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Stavanger, 15 June 2020

Peder Lindland

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(Peder Lindland)

Abstract

The Bitcoin market has grown to become relevant to financial markets and there are still a number of unanswered questions relating to Bitcoin as an asset class and how the Bitcoin market behave relative to traditional financial markets. The aim of the thesis is to further investigate the technological and financial properties of Bitcoin and disclose how these relate to the Bitcoin market and the broader aspects of the financial world. The topic of interest is formulated into a set of research questions.

RQ1: *“What is driving the Bitcoin market?”*

RQ2: *“How does the future look like for the Bitcoin market?”*

The thesis answers the research questions of interest by a set of different quantitative analyses in combination with existing economic theory, models, and economic thoughts. The quantitative analyses conducted for the thesis are a cost of production analysis of Bitcoin, a set of regression analyses and a portfolio analysis. The data retrieved for the different analyses is carefully inspected and retrieved from trusted sources. The aspects of modern portfolio theory in terms of diversification and hedging properties is essential for the thesis. In addition, the economic thoughts of the Austrian School are reasonably weighted in the discussion and the concluding remarks in order to answer the set of research questions.

The technological and financial properties of Bitcoin reveal that the supply side is fixed, and the demand side is ultimately the most important factor driving the Bitcoin market. The findings of the cost of production analysis reveal a significant relationship between the Bitcoin spot price and underlying fundamental cost of production and correspondingly Bitcoin tend to gravitate towards the production cost, likewise other commodities. The set of regression analyses supports the significant relationship between the Bitcoin spot price and underlying fundamental cost of production.

Finally, the results of the portfolio analysis reveal Bitcoin as great diversifier in terms of low correlation to a number of other assets and indices. The concluding remarks of the thesis covers that the demand in the Bitcoin market is expected to increase, given that regulation is fully set, as the properties of Bitcoin is presumably equal to gold and given the existing uncertainty in the financial markets.

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Abbreviations and Concepts

ABCT	Austrian Business Cycle Theory
BLUE	Best Linear Unbiased Estimators
CAPM	Capital Asset Pricing Model
CBECI	Cambridge Bitcoin Electricity Consumption Index
CFTC	Commodity Futures Trading Commission
CLRM	Classical Linear Regression Model
CME Group	Chicago Mercantile Exchange Group
CML	Capital Market Line
ETF	Exchange-Traded Fund
EU	European Union
FED	Federal Reserve
FTC	Federal Trade Commission
IRS	Internal Revenue Service
OLS	Ordinary Least Squares
PBOC	Peoples Bank of China
PoW	Proof of Work
PUE	Power Usage Effectiveness
SEC	Securities and Exchange Commission
U.S	United States
USD	United States Dollar
USDT	The Department of the Treasury
Fiat Currencies	Government-issued Currencies
Forex Markets	Foreign Exchange Markets of Fiat Currencies

1 Introduction

On January 3 of 2009, in the ending of the financial crisis, Satoshi Nakamoto mined the genesis block of the Bitcoin blockchain (Blockchain, 2009). The pseudonym Satoshi Nakamoto, person or group of people, is known to be the creator of Bitcoin and is to this date still unknown to public (Nakamoto, 2008). The genesis block is known to be the first block of the Bitcoin blockchain and marks the creation of a new financial system independent of central authorities. Inspecting the genesis block further reveals that a message was left in the raw data of the block referring to the headlines of the British newspaper, The London Times, that very day.

"The Times 03/Jan/2009 Chancellor on brink of second bailout for banks" (The Times, 2009).

This quote may be interpreted as an apprehensive critic to the governments and central banks for their poor management of financial regulation and monetary policy during the period preceding to the financial crisis. Investment banks were also responsible of this financial crisis by operating with extreme leverage in which implied great risk and eventually caused a liquidity crisis when the housing market collapsed making big corporations as Lehman Brothers go bankrupt.

Despite the aftermath of this crisis, fast forward just over a decade later, Bitcoin has become a global financial asset that has grown exponentially in bull markets and had several market crashes causing bear markets of considerable length. The Bitcoin market has gained a significant amount of interest from different stakeholders and become an asset valued at a total of $175 billion. In comparison the value of the entire cryptocurrency market is valued at a total of $270 billion (Tradingview, 2020). The Bitcoin market has grown to become relevant to global financial markets making it interesting to analyze the underlying fundamentals of the Bitcoin market in order to support the overall understanding of this asset class.

1.1 Background

The background for this thesis is to provide a financial analysis of the Bitcoin market in a time where conflicting stakeholders and especially the public conceivably have a lot of misconceptions about the market. Well known investors such as CEO (Chief Executive Officer) of JPMorgan Chase, Jamie Dimon, featured the Bitcoin market as a fraud in 2017 (Hugh Son, 2017). These statements may be fueling the misconceptions and enhances loss of confidence in the financial state-of-the-art technology, Bitcoin.

Financial markets are dependent on trust to thrive and succeed and this is arguably not an exception for the Bitcoin market. The Bitcoin market has become more mature, new approaches has been taken, and more data has become available. There is a significant amount of data and information to be analyzed and interpreted making the topic being studied of great interest.

1.2 Objectives and Limitations

The main objective of the thesis is to further investigate the technological and financial properties of Bitcoin and disclose how these relate to the Bitcoin market and the broader aspects of the financial world. The literature on the underlying fundamentals of the Bitcoin market is rather narrow and as a result of this, the topic of choice is investigated throughout the thesis. To achieve the objective of the thesis a literature review is conducted, and a set of quantitative analyses are chosen based on a set of research questions. In order to limit the scope of the thesis the following research questions are chosen and sought to be answered.

RQ1: *"What is driving the Bitcoin market?"*

RQ2: *"How does the future look like for the Bitcoin market"?*

1.3 Thesis Structure

The structure of the thesis is organized in an uncomplicated manner to ensure systematic reading. Firstly, an introduction followed by a literature review of valuable insights on previous research and analyses of Bitcoin and the Bitcoin market expressed by relevant technological and economic theory. Then, a chapter of relevant economic theory, models, and economic thoughts for the thesis. Next, a methodology chapter of the research strategy, design, and methods. Furthermore, the results of the quantitative analyses are presented and interpreted. Finally, a discussion of the results and the corresponding conclusion of the thesis.

2 Bitcoin

Bitcoin is a digital decentralized peer-to-peer currency better known as a cryptocurrency. A cryptocurrency is a virtual currency designed to function as a medium of exchange, a payment system based on mathematical proofs rather than a trusted central financial authority. The decentralization aspect of Bitcoin is the feature of distributing power and responsibility to mathematics rather than human behavior making Bitcoin arguably more resilient, efficient and democratic (Cointelegraph, 2020). The mathematical proofs that the payment system is based on is advanced mathematics and cryptography to verify the transactions, limit the creation of new Bitcoins and securing the Bitcoin network (Cointelegraph, 2020).

2.1 How Does Bitcoin Work?

The key elements of the Bitcoin network are the nodes, transactions, underlying blockchain technology and mining consensus mechanism. A node is to be interpreted as a server which stores the entire blockchain and runs a Bitcoin software that confirms all transaction data and the blockchain. The blockchain is a public ledger that keeps track of all confirmed transactions up to the first block, the genesis block. There are thousands of nodes operating in the Bitcoin network ultimately checking if the transactions and blocks added to the blockchain conform to the open source Bitcoin code (Antonopoulos, 2017). A transaction on the Bitcoin network is an exchange of value between Bitcoin wallets. For a transaction to be validated it must be proven that the amount of Bitcoin that are about to be spent exists on that wallet and has not already been sent to someone else. Once a transaction has been validated it gets included into a block with a number of other transactions. The block is then attached to the previous blocks, thereby the blockchain. (Antonopoulos, 2017)

In order to acquire Bitcoin, there is an advanced liquid market online not presumably different from regular financial markets (Blockchain, 2020). Each Bitcoin are highly divisible which makes it possible to exchange as low amounts as 10^{-8} of a Bitcoin. The price of Bitcoin is decided by market making between buyers and sellers on hundreds of various cryptocurrency exchanges (Blockspot, 2020). Buyers sets a bid price, a price they are willing to buy Bitcoin. Sellers sets an ask price, a price they are willing to sell Bitcoin. When the bid and ask coincides a trade is made.

2.1.1 Transactions

In more depth, each Bitcoin wallet has an address with a public key, a long string of numbers and letters which keeps a record of all transactions and the balance of that wallet. In addition to the public key each wallet has a private key. The private key is essential to keep secret just like a password. The public and the private keys are related but it impossible to configure the private key by the public key (Coindesk, 2018). For every transaction there is a small transaction fee to prevent spamming the network. In order to request a transaction, the private key of Alice, Figure 1, and the receivers address Bob is plugged into a Bitcoin software and encrypted to a digital signature. The transaction is then validated by miners and sent to the nodes configuring the match of the digital signature and the public key retrieved from the address of Bob's wallet. If the digital signature created with the private key by Alice corresponds to the public key of Bob, the nodes are then able to verify the transaction without knowing the private key of either Alice or Bob. This feature is unique and a highly advanced form of cryptography and essential for a trusted decentralized network (Coindesk, 2018).

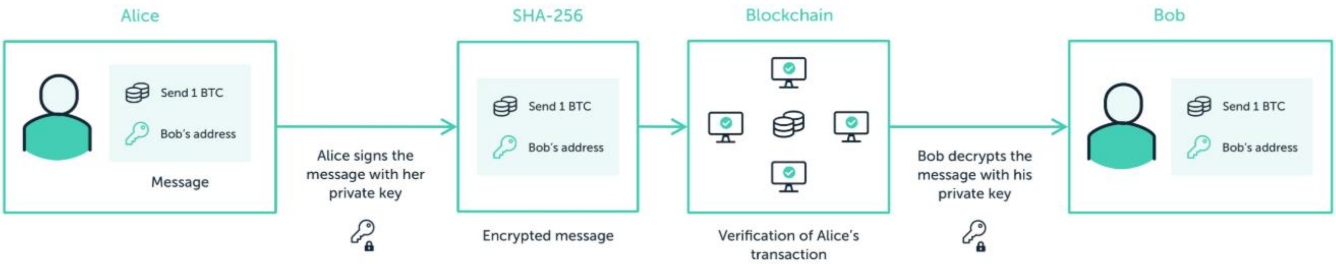
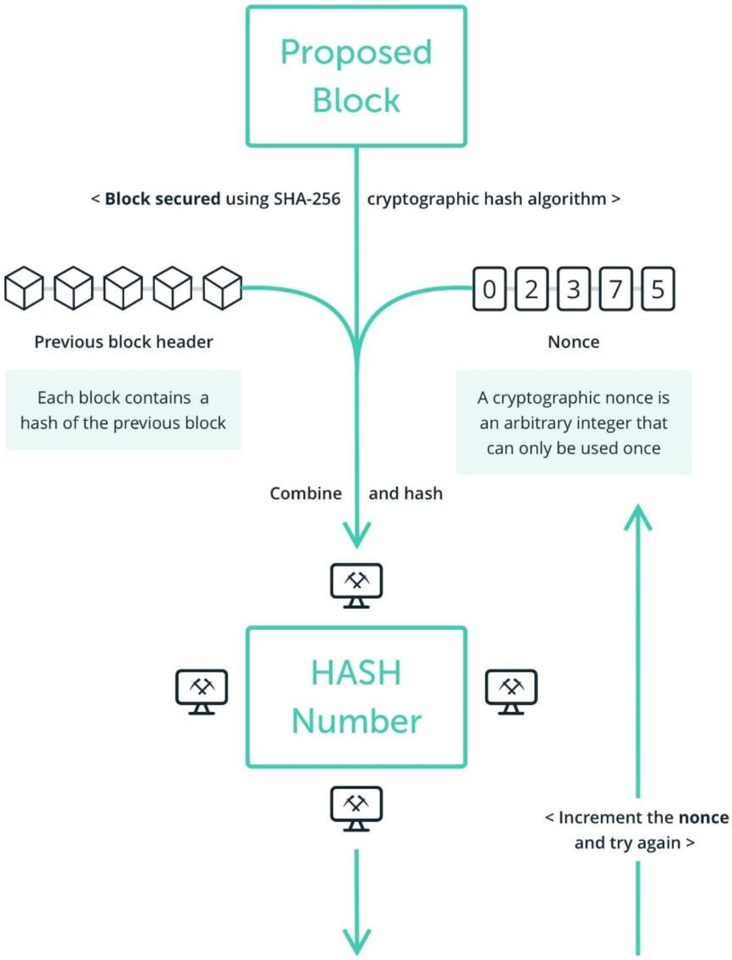


Figure 1: Alice and Bob, Bitcoin Transaction (Ledger Academy, 2019)

2.1.2 Mining

To secure the Bitcoin network and create new Bitcoins a huge number of miners are continuously operating to solve advanced mathematical problems by a cost heavy time-consuming computational process. This process is called mining in reference to gold miners who extracts gold (Coindesk, 2018). In reference to the transaction process described, nodes ultimately validate the transactions, but first miners are processing the transactions. The transactions are bundled into a block. The new block contains a block header that refer to the previous block based on the hash of that block. A hash is a complex mathematical algorithm that in this case secures that the previous block has not been changed. For the new block to be accepted by the network and added to the blockchain the nodes must prove that the new block was difficult, in the sense of time consuming and costly, to be made. This advanced consensus mechanism is better known as Proof of Work (PoW) (Bitcoinmining, 2020). Initially a regular personal computer could operate as a miner and solve the PoW cryptographic problems and be rewarded Bitcoin, but as the Bitcoin market has gained more interest this process has become far more complex.

PoW is based on a cryptographic hash function called secure-hash-algorithm-256. The PoW algorithm has a target value, a hash, set by the network and the miners need to generate a hash less than this value to be validated. The hash is extremely difficult and costly to generate due to the consumption of electricity of the computational power used but is easily verified by the network when first achieved. By combining a nonce, a number, and the block header of the previous block in the cryptographic hash function a hash is generated. For the miners to generate a hash less than the target value a lot of trial and error is required before the correct value is generated, and the PoW is validated. The first miner to provide a hash less than the target value may add the new block to the blockchain and are rewarded with new Bitcoins, Figure 2, (Ledger Academy, 2020).



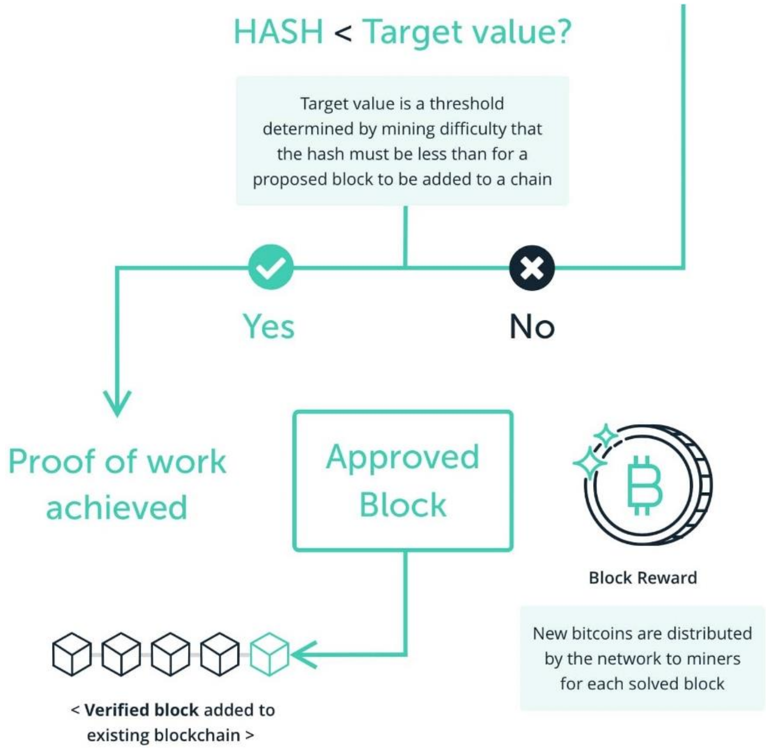


Figure 2: Proof of Work, Mining Consensus Algorithm (Ledger Academy, 2020)

The time to mine a block is on average about 10 minutes by design in the open source Bitcoin code since the first block created over a decade ago (Data.Bitcointity, 2020). When additional miners join the network and compete to mine the block, the block creation rate increases, and the average mining time decreases. To counterfeit this and ensure that the mining process of the block was time consuming and costly the mining difficulty set by the network increases. When the mining difficulty increases the block creation rate decreases and average mining time goes back to normal. The mining difficulty in the Bitcoin network are recalculated every 2016 blocks equally about every two weeks given the average mining time of 10 minutes (Bitcoinmining, 2020).

The block reward of mining and adding the new block to the blockchain is currently 6.25 Bitcoins and additional transaction fees as of the halving of the block reward 11 May 2020. Initially the mining reward was 50 Bitcoins, but the block reward is cut in half every 210 000 blocks mined by design in the open source Bitcoin code, equally a cycle of approximately 4 years given the average mining time of 10 minutes, hence equation.

$$\frac{\sum_{i=0}^{32} 210\,000 \left\lfloor \frac{50 * 10^8}{2^i} \right\rfloor}{10^8} \tag{1}$$

As stated in the open source Bitcoin code the ultimate number of Bitcoins ever to be created is about 21 million and is estimated to be at year 2140. Every Bitcoin in existence must be created through this advanced process. For individual miners to generate a more stable income, computational power is often bundled up in a mining pool to increase the power and probability of mining the block, and the reward is shared between the members of the pool. When the ultimate number of Bitcoins are mined the miners are then believed to be incentivized to continue mining and securing the network by being rewarded greater transaction fees.

2.1.3 Decentralization

Decentralization is an important feature of the Bitcoin network to distribute power and responsibility. The Bitcoin network does not have as stated a central financial authority monitoring monetary policy. Issuance of new Bitcoins is decided by a competing mining process which is highly democratic. Anyone may become a miner strengthening the argumentation of a decentralized network. There is no central administrator or decision maker. In addition, there is no central server that could potentially shut down the network, in order to do so the whole internet would have to be shut down. Other arguments for decentralization are that genuinely anybody with an internet connection may create a Bitcoin wallet without the approval of central authority. As to this distinctive feature anybody may use Bitcoin as a medium of exchange (Ghassan O. Karame, 2014).

On the other hand, the aspect of a trusted decentralized network may be threatened by internal governance in the mining community. For the mining community to become centralized and threaten the Bitcoin network, mining pools need to obtain more or equal than 51% of the total hashing power. If a mining pool were to achieve most of the computational power, it would allow the mining pool to double spend Bitcoins, prevent transactions of being verified, roll back the blocks in the blockchain, and prevent other miners to obtain income. The mining community have faced this kind of challenges in the past when a mining pool called GHash achieved most of the hashing power. As a response to this challenge for the Bitcoin network, GHash acted responsible and ethical by reducing their hashing power to about 40% of the total hashing power. As of today, the hashing power is distributed more decentralized, Figure 3, and to conduct such an attack would be practically impossible for a single entity given the hardware costs and electricity consumption (Rainer Böhme, 2015).

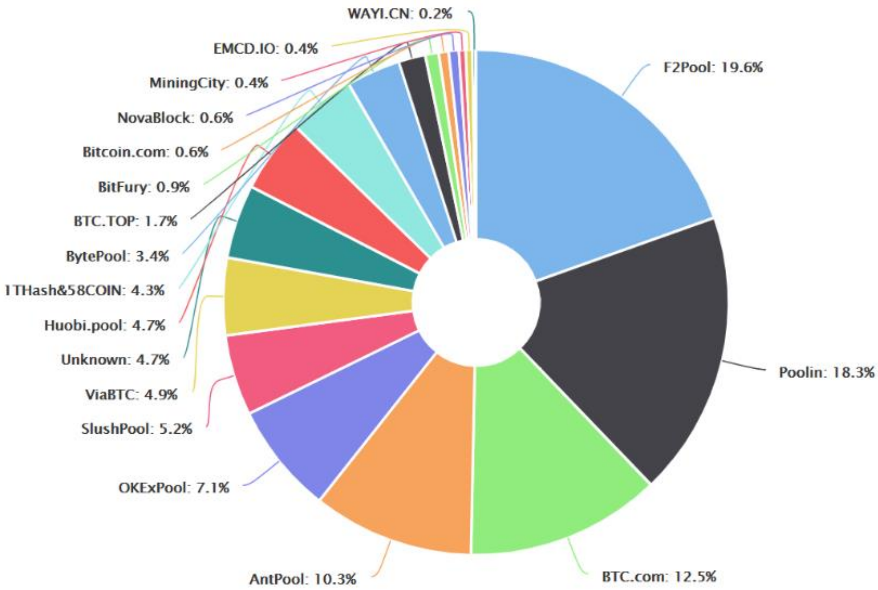


Figure 3: Bitcoin Hashrate Distribution (Blockchain, 2020).

2.1.4 Hacks

Since the advent of Bitcoin just over a decade ago the Bitcoin network remains to be hacked. It is essentially impossible to hack the Bitcoin blockchain, in order to do so one would have to control most of the total hashing power which would be extremely costly and not profitable for the attackers. Despite that the blockchain has never been successfully hacked and probably never will be, several exchanges where Bitcoin is stored on has been hacked. It has been estimated by researchers that the total cumulative amount of value hacked and stolen from cryptocurrency exchanges is about $1.7 billion (Ledger Academy, 2020).

One of the most iconic cryptocurrency exchange hacks is the hack of the exchange Mt.Gox. Mt.Gox was founded in 2010 and was the leader in innovation of cryptocurrency exchanges at the time and handled over 70% of the Bitcoin transactions. Anonymous hackers were able to compromise a computer belonging to the owner of the exchange (Ledger, 2019). In the period from 2011 to 2014 a total of 850 000 Bitcoins were stolen unfamiliar to the owner of the exchange due to an exploit in the code of the exchange. The total amount that were stolen were equal to a total of 7% of the supply at that time. When this exploit was discovered Mt.Gox filed for bankruptcy causing a shock to the Bitcoin market (Yoshifumi Takemoto, 2014). A lot of stakeholders lost their Bitcoins and the overall confidence in the Bitcoin market dropped significantly, and as a result the price of Bitcoin decreased over 50% the following month (Ledger, 2019).

2.2 Supply & Demand of Bitcoin

The law of supply and demand applies to all forms of financial markets such as commodities, equities, and forex markets. The law set out the relationship between the quantity of an asset and the desire for that asset resulting in an equilibrium price. Correspondingly low supply and high demand will increase the price and the other way around (Marshall, 1890).

2.2.1 Supply

The law of supply and demand is highly relevant to the Bitcoin market but is assumed to be applied somewhat different than to most traditional financial markets. The ultimate supply of Bitcoin is a fixed reliable quantity of 21 million coins. As of today, a total of 18.4 million Bitcoin are circulating in the Bitcoin market (Blockchain, 2020). Equally 87.6 % of the total supply to ever be created, Figure 4.

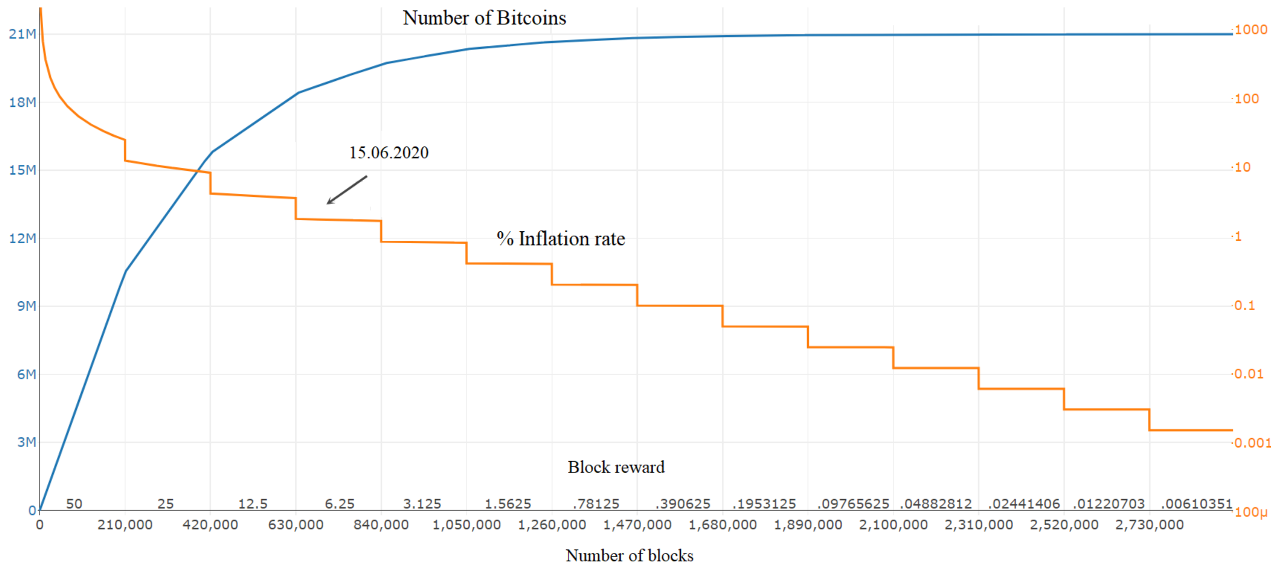


Figure 4: Controlled Supply of Bitcoin (BashCo, 2020)

The rate of which new Bitcoins is added to the market is arguably unusually predictable and unaffected by price fluctuations due to the mining process and the properties in the open source Bitcoin code. These features make the supply of Bitcoin assumedly perfectly inelastic. The percentage change in price is greater than the percentage change in supply. In fact, any percentage change in price would not affect the reliable supply of Bitcoin, hence formula.

$$E_s = \frac{\%\Delta Q}{\%\Delta P} \quad (2)$$

0 < E_s *< 1 - supply is inelastic*

E_s *= 0 - supply is perfectly inelastic (vertical line)*

The supply inelasticity arguably reinforces great price volatility of Bitcoin due to assets with inelastic supply tend to react more to demand shifts than assets with elastic supply, Figure 5 (Bluford Putnam, 2018).

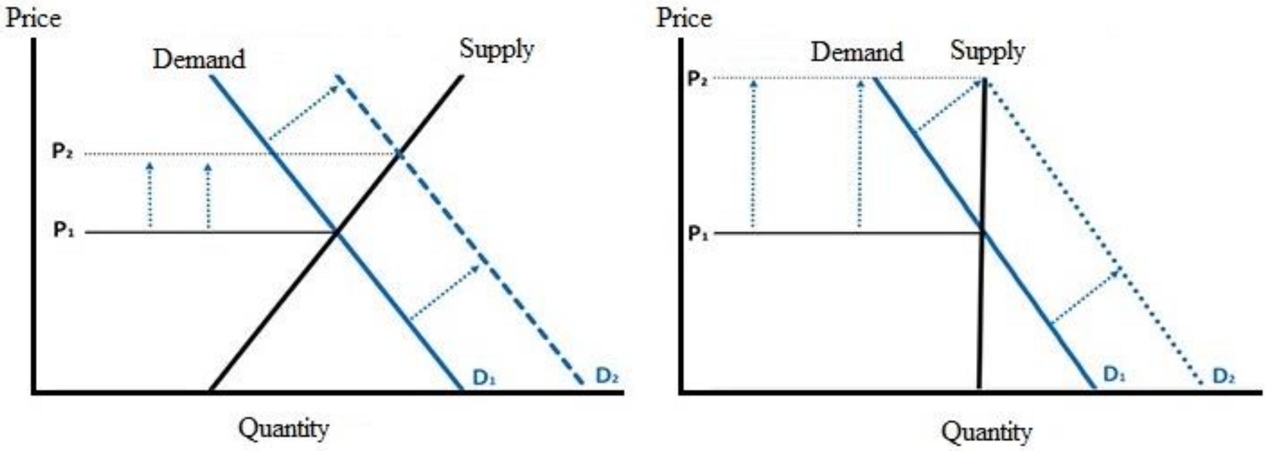


Figure 5: Supply and Demand Chart, Supply and Demand Chart with Inelastic Supply (Bluford Putnam, 2018).

2.2.2 Demand

As to the demand side of Bitcoin there are more uncertainty. Determinants of demand of an asset is usually determined by expectation of future price, income, price of related assets, numbers of buyers and consumer preferences. As to the Bitcoin market it is arguably only some of the determinants that applies. Demand in the Bitcoin market will increase if the stakeholders expect a higher future price and the other way around. A significant decrease in price of Bitcoin will probably attract more stakeholders looking to take advantage of an expected higher future price. As to price of related assets, in this case there are several competing cryptocurrencies that may provide the same utility for the stakeholders. In addition, income of buyers is also probably a significant determinant as Bitcoin and other assets are not essential assets and may be liquidated in times of decrease in income. As to the number of buyers there are mainly two types of stakeholders that are participating in the market.

The stakeholders in the Bitcoin market are retail investors and institutional investors such as hedge funds, mutual funds, and investment banks. Retail investors drove the Bitcoin market to an all-time high in late 2017 and institutional investors caught interest along the way (Higgins, 2017). As the Bitcoin market had grown exponentially CME Group launched futures contracts to balance the market making it available to sell short Bitcoin. The futures contracts created a downward pressure on the market which resulted in a tedious bear market. (CMEGroup, 2019).

The number of stakeholders both retail investors and institutional investors are increasing. One of the most trusted cryptocurrency exchanges, Coinbase, are reporting of an increase of 8 million customers the last year. In comparison the total customers on Coinbase since launch in 2012 were 30 million (Partz, 2019). As to the institutional investors side, Grayscale Investments, which is one of the leaders in digital currency investing and custody are also announcing increase in demand. In 2019 a total of $607.7 million was raised, equal to the cumulative amount from 2013 to 2018, and reports of increased investor base by a total of 24% (Grayscale Investments, 2019). The latest report for Q1 2020 supports the trend of increasing demand as the quarterly amount raised doubled in comparison to the previous high of Q3 2019 (Grayscale Investments, 2020). Another measure of demand may be retrieved by inspecting the network activity of the Bitcoin blockchain. The transaction volume, unique addresses used, confirmed transactions per day, and exchanged traded volume are all increasing (Blockchain, 2020).

2.3 Bitcoin as a Commodity

Bitcoin were initially designed to function as a decentralized peer-to-peer digital currency. As the Bitcoin market has gained more interest both the transaction costs and the time of transactions have increased a considerable amount (Blockchain, 2020). Considering these challenges, stakeholders and researchers have questioned other use cases of Bitcoin and discussed commodity like approaches. In addition to have all the properties of a currency; scarce, divisible, utility, transportability, durability, counterfeitability, Bitcoin may be considerably comparable to the value characteristics of gold, Table 1. As of these characteristics Bitcoin may have the potential to become a modern digital alternative to gold, digital gold.

Traits of Money	**Gold**	**Government Issued (U.S Dollar)**	**Bitcoin**
Fungible (Interchangeable)	High	High	High
Non-consumable	High	High	High
Portability	Moderate	High	High
Durable	High	Moderate	High
Highly divisible	Moderate	Moderate	High
Secure (cannot be counterfeited)	Moderate	Moderate	High
Easily transactable	Low	High	High
Scarce (predictable supply)	Moderate	Low	High
Sovereign (Government issued)	Low	High	Low
Decentralized	Low	Low	High
Smart (Programable)	Low	Low	High

Table 1: Comparison of Properties of Gold, USD, and Bitcoin (Vaneck, 2020)

2.3.1 Monetary Value

There are mainly two types of categories that distinct the value properties of an asset. The two categories are intrinsic value and monetary value. An asset may have intrinsic value if an economic asset produces cash flow or have clear utility as equities, fixed income, real estate, or consumable commodities. On the other hand, an asset may have monetary value that exist despite the lack of the properties of an asset with intrinsic value such as currencies, gold, precious metals, and artwork. Monetary value is inherently a bet that an asset will retain its value or increase in the future. For an asset to obtain monetary value it is dependent on trust and collective belief. In reference to these aspects Bitcoin may become a respected asset of monetary value just like gold. (Vaneck, 2020).

2.3.2 Deflation

In a centralized economy increase in money supply of a currency is determined by central banks to meet the inflation rate target. Inflation is a measure of how much the price of goods and services have increased over time. The annual inflation rate target is set to 2% by central banks in order to increase economic growth by incentive spending, investments, and employment. In order to achieve this target central banks buys assets from private sector, often referred to as quantitative easing, to generate capital and increase money supply. As a result of this monetary policy, central bank issued currencies become less rare and tend to decrease in value over time (BankofEngland, 2020).

In comparison, the supply of gold is rather hard to influence and the supply of Bitcoin cannot be changed as it is determined by design in the open source Bitcoin code with a deflationary approach. Economists argue that deflation incentive hoarding of assets. Hoarding in this case may be interpreted as stakeholders are buying assets with the intent of storage of value or benefiting from future price increase. As presented, every four years the additional supply added to the Bitcoin market is halved. This mechanism in the open source Bitcoin code will arguably cause the value of Bitcoin to increase as it will become increasingly rare.

2.3.3 Stock to Flow Ratio

For a non-consumable commodity to be valuable the aspect of scarcity is one of the most valuable properties. Scarcity may be interpreted as our wants exceeds the resources required to fulfill them (Scott A. Wolla, 2019). Modelling scarcity of gold and other precious metals with a stock to flow reveals an interesting relationship and value feature. Stock to flow ratio is a measure of the existing stock of a commodity divided by the annual production. Equally,

$$Stock\ to\ Flow = SF = \frac{1}{Supply\ Growth\ Rate} \tag{3}$$

	Stock(tn)	**Flow(tn)**	**SF**	**Supply Growth**	**Price $/Oz**	**Market Value**
Gold	185 000	3000	62	1.6%	$ 1730	$ 10 241 600 000 000
Silver	550 000	25 000	22	4.5%	$ 17.48	$ 307 648 000 000
Palladium	244	215	1.1	88.1%	$ 1990	$ 15 537 920 000
Platinum	86	229	0.4	266.3%	$820	$ 2 256 640 000

Table 2: Stock to Flow Ratio of Non-consumable Commodities (Andersch, 2019).

The stock to flow ratio of gold, Table 2, is 62 and the scarcest non-consumable commodity. In order to achieve the current stock of gold a total of 62 years of production at the current rate is required. This feature arguably strengthens the scarcity and monetary value assumption of gold. For the other non-consumable commodities to achieve a higher stock to flow ratio is rather difficult. As soon as somebody hoards them, prices rise, production rise and price fall again by the law of supply and demand. On the other hand, modelling scarcity of Bitcoin with stock to flow ratio presents an interesting relationship to gold. Bitcoin currently has a stock of about 18.4 million coins and a supply growth rate of 1.785% equally a stock to flow ratio of 56. This ratio is expected to increase as the issuance of new Bitcoins is decreasing due to the deflationary properties in the open source Bitcoin code (Andersch, 2019).

2.4 Legal Status and Regulation

There are a number of factors that governments have taken into consideration when it comes to Bitcoin regulation. Even though Bitcoin is highly transparent with its public ledger some governments remains skeptical and wants to make any interaction with Bitcoin illegal. Money laundering and criminal activity have been one of the main topics. Bitcoin has previously evidently been used in such activities, but the same argument arguably holds for every other fiat currency in the world. In comparison, money laundering and criminal activity through fiat currencies are practically impossible to trace, but illegal Bitcoin transactions leaves digital trails. As a matter of fact, illegal activity with Bitcoin would essentially make overseeing money laundering and criminal activity by governments and central authorities easier. There are certain ways to make illegal Bitcoin activity harder to trace by exchanging Bitcoin to cryptocurrencies such as Monero and back to Bitcoin. As this is an option for criminal activity the question of making Bitcoin illegal is rather a question of making practically untraceable cryptocurrencies such as Monero illegal (Europol, 2019).

The current legal status and regulation of Bitcoin is widely applied among different continents and countries. A selective overview of continents and countries reveals the non-consistent relationship of regulation. The U.S have a generally positive outlook on Bitcoin and other cryptocurrencies despite the lack of clear guidelines and regulation. The federal government has not been regulating Bitcoin and other cryptocurrencies at national level and thereby left individual states and financial departments responsible. The Department of the Treasury (USDT), Securities and Exchange Commission (SEC), Federal Trade Commission (FTC), Internal Revenue Service (IRS) and Commodity Futures Trading Commission (CFTC), individually characterizes the regulation of Bitcoin making it inconsistent. For instance, the IRS characterizes Bitcoin and other cryptocurrencies as property, and tax guidance accordingly (Dolan, 2020). The CFTC characterizes Bitcoin and other cryptocurrencies as commodities and are taxed like other derivative contracts (CMEGroup, 2020). In addition, the SEC has received a number of applications for Bitcoin Exchange-Traded Funds (ETF) from private sector, but they have all been postponed or denied to some extent by lack of regulation (Securites and Exchange Commission, 2020).

In Europe, the regulators are welcoming the new blockchain technology but at the same time they are very aware that the Bitcoin and cryptocurrency market may still be vulnerable to money laundering, terror financing and other criminal activity. The EU published its 5th Anti-

Money Laundering Directive into law as of January 10, 2020 making cryptocurrencies and exchange providers under strict regulatory requirements (EuropeanCommission, 2020). The law enhances transparency around the owners of cryptocurrencies and the exchanges and falls under the same regulatory requirements as banks and other financial institutions. As of this law any cryptocurrency exchange in charge of financial activity of cryptocurrencies must register with financial authorities in their respective country and report suspicious activity of identified customers (Dolan, 2020).

While China has officially emphasized the potential of blockchain technology as a part of the five-year plan of strategic frontier technologies, authorities remains skeptical with a restrictive attitude towards Bitcoin and other cryptocurrencies. Officials in China have stated that Bitcoin offers as a potential threat to social and financial stability in the society. As of late 2013 Peoples Bank of China (PBOC) officially prohibited financial institutions to interact with Bitcoin and as of 2018 the private cryptocurrency exchanges were shut down. PBOC characterizes Bitcoin as a “Virtual Commodity” and there are no current specific tax laws on Bitcoin. In addition, PBOC announced in 2018 that the next step of regulation of Bitcoin is to prohibit Bitcoin mining causing a number of miners to shut down their business. For individual users of Bitcoin, it is still legal to own and transact with Bitcoin but as of the strict regulation, acquiring Bitcoin has become less manageable (Jakob Blacklock, 2020).

As the technological development is increasing and the world becomes ever more digitalized, central banks have raised a number of questions about issuing their own digital cryptocurrency. A survey of a number of central banks, conducted by the Bank for International Settlements (BIS), reveals that more than 80% are working on Central Bank Digital Currencies (CBDC) (Codruta Boar, 2020). The U.S, EU and China are some of them. The positive outlook on Bitcoin regulation by the U.S and EU may change as central banks arguably wants monopoly of monetary policy. The restrictive attitude of Bitcoin regulation by China may reflect this assumption of governmental control of monetary policy. A central bank issued digital cryptocurrency could ultimately be a potential threat to Bitcoin as governments may officially ban “unofficial cryptocurrencies” that are not issued by central banks.

3 Finance Theory & Economic Thoughts

Finance is to be interpreted as the art and science of managing money. In the financial world there are a number of different theories, models and economic thoughts that have strong presence in the scientific field of statistics and mathematics. Despite the strong presence of advanced statistics and mathematics it is proven that the financial world cannot be fully predicted by these financial theories, models, and economic thoughts as there are other factors that may influence such as human behavior, psychology, governments, and extreme events. Even though the financial theories, models, and economic thoughts cannot fully predict the future it is assumed that in combination they offer the best alternative of support in financial decisions.

3.1 Modern Portfolio Theory

Modern portfolio theory is a theory that states that investors are maximizing their expected return on investments given their risk tolerance by balancing assets in a portfolio. Investors are assumed to take risk into consideration in any financial investment decisions to maximize their utility. Level of utility in this case may be different for every investor as the risk tolerance of every investor are assumed to be viewed independently. Some investors may be risk averse, others may be risk neutral and some even risk seeking. Risk and return of assets are not viewed individually, but in combination to construct a portfolio based on statistical measures such as variance, covariance, and correlation. According to the theory there is a relationship between expected return and risk of a portfolio (Markowitz, 1952).

3.1.1 Capital Asset Pricing Model (CAPM)

The Capital Asset Pricing Model (CAPM) was introduced by economists such William Sharpe and John Lintner. The CAPM builds on the theory of modern portfolio theory by Harry Markowitz (Eugene F. Fama, 2004). The model illustrates the relationship between systematic risk and expected return of an asset and is used to evaluate assets for an optimal portfolio. The formula of calculating expected return of an asset is dependent on relative risk in the market.

$$E(r_i) = r_f + \beta_i\big(E(r_m) - r_f\big) \tag{4}$$

$E(r_i)$ - *expected return on asset*

r_f - *risk-free rate*

β_i - *beta, market risk* = $\frac{\sigma_{i,m}}{\sigma_m^2}$

$\sigma_{i,m}$ - *covariance of asset* i *and market* m

σ_m^2 - *variance of the market* m

$(E(r_m) - r_f)) - market\ risk\ premium$

CAPM covers the risk aspect of an asset compared to the market portfolio and the time value of money. The risk-free rate accounts for the time value of money and the beta is a measure of an asset compared to market risk. A beta higher than 1 indicates that an asset is riskier than the market and similarly a beta less than 1 indicates that an asset is less risky than the market. The market risk premium is the expected return of the market portfolio subtracted by the risk-free rate.

The theory by Sharpe and Lintner states that by weighting a different set of portfolios with different assets an efficient frontier set may be displayed by plotting the expected return and risk (Eugene F. Fama, 2004). An efficient frontier is displayed by the purple line, Figure 6, and is a set of portfolios that offers the optimal return of a portfolio given associated level of risk, variance. Portfolios under the purple line are inferior as the expected return on investment is less than the portfolios on the efficient frontier given the same magnitude of risk. Portfolios above the line are superior as they provided higher expected return on investment given the same magnitude of risk. In addition, there is a capital market line (CML) that displays the additional expected return on a portfolio investment given even more risk exposure. Intersection of the CML and the efficient frontier is to be interpreted as the market portfolio. Portfolios on the CML are all superior in terms of expected return and risk. CML is often referred to as Sharpe ratio and may be an indicator of investment strategies and valuation of portfolios. If the Sharpe ratio is expected to be above the CML investors tend to buy these portfolios and similarly sell if the Sharpe ratio is expected to be below the CML.

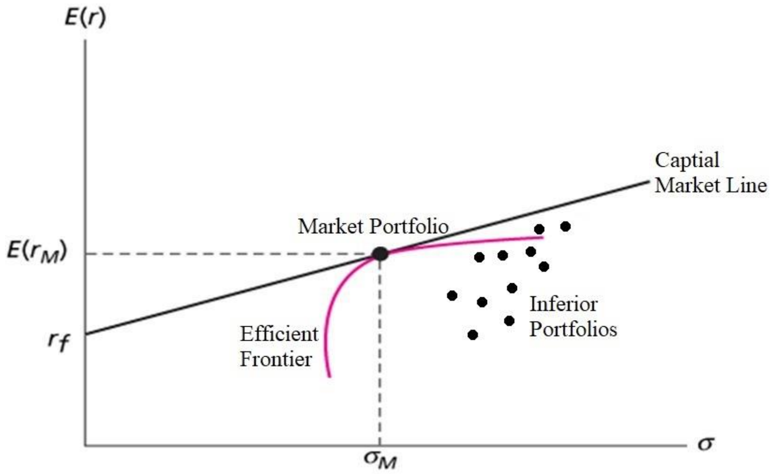


Figure 6: Capital Asset Pricing Model

3.1.2 Diversification

Diversification is a term derived from modern portfolio theory and covers additional aspects of balancing a portfolio. As described investors tend to balance, diversify, their portfolio with different allocations of assets in order to reduce risk and maximize expected return. A portfolio may be diversified by investing in assets such as equities, bonds, real estate, and commodities. For every portfolio there will always be a level of risk determined by systematic risk and unsystematic risk. Systematic risk is to be interpreted as non-diversifiable due macro-economic changes that applies to all assets such as interest rates, inflation, and recessions. On the other hand, unsystematic risk is to be interpreted as individual risk of an asset and may be reduced by diversifying the portfolio, Figure 7. As the number of assets increase, the portfolio risk tends to decrease as the risk exposure of individual assets become less significant to the overall portfolio as it is adequately diversified.

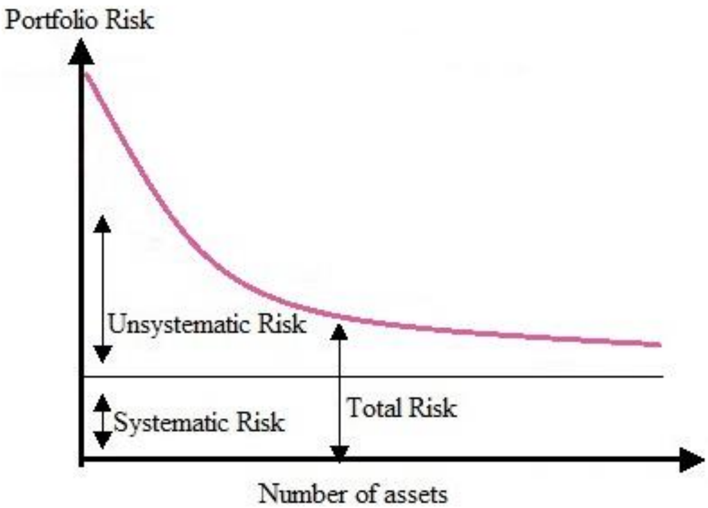


Figure 7: Systematic Risk and Unsystematic Risk

3.1.3 Hedging

Hedging is an additional investment strategy that aims to reduce the risk exposure for investors. A hedge may be interpreted as an insurance for the investors. A common strategy is to establish a hedge by negotiating derivatives contracts like options, futures and forwards that are financial instruments derived from their underlying assets. Futures and forward contracts allow investors to offset risk of price change of assets over time. The contracts are standardized with specific quality, quantity, physical delivery location and time for the given asset. The only contract variable is price that is set by buyers and sellers. In addition, the contracts are traded on exchanges that guarantee that the contracts are honored. The exchanges are the buyer to every seller and the seller to every buyer, eliminating counterparty risk (CMEGroup, 2020).

In comparison to the theory of diversification another essential feature of hedging is investments based on correlation. Historically some assets tend to be negative correlated, moving in different directions, and by investing in different weights of the assets some risk may be offset. If asset A increase in value, asset B is expected to decrease in value. For instance, the Trade Weighted U.S. Dollar Index versus the Gold Fixing Price Index (Macrotrends, 2020). The significance of the hedge is determined by the magnitude of negative correlation. Hypothetically a correlation of -1 it to be interpreted as a perfect hedge. A special case of hedging is hedging by safe haven assets. Safe haven assets are assumed to be negative correlated in times of financial instability in the equity markets. Traditionally bonds were preferred in such times but as yields has become close to zero and some are even negative, investors seek other assets to insure their portfolio. JPMorgan reports of increasing interest in private core real estate, infrastructure, currencies and gold to build a resilient portfolio (Thushka Maharaj, 2020).

3.2 Austrian School

The Austrian School of Economics is a school of economic thought, one of many, that originates from Vienna, Austria in the late-19th and early-20th century. Economists such as Carl Menger, Ludwig von Mises, Eugen von Bohm-Bawerk, and Friedrich A. Hayek are essentially the main contributors to the economic thoughts of the Austrian School of Economics. The Austrian School of Economics have contributed to modern economic theory by the theory of opportunity cost, business cycles, subjective theory of value, marginalism, and other thoughts on capital, interest rates and inflation. The economic thoughts of the school are assumed to be rather different than the mainstream economic theory of Neoclassical school and Keynesian Economics that is mainly applied and learned in today's society (Scumpeter, 1996).

3.2.1 Austrian Business Cycle Theory

The Austrian Business Cycle Theory (ABCT) is an economic theory established by the Austrian School of Economics. The theory enlightens the impact of central bank's monetary policy and fractional reserve banking on financial business cycles. ABCT argues that a significant period of artificially low interest rates and cheap credit creation by fractional reserve banking results in an unstable disparity between saving and investment. An artificially low interest rate is to be interpreted as a free market would rather have a higher interest rate than the interest rate set by the central banks. According to ABCT the business cycle evolves in the following way. Artificially low interest rates encourage borrowing which leads to increased capital spending powered by newly issued central bank credit. As investment banks, companies and private investors takes on extended borrowing this credit is essentially fueling the financial markets by malinvestments. Malinvestments is to be interpreted as poorly allocated business investments powered by cheap credit and unsustainable increase in money supply. Over time these malinvestments are inflating the real value of assets and would inevitably cause a bust, a downturn in the business cycle. The longer the period of economic boom caused by inflating assets the more violent the economic downturn will be in order to rebalance the "true" value of the assets (Mises, The Theory of Money and Credit, Part 3 and 4, 1912).

The core insight of Hayek's theory on economic booms and bust is that any government interference even when done with the best of intentions changes people's behavior by changing incentives and changing signals in the market. These changes result in investments that are not sustainable, and which ultimately lead to recessions or busts.

Austrians argue that “real” savings would have required higher interest rates to incentive investors to save their money in term deposits to invest in long-term sustainable projects under a stable money supply. The artificial increase in value of the financial markets caused by cheap credit spending is generally a speculative investment bubble which does not represent the long-term outlook of the market. Continuously expanding the bank credit in economic downturns by additional cheap credit by the central banks would eventually just postpone the reality of a violent economic bust given the highly inflated market. The monetary easing would only end when bank credit fully stops and there are no investments available which may provide acceptable expected returns for investors. The longer the monetary easing goes on, the higher the markets are inflated and the longer the period of necessary economic downturn with bankruptcies, foreclosures, and economic readjustment (Mises, Human Action, Chapter XX, Section 8, 1949).

3.2.2 Gold Standard

The gold standard is a monetary system where the value of the government issued currencies are pegged to the underlying assets of gold. Equally, gold backs the value of the currency. Brief historical background, in the 18th and 19th century the establishment of the gold standard occurred due to increasing challenges of paper currency. In 1789 the U.S Constitution granted Congress the rights to make gold into currency and regulate its value. As of 1871 the gold standard was the international monetary standard and succeed until the outbreak of World War I. Initially the value of gold was set to \$20.67/oz but increased to \$35/oz after the war by central governments in the U.S. to prop up the economy. As other nations could convert gold to USD at a higher rate this heavily devalued the USD and allowed the U.S to achieve a large amount of gold. After World War II the U.S had a total of 75% of the market share of gold in reserves which made the USD the most trusted and official world currency. The gold standard came to an end in 1971 when President Richard Nixon announced that the U.S no longer converts USD to gold at a fixed rate and the invention of fiat currencies were established (Meltzer, 2003).

Austrian economists are generally supporters of the gold standard and argue that a free market would eventually turn back to the gold standard. As the nature of the Austrian School of free markets and less governmental intervention the gold standard offers a more reliable monetary system. Austrians argue that fiat currencies are a threat to inflation of the monetary system and did not evolve from a free market. The supply of gold cannot be increased by central governments and political behavior and therefore, the gold standard is arguably a safer bet against inflation. Gold used to be the preferred money of a free market for thousands of years until the implementation of fiat currencies. Austrian also argue that historically gold tend to be investors preferred safe haven in financial instability, revealing the “true” monetary system, and acting as an unofficial world currency.

An objection to the gold standard by mainstream economists is that it leads to waste of resources as gold is extracted from the ground by time consuming and costly mining operations. In reference to mainstream economists, these costs may be avoided by central bank issued fiat currencies at a significant reduced cost. Austrians rejects this argument and states that the principle of opportunity cost is the only relevant cost in this matter. Opportunity cost is to be interpreted in this case as the alternative cost of providing the gold standard. If the true costs of a gold standard could be calculated at all, it would have to consider the monetary instability associated with alternative standards and the consequent loss of output. The gold standard has net benefits, not net costs, which is providing a stable monetary policy in a free market. An appreciation of these benefits, but not a precise quantitative estimate, may best be gained by comparisons of historical performance under a gold standard and economic performance under a paper standard. The cost of sound money is forgoing unsound money (Jr, 1992).

4 Methodology

The methodology is an overview of the general research strategy, design, and methods that provides the basis and support of answering the research questions. The overall general research strategy is chosen with the highest respect to conduct an empirical and ethical analysis. The research design is derived from a set of assumptions that has become available during the thesis. Correspondingly, the research methods consist of a set of quantitative analyses that are interesting in relation to the research questions.

4.1 Research Strategy

The fundamental aspects of the Bitcoin market are arguably unknown to most people and the limited research in the field reflects this assumption. In order to get up to date on the state of the Bitcoin market a comprehensive literature review was required to get an understanding of both the technical and economic aspects. The literature review disclosed various interesting properties of Bitcoin which lead to developing a set of research questions sought to be answered. A set of quantitative analyses were chosen based on the literature review and the assumption of that these analyses would be the most important and critical in order to answer the research questions.

4.1.1 Selection of Literature

Despite limited research available on Bitcoin and the Bitcoin market a number of sources are investigated to gather the most trusted sources of information. The main sources of information are retrieved from the Bitcoin whitepaper, highly respected contributors to the field of research of Bitcoin, and a number of leading unbiased cryptocurrency digital media platforms. Additionally, a number of sources are retrieved from suppliers of information with direct link to the open source Bitcoin code. As both the technical and economic properties of Bitcoin were disclosed the finance theory and economic thoughts were chosen with respect to support and strengthen the argumentation of the concluding remarks.

4.1.2 Selection of Research Methods

The literature review reveals the underlying technology that empowers the Bitcoin blockchain. The mining consensus mechanism, PoW, is known to be costly in terms of computational power and electricity consumption and is thereby essential to analyze the costs associated with this process and the impact on the Bitcoin market. In order to do so a cost of production analysis and a regression analysis is conduct. In reference to the finance theory and the economic thoughts the aspects of different allocation of weights of Bitcoin in a portfolio is interesting to analyze in terms of diversification and hedging properties. Limitations of the different quantitative analyses in comparison to likewise analyses are that the results are based on historical data and past performance may not be indicative of future results.

4.2 Research Design & Methods

In order to answer the research questions the empirical results of the quantitative analyses and interpretation of these results are essential. The data collected is retrieved from the first date available of the respecting variables until the latest date possible. Note that the data collected is intentionally postponed to the latest dates after the halving of the block reward, 11 May 2020, to cover the impact of this event. The results are carefully inspected and interpreted with critical and logical reasoning. Additionally, the economic thoughts of the Austrian School are reasonably weighted in the argumentation of the concluding remarks as these economic thoughts are assumed to be highly relevant in order to answer the research questions.

4.2.1 Cost of Production Analysis of Bitcoin

In order to conduct the different analyses in the thesis a number of various data is collected. The data retrieved are retrieved from various trusted sources to strengthen the analysis. The historical daily spot price data of Bitcoin is retrieved from Investing.com (Investing, 2020). For the cost of production analysis of Bitcoin, the data for electricity consumption and price of electricity are retrieved from Cambridge Bitcoin Electricity Consumption Index (CBECI) (Cambridge Center for Alternative Finance, 2020). The CBECI provides a real-time estimate of the total electricity load and consumption of the Bitcoin network based on the following parameters, Table 3.

Parameter	Description	Measure/Unit	Source
Network hashrate	Total number of hashes produced by miners	Exahashes per second (Eh/s)	Dynamic: Blockchain.info
Miners revenues	Total value of block rewards and transaction fees paid to miners	USD	Dynamic: Blockchain.info
Mining equipment efficiency	Measures the energy efficiency of a given mining hardware type	Joules per Gigahash (J/Gh)	Static: hardware specs from 60+ equipment types, taken from various sources

Electricity cost	Average electricity incurred by miners	USD per kilowatt-hour ($/kWh)	Static: estimate (assumption)
Data center efficiency	Measures how efficiently energy is used in a data center: expressed via power usage effectiveness (PUE)		Static: estimate (assumption)

Table 3: Cambridge Bitcoin Electricity Consumption Index (CBECI) Model Parameters

The model is based on a bottom up approach that takes different types of available mining hardware into consideration as a starting point. The exact electricity consumption cannot be fully determined, but the index provides a lower and upper bound estimate based on the available mining hardware for miners in the market. The model assumes that miners will only run their mining hardware if it remains profitable in terms of electricity costs, hence equation.

$$v * P_{el} \leq SRev \tag{5}$$

v *- energy efficiency of mining hardware [J/h]*

P_{el} *- electricity cost [USD/J]*

$SRev$ *– mining revenue per hash [USD/h]*

The cost of electricity is set to $0.05/kWh as this offers the best estimate of global mining electricity costs.

The lower bound estimate assumes that all miners use the most energy-effective hardware which implies upgrading to the most recent energy effective hardware as soon it is available. Another assumption is the power usage effectiveness (PUE) which is a measure of data center energy efficiency is set to 1.01. In comparison, Google's average PUE is 1.11.

The lower bound estimate can be mathematically expressed in the following terms:

$$E_{lower}(P_{el}) = min\left(Eq_{prof}(P_{el})\right) * H * PUE * 3.16 * 10^{7} \tag{6}$$

E_{lower} *– lower bound power consumption [W]*

$min\left(Eq_{prof}(P_{el})\right)$ *– energy efficiency of the most efficient hardware [J/h]*

H – hashrate [h/s]

PUE*- power usage effectiveness*

Correspondingly, the upper bound estimate assumes that all miners use the least energy-effective hardware as long as it remains profitable in terms of electricity costs. The PUE is set to 1.2.

The upper bound estimate can be mathematically expressed in the following terms:

$$E_{upper}(P_{el}) = max\left(Eq_{prof}(P_{el})\right) * H * PUE * 3.16 * 10^{7} \tag{7}$$

E_{upper} *– upper bound power consumption [W]*

$max\left(Eq_{prof}(P_{el})\right)$ *– energy efficiency of the least efficient but still profitable hardware [J/h]*

H *– hashrate [h/s]*

PUE*- power usage effectiveness*

Additionally, a best-guess estimate is provided that is based on the average assumptions of the upper and lower bound which is used in this analysis.

The best-guess estimate can be mathematically expressed in the following terms:

$$E_{estimated}(P_{el}) = \frac{\sum_{i=1}^{N} v_i}{N} * H * PUE * 3.16 * 10^{7} \tag{8}$$

$E_{estimated}$ *– best guess power consumption [W]*

$\frac{\sum_{i=1}^{N} v_i}{N}$ *– average energy efficiency of profitable hardware [J/h]*

H *– hashrate [h/s]*

PUE*- power usage effectiveness*

Note that the total annual electricity consumption of the Bitcoin network is expressed in terawatt-hours (TWh). The electricity consumption is annualized assuming continuous power usage at the given time over the period of one year. A seven-day moving average is added to the data to avoid short term volatility in the hashrate. Unfortunately, the data retrievable is limited to 1 December 2014 to 12 June 2020, but the total number of observations is assumed to be sufficient to conduct the analysis, Figure 8.

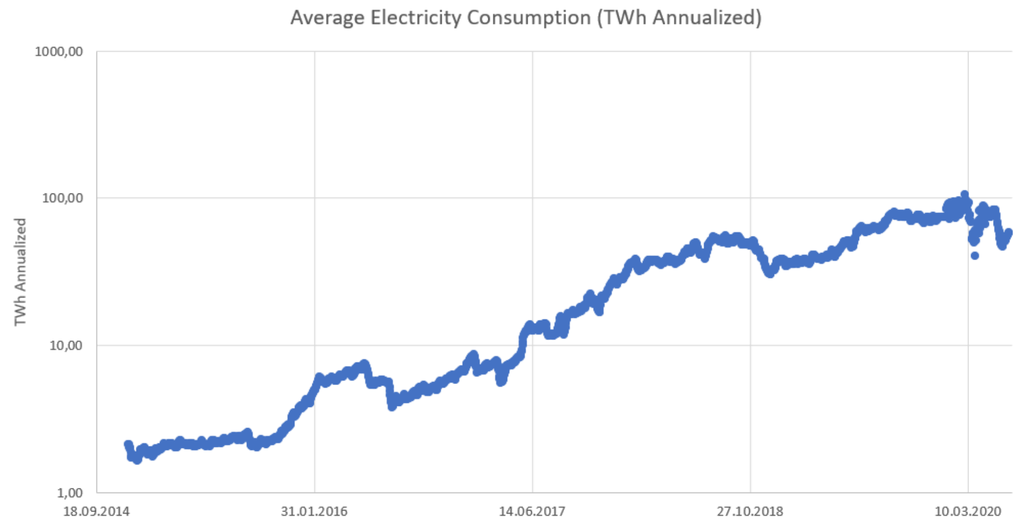


Figure 8: Average Electricity Consumption (TWh Annualized) Log-Scale

As every model is an estimate of reality that depends on various assumptions this model also has some limitations, but arguably provides the best-guess of electricity consumption of the Bitcoin network available in today's public research. Limitations of the model are that electricity costs may vary between different mining pools and are vulnerable to seasonality. Maintenance costs and cooling of the hardware have not been included into the model. In addition, the energy efficiency of the different hardware may not perform as stated by the manufacturers of the hardware.

The cost of production analysis is conducted in Excel and in order to conduct the analysis the data from CBECI is carefully inspected. Furthermore, given the properties in the open source Bitcoin code the daily output of Bitcoin as reward to miners may be estimated rather precisely, and the miners are assumed to break even. This provides the basis of developing an accurate estimation of the cost of production of Bitcoin, hence equation.

$$P_{cost\ of\ production} = \left(\frac{E_{estimated}}{(M_{reveune} * 365 * 1.005)}\right) * 10^9 * C_{el} \tag{9}$$

$P_{cost\ of\ production}$ – *estimated cost of production [USD]*

$E_{estimated}$ – *best guess annualized power consumption [TWh]*

$M_{reveune}$ – *estimated daily mining revenue in terms of number of Bitcoins*

C_{el} - *electricity cost [USD/kWh]*

The cost of electricity is set to $0.05/kWh as this offers the best estimate of global mining electricity costs. Note that the estimation of daily mining revenue in terms of number of Bitcoins is adjusted for additional transaction fees and discounted for certain time periods to match the deflationary properties in the open source Bitcoin code, Table 4.

Date	**Block reward**	**Mining revenue daily**	**Estimated Transaction fees**	**Total Mining revenue**
03.01.2009 – 28.11.2012	50	$50 * \left(\frac{24 * 60}{10}\right) = 7200$	0.5 %	7236
29.11.2012 – 09.07.2016	25	$25 * \left(\frac{24 * 60}{10}\right) = 3600$	0.5%	3218
10.07.2016 – 11.05.2020	12.5	$12.5 * \left(\frac{24 * 60}{10}\right) = 1800$	0.5%	1809
12.05. 2020 –	6.25	$6.25 * \left(\frac{24 * 60}{10}\right) = 900$	0.5%	904.5

Table 4: Total Mining Revenue Daily, Adjusted for Transaction Fees and Discounted for Deflationary Properties

4.2.2 Regression Analysis

A regression analysis is a powerful statistical method that presents the relationship between two or more variables of interest. In a simple regression model, an explanatory independent variable X_1 is used to explain a dependent variable Y, hence formula.

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon_t \quad (10)$$

Models where multiple independent explanatory variables are used to explain a dependent variable is referred to as a multiple regression analysis, hence formula.

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_i X_i + \varepsilon_t \quad (11)$$

ε_t represents the error term in the models equally a measure of the difference between the observed value of the dependent variable Y and the predicted value $\hat{Y}$.

The variables of interest in this analysis is the hashrate, Network Difficulty, and the electricity consumption, Average Electricity Consumption, and the impact on the price of Bitcoin, Bitcoin Spot Price.

Null hypothesis – $H_0: \beta_1 ln(Network\ Difficulty) = 0$

Null hypothesis – $H_0: \beta_1 ln(Average\ Electricity\ Consumption) = 0$

As the two variables tend to be very strongly correlated a multiple regression analysis is not suited for this analysis as the regression analysis would suffer from multicollinearity, Table 5.

	Average Electricity Consumption (TWh Annualized)	***Network Difficulty***
Average Electricity Consumption (TWh Annualized)	1	
Network Difficulty	0.956	1

Table 5: Correlation Matrix Average Electricity Consumption (TWh Annualized), Network Difficulty

Multicollinearity is a state in which some of the independent variables are highly correlated and the variance tends to inflate and may cause regression coefficients to have the wrong sign. In order to conduct the regression analysis a number of simple regression analyses are chosen.

$$\ln(\widehat{Bitcoin\ Spot\ Price}) = \beta_0 + \beta_1 \ln(Network\ Difficulty)$$

$$\ln(\widehat{Bitcoin\ Spot\ Price}) = \beta_0 + \beta_1 \ln(Average\ Electricity\ Consumption)$$

$$\ln(\widehat{Average\ Electricity\ Consumption}) = \beta_0 + \beta_1 \ln(Network\ Difficulty)$$

The regression analysis is conducted with respect to the method of Ordinary Least Squares (OLS) and the following assumptions of a Classical Linear Regression Model (CLRM) (Wooldridge, 2009).

1. The regression model is linear in the coefficients and the error term
2. No independent variable is a perfect linear function of other explanatory variables
3. The error term has a population mean of zero
4. The error term has a constant variance (no heteroscedasticity)
5. No autocorrelation of the error term (the error term does not exhibit a systematic relationship over time)
6. The error term is normally distributed with a mean of zero

If assumption 1-3 are satisfied the estimation is assumed to be sufficient. The estimators are Best Linear Unbiased Estimators (BLUE) if assumption 1-5 are satisfied. Additionally, assumption 6 must be satisfied for the regression analysis to provide optimal results in terms of F and t-statistics and standard deviation for further analyses.

The data retrieved for the regression analysis is retrieved from the first observation of the respecting variables to 12 June 2020. In order to compare and interpret the results the data has to be limited to 1 December 2014 to 12 June 2020. The historical daily spot price data of Bitcoin is retrieved from Investing.com for the variable Bitcoin Spot Price (Investing, 2020). The data for the variable Average Electricity Consumption is retrieved from CBECI (Cambridge Center for Alternative Finance, 2020). The data for the variable Network Difficulty is retrieved from Data.Bitcoinity.org (Data.Bitcoinity, 2020). Furthermore, the analysis is conducted in Excel and the data is log transformed in order to satisfy the assumptions of CLRM and a clearer interpretation of the results.

4.2.3 Portfolio Analysis

The aspects of the modern portfolio theory that are presented in the literature review are applied in this analysis. A selective number of assets and indices are retrieved from Investing.com; Bitcoin, Gold, Brent Crude Oil, United States 10-Year Bond Yield, S&P 500 Index, Nasdaq Index, USD Index, and Euro Index. As the Bitcoin market is trading continuously twenty-four hours a day, seven days a week the data for Bitcoin is adjusted to fit the trading days for the other assets and indices. The historical price data are retrieved from 19 July 2010 to 12 June 2020.

The prices are transformed into logarithmic returns, percentage changes, to fit the analysis conducted in Excel by the following formula.

$$R_d = ln\frac{price_t}{price_{t-1}} \tag{12}$$

R_d *– daily return*

$price_t$ *– price on day t*

$price_{t-1}$ *– price on previous day*

As the prices are transformed to percentage changes the daily expected return and standard deviation can be calculated. In order to transform the daily values into annual expected return and standard deviation the following formulas are applied.

$$year\left(E(r)\right) = (avg(R_d + 1)^{255}) - 1 \tag{13}$$

R_d *– daily return*

255*– number of trading days*

$$year(std.dev) = std.dev_d * \sqrt{255} \tag{14}$$

$std.dev_d$ *– daily standard deviation*

255*– number of trading days*

Furthermore, a variance – covariance – matrix is calculated based on the values. The diagonal elements of the matrix contain the variances of the assets and indices, and the off-diagonal elements contain the respective covariances between all possible pairs of assets and indices. The variance – covariance – matrix is essential to calculate the standard deviation of the different set of portfolios. A total of 20 portfolios are constructed with different allocation of weights of the assets and indices in order to analyze the annual expected return and standard deviation of the portfolios. The allocation of weights of the different assets and indices is chosen with the best intention to reflect the typical portfolios that exists in the financial world.

The expected annual return and standard deviation of the portfolios are plotted to inspect the efficient frontier of the portfolios. For calculation of the CML the risk-free rate is estimated as the average of the USD London Interbank Offered Rate (LIBOR), given the time period of research from 19 July 2010 to 12 June 2020 the risk-free rate is set to 1.326% (Macrotrends, 2020). Additionally, the risk-adjusted returns in terms of Sharpe ratio is calculated for the different portfolios to support this analysis by the following formula.

$$Sharpe\ Ratio = \frac{R_p - R_f}{\sigma_p} \tag{15}$$

R_p − *annual expected return of portfolio*

R_f − *annual risk-free rate*

σ_p − *annual standard deviation of portfolio*

5 Results

The results of the quantitative analyses are presented and interpreted in this chapter to support further assessment of the research questions. Firstly, the results of the cost of production analysis of Bitcoin, a comparison of the Bitcoin spot price and the underlying estimated cost of production. Second, the results of the regression analysis, statistical measures, and dependencies of the respective variables. Finally, the results of the portfolio analysis, historical performance of allocation of weights of Bitcoin in a portfolio and respective financial measures.

5.1 Cost of Production Analysis of Bitcoin

The cost of production analysis of Bitcoin reveals a significant relationship between the estimated cost of production and the Bitcoin spot price, Figure 9.

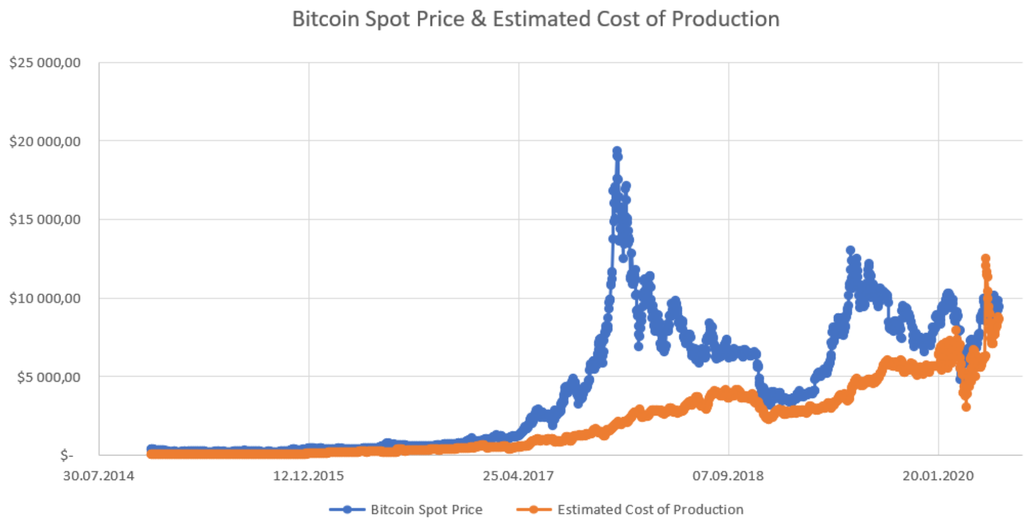


Figure 9: Plot of Bitcoin Spot Price & Estimated Cost of Production

The estimated cost of production is displayed by the orange line and the Bitcoin spot price by the blue line. The Bitcoin spot price diverge from the estimated cost of production significantly at certain time periods, but the interesting part of this analysis is that the estimated cost of production tends to act as a price floor for the Bitcoin spot price. The Bitcoin spot price tends to revert to the estimated cost of production despite the time periods of euphoric price increases and similar crashes. As both the value of the Bitcoin spot price and the estimated production costs has grown exponentially the relationship is displayed more appropriately on a logarithmic scale, Figure 10.

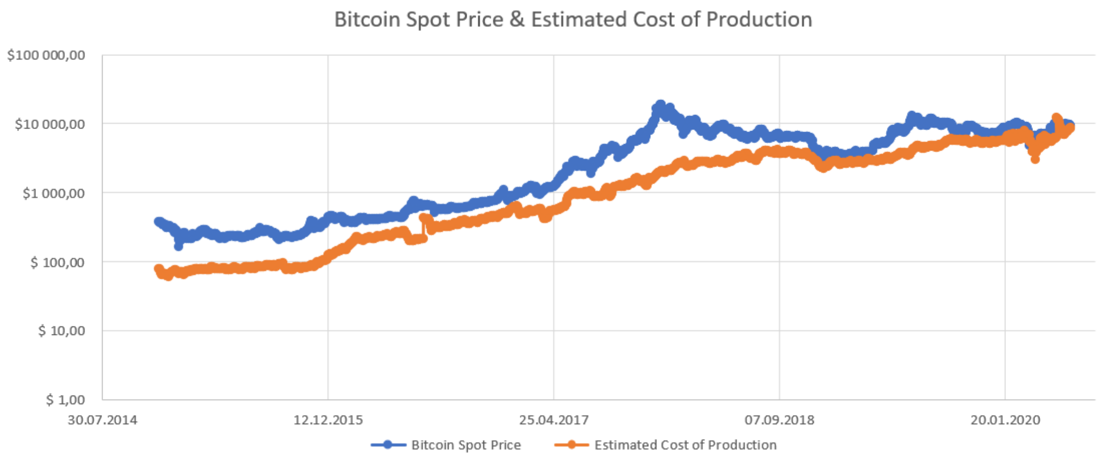


Figure 10: Plot of Bitcoin Spot Price & Estimated Cost of Production Log-Scale

The estimated cost of production is displayed by the orange line and the Bitcoin spot price by the blue line. Note that the estimated cost of production spikes on 10 July 2016 and on 11 May 2020 due to the halving of the block reward and impact on miners revenue. As the miners revenue is cut in half, the estimated cost of production correspondingly increases the opposite magnitude holding average electricity consumption fixed. Mathematically, the estimated cost of production increase 100% as miners revenue decrease 50 % to generate the same amount of revenue for the reduced block reward. Correspondingly, as the estimated cost of production increase the Bitcoin spot price arguably increase to match the price relationship of miners revenue and costs.

The results of the significant relationship between the estimated cost of production and the Bitcoin spot price is presented by the respective ratios to support this analysis, Figure 11. The figure reveals a trend of an increasing correlation of the Bitcoin spot price and the estimated cost of production despite periods of considerable volatility.

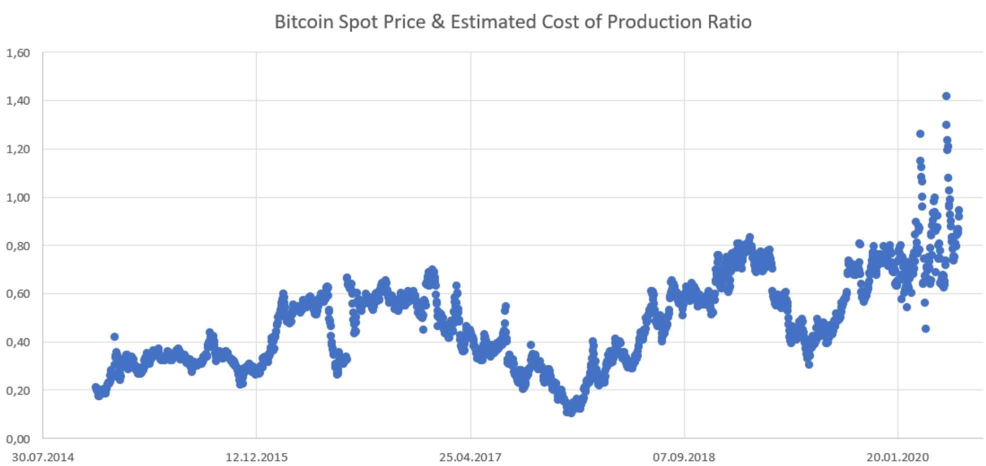


Figure 11: Bitcoin Spot Price, Estimated Cost of Production Ratio

5.2 Regression Analysis

5.2.1 CLRM Assumptions

Assumption 1 of CLRM is assumed to be satisfied for the different regression analyses conducted by log transforming the data, Figure 12, 13, 14.

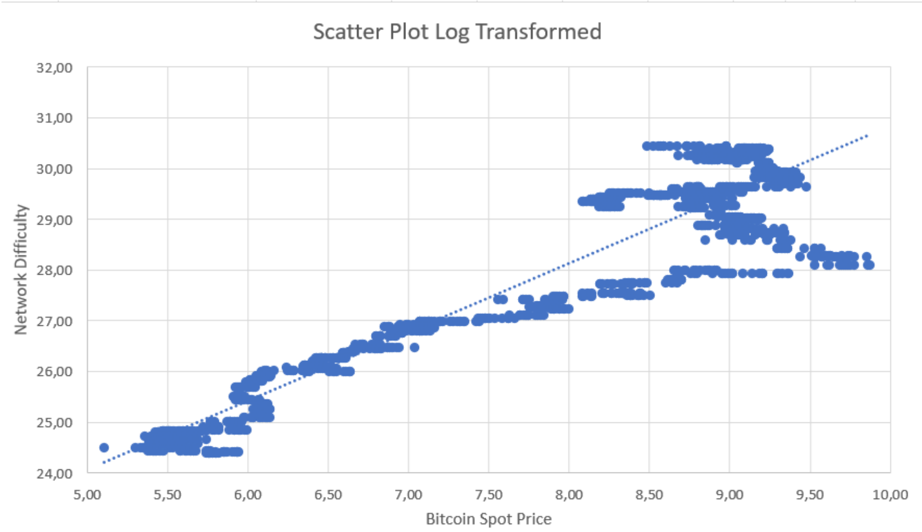


Figure 12: Scatter Plot Log Transformed, Bitcoin Spot Price & Network Difficulty

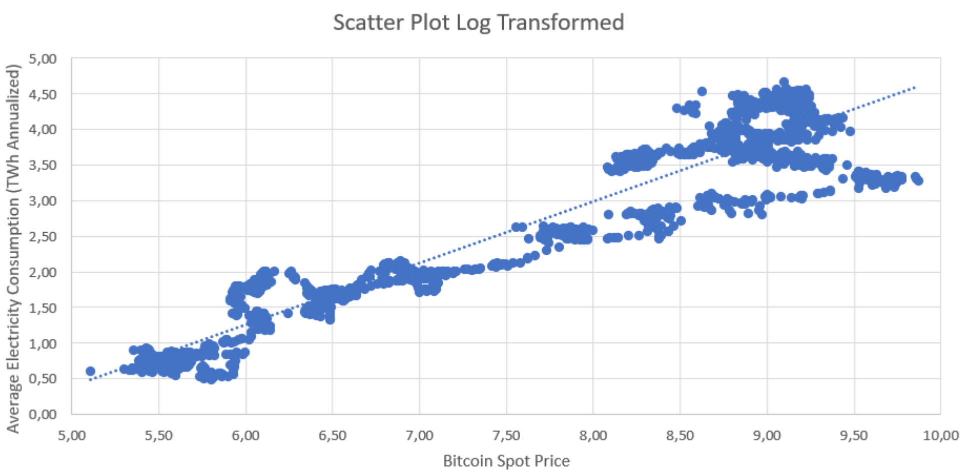


Figure 13: Scatter Plot Log Transformed, Bitcoin Spot Price & Average Electricity Consumption

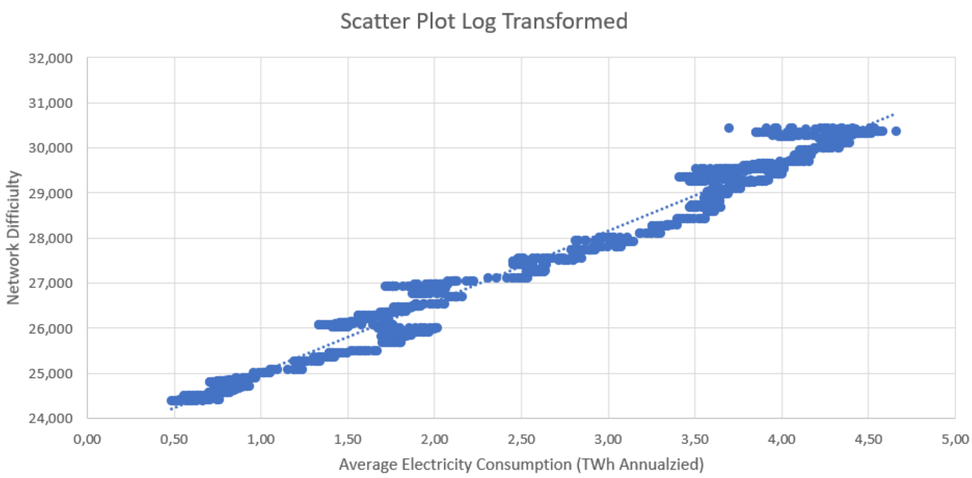


Figure 14: Scatter Plot Log Transformed, Average Electricity Consumption & Network Difficulty

Furthermore, assumption 2-3 is assumed to be satisfied, hence the residual plots and the histograms of distribution of residuals, Figure 15, 16, 17, 18, 19, 20.

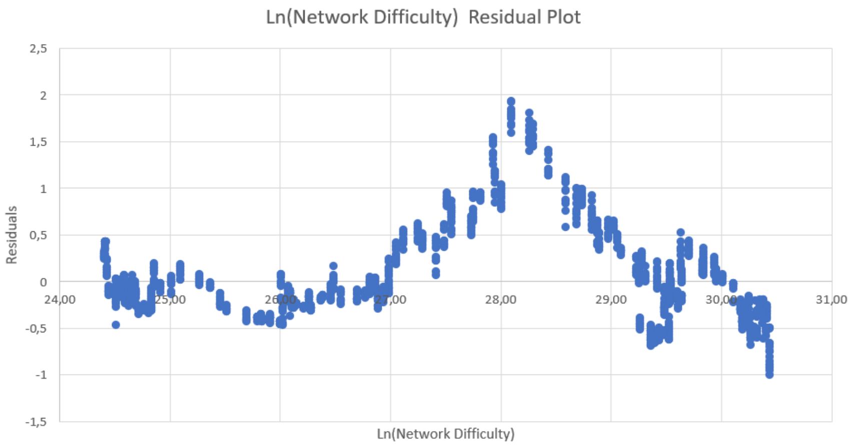


Figure 15: Residual Plot, Bitcoin Price & Network Difficulty

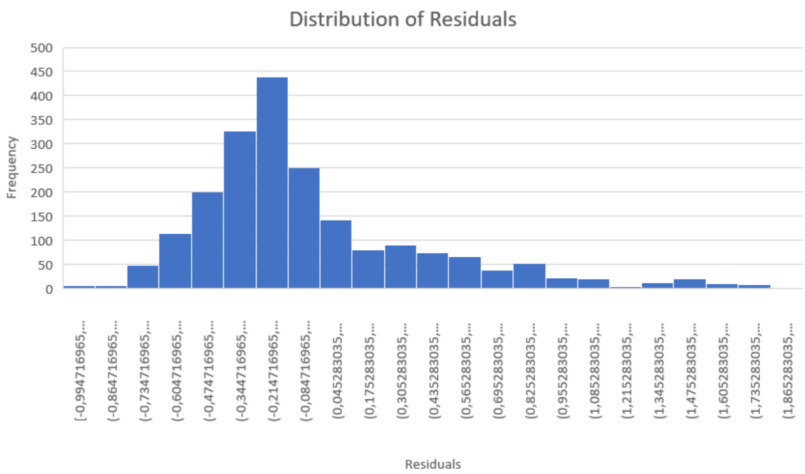


Figure 16: Histogram, Bitcoin Price & Network Difficulty

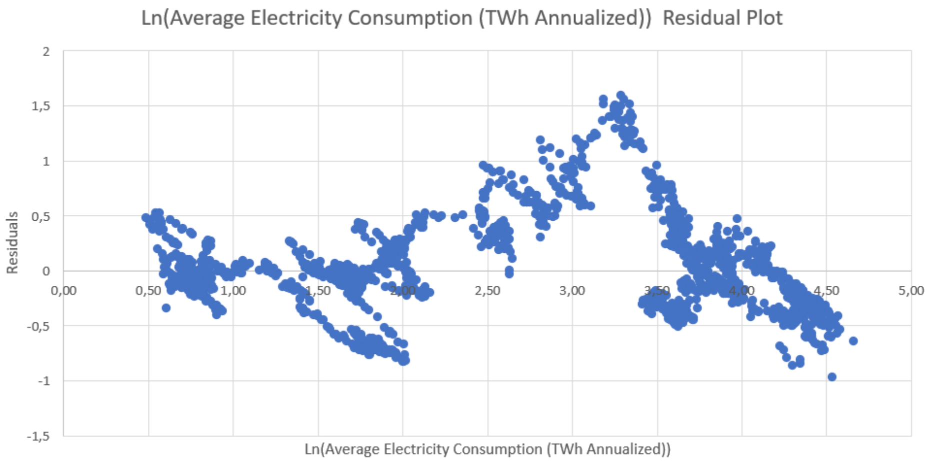


Figure 17: Residual Plot, Bitcoin Price & Average Electricity Consumption

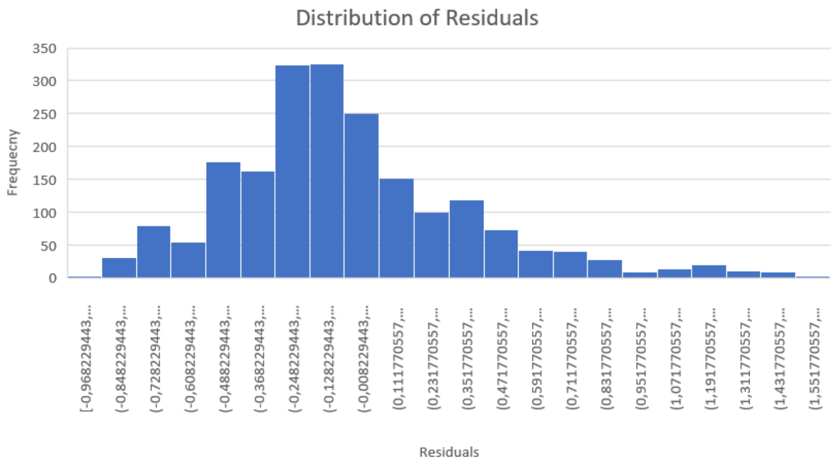


Figure 18: Histogram, Bitcoin Price & Average Electricity Consumption

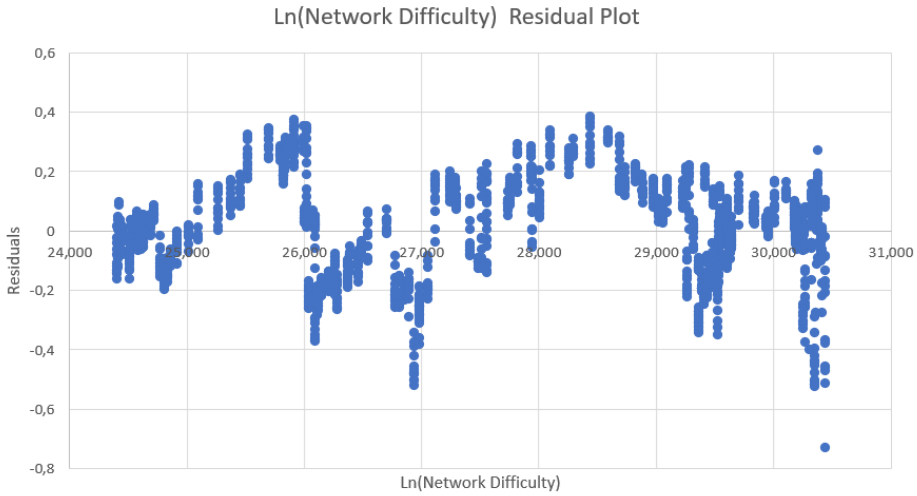


Figure 19: Residual Plot, Average Electricity Consumption & Network Difficulty

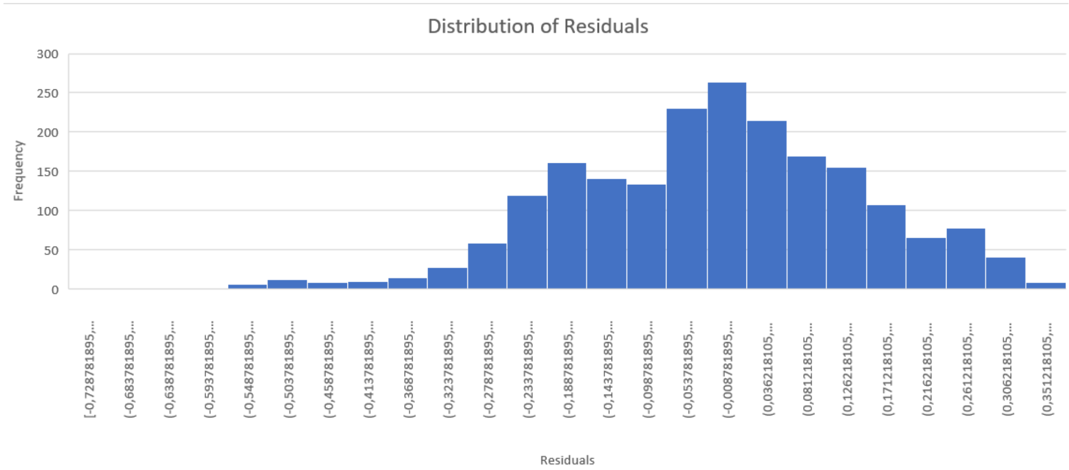


Figure 20: Histogram, Average Electricity Consumption & Network Difficulty

As presented by the plots, assumption 1-3 is assumed to be satisfied for the different set of regression analyses, and partly violated for assumption 4-6. Challenges with regression analyses is that time series tend to be impacted by heteroskedasticity and or autocorrelation of the residuals. It is reasonable to assume that these challenges also are present in these analyses. Despite the violation of a BLUE estimation the estimation is assumed to be sufficient to present the results from the regression analyses. The objective of the analyses is not to establish a perfect statistical model, but to disclose the relationship between the variables.

5.2.2 Regression Outputs

The regression outputs of the different regression analyses are retrieved from the Data Analysis in Excel. The regression outputs provide valuable statistical information and the essential statistical measures and coefficients are presented and interpreted, Table 6, 7, 8.

Regression Statistics	
Multiple R	0.94550282
R Square	0.89397558
Adjusted R Square	0.89392306
Standard Error	0.46378175
Observations	2021

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3661.704967	3661.705	17023.78	0
Residual	2019	434.2737925	0.2150935		
Total	2020	4095.978759			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-10.5944719	0.139827789	-75.768	0	-10.86869375	-10.32025011
Ln(Network Difficulty)	0.65941378	0.005053939	130.47522	0	0.649502297	0.669325257

Table 6: Regression Output, Bitcoin Price & Network Difficulty

R^2 for the first regression model equals 0.89, hence 89% of the fraction of the variance of the dependent variable, Bitcoin Spot Price, is explained by the independent variable, Network Difficulty. Furthermore, the P-values equals $0 \leq 0.05$ and the null hypothesis is rejected, and the coefficients are assumed to be statistically significant. The coefficients can be formulated by a linear regression equation.

$$ln(\widehat{Bitcoin\ Spot}\ Price) = -10.59 + 0.66ln(Network\ Difficulty)$$

The coefficient of $\ln(\text{Network Difficulty})$ is the estimated elasticity of $\ln(\text{Network Difficulty})$ with respect to $\ln(\text{Bitcoin Spot Price})$. It implies that a 1% increase in $\ln(\text{Network Difficulty})$ equals a 0.66% increase in $\ln(\text{Bitcoin Spot Price})$.

Regression Statistics	
Multiple R	0.956260975
R Square	0.914435052
Adjusted R Square	0.914392672
Standard Error	0.416637766
Observations	2021

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3745.506549	3745.5065	21577.111	0
Residual	2019	350.4722102	0.173587		
Total	2020	4095.978759			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.805478762	0.021160916	227.09219	0	4.7639792	4.84698
Ln(Average Electricity Consumption (TWh Annualized))	1.056660563	0.007193477	146.89149	0	1.0425532	1.07077

Table 7: Regression Output, Bitcoin Price & Average Electricity Consumption

R^2 for the second regression model equals 0.91, hence 91% of the fraction of the variance of the dependent variable, Bitcoin Spot Price, is explained by the independent variable, Average Electricity Consumption. Furthermore, the P-values equals $0 \leq 0.05$ and the null hypothesis is rejected, and the coefficients are assumed to be statistically significant. The coefficients can be formulated by a linear regression equation.

$$ln(\widehat{Bitcoin\ Spot\ Price}) = 4.81 + 1.06ln(Average\ Electricity\ Consumption)$$

The coefficient of ln(Average Electricity Consumption) is the estimated elasticity of ln(Average Electricity Consumption) with respect to ln(Bitcoin Spot Price). Equally a 1% increase in ln(Average Electricity Consumption) equals 1.06% increase in ln(Bitcoin Spot Price).

Regression Statistics	
Multiple R	0.99195809
R Square	0.98398084
Adjusted R Square	0.98397291
Standard Error	0.16314412
Observations	2021

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3300.853176	3300.85318	124018	0
Residual	2019	53.73771291	0.026616		
Total	2020	3354.590889			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-14.6300417	0.049187106	-297.43652	0	-14.7265	-14.533579
Ln(Network Difficulty)	0.62607944	0.00177782	352.161337	0	0.6225929	0.629566

Table 8: Regression Output, Average Electricity Consumption & Network Difficulty

Finally, R^2 for the last regression model equals 0.98, hence 98% of the fraction of the variance of the dependent variable, Average Electricity Consumption, is explained by the independent variable, Network Difficulty. Furthermore, the P-values equals $0 \leq 0.05$ and the null hypothesis is rejected, and the coefficients are assumed to be statistically significant. The coefficients can be formulated by a linear regression equation.

$$ln(\widehat{Average\ Electricity\ Consumption}) = -14.63 + 0.63 ln(Network\ Difficulty)$$

The coefficient of $\ln(\text{Network Difficulty})$ is the estimated elasticity of $\ln(\text{Network Difficulty})$ with respect to $\ln(\text{Average Electricity Consumption})$. Equally a 1% increase in $\ln(\text{Network Difficulty})$ equals a 0.63% increase in $\ln(\text{Average Electricity Consumption})$.

5.3 Portfolio Analysis

5.3.1 Historical Risk and Return

The portfolio analysis conducted in Excel reveals an interesting overview of the annual expected risk and return of a different set of portfolios. Introductory to this overview the annual expected return and standard deviation for the individual assets and indices in the portfolios are calculated based on the historical price data, Table 9.

	Bitcoin	*Gold*	*Brent Crude*	*US 10Y*	*S&P 500*	*Nasdaq*	*USD Index*	*Euro Index*	
Expected return	0.413%	0.011%	-0.031%	-0.050%	0.042%	0.067%	0.009%	0.001%	pr day
Standard dev.	7.535%	1.086%	2.303%	2.958%	1.095%	1.225%	0.450%	0.408%	pr day
Expected return	185.868%	2.714%	-7.671%	-12.011%	11.255%	18.611%	2.336%	0.297%	pr year
Standard dev.	120.325%	17.341%	36.776%	47.239%	17.492%	19.567%	7.187%	6.509%	pr year

Table 9: Expected Return and Standard Deviation of Assets and Indices

Note that the annual expected return for Brent Crude Oil and United States 10-Year Bond Yield is negative for the time period of research as of the recent collapse in these markets. For Gold, USD Index and Euro Index the expected return and standard deviation is relatively low as expected. For the S&P 500 Index and Nasdaq Index the expected return and standard deviation is significantly higher as of the bull market since the financial crisis. However, the annual expected return and standard deviation of Bitcoin is significantly superior to the other assets and indices in this analysis given the volatile exponential growth.

5.3.2 Variance – Covariance – Matrix

The variance – covariance – matrix reveals the dependencies between the assets and indices. The covariance between Bitcoin and the other assets and indices is arguably low and there are no clear tendencies of a significant relationship, Table 10.

	Bitcoin	*Gold*	*Brent Crude*	*US 10Y*	*S&P 500*	*Nasdaq*	*USD Index*	*Euro Index*
Bitcoin	0.00567539	-0.00000046	0.00004650	-0.00004835	-0.00001910	-0.00001664	0.00000121	0.00000564
Gold	-0.00000046	0.00011788	0.00000274	-0.00002259	-0.00000195	-0.00000110	-0.00000097	0.00000066
Brent Crude	0.00004650	0.00000274	0.00053018	0.00009959	0.00003375	0.00003523	0.00000001	-0.00000289
US 10Y	-0.00004835	-0.00002259	0.00009959	0.00087476	0.00007924	0.00007807	0.00000885	0.00000138
S&P 500	-0.00001910	-0.00000195	0.00003375	0.00007924	0.00011994	0.00012560	-0.00000007	0.00000003
Nasdaq	-0.00001664	-0.00000110	0.00003523	0.00007807	0.00012560	0.00015009	0.00000061	0.00000035
USD Index	0.00000121	-0.00000097	0.00000001	0.00000885	-0.00000007	0.00000061	0.00002025	0.00000038
Euro Index	0.00000564	0.00000066	-0.00000289	0.00000138	0.00000003	0.00000035	0.00000038	0.00001661

Table 10: Variance – Covariance – Matrix

5.3.3 Portfolios

A set of hypothetical portfolios for the time period of research are calculated. The weight of Bitcoin in the portfolios vary from 0% - 4.75% with increments of 0.25%. Correspondingly, the weight of S&P 500 index is set to 30% with decrements of 0.25% to match a fully invested unleveraged portfolio of 100%, Table 11.

	Bitcoin	Gold	Brent Crude	US 10Y	S&P 500	Nasdaq	USD Index	Euro Index	Sum	Std.dev	Expected return	year(std.dev)	year(E(r))	Risk free rate	Sharpe Ratio
1	0.00%	10.00%	5.00%	5.00%	30.00%	35.00%	10.00%	5.00%	100.00%	0.825%	0.034%	13.175%	9.035%	1.326%	0.59
2	0.25%	10.00%	5.00%	5.00%	29.75%	35.00%	10.00%	5.00%	100.00%	0.822%	0.035%	13.132%	9.293%	1.326%	0.61
3	0.50%	10.00%	5.00%	5.00%	29.50%	35.00%	10.00%	5.00%	100.00%	0.820%	0.036%	13.096%	9.551%	1.326%	0.63
4	0.75%	10.00%	5.00%	5.00%	29.25%	35.00%	10.00%	5.00%	100.00%	0.818%	0.037%	13.066%	9.811%	1.326%	0.65
5	1.00%	10.00%	5.00%	5.00%	29.00%	35.00%	10.00%	5.00%	100.00%	0.817%	0.038%	13.044%	10.070%	1.326%	0.67
6	1.25%	10.00%	5.00%	5.00%	28.75%	35.00%	10.00%	5.00%	100.00%	0.816%	0.039%	13.029%	10.331%	1.326%	0.69
7	1.50%	10.00%	5.00%	5.00%	28.50%	35.00%	10.00%	5.00%	100.00%	0.815%	0.039%	13.021%	10.592%	1.326%	0.71
8	1.75%	10.00%	5.00%	5.00%	28.25%	35.00%	10.00%	5.00%	100.00%	0.815%	0.040%	13.020%	10.854%	1.326%	0.73
9	2.00%	10.00%	5.00%	5.00%	28.00%	35.00%	10.00%	5.00%	100.00%	0.816%	0.041%	13.026%	11.116%	1.326%	0.75
10	2.25%	10.00%	5.00%	5.00%	27.75%	35.00%	10.00%	5.00%	100.00%	0.817%	0.042%	13.039%	11.379%	1.326%	0.77
11	2.50%	10.00%	5.00%	5.00%	27.50%	35.00%	10.00%	5.00%	100.00%	0.818%	0.043%	13.060%	11.643%	1.326%	0.79
12	2.75%	10.00%	5.00%	5.00%	27.25%	35.00%	10.00%	5.00%	100.00%	0.820%	0.044%	13.087%	11.907%	1.326%	0.81
13	3.00%	10.00%	5.00%	5.00%	27.00%	35.00%	10.00%	5.00%	100.00%	0.822%	0.045%	13.122%	12.172%	1.326%	0.83
14	3.25%	10.00%	5.00%	5.00%	26.75%	35.00%	10.00%	5.00%	100.00%	0.824%	0.046%	13.164%	12.437%	1.326%	0.84
15	3.50%	10.00%	5.00%	5.00%	26.50%	35.00%	10.00%	5.00%	100.00%	0.827%	0.047%	13.212%	12.703%	1.326%	0.86
16	3.75%	10.00%	5.00%	5.00%	26.25%	35.00%	10.00%	5.00%	100.00%	0.831%	0.048%	13.267%	12.970%	1.326%	0.88
17	4.00%	10.00%	5.00%	5.00%	26.00%	35.00%	10.00%	5.00%	100.00%	0.835%	0.049%	13.329%	13.237%	1.326%	0.89
18	4.25%	10.00%	5.00%	5.00%	25.75%	35.00%	10.00%	5.00%	100.00%	0.839%	0.050%	13.398%	13.505%	1.326%	0.91
19	4.50%	10.00%	5.00%	5.00%	25.50%	35.00%	10.00%	5.00%	100.00%	0.844%	0.051%	13.473%	13.774%	1.326%	0.92
20	4.75%	10.00%	5.00%	5.00%	25.25%	35.00%	10.00%	5.00%	100.00%	0.849%	0.052%	13.555%	14.043%	1.326%	0.94

Table 11: Portfolios, Allocation of Weights, Expected Return, Standard Deviation, and Sharpe Ratio

The allocation of weights of Bitcoin in the portfolio reflects the risk associated in terms of historical price volatility and standard deviation. As the portfolios have different allocation of weights of Bitcoin and S&P 500 Index the annual expected return, standard deviation, and Sharpe Ratio varies. As the weight of Bitcoin increase in the portfolios the annual expected returns increase significantly exclusive of a significant increase in standard deviation. Complementary, the Sharpe Ratio increase significantly as the weight of Bitcoin increase in the portfolios.

5.3.4 CAPM

The portfolios are plotted in a scatter plot to construct the CAPM with the respective efficient frontier and CML, Figure 21. The efficient frontier is constructed by the connected dots on the plot and reveals the superior portfolios of the portfolio analysis. Portfolio 1-7 are all inferior as there are other portfolios that are significantly superior in terms of annual expected return given a relatively equal expected standard deviation. The slope of the CML is significantly steep in which may be interpreted as additional weighting of Bitcoin in the portfolios tend to increase the annual expected return with relatively low impact on standard deviation.

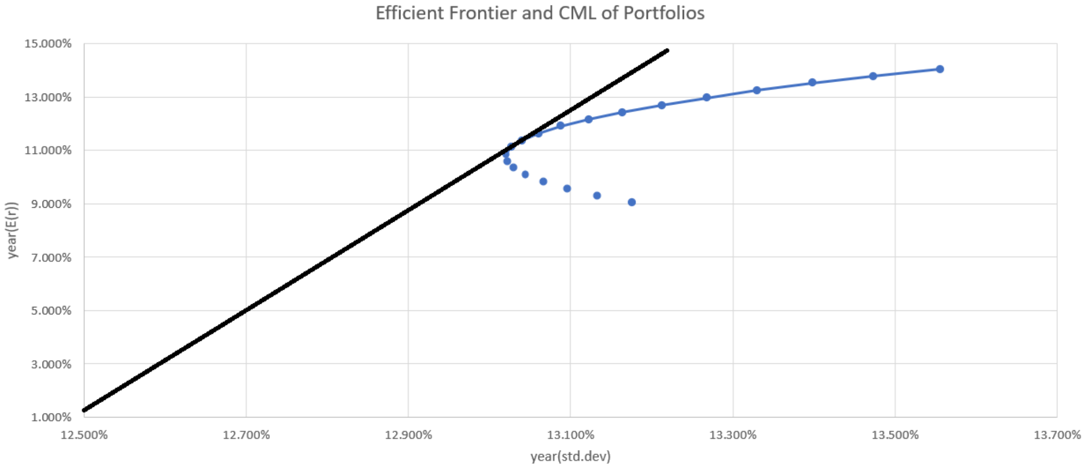


Figure 21: Capital Asset Pricing Model, Efficient Frontier and CML of Portfolios

6 Discussion

The empirical results presented and interpreted in the previous chapter are assessed and discussed in this chapter. The assessment and discussion of the results is based on the overall understanding of the Bitcoin market reflecting the financial theory, models and economic thoughts presented. The significant findings of the quantitative analyses and the academic work is assumed to be sufficient in order to answer the set of research questions sought to be answered.

RQ1: *“What is driving the Bitcoin market?”*

RQ2: *“How does the future look like for the Bitcoin market”?*

6.1 Cost of Production Analysis of Bitcoin

The findings of the cost of production analysis reveals a significant relationship between the Bitcoin spot price and the estimated cost of production. Based on the given time period of research the estimated cost of production is trending closer to the Bitcoin spot price. Assuming Bitcoin as a commodity in this analysis, the results are rather interesting as the price of Bitcoin and really any commodity tends to gravitate towards the production cost. If the Bitcoin spot price is below the estimated cost of production the incentive of production decelerate. If the Bitcoin spot price is above the estimated cost of production the incentive of production accelerates. The increased incentive of production would increase network difficulty and electricity consumption and ultimately creating an equilibrium of the Bitcoin spot price and the estimated cost of production. However, this price relationship may not be present at all times as it could also be argued that miners would continue to operate their business for short time periods at a slight loss given that they may sell Bitcoin at a higher price in the future. Additionally, there is also a possibility for miners to negotiate futures contracts and hedge price risk by selling at fixed rates in advance.

The model of estimated cost of production may be rather optimistic as the model ultimately model a higher price of the Bitcoin spot price holding the demand for Bitcoin constant in terms of electricity consumption and electricity costs. As the block reward is cyclically cut in half so are miners revenue and this may cause a potential threat to the model if demand for Bitcoin experience a prolonged significant drop. If demand for Bitcoin decrease the Bitcoin spot price would decrease and the incentive for miners to continue their business will decelerate. This situation may offer a potential mining death spiral for the Bitcoin network as miners would eventually capitulate and shut down their business as it is no longer profitable. However, a mining death spiral is rather unlikely as the main contributors to the mining business are aware of this potential threat and are acting accordingly with long-term perspectives and strategies.

A reasonable significant finding, in reference to the research questions, for this particular analysis is the assumption of that the Bitcoin spot price is highly influenced by the underlying production costs, likewise other commodities. Even though the Bitcoin spot price diverge significantly at certain time periods compared to the model, the price tends to correct to the fundamental value in which is the estimated cost of production.

6.2 Regression Analysis

The regression analysis discloses the relationship between the variables of interest. For the first simple linear regression equation a 1% increase in $\ln(\text{Network Difficulty})$ equals a 0.66% increase in $\ln(\text{Bitcoin Spot Price})$. These results are rather interesting as one would expect that increase in $\ln(\text{Network Difficulty})$ would be a more significant determinant of change in $\ln(\text{Bitcoin Spot Price})$. A possible explanation for these results may be that the increasing efficiency of mining hardware outperforms the increase in network difficulty. As demand for Bitcoin mining increase the network difficulty increase, electricity consumption increase, and similarly the Bitcoin spot price is expected to increase. However, the price increase less than expected as the Bitcoin spot price is less dependent on increase in network difficulty as the miners are able to solve the PoW relatively more efficiently and consume less energy.

For the second linear regression equation a 1% increase in $\ln(\text{Average Electricity Consumption})$ equals 1.06% increase in $\ln(\text{Bitcoin Spot Price})$. The coefficients of the linear regression equation are statistically significant and confirms the results of the cost of production analysis. The changes in Bitcoin spot price may be explained by the underlying cost of production in terms of electricity consumption. The slight premium of change in $\ln(\text{Bitcoin Spot Price})$ explained by $\ln(\text{Average Electricity Consumption})$ may be explained by the relationship of the network difficulty and the Bitcoin spot price. For the average electricity consumption to increase the network difficulty would need to increase with a greater magnitude in which may reflect significant demand for both Bitcoin mining and Bitcoin itself.

Finally, the last linear equation presents a 1% increase in $\ln(\text{Network Difficulty})$ equals a 0.63% increase in $\ln(\text{Average Electricity Consumption})$. The results of this linear equation confirm the assumptions stated. Increase in network difficulty offers less change in electricity consumption. However, this relationship may be inverted in the future if the network difficulty increases to a level where miners would have difficulties keeping up solving the PoW. If the network difficulty increases and miners are unable to solve the PoW efficiently the miners would either need to acquire more efficient hardware or consume more energy in which would increase the average electricity consumption.

6.3 Portfolio Analysis

The results of the portfolio analysis are rather interesting in terms of hedging and diversification properties. As presented by the variance – covariance – matrix the correlation of Bitcoin and the other assets and indices is arguably low and rather inconsistent. This feature of Bitcoin offers a unique feature in terms of hedging and diversification properties. Traditionally a negative correlation is assumed to be decisive for a hedge, however it could also be argued that this risk exposure may be constructed in the financial markets by short-selling assets. The unique feature of Bitcoin is the zero correlation that is arguably impossible to construct in the same way by futures contracts. As of this unique feature Bitcoin may offer as a great diversifier in an investment portfolio.

For the time period of research, the annual expected return for the portfolios varies significantly given the different allocation of weights of Bitcoin in the portfolios. As of the exponential growth of Bitcoin the annual expected return for the portfolios increase significantly, despite fairly limited weighting. These results in themselves may not be as surprising given the preconditions of the data and it is more a question of whether this trend continues. The Sharpe Ratio of the respective portfolios are lower than expected and this may be explained by the negative annual expected return of Brent Crude Oil and United States 10-Year Bond Yield. The negative annual expected return for the time period of research for these assets is arguably not representative for the longer-term perspective and thereby the respective ratios of the portfolios should be weighted accordingly in the assessment. Despite lower expected risk-adjusted returns for the portfolios, with the respective weighting of Bitcoin, the CML supports the assumption of Bitcoin as great diversifier.

6.4 Predictions

As presented the supply side of Bitcoin is rather predictable by design in the open source Bitcoin code. Recently the block reward halved for the third time and the inflation rate of Bitcoin continues to decrease. For the experienced stakeholders involved in the Bitcoin market these features are mostly known, but the outcome of this event is rather unknown. Previously the halving of the block reward has caused a price increase of Bitcoin, Figure 22.

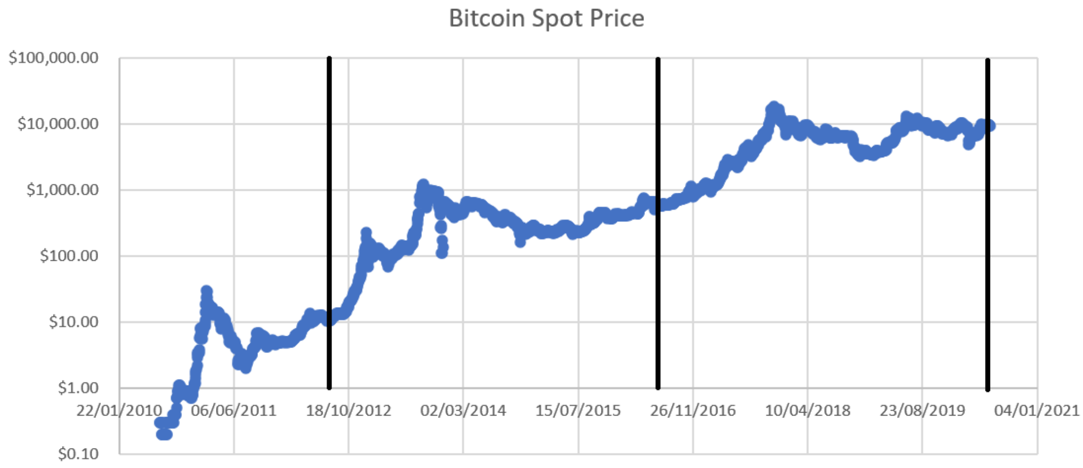


Figure 22: Bitcoin Spot Price Log-Scale, Halving Dates Represented by Vertical Bars

The price increase tends to lag as of the event and eventually reaching a new all-time high. This is rather expected as the Bitcoin market experiences a supply shock. However, there are very limited observations of this event and there are not enough data to draw a definite conclusion. Inspecting the futures market of Bitcoin reveals that the futures prices are relatively equal to the spot price and it could also be argued that this event is already priced in by the market. (CMEGroup, 2020)

As to the demand side the interest in terms of network difficulty, average electricity consumption, transaction volume, unique addressed used, confirmed transactions per day and exchanged traded volume are all trending upwards reflecting increased demand. In addition to these rather quantitative measures of demand the narrative of Bitcoin as digital gold is rather interesting in terms of future demand. The monetary value of gold has existed for thousands of years due to its properties and mainly because of its scarcity. In reference to the properties of monetary value, deflation, and stock to flow ratio Bitcoin may have the potential to become a supplementary asset to gold as digital gold. The total market cap of gold recently surpassed a total of $10 trillion and reached new heights reflecting an extremely valuable asset and the uncertainty in the financial markets. In addition to all the properties of gold, Bitcoin may offer as a superior alternative in terms of the digital aspects and decentralization and could potentially continue to gain market share of gold based on the assumption that the regulatory conditions are fully set and both retail and institutional adoption increases.

Despite increased demand in digital assets lead by private actors such as Grayscale investment, it is still a number of regulatory conditions that are incomplete in order for institutional investors to fully participate in the Bitcoin market. The rejection of the recent Bitcoin ETF proposal was rejected due to the lack of capital market infrastructure such as custodians, prime brokers, clearing entities, settlement entities, and transfer agents as this offers a potential threat in terms of liquidity and manipulation (Securites and Exchange Commission, 2020). Another potential threat may be central bank issued digital currencies and a ban of “unofficial cryptocurrencies” such as Bitcoin. As the Bitcoin market is still vulnerable to regulatory uncertainty and great volatility the demand may be depressed by these factors. However, as presented in the portfolio analysis even limited weighting of Bitcoin in a typical financial portfolio may offer a significant increase in risk adjusted returns and correspondingly a great diversifier. On the other hand, despite that the demand is expected to increase, the extreme exponential growth of Bitcoin is not expected to continue as the number of additional stakeholders are limited and the valuation of Bitcoin would eventually become irrational compared to other assets.

In reference to the economic thoughts of the Austrian School, the recent collapse in the financial markets are rather interesting in comparison with Bitcoin. The collapse in the financial markets caused the central banks to lower the interest rates to zero in order to stimulate the markets. Despite the monetary policy of the central banks, the financial markets continued to fall. As the fear and uncertainty spread in the markets a number of investors liquated their assets and allocated their investments in USD causing the bond market to collapse, resulting in yields of close to zero. As a result of this crisis the central banks, and especially the Federal Reserve (FED), has increased the quantitative easing to further attempt stimulating the financial markets. As of today, the FED balance sheet exceeds a total of $7 trillion, Figure 23, and the consequences of this quantitative easing is arguably unknown.

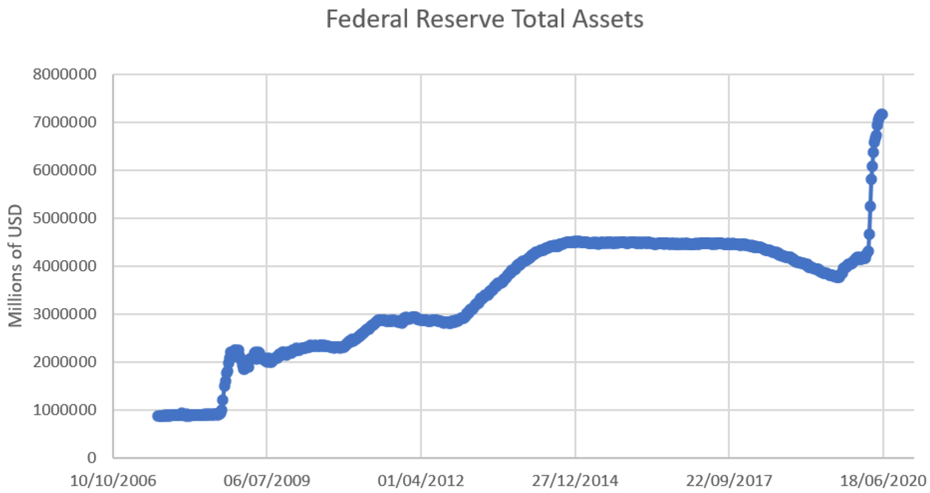


Figure 23: Federal Reserve Balance Sheet (Federal Reserve Bank of St. Louis, 2020)

As the FED balance sheet is extensively increasing a potential consequence of the quantitative easing may be an unprecedented level of inflation of USD as the amount of additional fiat currency added to the financial system is increasing rapidly with great magnitude. However, the quantitative easing has not been a problem since the significant increase of the balance sheet since the financial crisis of 2008. Another consequence of the quantitative easing may occur when these assets ultimately are offloaded to the financial markets. On the other hand, Bitcoin remains scarce and decentralized and may offer as a great hedge against inflation and easing monetary policies. As bond yields are close to zero and the financial markets are arguably highly inflated by the quantitative easing, the demand for scarce assets such as gold and Bitcoin is expected to increase as investors may be better off allocating a greater proportion of their portfolio in these assets.

7 Conclusion

The aim of the thesis was to further investigate the technological and financial properties of Bitcoin and disclose how these relate to the Bitcoin market and the broader aspects of the financial world. The topic was formulated into a set of research questions.

RQ1: *“What is driving the Bitcoin market?”*

RQ2: *“How does the future look like for the Bitcoin market?”*

In reference to the quantitative analyses and their respective results it is reasonable to assume that the Bitcoin market is highly influenced by the underlying cost of production of Bitcoin. The technological and financial properties of Bitcoin reveal that the supply side is fixed, and the demand side is ultimately the most important factor driving the Bitcoin market. The statements of future demand are assuming Bitcoin as a commodity, likewise gold. As presented by the portfolio analysis, the analysis reveals great diversification properties of Bitcoin in a time where the financial markets once more are facing great uncertainty. The technological and financial properties of Bitcoin is distinctly unique and may offer as a great hedge against potential inflation of fiat currencies as of the increasing easing monetary policy by central banks. As the regulation of Bitcoin is fully set the institutional demand for Bitcoin is expected to increase due to the considerably equal financial properties of gold and the financial uncertainty in the markets.

Limitations of the thesis in comparison to similar quantitative theses are that the results of the quantitative analyses are based on historical data and past performance may not be indicative of future results. The thesis may be used in further studies when more data is available, and regulation of the Bitcoin market is fully set as the market may be depressed by the regulatory uncertainty. Possible topics of interest discovered for further studies in reference to the Bitcoin market may be short term price volatility and Bitcoin as a safe haven.

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