

# **Bitcoin price forecast using quantitative models**

*March 2021*

*Daniele Bernardi, Ruggero Bertelli*

## **Abstract**

Bitcoin was designed to grow in value indefinitely. The smallest quantity, known as a Satoshi, is equal to 0.00000001 of a Bitcoin. It's obvious that its creator imagined a deflationary system for his creation, one that could help it reach ever increasing values.

In the moment that a Satoshi has grown to be worth a dollar, a Bitcoin will equal to \$ 100,000,000 (one hundred million dollars!). This is the value that Mr. Satoshi Nakamoto had in mind for his own Bitcoin.

Why is it possible for Bitcoin to reach this value? What is the "fundamental value" of Bitcoin?

In this paper we aim to build a framework that permits to answer this question.

First step of our framework is based on "The value of scarcity". The concept of scarcity is well present and known in Commodities, such as with Gold, Silver, Palladium or Platinum.

These precious materials are all the more precious the more scarce their production is.

In fact, there is a mathematical model known as Stock to Flow, that estimates price based on the quantity already present in the world (Stock) with the quantity that is extracted every year (Flow).

Second step is explaining the "bubbles" (or the "waves", considering Shiller's narrative environment) in a fundamental picture based on the "halving rule".

Third step is the determinants of the Bitcoin demand and price. The "rate of adoption" model.

Fourth step is the "cost and revenues of production" model based on mining process, and the hash rate. The supply chain of bitcoin model is built to create price growth.

## 1. THE VALUE OF SCARCITY

These recent months (in full 2020 pandemic linked to Covid-19), central banks around the world have issued never seen before quantities of money in order to try to counter an inevitable economic crisis.

We live in a world where each generation of newly issued money, printed by central banks, leads to inflation, or the reduction of the purchase value of the currency itself and consequently, an increase in the price of goods.

To give an example, this year alone, the amount of dollars printed equals 20% of all dollars generated in time, based on the registered value of the money supply of dollars in the world.

20% in a single year is absurd, only made possible by breaking the pact that obligates governments to keep the dollar quantity in circulation linked to the quantity of gold in the central bank's vaults (the famous 1971 Bretton Woods Pact).

Consequently the more dollars are printed, the more we can see that their worth decreases over time.

The opposite of inflation is deflation. In other words, the more time passes, the more a currency appreciates and its purchasing power grows.

It is important to understand that Bitcoin was designed to grow in value indefinitely; I say this because the smallest quantity, known as a Satoshi, is equal to 0.00000001 of a Bitcoin. It's obvious that its creator imagined a deflationary system for his creation, one that could help it reach ever increasing values.

In the moment that a Satoshi has grown to be worth a dollar, a Bitcoin will equal to \$ 100,000,000 (one hundred million dollars!).

This is the value that Mr. Satoshi Nakamoto had in mind for his own Bitcoin.

Not immediately, obviously, not even in the short term. The path will likely be long and paved with several bubble bursts. Only the most courageous and tenacious who resist will succeed in the enterprise. But alas, this is the story of the financial markets.

Why is it possible for Bitcoin to reach this value?

Because there are 7 billion people in the world, and there will only be 21 million Bitcoins circulating at the end of its generation cycle.

Worldwide, an estimated 40+ million people have more than a million dollars in cash (source Wall Street Italy), do you think there is enough Bitcoin for all these rich people?

Many of them won't be able to own a whole Bitcoin, because getting one will cost too much in a few years and because those who own them would never think about selling them.

This is the phenomenon of scarcity. Whereas we are used to inflation, or the increasing amount of money being printed by central banks, this doesn't exist in the Crypto world, and in some cases there are special Cryptos, such as the PHI Token that are designed to decrease the amount of tokens in circulation over time.

Scarcity, coupled with an increasing circulation of Cryptos, are the main reason why the price tends to rise and will continue to do so over time.

You understand now that owning an entire Bitcoin will be a luxury that only a few people will be able to afford, at most a few million people (given that the first million is rumored to be firmly deposited in Satoshi's wallets).

This is the most concrete possibility I know of in terms of getting rich fast, in a relatively short amount of years.

Still, for a small group of people the scenario of becoming millionaires thanks to Cryptocurrencies (about 100,000 in the world) has already happened.

The concept of scarcity is well present and known in Commodities, such as with Gold, Silver, Palladium or Platinum.

These precious materials are all the more precious the more scarce their production is.

But is there a mathematical model that can estimate what the correct value of a good should be, based on its scarcity?

If we think about phenomena such as Ferrari, Rolex, ancient paintings by famous painters, etc ... all these assets are valued significantly higher than their cost of realization due to their scarcity, induced or generated by those who created the assets themselves..just like Bitcoin. In fact, there is a mathematical model known as Stock to Flow, that estimates price based on the quantity already present in the world (Stock) with the quantity that is extracted every year (Flow).

The smaller the quantity extracted every year, the higher the value the precious metal has. And since it takes many years to double the stock currently in circulation, it itself has value because it is scarce.

	Stock (tn)	Flow (tn)	SF	supply growth	Price \$/unit	Market Value
gold	190,000	3,500	54	1.8%	\$ 1,425	\$ 9,476,250,000,000
diamonds	2,812	150	19	5.3%	\$ 533	\$ 1,500,000,000,000
silver	71,000	25,000	3	35.2%	\$ 16	\$ 39,760,000,000
palladium	244	215	1	88.1%	\$ 1,488	\$ 12,707,520,000
platinum	86	229	0.4	266.7%	\$ 844	\$ 2,532,000,000

Table 1: Main Commodities and Capitalization Data

In this table, SF is measured as years required for the current stock to double.

As you can see, gold is extracted at an amount of 1.8% per year compared to the current stock, so its total value is greater than the other commodities.

This relationship is more evident if the relationship between Market Value and Supply Growth is applied to a power diagram (Cartesian plane with both axes using a logarithmic scale).

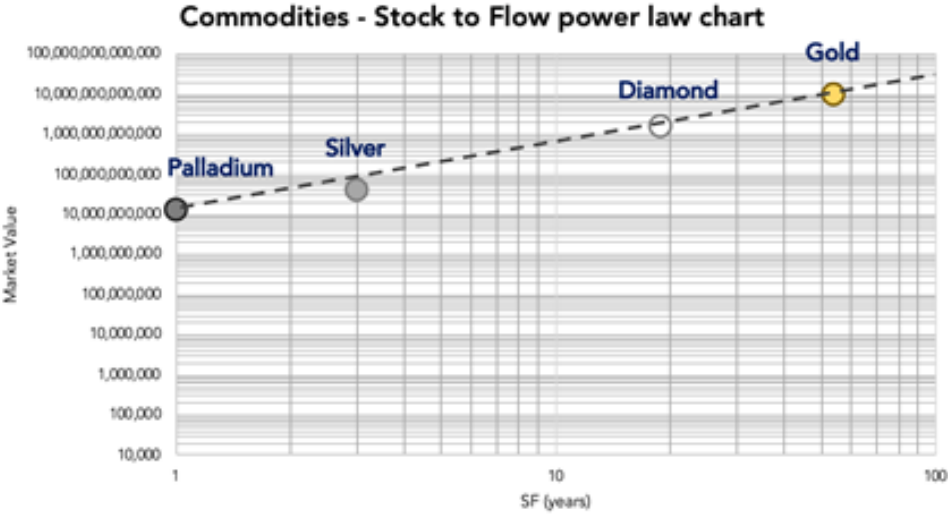
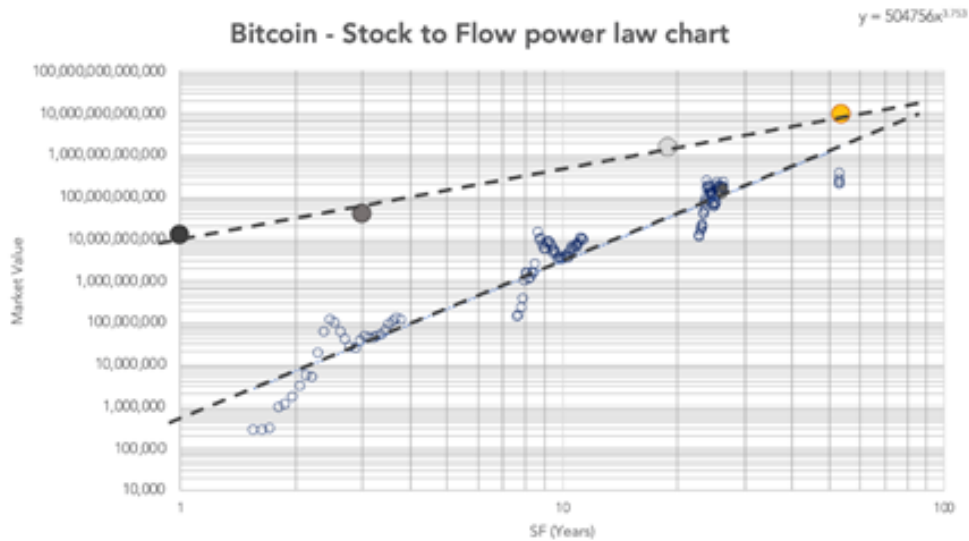


Figure 1 - Power Law of Commodities based on scarcity.

From this graph you can clearly see that there is a power law governing the scarcity of a good along with its overall market value.

The power law is deduced by how linear the existing relationship manifests on a Cartesian plane with both logarithmic axes, as shown in the previous figure.

Does this law also apply to Bitcoin, designed to have an ever increasing Stock to Flow ratio? (i.e. an ever decreasing number of Bitcoins mined over time).



*Figure 2 - Power Law of Bitcoin based on scarcity.*

From the graph it is clear that even Bitcoin, albeit with a different scale, follows the same power law.

The three breaks in the graph represent the three Halvings, a phenomenon of halving of mined Bitcoins that occurs approximately every four years and which makes Bitcoin increasingly scarce compared to the stock in circulation.

From this graph we can see that the value of 20 Trillion Dollars is anything but impossible to achieve, and indeed it is only a matter of time. Once the percentage of Bitcoins mined in a single year will be equal to or less than 1%; a situation that will occur at the next Halving in 2024.

But what exactly is Halving? Halving is a planned reduction of the Bitcoin given as remuneration to Miners for each block.

## **2. THE MARKET MOVES IN BUBBLES**

In recent months or even years, there's been a lot of talk about the "bubbles developing in the bond markets": newspapers, both financial and non-financial talked about it, as well as specialized television stations and prestigious "macro economists" from all over the world, are discussing how world debt today has negative interest rates.

It is financially counterintuitive to have to pay to lend money to someone, even if that person is a state. We are experiencing an absurd situation that has never happened before in the financial market landscape. The main cause is linked to the enormous liquidity injected into the markets by central banks, which they used as funding to avoid

their own bankruptcy only to then, prudently, reverse it back onto the States (they themselves in difficulty).

Afterall, Keynes's famous phrase reads: "Financial markets can remain irrational for much longer than you can remain solvent".

In actuality, this absurdity has made it possible to avoid the bankruptcy of the financial system, so it is welcome, even though it feeds irrational phenomena, such as bond markets with negative yields (and therefore senseless bond prices), and stock markets touching (not all, but most) new highs day after day.

One phenomenon that isn't actually fueled by central bank money, that everyone labeled a meaningless mega bubble, is Bitcoin in 2017.

The price of Bitcoin rose from a high of over € 18,000 in December 2017, coinciding with the launch of the Bitcoin Future by the CBOE and the CME, the two largest Commodities Exchanges in the world, to a minimum of around € 3,000 in 2018, effectively losing over 80% of its value.

Does it represent the bursting of a bubble? Sure.

Does it represent the end of Bitcoin? Certainly not!

Could there be more Bitcoin bubbles in the future? Of course.

As always, I would like to approach the problem as analytically as possible. So I reconstructed the table created by the founder of Bitcoin, Satoshi Nakamoto using Excel, to make sure that Bitcoin was deflationary and not inflationary.

The Dollar (and all currencies in the world truthfully, including the Euro), due to inflation, are worth less and less over time.

We can better understand the phenomenon if we think about the value of assets. Buying a car forty years ago cost about thirteen times less than it does today, so a nice car that cost \$ 10,000 in 1980, today would cost \$ 130,000.

This phenomenon is called inflation and is induced by a rule that links the total value of goods in the world to the total currency in circulation. If the number of dollars in circulation doubles, the same good will tend to cost twice as much.

I say it will tend not by chance, because they are not linear phenomena, and they may take some time to happen.

In the eighties, inflation reached rates close to 20% per year, creating many difficulties for those who didn't have the knowledge and the means to counter it.

Bitcoin was created with a deflationary logic, more similar to commodities such as gold and silver

This is why it's considered by many to be the new Digital Gold, because it has preservation of value characteristics and not of impoverishment like the dollar or the euro.






But let's see how this was possible to create and what the effects resulting from these choices are.

Satoshi Nakamoto decided that the maximum number of Bitcoins created and available should be 21 million (the number 21 will occur many times, it is the Greek letter PHI which we will also talk about later).

He could have decided to enter a fixed amount of Bitcoin for each block that got mined, but doing so wouldn't have created the exponential growth effect that instead characterizes Bitcoin, or at least not as marked as it is today.

Consequently, he decided to halve the amount of newly issued Bitcoin every four years, to create a very marked and interesting stock to flow effect that would push the price higher and higher.

**How Halving works**

	<b>First Block</b>		<b>Each block 50 BTC</b>	10,5 millions BTC
	<b>After 210.000</b>	2012	<b>Each block 25 BTC</b>	5,25 millions BTC
	<b>After 420.000</b>	2016	<b>Each block 12,5 BTC</b>	2,62 millions BTC
	<b>After 630.000</b>	2020	<b>Each block 6,25 BTC</b>	1,31 millions BTC
	...		...	...

*Figure 3 - Diagram of How Bitcoin Halving Works.*

So for the first 210,000 blocks, miners were paid 50 Bitcoins for each block written on the distributed ledger, at a time where the value of Bitcoin fluctuated from a few cents up to a few euros, so the remuneration was not in the least comparable with that of today. Neither was it difficult to win the challenge, in fact in the early years, simple computers were enough to do the mining.

The first Halving took place in 2012, i.e. from the 210,001st block onwards, remuneration was halved to 25 BTC for each writing on the Distributed Ledger.

In 2016 the second Halving took place (which brought the remuneration down to 12.5 BTC) and in May 2020, the third Halving took place, bringing the remuneration for each block to 6.25 Bitcoins, which in any case at today's values is still over 120,000 USD for a single writing.

The next Halving is scheduled for 2024, where remuneration will be further cut by 50%, to continue, probably until 2140, the year in which

the last halving is expected, which will distribute less than one Bitcoin in the last year.



Figure 4 - Percentage of Bitcoin distributed throughout the year.

But how does this halving phenomenon impact the price of Bitcoin? Does the halving of the so-called "Flow", or the flow of new capital into the market, affect the price of Bitcoin itself?

As we saw previously, Bitcoin seems to follow the Stock to Flow model, therefore a reduction in Flow, while maintaining the same Stock, should correspond to an increase in price.

Therefore, now that we've had three Halvings, shouldn't there have been as many bubbles? Do you know how many bubbles Bitcoin has had in its short life? Three fatalities, here they are represented graphically:

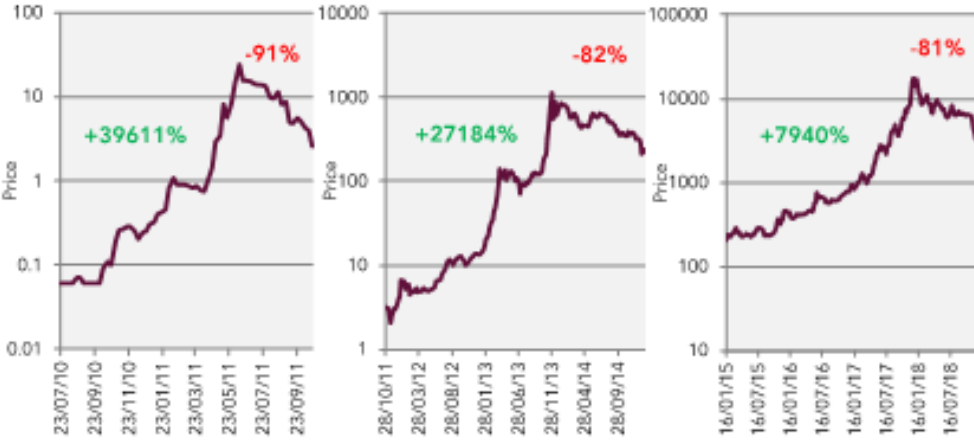


Figure 5 - The three Bitcoin bubbles from 2010 to 2020.



These are the three bubbles Bitcoin has faced so far, each time the next maximum price became at least 10 times higher. Obviously, it is not a guarantee that it will do so in the future, but there are many factors that lead us to believe that what we experienced in 2017 will not be the last bubble and many more will follow in the future. So can this information be used to determine a correct price for Bitcoin? Or at least, a potentially achievable price according to this model?



Figure 6 - The three bubble of Bitcoin (normalized)

In fact we can, if we take a look at this graph where the Halvings are highlighted by jumps in the X axis in correspondence with the change in status of Halving. We can estimate the fair value price, that is, the correct price at which Bitcoin could tend towards.

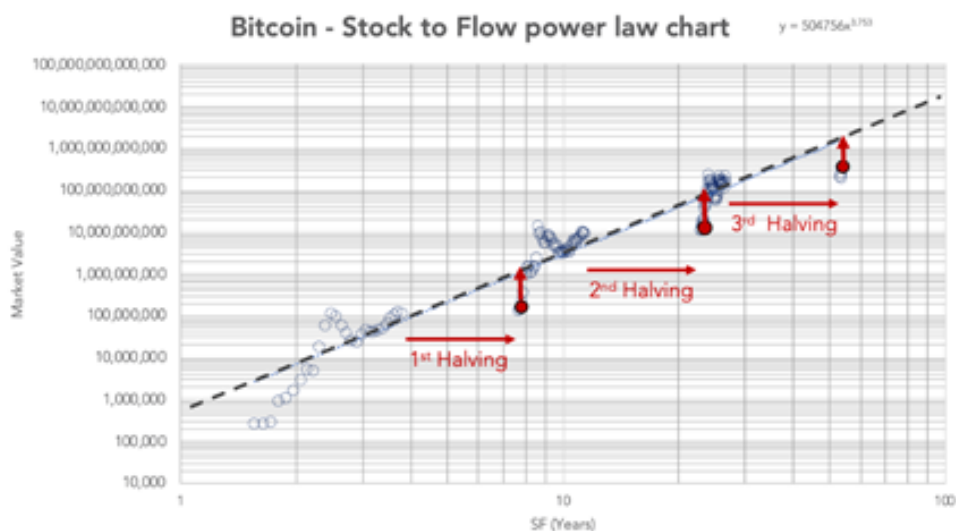


Figure 7 - The effect of Halving on the Stock to Flow graph.

If the price of Bitcoin tends to return around the line described in the figure above, it is clear that we can estimate what the future target price of Bitcoin will be, based on the various Halvings that await us.



Figure 8 - Price of Bitcoin over time with respect to Stock to Flow.

From the graph, it is clear that the target price of Bitcoin is between € 90,000 and € 100,000. This information is very useful not because it guarantees we will arrive at those prices, but because we should take into account, for our investment decisions, that it could actually get there and even exceed those price levels.

Obviously, these estimates must be taken as an intellectual attempt to understand the dynamics of Bitcoin and absolutely cannot be considered a suggestion or advice from the author.

Understanding how Bitcoin can reach such values is not easy, anyone approaching this fascinating world for the first time would have a hard time imagining how a seemingly worthless asset could have such a high price, especially if you fall into the trap of thinking of it as a dollar-par currency.

To do this, it is important to know its various aspects, one of which, certainly fundamental for determining the price of Bitcoin, is the adoption rate described next.

### 3. RATE OF ADOPTION

If more and more people desire a certain good, and the same amount of units are in circulation, the price will obviously tend to rise.

It's the demand and supply rule that governs any market in the world.

If one year a hailstorm destroys the tomato crop, and there are many less than expected, it makes sense for the tomato prices on the market to rise, considering the demand has remained the same.

But imagine for a moment that suddenly people want to use tomatoes much more than in previous years, therefore the demand goes up and the availability of tomatoes goes down, the price will go up a lot more than in the previous case.

Demand can grow due to two factors: participants are stable, and the amount of request increases, or the amount of request is stable but the number of participants increases, or even a combination of these two.

In the example that follows we've only assumed that the number of participants goes up for the same amount of goods.

So on the one hand we have Satoshi Nakamoto who defined that Bitcoin must become increasingly scarce over time, and on the other, a possible boost in the price of Bitcoin coming from new people who progressively enter the market.

It is therefore a question of studying the adoption rate of Cryptocurrencies in the world to understand where the value of Bitcoin is headed and overall where the Cryptocurrency Asset Class can go in the future.

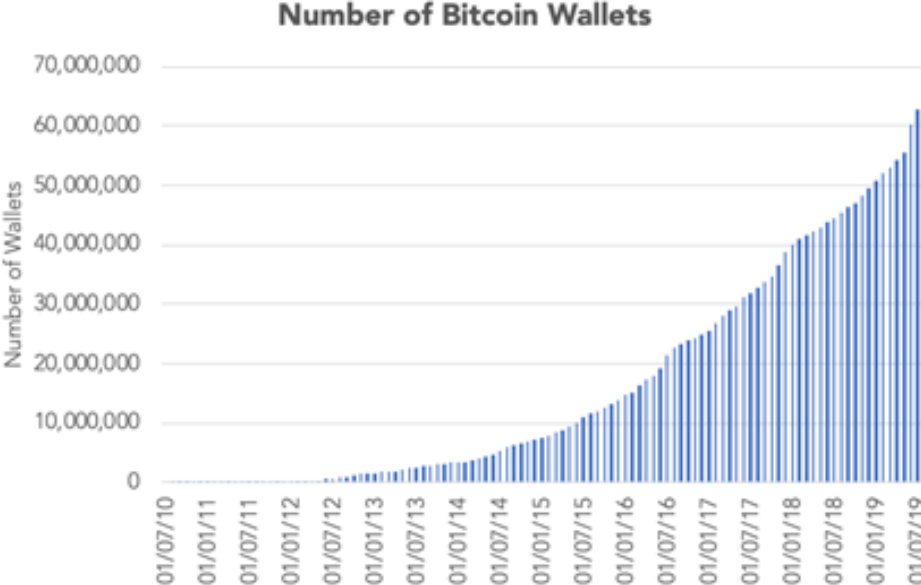


Figure 9 - Growth of Bitcoin wallets over time.

The growth in the number of wallets is not exactly exponential, but close to it, so in order to predict its growth in the future, you need to use a "power law" function that is able to best estimate its curvature. To do this, first we put the graph in logarithmic scale, and then calculate the function that best approximates it. Though the function does not consider any potential future increases based on a rise in interest that could manifest in 2021 following an unexpected growth in Bitcoin, this exercise is used to estimate the growth over time in the number of wallets.

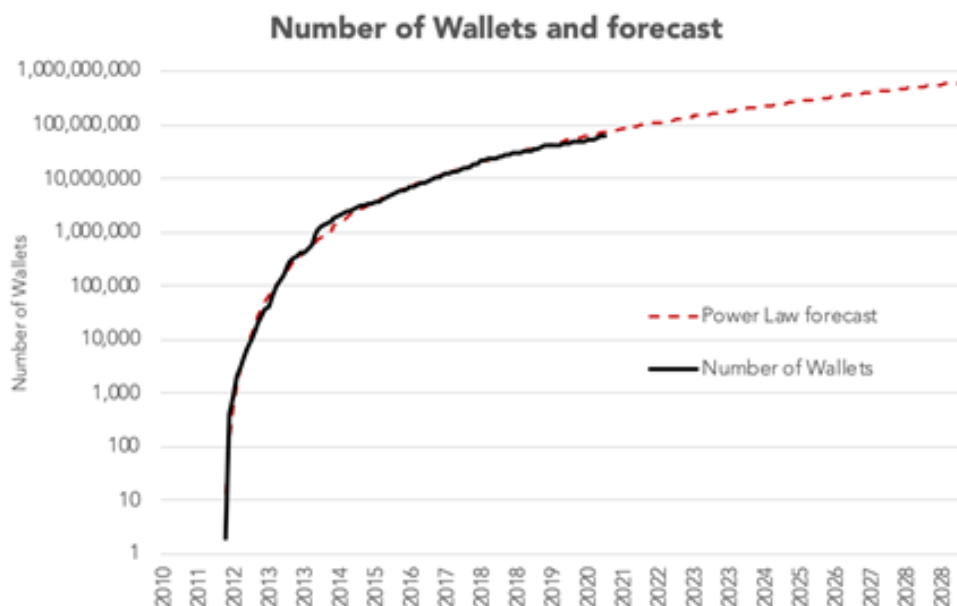


Figure 10 - Growth rate in number of wallets over time.

To estimate the growth in the value of Bitcoin using the number of wallets in circulation, we'll need to estimate the average amount contained in each individual wallet using a fairly simple function:

*Bitcoin Capitalization / Number of Wallets*

Now we have an estimate of the Bitcoin value each wallet has on average. Official data tells a completely different story, that is, that 70% of Wallets have 0.01 BTC or less, while 2% of wallets, ie. about 1.6 million wallets own over 90% of Bitcoins in circulation and the Exchanges own about 7%.

These reports help us understand the enormous growth potential of Bitcoin in the future, because those who own a large part obviously do not sell it since they know Bitcoin and its potential well, those who have 0.01

BTC or less will be tempted to buy more, and of course there are always new wallets opening every month.

However, by taking the average we can highlight an average value expressed in Dollars, of the content of these wallets:

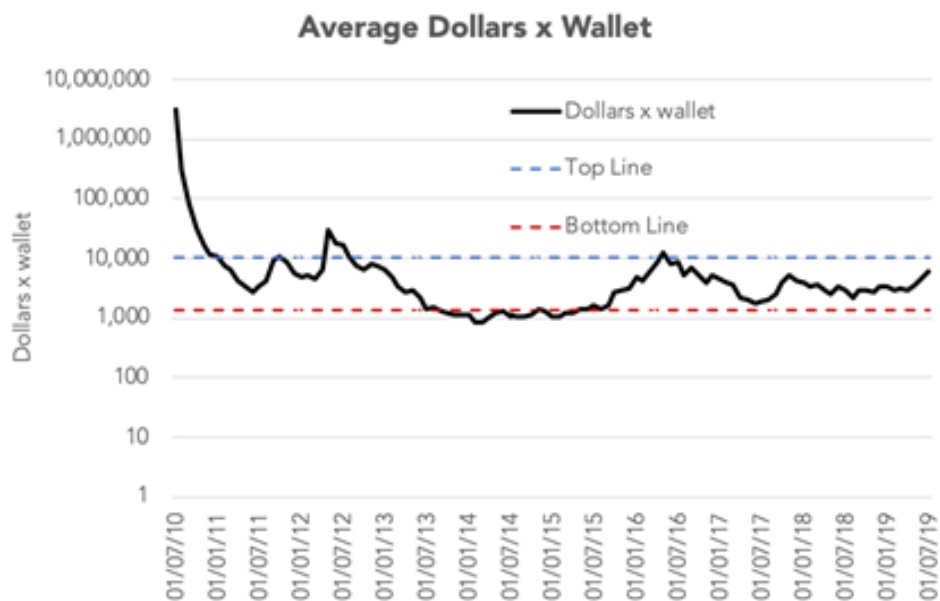


Figure 11 - Average deposits in wallets in USDs.

Since the average of these deposits are conditioned by the value of Bitcoin's price, to best estimate a "range" of prices where Bitcoin could go, the red dotted line represents the tenth percentile of USD deposited wallets; while the dashed blue line represents the 90th percentile. This "range" allows us to frame what the entire capitalization of Bitcoin should be over time based on the estimated adoption rate of Bitcoin. This estimate doesn't consider several factors that could make it very prudent, namely that for institutional investors entering the market, the average amount per wallet could go much higher than the blue band identified in the example.

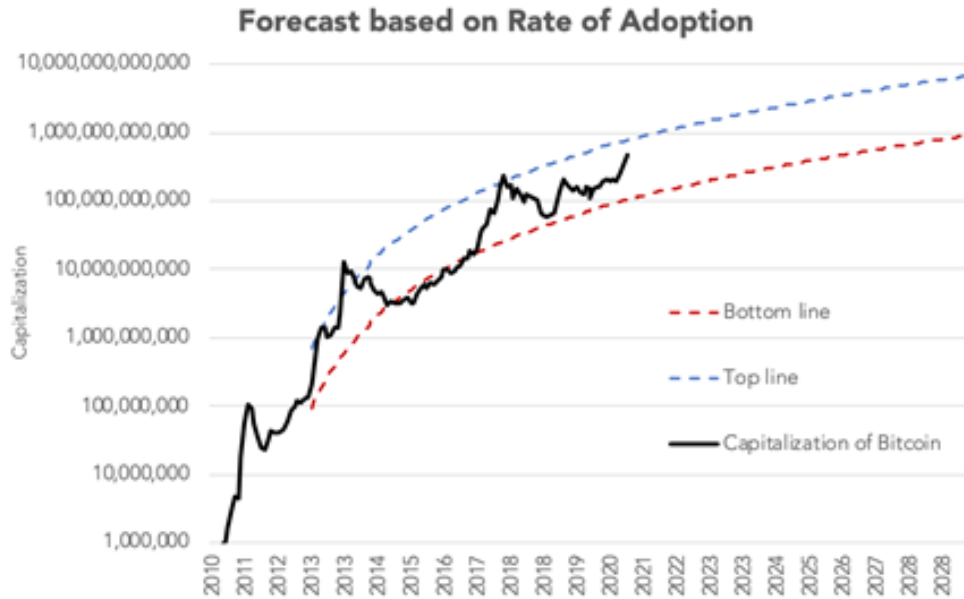


Figure 12 - Estimated capitalization based on rate of adoption.

Obviously, these estimates should be taken as an intellectual attempt to understand the dynamics of Bitcoin and absolutely cannot be considered a suggestion or advice on behalf of the author.

This graph shows that a goal of reaching a trillion in capitalization, or, one trillion dollars, is far from impossible, especially if interest in Bitcoin continues to rise in the coming months. (As I write this, it is December 2020).

Similar growth is also estimated by the makers of the rainbow chart, which you can find on the website [www.blockchaincenter.net](http://www.blockchaincenter.net):

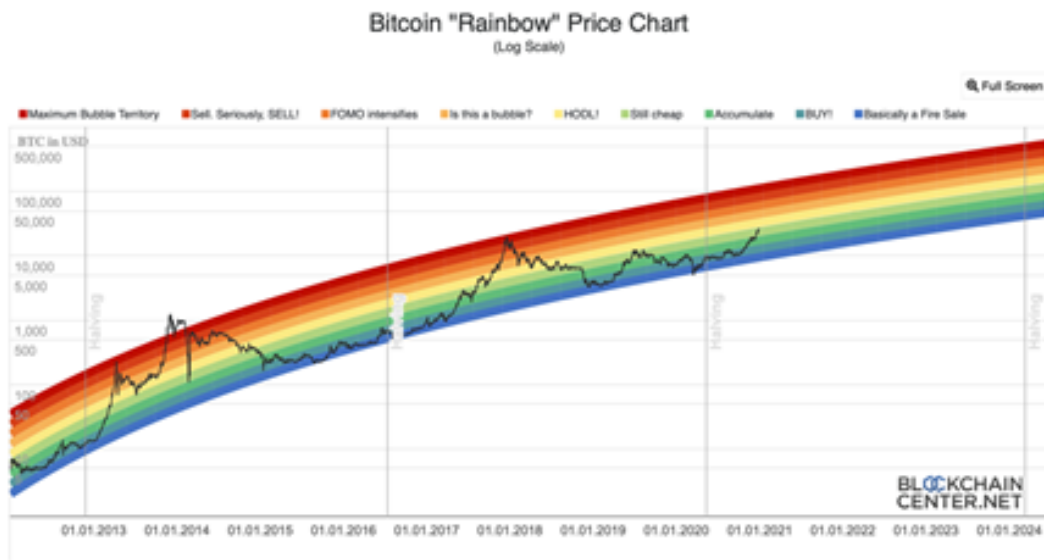


Figure 13 - Rainbow chart indicating the price levels of Bitcoin.

This graph is very useful because it summarizes the presumed growth rate of Bitcoin's value and its bubble trend following each Halving. Clearly, there is no guarantee that Bitcoin will continue to move with this logic, but it is important to note that it could do so in order to be able to make objective and reasonable investment decisions according to these assumptions as well.

**4. HASH RATE AND THE ESTIMATED PRICE OF BITCOIN**

In Data Mining, the term Hash Rate is a security metric. The greater the hashing, the greater its safety and resistance to external attacks. One thing is a hacker attacking your home computer, another is when a hacker tries to attack tens of thousands of computers around the world at the same time.

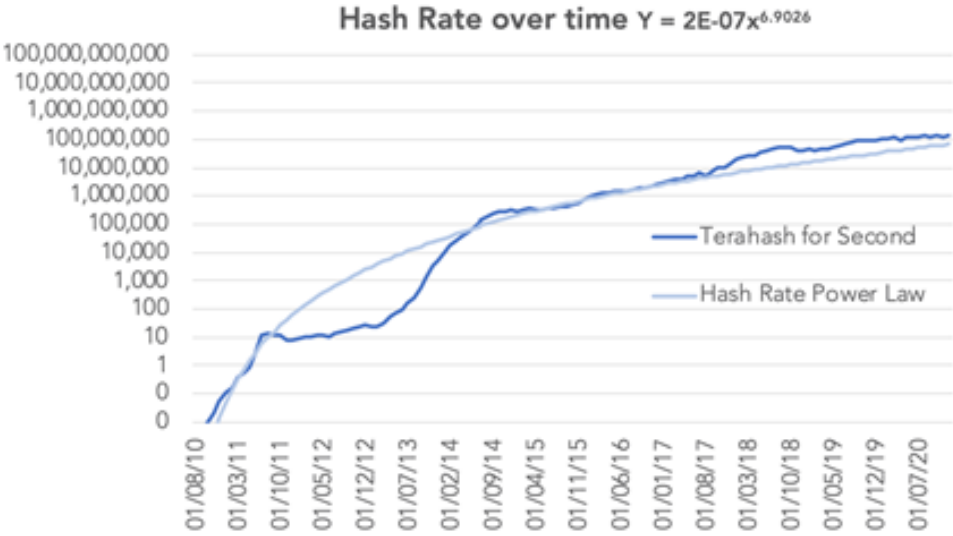


Figure 14 - Representation of Hash Rate growth over time.

The Hash Rate growth is due to the ever increasing computing power of Mining servers, which also means increasing costs to mine Bitcoin. A simple rule tells us that a given activity must have economic convenience in order for it to be sustainable over time. Those who extract oil from the ground must sell it at a cost greater than the cost of extraction, those who produce electricity must sell it at a cost greater than the cost of production, and so on. The same rule applies to Bitcoin Mining, whereby the cost of electricity, the amortization of increasingly powerful servers, etc., must be lower

than the revenues generated by receiving Bitcoin for the activity carried out. Therefore, the growing difficulty of mining Bitcoin must be matched by economic convenience.



Figure 15 - Monthly remuneration for miners in USD.

In the first months of 2010, Bitcoin paid Miners about 10,000 USD per month. Today, thanks to the growth of the price of Bitcoin, the network of Miners in the world distribute a wealth of over 500 million per month and this value is destined to grow.

The figure is enormous, even if partially commensurate with the consumption of electricity, but it allows us to understand the generation of wealth that this "social experiment" is able to create.

As we can see from the graph, the growth of the Hash Rate is higher than the growth of monthly remuneration.

Therefore, in order to estimate the correct price of Bitcoin based on Hash Rate, it is first of all necessary to understand the trend of remuneration for each unit of Hash over time.



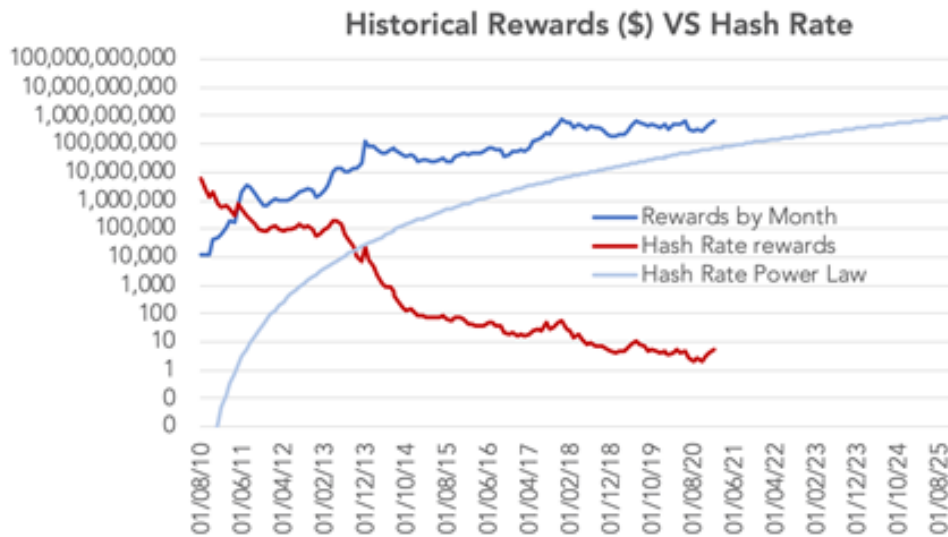


Figure 16 - Monthly remuneration in USD per Hash.

As we can see, the dollar remuneration of the Hash Rate is in sharp decline.

This means that security increases almost exponentially over time, but the cost of security drops considerably over time.

Let me explain better, while the remuneration for each block grows, despite/thanks to the halving that increases scarcity, the difficulty of undermining a new block increases, at least for now, much more quickly, so the *price / hash rate* ratio goes down because the denominator goes up much more than the numerator.

So to estimate the (non-linear) trend of decline in remuneration for Hash Rate, the function that best represents this trend is, as always, is the power law function, as shown in the following figure.

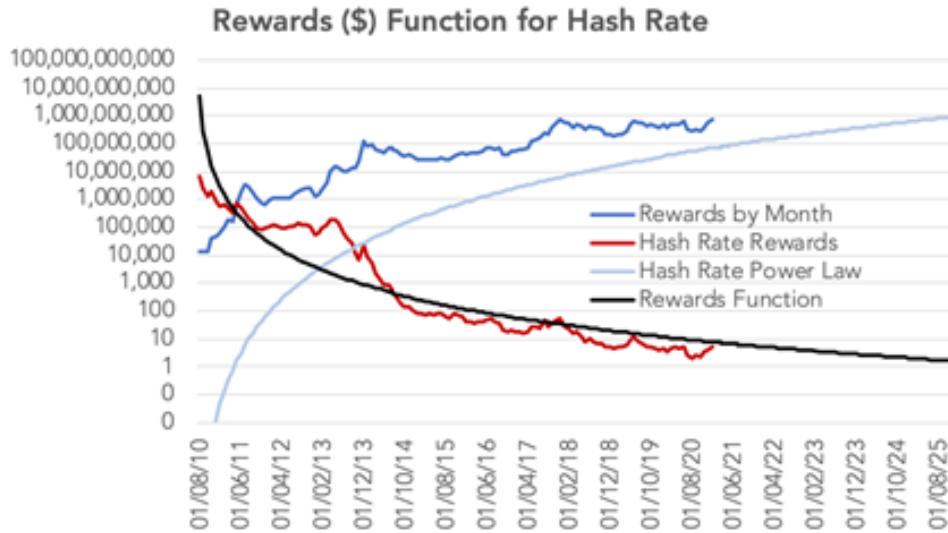


Figure 17 - Remuneration function over time in USD.

Once we obtain this function, by multiplying the two functions of Hash Rate growth and payment by single Hash Rate, it is possible to obtain the function that approximates the monthly remuneration in Dollars over time.

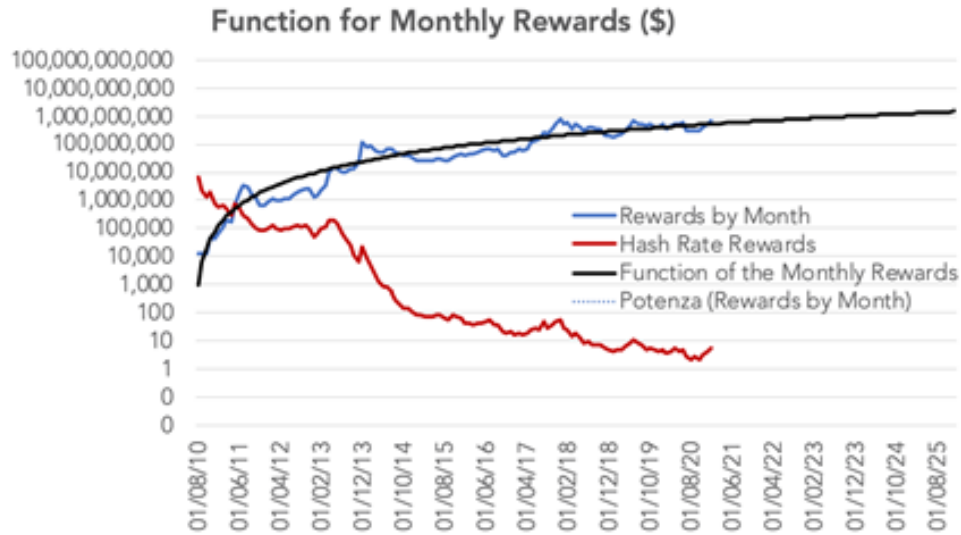


Figure 18 - Growth curve of monthly remuneration for Mining.

This result does not approximate the value of the price of the single Bitcoin, but of the monthly remuneration that is growing over time, as can be seen on the previous graph.

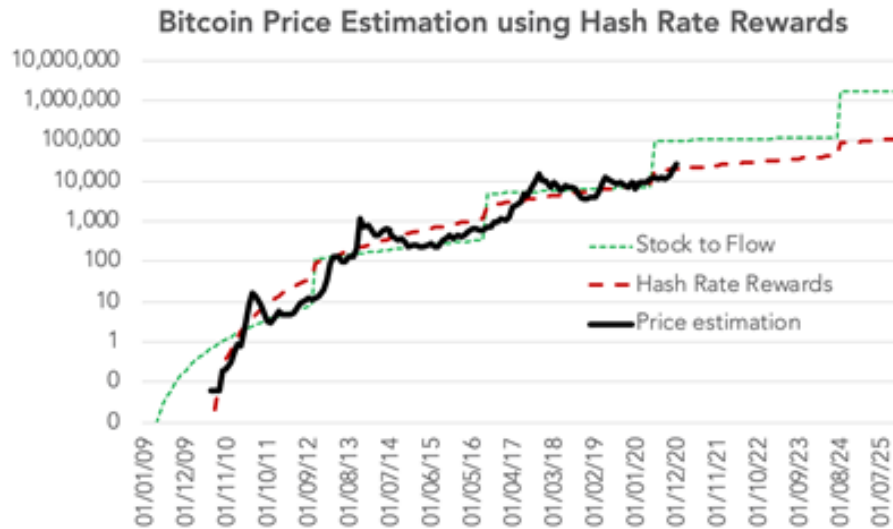


Figure 19 - Price predictions based on Hash behavior.

To estimate the Bitcoin price, corrected according to this Hash Rate metric, divide this value by the number of Bitcoins that are mined in a given month.

By doing so, we obtain the typical stepped trend of the stock to flow model described earlier, albeit a more moderate trend than the previous forecast described in Figure 24.

## 5. CONCLUSION

We can conclude, even in front of strong volatility and apparently incomprehensible price movements, that the principal three factors that move the price of the Bitcoin, the scarcity, the demand and the cost of production, can be really useful to understand the dynamics of the bitcoin price movements.

We can argue that there are a long term fundamental value trends that can help to consider Bitcoin as a "Strategic Asset Class" of investment.

## BIBLIOGRAPHY

- Satoshi Nakamoto (2009). Bitcoin White Paper: A Peer-to-Peer Electronic Cash System
- Buterin, Vitalik (2013). Ethereum White Paper: A next-generation smart contract and decentralized application platform
- DIAMAN Capital (2018). The PHI Token White Paper
- Daniele Bernardi e Ruggero Bertelli (2014): The DIAMAN Ratio
- Daniele Bernardi e Ruggero Bertelli (2016): The Return Parity Approach
- Daniele Bernardi e Ruggero Bertelli (2016): Target Strategy: A Practical Application to ETFs and ETCs
- Francesco Canella, Tiziano Vargiolu e Enrico Edoli (2013): The Right Time to Enter
- Mebane Faber (2013), A Quantitative Approach to Tactical Asset Allocation
- Edward Qian (2005): Efficient portfolios through true diversification
- Didier Sornette (2018): Are Bitcoin Bubbles Predictable? Combining a Generalized Metcalfe's Law and the LPPLS Model
- Didier Sornette (2018): Can We Use Volatility to Diagnose Financial Bubbles? Lessons from 40 Historical Bubbles
- Didier Sornette (2010): Bubbles Everywhere in Human Affairs
- M.E.J. Newman (2006): Power laws, Pareto distributions and Zipf's law
- PlanB: (2019): Modeling Bitcoin's Value with Scarcity
- Andrew Lo (2002) A non-random walk down Wall Street