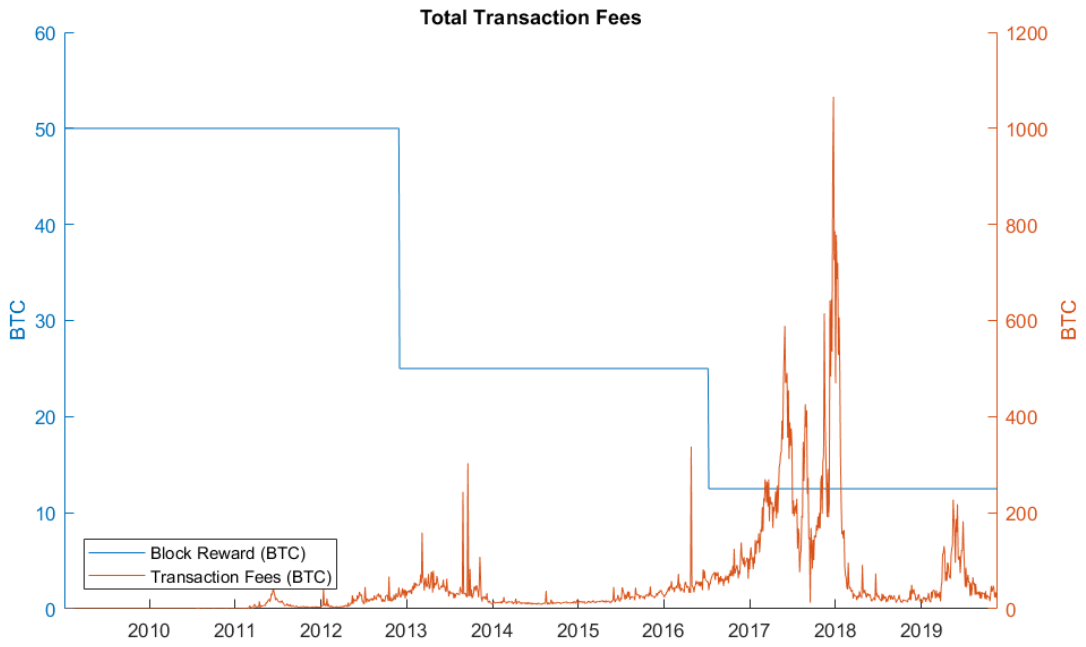

Figure 19 - Total Daily Transaction Fees. Data source [13]

Data shown here reveals the transaction fees paid (in BTC) spiking through 2017 and early 2018. If the hash rate drops significantly in 2020, it will likely cause a similar spike in the transaction fees. [25]

5.2 Reducing Downward Price Pressure

As mentioned in 4.2 Restricting Supply, the daily quantity of mined Bitcoin will be reduced. This means the amount of Bitcoin potentially making it into the market is going to go down.

Exchange	Volume [BTC] (Six Months)	Volume [BTC] (Averaged Daily)	Market Share
Coinbase	3.24M	17753	22.72%
Kraken	2.22M	12164	15.56%
Bitfinex	1.93M	10575	13.56
Bitstamp	1.91M	10466	13.41
Bit-x	1.67M	9151	11.74
Bitflyer	1.14M	6247	8.00%
Bithumb	729K	3995	5.11%
(Others)	671K	3677	4.71%
Bitbay	378K	2071	2.65%
Gemeni	359K	1967	2.52%

Table 1 - Exchange Traded Volume (13/05/2019 - 19/11/2019). Data source: [26]

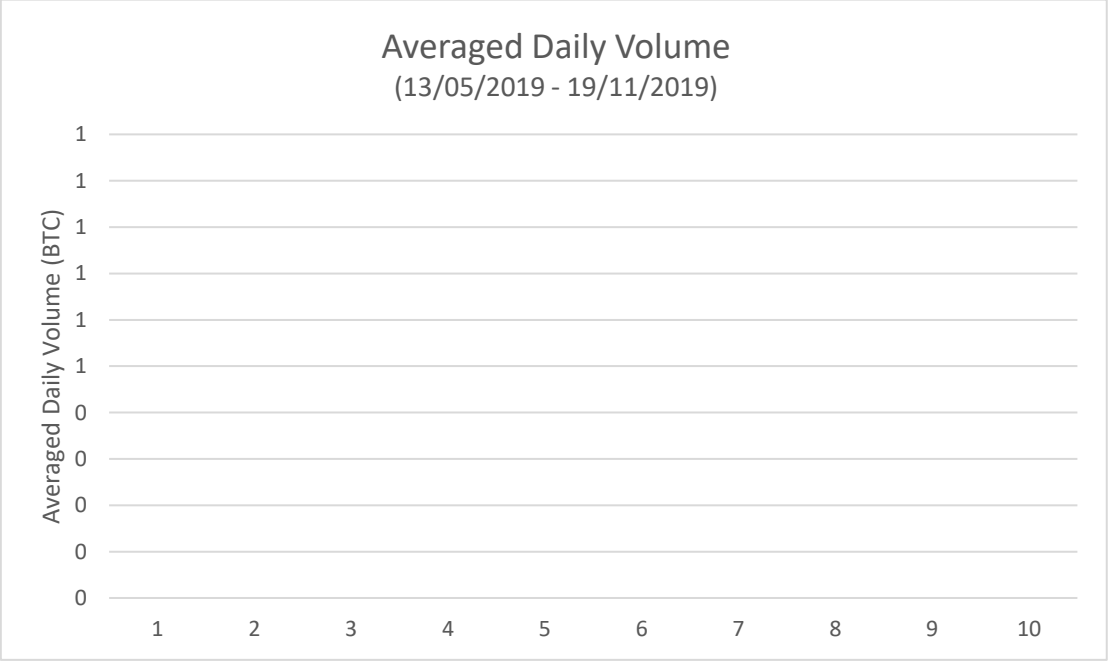

Figure 20 - Exchange Averaged Daily Volume. Data source: [26]

In total there is approximately 78K Bitcoin traded every day, and 1.8K mined every day. Assuming 80% of mined Bitcoin is sold as it is mined, liquidating mined assets is responsible for 1.84% of global market activity. This creates small but constant downward pressure on the price of Bitcoin. This downward pressure will be cut in half after the halving, which has the potential to cause the market price to increase.

It should also be noted that there are several allegations that many crypto exchanges engage in loss trading and that some even fraudulently increase their reported volume [15] [14]. This would increase the percentage of daily trade that mining liquidation is responsible for, making the 1.84% figure the lower bound, increasing the effect of the current downward pressure. This means the halving of the downward pressure could result in an even greater increase of the Bitcoin price.

6.0 2020 Halving – Third Order Consequences

As this section deals with third order consequences, it is much more speculative than the previous analysis. This section does not aim to make predictions about what will happen, only discuss the implications in the case the previous consequences are realised.

6.1 Bitcoin Utility

If transaction fees spike and confirmation times increase after the halving as discussed in 5.1 Mempool Congestion (p21), the utility of Bitcoin as a means of transaction decreases [27]. This could potentially scare traders as long confirmation times paired with Bitcoin volatility means by the time a transaction is confirmed it's likely the value of Bitcoin will have changed [28]. Speculative investors may also be sacred, as concerns arise around whether Bitcoin can adequately be used to facilitate trade [29].

6.2 Bitcoin Security

Concerns around Bitcoin security arise from the planned decrease of block reward in general [30]. As the reward decreases miners will rely more and more on the transaction fee applied to each transaction. However, users of the network have an upper limit on how much they are willing to pay for a transaction; obviously dependant on the transaction volume, but transaction fees are not dependant on the transaction volume. This means there is a bell curve of the upper limit of transaction fees on transactions, meaning there is an upper limit on the available fees to be collected. This upper limit is likely lower than the current reward value (in present and future USDe), meaning the number of miners working on each block is likely to decrease over time. The final bitcoin is projected to be mined in 2040. If this decrease in mining effort happens, the Bitcoin network may become vulnerable to a 51% attack [31]. This risk of attack may result in uncertainty for traders and increased volatility.

In the short term, a drop in mining resources caused by the halving will likely not be dramatic enough to cause any concern around a 51% attack, it may cause speculators to briefly consider the future of Bitcoin and arrive at this same conclusion, impacting their purchasing decisions.

6.3 Bitcoin Scarcity

As the supply of Bitcoin becomes restricted the scarcity increases. This restriction of supply could have positive effects on the value of Bitcoin and is an intended part of the Bitcoin protocol. Increasing scarcity is intended to be a means to prevent inflation of the currency [1] [7].

It's important to note however, there are many large Bitcoin wallets.

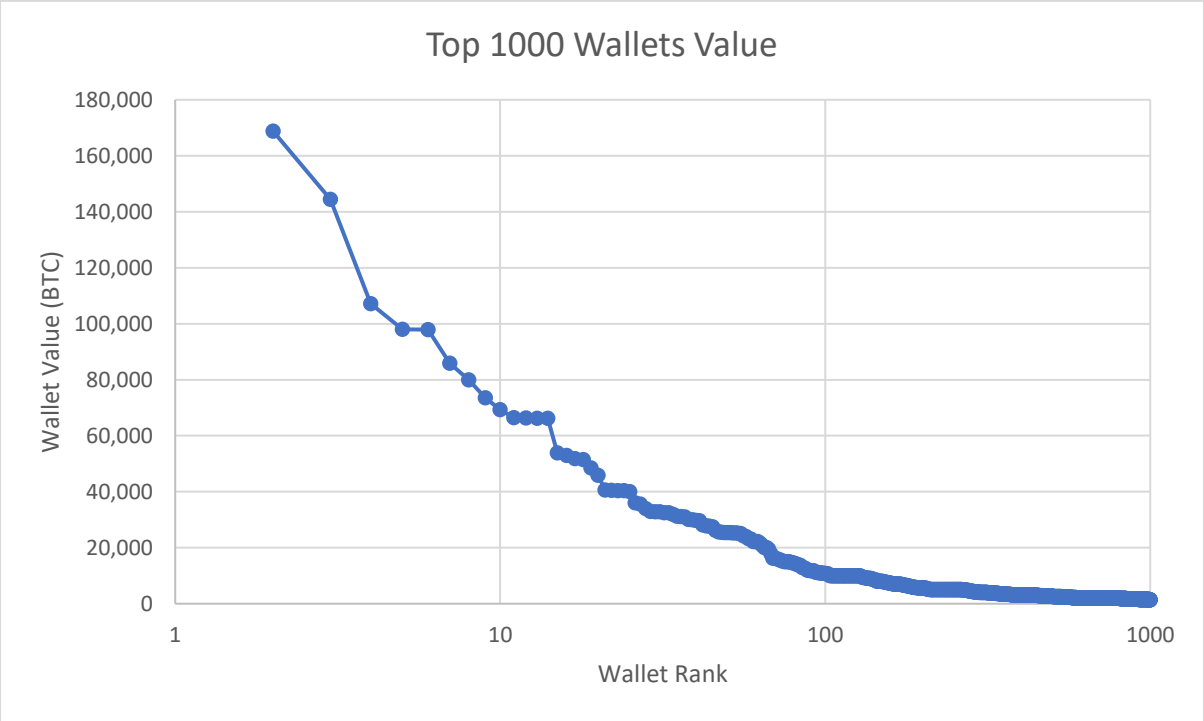

Figure 21 - Top 1000 BTC Wallets Value. Data Source: [32]

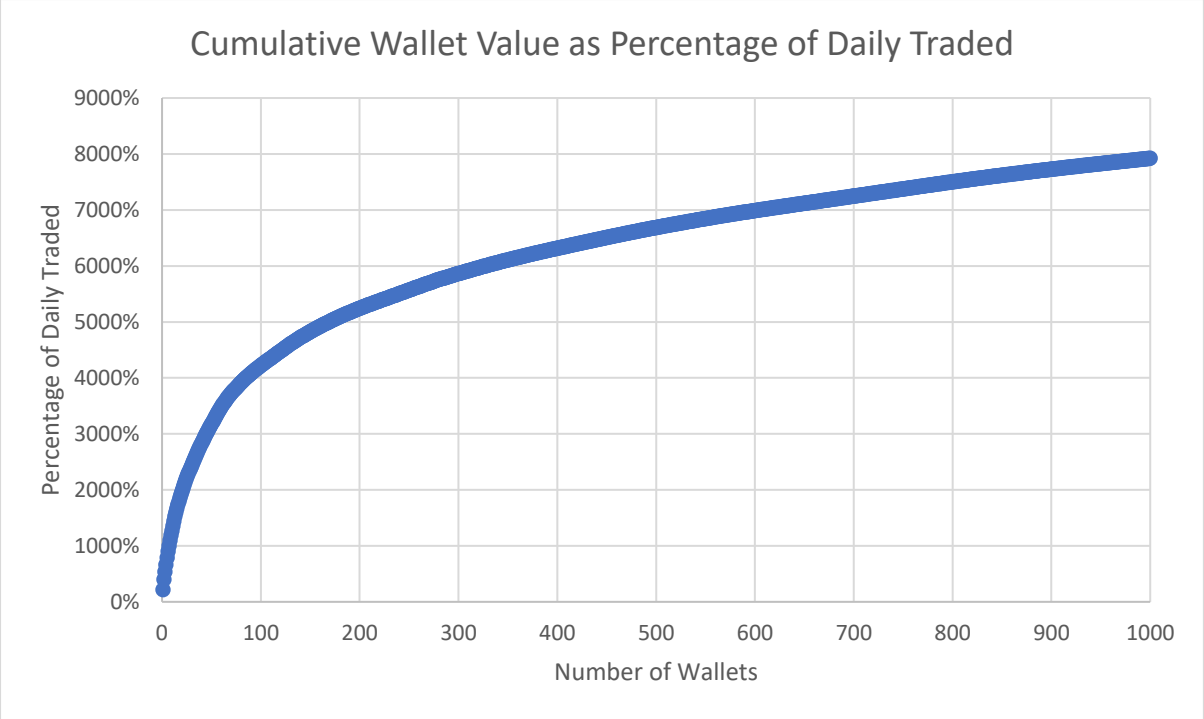

Figure 22 - Cumulative wallet value as percentage of daily traded volume

This graph shows the cumulative value of Bitcoin wallets as a percentage of daily traded (as at 26/November/2019). This information in interesting because the top 100 wallets have approximately 4200% of daily traded value. This means that if the top 100 wallets liquidated ~2.5% of their Bitcoin on the same day, it would easily crash the market [3] [4]. When considering Bitcoin scarcity it's important to remember that there are private actors and individuals who can easily and dramatically increase the supply by shifting small percentages of their holdings.

7.0 Market Speculation

The market has become significantly more aware of Bitcoin halving leading up to the 2020 halving when compared to the 2016 halving.

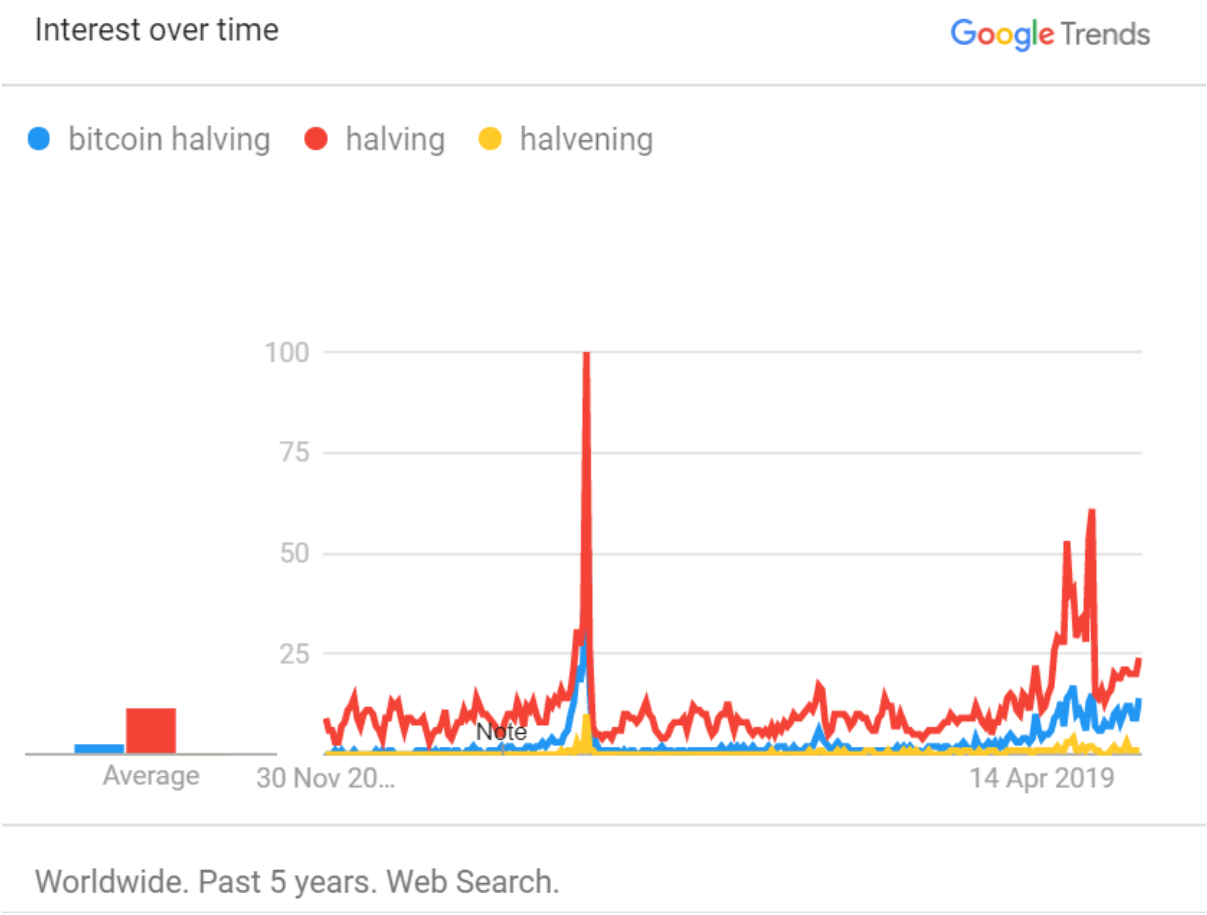

Figure 23 – Google Search Trends for Halving (and other key words). Data source: [33]

Here there is a significant spike of google searches on the day of and week leading up to the 2016 halving. There is also significant interest being generated from mid-2019, a full 11 months before the projected date of the halving mid-May 2020.

This has not prevented the market from trading derivative products such as futures and options which cross the estimated date of the halving. Below is an analysis of the BTC Options market, sourced from Deribit [34].

7.1 Call Options

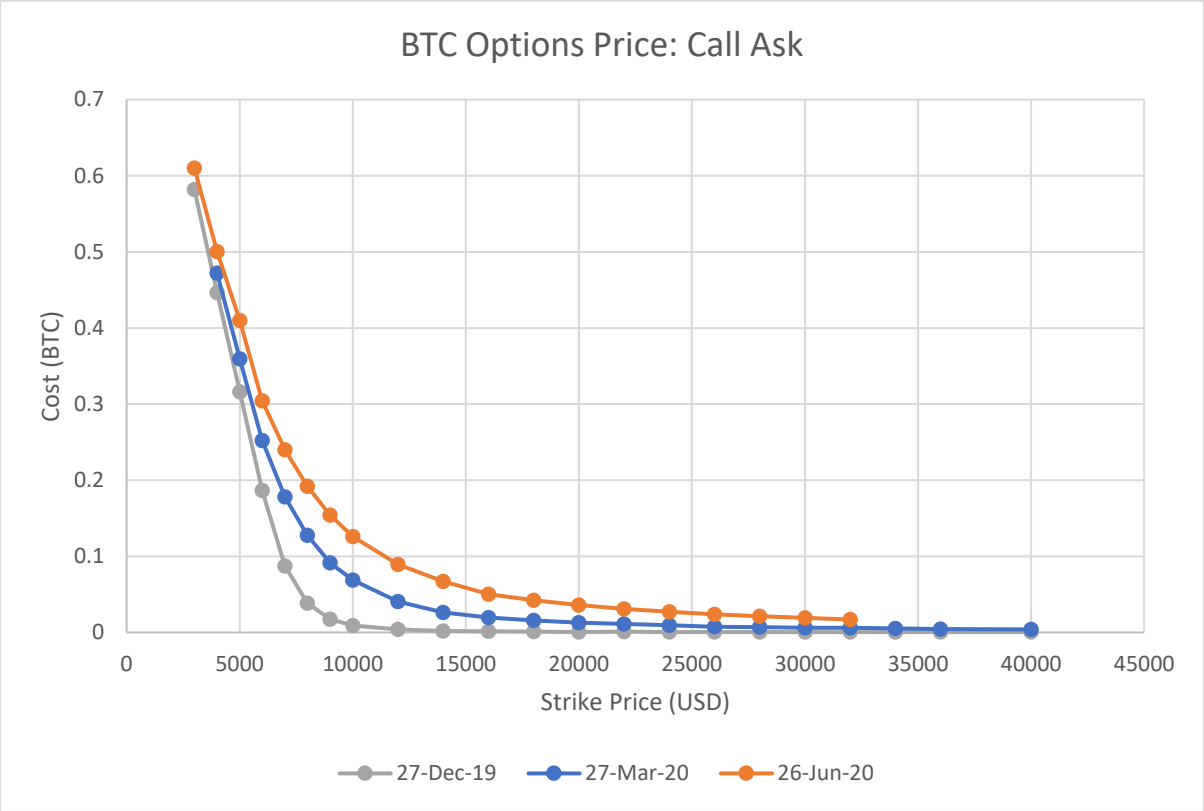

Figure 24 - BTC Option CALL Price for several expiry dates. Data Source: [34]

This graph shows the ask price of call options (the right to buy BTC at the strike price) for three different expiry dates, three months apart. As of writing, 26/June/2019 is the latest expiry available on the site, meaning the last two expiry dates shown (27/March/2020 and 26/June/2020) are either side of the halving event. The first two expiry dates occur before the projected halving.

This shows an interesting result, where the gap in cost is smaller between the second two than it is the first two. Not necessarily surprising since the first date is a month from the time this data was captured and the second date is 4 months, meaning the influence of volatility would have a much greater effect on the second date. However, this shows that the traders offering these contracts either aren't aware of the halving, or consider the volatility caused to be smaller than the step from 1 month to 4 months.

For more information on these options, see:

- Appendix 10.3 Call Options [27-Dec-2019], p39
- Appendix 10.5 BTC Call Options [27-Mar-2020], p41
- Appendix 10.7 BTC Call Options [26-Jun-2020], p42

7.2 Put Options

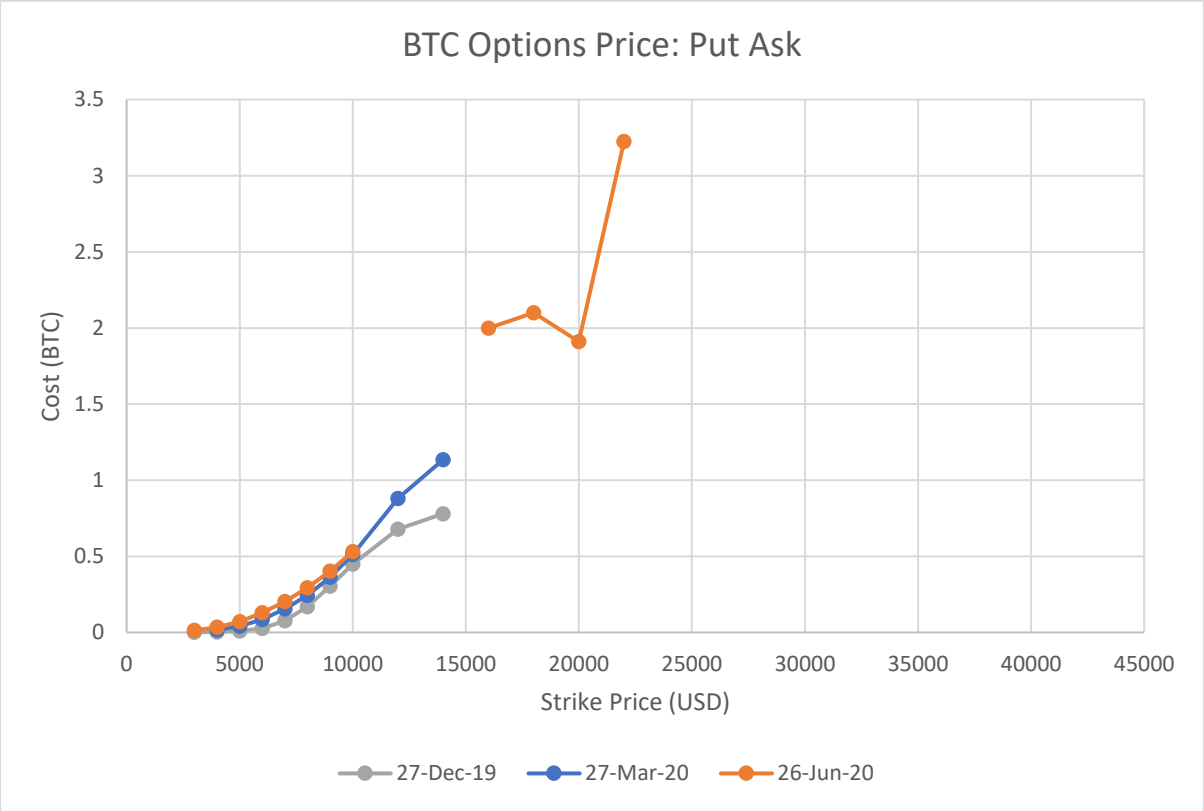

Figure 25 - BTC Options Pricing Expiring after Halving. Data Source: [34]

This graph shows the ask price of put options (the right to sell BTC at the strike price). Notably here the prices available only go up to $14,000 USD for before the halving. This indicates that traders aren't willing to take the risk that Bitcoin value won't go above $14,000 for any reasonable price. However, after the halving there are some speculative traders willing to take the chance that Bitcoin value will be $16,000 USD or above.

Another thing worth noting about this graph is the gap in post-halving strike prices, from $10,000 to $16,000. This would suggest that traders aren't sure how to price the risk for the $12,000 and $14,000 put options and have simply avoided them.

For more information on these options see:

- Appendix 10.4 Put Options [27-Dec-2019], p40
- Appendix 10.6 BTC Put Options [27-Mar-2020], p41
- Appendix 10.8 BTC Put Options [26-Jun-2020], p42

8.0 Conclusion

8.1 Bitcoin Price

Several factors affecting the value of Bitcoin, directly arising from the halving have been discussed here. These have opposing influence on the value, and it's difficult to predict which one will have a bigger influence. These factors include: scarcity, mining downward price pressure, security and utility.

8.2 Bitcoin Miners

The impact of the 2020 halving will be significant for miners. It's very likely that in the short term a significant percentage will switch their mining efforts to other cryptocurrencies.

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10.0 Appendix

10.1 Block References

First block at 50 BTC

- Source 1: https://btc.com/000000000019d6689c085ae165831e934ff763ae46a2a6c172b3f1b60a8ce26f
- Source 2: https://www.blockchain.com/btc/block/000000000019d6689c085ae165831e934ff763ae46a2a6c172b3f1b60a8ce26f

Last block at 50 BTC

- Source 1: https://btc.com/00000000000000f3819164645360294b5dee7f2e846001ac9f41a70b7a9a3de1
- Source 2: https://www.blockchain.com/btc/block/00000000000000f3819164645360294b5dee7f2e846001ac9f41a70b7a9a3de1

First block at 25 BTC

- Source 1: https://btc.com/000000000000048b95347e83192f69cf0366076336c639f9b7228e9ba171342e
- Source 2: https://www.blockchain.com/btc/block/000000000000048b95347e83192f69cf0366076336c639f9b7228e9ba171342e

Last block at 25 BTC:

- Source 1: https://btc.com/00000000000000003035bc31911d3eea46c8a23b36d6d558141d1d09cc960cf
- Source 2: https://www.blockchain.com/btc/block/00000000000000003035bc31911d3eea46c8a23b36d6d558141d1d09cc960cf

First bock at 12.5 BTC

- Source 1: https://btc.com/00000000000000002cce816c0ab2c5c269cb081896b7dcb34b8422d6b74ffa1
- Source 2: https://www.blockchain.com/btc/block/00000000000000002cce816c0ab2c5c269cb081896b7dcb34b8422d6b74ffa1

10.2 Mining Hardware Efficiency

Source: [21]

Miner name	Date of release		UNIX date of release	Hashing power (Th/s)		Power (W)	Efficiency (J/Gh)
Bitmain Antminer S3	07.2014	0.478Th/s	1404172800	0.478	366W	366	0.77
Bitmain Antminer S5	12.2014	1.155Th/s	1417392000	1.155	590W	590	0.51
Bitmain Antminer S7	09.2015	4.73Th/s	1441065600	4.73	1293W	1293	0.27
Bitmain Antminer S9 (11.5Th)	06.2016	11.5Th/s	1464739200	11.5	1127W	1127	0.10
Bitmain Antminer S7-LN	06.2016	2.7Th/s	1464739200	2.7	697W	697	0.26
Bitmain Antminer R4	02.2017	8.7Th/s	1485907200	8.7	845W	845	0.10
Bitmain Antminer S9 (12.5Th)	02.2017	12.5Th/s	1485907200	12.5	1225W	1225	0.10
Bitmain Antminer T9 (11.5Th)	04.2017	11.5Th/s	1491004800	11.5	1450W	1450	0.13
Canaan AvalonMiner 741	04.2017	7.3Th/s	1491004800	7.3	1150W	1150	0.16
Bitmain Antminer S9 (13Th)	07.2017	13Th/s	1498867200	13	1300W	1300	0.10
Bitmain Antminer T9 (12.5Th)	08.2017	12.5Th/s	1501545600	12.5	1576W	1576	0.13
Bitmain Antminer S9 (13.5Th)	09.2017	13.5Th/s	1504224000	13.5	1323W	1323	0.10
Pantech SX6	09.2017	8.5Th/s	1504224000	8.5	1000W	1000	0.12
Bitmain Antminer S9 (14Th)	11.2017	14Th/s	1509494400	14	1372W	1372	0.10
Bitfury B8	12.2017	49Th/s	1512086400	49	6400W	6400	0.13
Ebang Ebit E9+	01.2018	9Th/s	1514764800	9	1300W	1300	0.14
Bitmain Antminer T9+ (10.5Th)	01.2018	10.5Th/s	1514764800	10.5	1432W	1432	0.14
MicroBT Whatsminer M3	01.2018	12Th/s	1514764800	12	2000W	2000	0.17
Bitfily Snow Panther A1	01.2018	49Th/s	1514764800	49	5400W	5400	0.11
Pantech WX6	01.2018	34Th/s	1514764800	34	5000W	5000	0.15
Ebang Ebit E10	02.2018	18Th/s	1517443200	18	1650W	1650	0.09
Canaan AvalonMiner 821	02.2018	11.5Th/s	1517443200	11.5	1200W	1200	0.10
Bitmain Antminer V9 (4Th)	03.2018	4Th/s	1519862400	4	1027W	1027	0.26
MicroBT Whatsminer M3X	03.2018	12.5Th/s	1519862400	12.5	2050W	2050	0.16
Halong Mining DragonMint T1	04.2018	16Th/s	1522540800	16	1480W	1480	0.09
Canaan AvalonMiner 841	04.2018	13.6Th/s	1522540800	13.6	1290W	1290	0.09
ASICminer 8 Nano Pro	05.2018	76Th/s	1525132800	76	4000W	4000	0.05
Innosilicon T2 Terminator	05.2018	17.2Th/s	1525132800	17.2	1570W	1570	0.09
Bitmain Antminer S9i (14Th)	05.2018	14Th/s	1525132800	14	1320W	1320	0.09
Bitmain Antminer S9i (13.5Th)	05.2018	13.5Th/s	1525132800	13.5	1310W	1310	0.10
Bitmain Antminer S9i (13Th)	05.2018	13Th/s	1525132800	13	1280W	1280	0.10
Ebang Ebit E9.2	05.2018	12Th/s	1525132800	12	1320W	1320	0.11
Ebang Ebit E9.3	05.2018	16Th/s	1525132800	16	1760W	1760	0.11
Bitfily Snow Panther B1	07.2018	16Th/s	1530403200	16	1380W	1380	0.09
Aladdin Miner 16Th/s Bitcoin	07.2018	16Th/s	1530403200	16	1400W	1400	0.09
Ebang Ebit E9i	07.2018	13.5Th/s	1530403200	13.5	1420W	1420	0.11
Innosilicon T2 Turbo	08.2018	24Th/s	1533081600	24	1980W	1980	0.08
Bitfily Snow Panther B1+	08.2018	24.5Th/s	1533081600	24.5	2100W	2100	0.09
Bitmain Antminer S9j (14.5Th)	08.2018	14.5Th/s	1533081600	14.5	1350W	1350	0.09
Bitmain Antminer S9 Hydro (18Th)	08.2018	18Th/s	1533081600	18	1728W	1728	0.10
MicroBT Whatsminer M10S	09.2018	55Th/s	1535760000	55	3500W	3500	0.06
MicroBT Whatsminer M10	09.2018	33Th/s	1535760000	33	2145W	2145	0.07
Innosilicon T2 Turbo+ 32T	09.2018	32Th/s	1535760000	32	2200W	2200	0.07

Canaan AvalonMiner 921	09.2018	20Th/s	1535760000	20	1700W	1700	0.09
Ebang Ebit E11++	10.2018	44Th/s	1538352000	44	1980W	1980	0.05
ASICminer 8 Nano 44Th	10.2018	44Th/s	1538352000	44	2100W	2100	0.05
Ebang Ebit E11+	10.2018	37Th/s	1538352000	37	2035W	2035	0.06
Ebang Ebit E11	10.2018	30Th/s	1538352000	30	1950W	1950	0.07
GMO miner B2	10.2018	24Th/s	1538352000	24	1950W	1950	0.08
Bitfury Tardis	11.2018	80Th/s	1541030400	80	6300W	6300	0.08
Bitmain Antminer S11 (20.5Th)	11.2018	20.5Th/s	1541030400	20.5	1530W	1530	0.07
GMO miner B3	11.2018	33Th/s	1541030400	33	3417W	3417	0.10
Holic H22	12.2018	22Th/s	1543622400	22	1700W	1700	0.08
Holic H28	12.2018	28Th/s	1543622400	28	2100W	2100	0.08
Innosilicon T3 43T	01.2019	43Th/s	1546300800	43	2100W	2100	0.05
Innosilicon T3 39T	03.2019	39Th/s	1551398400	39	2150W	2150	0.06
Bitmain Antminer S17 Pro (53Th)	04.2019	53Th/s	1554076800	53	2094W	2094	0.04
Bitmain Antminer S17 Pro (50Th)	04.2019	50Th/s	1554076800	50	1975W	1975	0.04
Bitmain Antminer S17 (56Th)	04.2019	56Th/s	1554076800	56	2520W	2520	0.05
Bitmain Antminer S17 (53Th)	04.2019	53Th/s	1554076800	53	2385W	2385	0.05
Innosilicon T3+ 52T	05.2019	52Th/s	1556668800	52	2200W	2200	0.04
Bitmain Antminer T17 (40Th)	05.2019	40Th/s	1556668800	40	2200W	2200	0.06
StrongU STU-U8	07.2019	46Th/s	1561939200	46	2100W	2100	0.05
MicroBT Whatsminer M20S	08.2019	70Th/s	1564617600	70	3360W	3360	0.05
MicroBT Whatsminer M21	08.2019	31Th/s	1564617600	31	1860W	1860	0.06

10.3 Call Options [27-Dec-2019]

Source: [34]. Captured on 27/November/2019

Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta	Strike
0.8415	16	0.00%		0.7945	311.10%	16	-	1	**1500**
-	14	0.00%	0.7105	0.7235	253.20%	14	-	1	**2000**
-	13	0.00%	0.6405	0.6525	209.50%	13	-	1	**2500**
0.5835	11	0.00%	0.571	0.582	177.30%	11	-	1	**3000**
0.5625	10	0.00%	0.4995	0.5135	158.60%	10	-	0.99	**3500**
0.4255	10	0.00%	0.4285	0.4465	144.50%	10	-	0.98	**4000**
0.5285	13.2	0.00%	0.3575	0.38	129.90%	17.4	-	0.96	**4500**
0.4645	15	0.00%	0.2875	0.316	118.40%	15	-	0.93	**5000**
0.25	14	0.00%	0.22	0.255	108.40%	14	-	0.88	**5500**
0.19	25	67.80%	0.1715	0.1865	86.30%	25	-	0.8	**6000**
0.1345	19.9	69.70%	0.1245	0.1275	72.70%	15	16.5	0.7	**6500**
0.0865	26.9	68.90%	0.0845	0.0875	71.50%	20.6	8.5	0.56	**7000**
0.056	29.5	69.00%	0.0555	0.0585	71.70%	27.3	39.3	0.43	**7500**
0.039	14	70.30%	0.0365	0.0385	72.30%	32.9	52.5	0.31	**8000**
0.0175	37.3	73.40%	0.0155	0.0175	76.20%	49.7	55	0.16	**9000**
0.0085	62	78.30%	0.0075	0.009	81.60%	20	22.8	0.09	**10000**
0.006	167	83.20%	0.004	0.006	89.80%	81.1	8.2	0.05	**11000**
0.003	112.4	88.90%	0.0025	0.004	95.90%	38	1.7	0.03	**12000**
0.002	14	96.80%	0.002	0.003	102.80%	37.2	0.2	0.02	**13000**
0.001	14	102.00%	0.0015	0.002	106.00%	5	-	0.02	**14000**
0.001	14	105.30%	0.001	0.002	114.80%	65	4.2	0.01	**15000**
0.001	88.5	104.80%	0.0005	0.0015	118.60%	14	0.1	0.01	**16000**
0.0005	38.3	117.50%	0.0005	0.001	126.40%	13	0.2	0.01	**18000**
0.0005	-	-	-	0.0005	128.90%	8.7	6.5	0	**20000**
0.0005	-	-	-	0.001	148.80%	34	-	0	**22000**
0.0005	-	-	-	0.0005	148.00%	14	-	0	**24000**
0.0005	-	-	-	0.0005	156.20%	14	-	0	**26000**
0.0005	-	-	-	0.0005	163.70%	14	-	0	**28000**
0.001	-	-	-	0.0005	170.70%	14.9	-	0	**30000**
0.0005	-	-	-	0.0005	177.10%	14.9	-	0	**32000**
0.0005	-	-	-	0.0005	188.70%	14	-	0	**36000**
0.0005	-	-	-	0.0005	199.00%	19.8	-	0	**40000**
0.0005	-	-	-	0.0005	208.20%	15	-	0	**44000**
0.0005	-	-	-	0.0005	216.50%	14	-	0	**48000**
0.0005	-	-	-	0.0005	224.10%	46	-	0	**52000**

10.4 Put Options [27-Dec-2019]

Source: [34]. Captured on 27/November/2019

Strike	Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta
1500	0.001	-	-	-	0.0005	211.50%	91.9	-	0
2000	0.0005	-	-	-	0.0005	173.20%	11.1	-	0
2500	0.001	-	-	-	0.001	156.80%	125.6	-	0
3000	0.001	42	120.10%	0.0005	0.0015	138.50%	91	-	0
3500	0.0015	24	115.30%	0.0015	0.002	120.40%	1	1.1	-0.01
4000	0.004	25	106.80%	0.003	0.0035	109.80%	1	0.1	-0.03
4500	0.0055	75	94.80%	0.0045	0.0055	98.80%	4.2	2.8	-0.04
5000	0.0095	37.6	86.60%	0.008	0.0095	90.50%	68	6	-0.07
5500	0.014	33	79.50%	0.014	0.0155	82.10%	14	46.5	-0.12
6000	0.026	48.8	73.90%	0.025	0.027	76.50%	53.2	38.1	-0.19
6500	0.044	42	70.60%	0.044	0.047	73.60%	29	101.3	-0.3
7000	0.0765	36.9	69.30%	0.0745	0.0775	72.00%	38.9	60.3	-0.44
7500	0.114	24.2	68.90%	0.1155	0.1185	71.50%	20	1.3	-0.57
8000	0.1685	16.7	69.70%	0.1665	0.1715	74.60%	8.1	28	-0.69
9000	0.2545	1	0.00%	0.06	0.55	315.10%	1	0.8	-0.84
10000	0.39	1	0.00%	0.3435	0.555	223.30%	0.5	1	-0.92
11000	0.651	0.3	0.00%	0.405	0.88	405.90%	1	-	-0.95
12000	0.725	0.1	0.00%	0.678	-	-	-	-	-0.97
13000	0.638	0.2	0.00%	0.7	-	-	-	-	-0.98
14000	0.7205	0.2	0.00%	0.78	-	-	-	-	-0.98
15000	0.959	-	-	-	-	-	-	-	-
16000	1.261	-	-	-	-	-	-	-	-
18000	1.1125	-	-	-	-	-	-	-	-
20000	1.729	-	-	-	-	-	-	-	-
22000	2.217	-	-	-	-	-	-	-	-
24000	-	-	-	-	-	-	-	-	-
26000	-	-	-	-	-	-	-	-	-
28000	2.2765	-	-	-	-	-	-	-	-
30000	2.51	-	-	-	-	-	-	-	-
32000	2.744	-	-	-	-	-	-	-	-
36000	3.212	-	-	-	-	-	-	-	-
40000	2.58	1	0.00%	0.001	-	-	-	-	-1
44000	3.46	1	0.00%	0.001	-	-	-	-	-1
48000	-	1	0.00%	0.0005	-	-	-	-	-1
52000	3.59	1	0.00%	0.001	-	-	-	-	-1

10.5 BTC Call Options [27-Mar-2020]

Source: [34]. Captured on 27/November/2019

Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta	Strike
0.464	9	56.60%	0.445	0.472	96.10%	9	-	0.93	**4000**
0.4535	23	64.30%	0.3285	0.3595	87.50%	23	-	0.85	**5000**
0.2315	33.3	70.80%	0.244	0.252	75.10%	23.8	-	0.74	**6000**
0.1565	27.5	71.60%	0.174	0.178	73.40%	12.5	-	0.61	**7000**
0.1345	19.3	72.50%	0.1235	0.1275	74.20%	54.9	2.6	0.48	**8000**
0.0975	15	74.20%	0.0895	0.0915	75.10%	0.2	50.1	0.38	**9000**
0.068	14	75.90%	0.066	0.069	77.40%	28.7	78.2	0.3	**10000**
0.04	14	79.60%	0.0385	0.0405	80.80%	29.6	7.8	0.19	**12000**
0.026	31	83.20%	0.0245	0.0265	84.80%	15	2	0.13	**14000**
0.0195	29.6	87.40%	0.0175	0.0195	89.40%	15	0.2	0.09	**16000**
0.015	50.3	90.90%	0.013	0.016	94.60%	49.4	0.1	0.07	**18000**
0.0105	35	94.80%	0.0105	0.013	98.40%	35.1	-	0.06	**20000**
0.0105	64	97.80%	0.0085	0.011	102.10%	45.3	5	0.05	**22000**
0.0065	15	101.60%	0.0075	0.0095	105.40%	44.5	-	0.04	**24000**
0.0075	53	103.30%	0.006	0.0075	106.70%	1	-	0.03	**26000**
0.0065	25.8	106.60%	0.0055	0.007	110.30%	15	-	0.03	**28000**
0.005	48	107.80%	0.0045	0.006	112.10%	19	-	0.03	**30000**
0.004	36.5	110.00%	0.004	0.006	116.00%	48	-	0.02	**32000**
0.004	37	111.60%	0.0035	0.0055	118.20%	48	1	0.02	**34000**
0.0035	47	112.80%	0.003	0.0045	118.50%	19	-	0.02	**36000**
0.0035	35	116.20%	0.0025	0.004	122.70%	33	10	0.02	**40000**

10.6 BTC Put Options [27-Mar-2020]

Source: [34]. Captured on 27/November/2019

Strike	Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta
4000	0.0155	32	76.30%	0.014	0.017	80.40%	57	1.2	-0.06
5000	0.0405	15	73.20%	0.038	0.041	75.40%	19.2	6.1	-0.15
6000	0.0835	29.8	71.40%	0.082	0.0855	73.30%	1.6	3.1	-0.26
7000	0.1495	18.1	71.80%	0.1505	0.1545	73.60%	18.8	20.3	-0.39
8000	0.304	8.2	71.30%	0.236	0.244	74.70%	8.4	-	-0.52
9000	0.44	19	65.20%	0.325	0.362	82.10%	10.8	-	-0.62
10000	0.44	9	59.00%	0.429	0.5115	100.10%	17.1	3	-0.7
12000	0.77	1	0.00%	0.022	0.88	160.10%	1	-	-0.81
14000	1.1385	0.5	0.00%	0.4	1.135	167.00%	0.5	-	-0.87
16000	1.08	-	-	-	-	-	-	-	-
18000	1.23	-	-	-	-	-	-	-	-
20000	1.108	-	-	-	-	-	-	-	-
22000	1.545	-	-	-	-	-	-	-	-
24000	-	6	0.00%	0.01	-	-	-	-	-0.96
26000	-	-	-	-	-	-	-	-	-
28000	-	-	-	-	-	-	-	-	-
30000	-	-	-	-	-	-	-	-	-
32000	-	2	0.00%	0.01	-	-	-	-	-0.97
34000	-	-	-	-	-	-	-	-	-
36000	-	-	-	-	-	-	-	-	-
40000	4.54	2	0.00%	0.0005	-	-	-	-	-0.98

10.7 BTC Call Options [26-Jun-2020]

Source: [34]. Captured on 27/November/2019

Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta	Strike
0.6035	8	56.70%	0.5885	0.61	94.40%	8	-	0.96	**3000**
0.589	7	66.60%	0.4705	0.5005	89.60%	7	-	0.91	**4000**
-	7	63.50%	0.361	0.41	88.50%	7	-	0.83	**5000**
0.2835	13.4	71.90%	0.296	0.3045	75.30%	10.6	-	0.73	**6000**
0.22	10.7	73.30%	0.235	0.24	75.10%	11.1	-	0.64	**7000**
0.1895	12.7	73.90%	0.186	0.192	75.90%	18.3	0.9	0.55	**8000**
0.156	30.8	74.60%	0.1485	0.154	76.40%	12.3	10.7	0.47	**9000**
0.1245	15	76.30%	0.1225	0.126	77.50%	12.9	14.9	0.4	**10000**
0.09	20	78.80%	0.085	0.0895	80.50%	22.8	5.6	0.3	**12000**
0.067	15	81.10%	0.062	0.067	83.30%	23.8	7.5	0.23	**14000**
0.0525	30	83.60%	0.0475	0.0505	85.10%	1	0.1	0.18	**16000**
0.039	22	86.00%	0.038	0.0425	88.50%	25	-	0.15	**18000**
0.0335	13.8	89.70%	0.0335	0.036	91.20%	40	-	0.13	**20000**
0.041	9	91.60%	0.028	0.031	93.60%	40	-	0.11	**22000**
0.027	28	92.70%	0.023	0.027	95.70%	40	-	0.1	**24000**
0.02	19	94.80%	0.0205	0.024	97.80%	40	-	0.09	**26000**
0.023	34.7	95.90%	0.0175	0.0215	99.60%	25	-	0.08	**28000**
0.017	29	97.90%	0.016	0.019	100.90%	10.8	-	0.07	**30000**
0.0175	34	99.50%	0.0145	0.017	102.20%	10.9	-	0.06	**32000**

10.8 BTC Put Options [26-Jun-2020]

Source: [34]. Captured on 27/November/2019

Strike	Last	Size	IV	Bid	Ask	IV	Size	Vol	Δ|Delta
3000	0.012	20.2	76.80%	0.0105	0.0135	81.50%	39	3	-0.04
4000	0.0305	11.1	73.60%	0.03	0.034	76.70%	12	1	-0.09
5000	0.0675	12.8	72.60%	0.067	0.0705	74.40%	0.1	0.1	-0.17
6000	0.1165	12.7	72.30%	0.123	0.1295	74.90%	16.9	0.6	-0.27
7000	0.2035	12.4	72.80%	0.197	0.204	75.20%	18.3	1.5	-0.36
8000	0.35	18.3	72.30%	0.2825	0.293	75.70%	7	-	-0.45
9000	0.363	10.1	72.60%	0.3815	0.4035	79.90%	9.6	4	-0.53
10000	0.48	6.4	64.90%	0.4665	0.531	86.90%	6.4	1.1	-0.6
12000	0.783	0.2	0.00%	0.15	-	-	-	-	-0.7
14000	0.99	1	0.00%	0.5	-	-	-	-	-0.77
16000	1.22	1	0.00%	0.56	2	384.80%	0.1	-	-0.82
18000	1.5	1	0.00%	1.2	2.1	299.30%	0.1	-	-0.85
20000	1.765	1	0.00%	0.1	1.91	141.30%	0.1	-	-0.87
22000	-	1	0.00%	0.11	3.225	500.00%	0.7	-	-0.89
24000	-	-	-	-	-	-	-	-	-
26000	-	-	-	-	-	-	-	-	-
28000	-	-	-	-	-	-	-	-	-
30000	-	-	-	-	-	-	-	-	-
32000	-	-	-	-	-	-	-	-	-