A picture containing drawing

Description automatically generated

**ANALYSIS ON DIFFUSION EFFECTS OF BITCOIN**

Submitted by:

CHEN LUCAN

Supervisor:

PROFESSOR PEI SAI FAN

A capstone paper submitted in partial fulfilment of the requirements for

THE DEGREE OF MASTER OF PUBLIC ADMINISTRATION

In the College of Humanities and Social Sciences,

Nanyang Centre for Public Administration

NANYANG TECHNOLOGICAL UNIVERSITY

(2020)

# Abstract

Bitcoin positions itself as the first decentralized peer-to-peer payment network. Compared to traditional fiat currency which relies on the central bank, the Bitcoin network is powered by Blockchain. Bitcoin is the first real world implementation of Blockchain. In the last decade, Bitcoin impacts our society in ways far more than a simple cryptocurrency. Its design challenges all existing sovereign currency, disrupts existing business models and initiates decentralisation innovation. The paper studies Bitcoin diffusion impacts on our society in three domains: financial, social and technological. The paper does both qualitative and quantitative cost benefit analysis of Bitcoin diffusion on existing industries.

Given the huge volatility of Bitcoin price over US dollar, there are divided views on Bitcoin intrinsic values. Fluctuations of Bitcoin price hinders people from using it as reliable currency. Bitcoin volatility indicates its high risk and high return nature. The findings of this paper indicate that Bitcoin remains a speculative asset, not safe investment. Cryptocurrency pricing is not based on fundamental asset, therefore it is extremely volatile asset and is not ready to act as global currency. Only a small percentage of merchants are in support of Bitcoin payment.

Bitcoin network achieves payment transfer without a central financial authority. Bitcoin decentralization infrastructure is not backed by any sovereignty and price fluctuates much relative to US dollar. Bitcoin network security is ensured by mathematical algorithm and is reliable for payment transfer between any parties without involving a central authority.

Bitcoin price volatility creates trading opportunities for speculators like hedge funds for higher return. 150 crypto hedge funds with a total AUM US$1bn are actively trading crypto currencies. Current regulation rules are not suitable for cryptocurrency. Governments' banking policies are slow in catching up with regulating cryptocurrency portfolio.

Bitcoin daily trading volume attracts huge fund on speculative trading. The characteristics of Bitcoin volatility label Bitcoin as more speculation assets than safe currency. Bitcoin is most popular as a new way of payment transfer. Compared to traditional payment methods, Bitcoin handles much less transactions per second. The Bitcoin network processes only 128 million transactions annually, which is far less than Visa, 188 billions of transactions. Visa network can process 3.8 transactions per second, while Bitcoin processes 5,961 transactions per second. Taking into account the hidden cost of VisaNet, including huge data centres, large operation teams, security arrangement and operating cost of branches, the results show that Bitcoin network energy consumption bill is still much higher than Visa operating expenses. Bitcoin network scalability is the main obstacle to its wide adoption.

The paper applies Diffusion of Innovation Theory (Rogers, 2003) to Blockchain in various industries. Media data have been collected to identify industries according to five stages of the innovation-decision process, which are knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). Study shows software and finance industries are early adopters of Blockchain technology. Blockchain has mostly influenced the software industry and disrupted banking services. The paper identifies several practical use cases in supply chain, healthcare and real estate in which Blockchain technology is actively applied. Blockchain technology efficiently solve the issue of mistrust raised among multiple parties. Blockchain technology has been widely migrated into other application implementations including logistics industry and fintech start-ups. Blockchain technology stimulates decentralisation innovation and creates new jobs.

Bitcoin mining cost is calculated based on electricity price. Blockchain proof of work consumes excessive electricity. It is estimated that half of Bitcoin mining is done with hydropower which is clean and not causing global warming. 60% percent of Bitcoin mining facilities run in countries which heavily subsidizes electricity. Regions which have excessive power supply are favourite sites of Bitcoin mining farms. Bitcoin mining rewards expensive hydropower plant infrastructure and monetizes the infrastructure investment in a much shorter period through trading of Bitcoin. Bitcoin mining is acting as an efficient way of power arbitrage. Bitcoin mining farms migrate to countries which offer low electricity cost. In return mining activities provide positive cash flow to power plants which cost large capital investment.

Social impact studies changes in the society domain. The Bitcoin network consumes excessive electricity to maintain its proof-of-work. The cost per transaction is much higher than other payment designs. Visa network can handle 1000 times more transactions per second than Bitcoin. Anonymity in transaction is not a critical requirement in modern banking system. Anonymity of Bitcoin is abused by dark web, including drugs and, human trafficking, money laundering, etc. Bitcoin price volatility indicates its speculative nature rather than an investment vehicle. Bitcoin high volatility boosts human irrational behaviours, in extreme cases which causes social instability. The society need education on Bitcoin investment and its speculative nature.

Technology impacts studies technology evolution initiated by Blockchain, which is the technology in support of Bitcoin decentralized infrastructure. Blockchain is the Bitcoin network backbone which verifies transactions without central authority. Blockchain boosts decentralisation technology evolution. Though its bandwidth handling large volumes of transactions remains in seed stage, Blockchain has drawn dramatic attention in mainstream technology firms. Its decentralised design has stimulated a lot of innovation in other industries. The technology behind cryptocurrency can be applied to other domains. The design pattern solves the single failure issue in distributed systems. Hardware upgrading in a mining machine stimulates GPU and ASIC industry upgrades. Bitcoin mining machines upgrading process boosts IC company revenue and accelerates hardware adoption rate. Data shows 5 mining pools accumulated to 66.7% of total mining power. Private data centres act as central authority for running this asset, which defeat the purpose of decentralisation. The paper finds that Bitcoin decentralisation infrastructure have been compromised by large mining pools and data centres.

# Table of Contents

[Abstract 2](#_Toc39444608)

[Table of Contents 6](#_Toc39444609)

[List of Tables 7](#_Toc39444610)

[List of Figures 8](#_Toc39444611)

[Chapter 1. Introduction 9](#_Toc39444612)

[1.1 Terminology 10](#_Toc39444613)

[1.2 Research Background 12](#_Toc39444614)

[1.3 Purpose of Studies 14](#_Toc39444615)

[1.4 Research Questions 15](#_Toc39444616)

[1.5 Paper Outline 16](#_Toc39444617)

[Chapter 2. Literature Review 16](#_Toc39444618)

[Chapter 3. Data and methods 22](#_Toc39444619)

[3.1 Volatility index 22](#_Toc39444620)

[3.2 Covariance and Correlation 26](#_Toc39444621)

[3.3 Bitcoin Fund Data 30](#_Toc39444622)

[3.4 Bitcoin Ownership and Merchant Adoption 31](#_Toc39444623)

[3.5 VisaNet 34](#_Toc39444624)

[3.6 Other industry use cases 34](#_Toc39444625)

[3.7 Bitcoin Statistics 38](#_Toc39444626)

[3.8 Electricity Consumption 40](#_Toc39444627)

[3.9 Hardware Evolution 44](#_Toc39444628)

[Chapter 4. Results and Discussion 46](#_Toc39444629)

[4.1 Bitcoin is a highly speculative asset 46](#_Toc39444630)

[4.2 Bitcoin is not ready as a stable currency 48](#_Toc39444631)

[4.3 Scalability is the obstacle to wide adoption of Bitcoin as method of payment 49](#_Toc39444632)

[4.4 Bitcoin’s electricity consumption can be justified 51](#_Toc39444633)

[4.5 Bitcoin mining is electricity buyer of last resort 53](#_Toc39444634)

[4.6 Bitcoin is driving innovation initiatives 55](#_Toc39444635)

[Chapter 5. Conclusion 57](#_Toc39444636)

[Chapter 6. Future Studies 59](#_Toc39444637)

[References 61](#_Toc39444638)

# List of Tables

[Table 1 Volatility Index of Six Major Assets 26](#_Toc39442556)

[Table 2 Correlation Between Six Major Assets 29](#_Toc39442557)

[Table 3 Crypto Hedge Fund Management and Performance Fees 30](#_Toc39442558)

[Table 4 Crypto Hedge Fund Return and Beta 31](#_Toc39442559)

[Table 5 Bitcoin Wallet Balance Distribution 33](#_Toc39442560)

[Table 6 Bitcoin Address Richer Than 33](#_Toc39442561)

[Table 7 Annual Payment Volume and Transactions of Major Payment Systems 34](#_Toc39442562)

[Table 8 Visa and Bitcoin Operating Cost in Past Three Years 34](#_Toc39442563)

[Table 9 Bitcoin Network Statistics 38](#_Toc39442564)

[Table 10 Energy Consumption of the Bitcoin Mining Facilities by Location 38](#_Toc39442565)

[Table 11 Transaction Throughput of Bitcoin and Visa (accessed on Feb 26 2020) 39](#_Toc39442566)

[Table 12 Bitcoin cost breakdown. Includes cost incurred by all nodes 40](#_Toc39442567)

[Table 13 Estimated Lifetime Costs for an Antminer S9 under Various Lifetime Assumptions and a Production Cost of US$500 (Assuming Electricity Costs 5 US Cents per Kilowatt-Hour) 41](#_Toc39442568)

[Table 14 Electricity Capacity, Consumption and Price by Country 42](#_Toc39442569)

[Table 15 Breakdown of Global Renewables Penetration in Bitcoin Mining 43](#_Toc39442570)

# List of Figures

[Figure 1. Bitcoin Price in US Dollar 25](#_Toc39442579)

[Figure 2. Euro to US Dollar Exchange Rate 25](#_Toc39442580)

[Figure 3. US Dollar to Japanese Yen Exchange Rate 25](#_Toc39442581)

[Figure 4. Singapore Dollar to US Dollar Exchange Rate 25](#_Toc39442582)

[Figure 5. Crude Oil WTI Futures Listed on NYMEX 25](#_Toc39442583)

[Figure 6. Gold Futures Listed on COMEX 25](#_Toc39442584)

[Figure 7. Distribution of Crypto Hedge Fund AUM 30](#_Toc39442585)

[Figure 8. Crypto Hedge Fund Launch Median AUM 30](#_Toc39442586)

[Figure 9. Median 2018 Crypto Hedge Fund Return 31](#_Toc39442587)

[Figure 10. Major Companies Accepting Bitcoin Payments 32](#_Toc39442588)

[Figure 11. Number of Bitcoin Wallets Created 32](#_Toc39442589)

[Figure 12. Bitcoin Mining Pool Hash Power Shares 39](#_Toc39442590)

[Figure 13. Bitcoin Electricity Consumption, TWh (annualised) 41](#_Toc39442591)

[Figure 14. Bitcoin Electricity Consumption Ranking Across Global Countries 42](#_Toc39442592)

[Figure 15. Bitcoin Mining Total Hash Rate 44](#_Toc39442593)

# Chapter 1. Introduction

The Bitcoin white paper was published in 2008 by Nakamoto Satoshi. Since Bitcoin was introduced in 2009, there are thousands of cryptocurrencies that have been invented and 581 cryptocurrencies are being traded (Bitcoin.com). In contrast to the traditional banking system, where central banks, tax authorities and banks play a dominating role in regulating transactions, Bitcoin is a decentralized, self-governing payment network, where ordinary users are in charge of the transaction verifications. Bitcoin is decentralized digital currency that use cryptography to verify transactions. Bitcoin transactions are made and verified by peer-to-peer network in Blockchain. Blockchain allows direct payments between any two parties without approval from the central financial institute. Double-spending issue is solved without involving a trusted third party. The peer-to-peer network hash transaction records into a chain of hash based proof-of-work. The process of calculating hash transactions is referred to as Bitcoin mining. Changing a record requires redoing the proof-of-work. As the witness of proof of sequence of transaction records, the longest chain is created by the largest pool of computation power. When the majority of the network nodes are honest, Blockchain acts as the true decentralised payment network. The Bitcoin network is anonymous. Bitcoin is stored in a public address which can be observed by users, but transactions can only be created by people with the corresponding private address. There is no way to identify the holders of the private keys.

In the early days of Bitcoin, Bitcoin and Blockchain are vague concepts to most people. Due to the Bitcoin revolutionary design and open concept, software developers were the early adopters. Technology sector was attracted to Bitcoin’s decentralised infrastructure design. Bitcoin was regarded as the technology force to push for reform in the finance and banking sectors. Early adopters were able to generate hash sequences and confirm transactions using computers and even laptops with decent computing power.

Bitcoin price rose from US$433 on Jan 1st 2016 all the way up to US$19,346 on Dec 16 2017 (Bitcoin.com). The public started actively learning about Bitcoin. Bitcoin becomes one of the most searched topics of the year. Huge attention was drawn to Bitcoin by the public in the fear of losing the opportunity of getting rich overnight.

Bitcoin network infrastructure skirts the financial regulations and opens windows for possible money laundering and black market. Its popular adoption poses huge pressure on government because of opacity of Bitcoin transactions and hence the poor understanding of Bitcoin related activities.

## Terminology

### Blockchain

Blockchain is a distributed, decentralized, public ledger. It consists of a chain of data blocks. Each block records transactions of Bitcoin from a sender’s address to a receiver’s address. Each block stores information about transactions date, time, transaction sender and receiver, and unique identifier. The identifier is a 64-bit hexadecimal number generated by cryptography algorithm SHA-256. One block has the size of 1MB, which could potentially contain 250 transaction information. Complete Blockchain information are stored in every user or participant of the network. There is no need for a central authority to validate the transactions. There would be many versions of chains. The longest chain is established by majority decision and considered valid.

### Proof-of-work

The proof-of-work involves the work of calculating a value with predetermined cryptography algorithm SHA-256, which is referred to as hashing. A hash value beginning with a number of zero bits is considered valid. Finding a valid hash is exponentially time-consuming and costly. It is easy to verify whether data satisfies defined requirements. The probability of producing a valid hash value by random guessing is computationally infeasible. The characteristics of costly to produce and easy to verify a valid hash value make it difficult to change existing blocks. Changing an existing block requires to re-calculate the hash value.

### Bitcoin Mining

Participants of Bitcoin peer-to-peer network which validate Bitcoin transactions and confirm block hash value are named Bitcoin miners. Bitcoin miners create a new block by solving a proof-of-work problem and add the new block to Blockchain. The process of solving complex hash values by high performance computers, is called Bitcoin mining. Either new Bitcoins or transaction fees are granted as rewards to miners for supporting the network. Mining activities ensure a trustworthy and secure payment network by verifying its transaction information. The incentives encourage honest participants to follow the network rules and reward for their resources consumed, CPU time and electricity. The incentive mechanism acts as authority to issue new coins into circulation. At the time of this paper writing, 12.5 new Bitcoins are awarded to miners who create the next block. Every four years, reward for creating a new block is halved. When reward decreases to zero, a total of 21 millions of Bitcoins will be in circulation. The activities of creating new coins is analogous to gold miners expending resources to add gold to circulation.

### Hash Rate

Hash rate is the speed at which hash value is computed by Bitcoin mining hardware. Hash rate is measured by the number of hash calculations per second. Hash rate relates to Bitcoin mining difficulty. The current difficulty is set at which a new block is generated every 10 minutes. The difficulty is adjusted based on previous 2016 blocks. When the past 2016 blocks took more than two weeks to mine, the difficulty is adjusted smaller. If the past 2016 blocks took less than two weeks, the difficulty would increase accordingly. A higher hash rate indicates higher probability of mining a new block and receiving the reward. The higher hash rate would result in the higher mining difficulty. A higher mining difficulty ensures a more secure Blockchain. The total hash rate of Bitcoin network is 118 millions TH/s (blockchain.com, April 17 2020). One TH/s is one trillion hashes per second.

## Research Background

When Bitcoin was first introduced in 2009, it is intended to solve the pain point that the existing financial system relies on too much trust on centralised financial authority. Bitcoin is a cryptocurrency represented in a form of mathematical cryptography algorithm and initiated as a replacement to government-backed currencies. Bitcoin is the first asset people have complete control of. People have full control on payment transfer, during which no central authority can interfere with the transaction process. The transaction is maintained in the distributed ledger Blockchain. The transaction is broadcast to the global Blockchain network. Both sender and receiver identities are kept anonymous.

Bitcoin was first recognised by the developer community for its true decentralisation design. Developer community is the most motivated group discussing Blockchain. Blockchain technology is built on decentralized infrastructure design. Before Blockchain, every distributed system design requires a trusted central authority. Blockchain technology has motivated other industries to solve the verification issue of their existing transactions. The technology community voluntarily joined the Bitcoin network and confirmed transactions using personal computers and laptops. In the early years, regulations for Bitcoin trading were not in place and loopholes were exploited by black market and money laundering activities. Roaring Bitcoin price drew the public's attention. Bitcoin was traded at $992 on Jan 1 2017 and reached historically high at $19,346 at the end of 2017. A year later at the end of 2018, Bitcoin price dropped 80.7% to $3733. It is the crypto billionaire phenomenon that raises the public enthusiasm on Bitcoin. The whole world started talking about Bitcoin. Bitcoin is ranked in second place in keywords of Google Trends in 2017 global news. Large groups of people pay attention to Bitcoin. Huge investments were poured in Bitcoin mining facilities. Hedge funds began to allocate funds into Bitcoin trading in search for higher return. Chicago Mercantile Exchange launched Bitcoin Futures and Option trading. Nevertheless, few people understand the mechanism of bitcoin. Governments' regulations are lacking behind Bitcoin technology, which encouraged money laundering. Blockchain as a new trend of entrepreneurship draws interest from venture capital funds and disrupts existing business by providing more efficient solutions. Amid increasing trading volume and immense Google search interest, the concept of Bitcoin has rapidly gained traction, at the same time it also raised profound social and economic issues.

In finance, there are 150 hedge funds actively trading Bitcoin. Bitcoin daily trading volume has reached US$2bn in Feb 2020. Its price starts showing strong correlations to commodities such as goods oil and gold. Bitcoin is considered a safe asset by some investors. On the other hand, high volatility of Bitcoin price makes it an unreliable currency. Some felt that Bitcoin is akin to tulip mania in twenty-first century. Bitcoin enthusiasts treat it as money of the future and accumulates as digital assets. Only a small percentage of merchants accept Bitcoin as a payment method.  The divided views put Bitcoin regulations in a difficult situation.

To protect transaction records from attackers, large amount of computer systems are necessary to uphold the Blockchain network. Blockchain data integrity and security are guarded by all participating computers. Blockchain design sets far higher obstacles for hackers than a centralised system.

The design of Blockchain makes mining Bitcoin a high energy-consumption process. Verifying Bitcoin transactions requires a large amount of hash calculation which consumes a huge amount of electricity. Study (Alex de Vries, 2018) shows the Blockchain network consumed 2.55 gigawatts of electricity which is equivalent to Ireland (3.1 gigawatts) in verifying Bitcoin transactions. In 2018, the amount of electricity consumed by the Blockchain network has increased to 7.67 gigawatts (Alex de Vries, 2018) which is almost the same with Austria electricity consumption (8.2 gigawatts). Bitcoin mining farms are longing for cheap electricity and hoping to generate large cash flow for expensive power plants.

The Bitcoin network disrupted the financial system the most. China's central bank, The People's Bank of China (PBOC) has announced to launch its digital currency. It's a strategic move to take advantage of cryptocurrency in promoting RMB in global financial markets. The strategy is clearly motivated by the Bitcoin network, although the initial design is not built on Blockchain technology. It's a strategic move to protect China foreign exchange sovereignty and promote global use of the yuan. The new technology grants China yuan the opportunity to bypass the SWIFT system in international payment. Facebook initiates the development of Libra cryptocurrency based on Blockchain technology. Libra is designed to be backed by other safe assets, US Treasury securities and basket of currencies.

The main challenge to Bitcoin adoption is its scalability. Compared to mainstream transaction infrastructure Visa can process 5,961 transactions per second, Blockchain network achieves 3.8 transactions per second. Economic models have ignited heavy debate over the scalability of Bitcoin transactions over the past few years. To expand the scalability of the Bitcoin network to the same level of Visa, it requires to increase block size or reduce the hash complexity. Either change requires the participants of the whole network to upgrade systems.

## Purpose of Studies

The paper studies the speculative nature of Bitcoin. The paper calculates the cost and benefits of the Bitcoin network in various domains both qualitatively and quantitatively. Bitcoin remains a speculative asset in the finance industry though, its decentralized design has tremendously diffused to other industries and provides positive solutions to other industries. Bitcoin mining consumes excessive electricity, which otherwise would have been wasted if not used by Bitcoin mining facilities. Bitcoin mining generates large positive cash flows for power generators.

Regulatory policy making process is certainly lagging behind the development of Bitcoin. The study shows that regulatory policy making on Bitcoin should not narrowly take only banking sector into account, but also include Bitcoin trading and mining into consideration. The study identifies interest groups and industries should be included in the process of policy making. The study qualitatively examines which industries and interest groups would be largely affected by Bitcoin regulation policies.

The purpose of this paper is to examine the diffusion effects of Bitcoin to other industries. The mainstream researchers have focused on money laundering, price prediction and electricity consumption. Bitcoin has diffused into society far more than being just a crypto asset. The paper discovers the complete map of Bitcoin diffusion impacts on the society.

The paper discovers opportunities of applying Blockchain technology on solving existing use cases and examines challenges of implementing Blockchain technology across various industries.

The paper addresses the issue of Bitcoin speculative nature and the potential use case of Blockchain technology. The findings of this paper may have important implications for institutional investors, policymakers and law enforcement agencies. The study will assist policy makers and academics understand the complete picture of Bitcoin network and provide insights into the potentialities of Blockchain technology.

## Research Questions

The paper studies the diffusion effects of Bitcoin on our society. Bitcoin is invented as a payment instrument in the first place though, it’s obvious Bitcoin has diffused into other domains beyond finance. Bitcoin and other cryptocurrencies provide another asset class to asset managements. Other industries have found practical use cases of using the Blockchain network as distributed ledger. Blockchain gains significant traction in solving trust problems existed currently in many transactions. Though Bitcoin payment is not officially recognised and widely adopted in China, 70% of Bitcoin mining is operating in China. Since Bitcoin mining monetizes hydro power plants in a much shorter period, local governments are in favour of supporting mining and operation of data centres. The paper discusses the following three questions:

1. *Does Bitcoin serve as a type of currency or speculative assets or payment transfer method?*
2. *Apart from the banking system, what are the use cases of Blockchain in other industries?*
3. *How much can power plant infrastructure benefit from Bitcoin mining?*

## Paper Outline

Chapter 2 reviews previous works done to identify Bitcoin in specific domains. Previous papers have focused on Bitcoin investment or electricity consumption. A complete picture on Bitcoin is not covered. Chapter 3 presents data and methods the paper used. The data are collected from industries which are significantly disrupted by Bitcoin, including financial markets, hedge fund, crypto currency exchange and global energy consumption. Chapter 4 discusses Bitcoin impacts on society with systematic views. Costs of Bitcoin are estimated by electricity consumption. Benefits of Bitcoin are calculated with security level achieved by Blockchain cryptography, disrupted business model and innovation initiatives. Chapter 5 discusses conclusions from the observed data.

# Chapter 2. Literature Review

Forsyth referred to Bitcoin as the 21st century tulips. As Bitcoin comes to the centre of public attention, it reminds the public of tulip mania in the 17th century and dot-com bubbles at the end of the 19th century. The public debate on Bitcoin speculation to make easy money and fear of its price crash are actively being discussed. It is evident that Bitcoin does not have the price stability to be a usable currency or medium of exchange (Forsyth, 2017).

Data gathered from crypto hedge funds (PWC, 2019) shows that 150 crypto hedge funds with Asset Under Management (AUM) US$1bn are actively trading crypto assets. Fund size distribution shows a long tail. A few hedge funds have raised large AUM. Most of hedge funds manage small AUM. When Bitcoin price reached historical high level towards the end of 2017, fundraising was exceptionally successful. Bitcoin price was down 72% in 2018, compared to peak at end 2017. As a result, hedge funds showed the median return of the funds was -46% in 2018. The poor return is consistent with speculative nature of Bitcoin. The performance of hedge funds is better than the benchmark of Bitcoin price. Despite difficult market conditions, the AUM of median crypto hedge fund increased 200% in 2018. PWC report shows crypto funds are gaining popularity in 2018.

Many studies have identified relevant factors in driving Bitcoin price dynamics. Kjærland , Khazal , Krogstad, Nordstrøm and Oust found returns of S&P 500 and Google searches affected Bitcoin price. The paper (Khazal , Krogstad, Nordstrøm and Oust, 2018) found Bitcoin is not a safe asset, since it did not find strong correlation between CBOE volatility index (VIX), oil, gold, and Bitcoin transaction volume.

Cocco, Pinna, and Marchesi found the low number of transactions per block and the too high computational power required are the two main limitations to overall efficiency of Blockchain. Study (Cocco, Pinna, and Marchesi, 2017) shows Blockchain technology could potentially better support the current financial system. By overcoming the above two problems, Blockchain technology could address financial issues more efficiently than current financial systems.

Study (Ram, 2019) showed Bitcoin presents unique attributes which cannot be replaced by other assets. Ram showed that Bitcoin has little or no correlation with other asset classes. Therefore, investing in Bitcoin is able to reduce considerable risk and diversify risk and enhance return. Bitcoin is expected to continue to grow in popularity.

Since electricity cost is the primary cost of Bitcoin production, Bouri, Jalkh, Molnár and Roubaud studied the relationship between Bitcoin and commodities by assessing the ability of Bitcoin to act as a diversifier, hedge or safe asset. The study (Bouri, Jalkh, Molnár and Roubaud, 2017) showed Bitcoin is a safe-haven asset and strong hedge against commodity price movements. The result revealed that the hedge and safe-haven properties were much stronger before the Bitcoin price crash in December 2017.  After the price crash, Bitcoin is not a good option as a diversifier against energy commodities. The analysis showed insignificant correlation between Bitcoin and non-energy commodities.

Mircea showed Bitcoin may not replace fiat currency very soon. Business Intelligence (Mircea, 2017) showed that regulations need to be implemented in order for Bitcoin to gain traction and wider adoption.

Vries proposed methods to determine electricity consumption of the Bitcoin network. Vries told us that the amount of energy consumed by Bitcoin network is similar to Ireland (3.1 GW) and could have potentially reached that of Austria (8.2 GW). The paper estimated (Vries, 2018) energy consumption increases very fast. The study suggested the Bitcoin development community to improve the throughput to alleviate the excessive consumption of energy.

Sompolinsky and Zohar found incentives play a crucial role in the Bitcoin protocol to maintain the network security and transaction integrity.  The study (Sompolinsky and Zohar, 2018) showed that in order to encourage miners to stay in the network, the Bitcoin network should improve mining rewards, consensus mechanism, rewards in mining pools and transaction fee structure.

Barber, Boyen, Shi and Uzun identified Bitcoin’s success in its flexibility, simplicity and decentralisation. The study (Barber, Boyen, Shi and Uzun, 2012) showed irreversible loss and scalability issues were the main obstacles to its large-scale adoption.

Study (Crosby, Nachiappan, Pattanayak, Verma and Kalyanaraman, 2016) identified Blockchain as the emerging important technology beyond the Bitcoin network. It can be used as a general distributed database, in which records can never be erased. Though Bitcoin is controversial, the underlying Blockchain technology has drawn tremendous attention in the non-financial world and found practical applications. The study concluded the society will see significant adoption of Blockchain in a decade.

Google search data (Yelowitz and Wilson, 2015) showed four groups of clients with interest in Bitcoin: computer programming enthusiasts, speculative investors, libertarians and criminals. Yelowitz and Wilson found computer programming and illegal activity search terms are strongly correlated with Bitcoin interest, on the other hand Libertarian and investment terms are not.

Academic literature and Twitter data (Grover, Kar and Janssen, 2019) found Blockchain technology has diffused in most industries with different levels of diffusions. As the innovators of Blockchain, real estate, finance and insurance industries have reached the confirmation state of innovation-decision process (Rogers, 2003).  These industries are developing specific Blockchain applications for practical use cases. The implementation of Blockchain in most of the industries is still in early phase.

Nguyen, Bodisco and Thaver examined the factors that affect Bitcoin price. The results (Nguyen, Bodisco and Thaver, 2018) shows supply, market capitalisation, media attention and other cryptocurrency price fluctuation affect Bitcoin price.

A study (Gupta, 2017) examined the value of Bitcoin and potential as future currency or commodity or asset. Despite speculative activities, the study did not consider Bitcoin as a bubble. As the transaction and investment grows, Bitcoin has a stable future in world markets. Governments policies would resist Bitcoin as a pan-global asset. Bitcoin has been a successful digital commodity. The study was optimistic that Bitcoin would be successful as a store of value and a global currency.

Georgiadis shows the theoretical transaction capacity of the Bitcoin network is 27 TPS, falling far behind modern transaction infrastructure, VisaNet.

Chovin held the pessimistic view on Bitcoin value. The study (Chovin, 2018) showed that Bitcoin price has very little correlation with traditional safe assets, which suggest Bitcoin price is being driven purely by speculation. The study shows the Bitcoin bubble will burst. The study compared Bitcoin with other currency in daily trading volumes and concluded that Bitcoin is not the future of money. Bitcoin price is vulnerable to manipulation. The study showed individuals are believers and institutions are sceptics. The study rejected Bitcoin's role as money, payment system and commodity.

This paper (Cromam et al., 2016) explored the challenges in scaling Bitcoin and Blockchain. Cromam et al. (2016) showed changing block size and interval can improve Bitcoin network throughput substantially in short term. Longer term solutions require redesign on fundamental protocol of Blockchain. The paper (Cromam et al., 2016) illustrated the potential approaches to better scalability and their challenges for the community.

In contrast to the claim that Bitcoin mining mainly consumes clean energy, Vries (2019) shows excessive energy consumption is not the only way Bitcoin impacts the environment. The study (Vries, 2019) concluded renewable energy is not the answer to Bitcoin’s sustainability problem. Vries further examined other available mechanisms, Proof-of-Stake, which do not have significant environmental impact and is able to sustain Bitcoin network.

Cheah and Fry (2015) investigated Bitcoin fundamental value. The study (Cheah and Fry, 2015) undertook economic and econometric modelling of Bitcoin prices. The results showed Bitcoin prices contain substantial speculative bubbles. Cheah and Fry (2015) concluded the fundamental value of Bitcoin is zero.

A study (Stoll, Klaaßen and Gallersdörfer, 2019) proposed a method to calculate carbon emission during Bitcoin mining. The study investigated major mining hardware and mining facility operations and mining pool compositions. Based on localization of IP addresses, power consumption is converted to carbon emissions. The results showed carbon emissions by Bitcoin is comparable to the level of nations such as Jordan, Sri Lanka and Kansas City.

A study (Horra, Fuente and Perote, 2019) found Bitcoin show different properties in short and long term. The study found Bitcoin behaves as a speculative asset in the short term. In the long term, however, speculation does not seem to influence demand for Bitcoin. Instead, demand might be driven by expectations regarding Bitcoin's future utility as a medium of exchange.

Taylor (2017) traced the evolution of the Bitcoin miner hardware, which evolved from CPUs to GPUs to field-programmable gate arrays (FPGAs) to application-specific integrated circuits (ASICs). These ASIC clouds provide a glimpse into the future of planet-scale computing. The hardware evolution process benefits data centre infrastructure. Google has followed this trend and announced the creation of neural-network ASICs for reducing hardware cost and power consumption.

Kugler (2018) showed the electricity consumption of Bitcoin mining activities had raised many concerns. Kugler showed due to the design of proof-of-work, Bitcoin mining in nature is energy consuming. The only way to solve energy consuming issues is to change the protocol. Proof-of-stake has been explored and discussed.

Researchers from various domains have explored the nature of Bitcoin and looked into the potentialities of Blockchain technology. It’s a reflection that Bitcoin and the Blockchain technology have disrupted many business models. There are divided views on Bitcoin from many domains. Optimists from financial sectors believe that Bitcoin is going to replace fiat currency and central bank is to be replaced by cryptography algorithms. This group of people are actively working on pushing Bitcoin to public adoption. On the other hand, pessimists think Bitcoin has no fundamental value. Analysis based on modern financial pricing models are done on Bitcoin and a substantial bubble is found in its current trading price. Well known economists consider Bitcoin as 21st century tulips and it will end with bad results. Opportunists are in the middle of optimists and pessimists. Large crypto funds are setup and seeking for extreme high returns.

Many studies have concentrated on Bitcoin’s electricity consumption and negative environmental effects. Previous studies showed that comparing to mainstream payment network, VisaNet, Bitcoin network consumes much more energy and however the results achieved by Bitcoin network are discouraging. Previous studies failed to uncover the hidden operating cost of VisaNet, which includes data center, fraud detection and human resources. Solutions to the issue of low transaction are being actively discussed in the community. Though researchers have criticized the inability of Bitcoin network handling large volume transactions, the issue is expected to be resolved soon.

Large benefits of Bitcoin brought to the society are not yet quantified. Venture capitalists and private equity funds have invested in Blockchain ecosystem. Hundreds of fintech companies have been incorporated and created thousands of jobs. Blockchain network is applied to other industries and is perfect solution for some use cases. Previous studies failed to identify the benefit of Bitcoin as an innovation initiative. The overall effects of Bitcoin are positive to the economy.

# Chapter 3. Data and methods

## Volatility Index

Volatility index is to measure price deviation. Therefore, volatility index is popular in determining the relative risk of trading certain financial assets. Volatility index measures the average amount which the asset price has deviated from the mean over a period.

* N: a period of time during which asset price is accessed
* : price of asset at period
* : relative to opening price p1 of the period, price change of period
* : price variance over the period of N
* : standard deviation of var

The paper examines Bitcoin price and five assets with high liquidity. Historical trading data are collected from Investing.com. The calculation below is based on two years of one-minute trade data.

* BTCUSD: Bitcoin price in US dollar traded at Bitfinex
* EURUSD: Euro to US dollar exchange rate
* USDJPY: US to Japanese Yen exchange rate
* SGDUSD: Singapore to US dollar exchange rate
* Crude Oil: Crude oil WTI Futures listed on NYMEX
* Gold: Gold Futures listed on COMEX

|  |  |
| --- | --- |
| Figure . Bitcoin Price in US Dollar | Figure . Euro to US Dollar Exchange Rate |
| Figure . US Dollar to Japanese Yen Exchange Rate | Figure . Singapore Dollar to US Dollar Exchange Rate |
| Figure . Crude Oil WTI Futures Listed on NYMEX | Figure . Gold Futures Listed on COMEX |

Table 1 Volatility Index of Six Major Assets

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | BTCUSD | EURUSD | USDJPY | SGDUSD | CrudeOil | Gold |
| volatility | **6.193** | 0.584 | 0.606 | 0.348 | 2.614 | 1.164 |

BTCUSD has the highest volatility index among all assets. Commodities (Crude Oil, Gold) are generally more volatile than currencies (EURUSD, USDJPY, SGDUSD).

## Covariance and Correlation

The paper calculates covariance and correlation between Bitcoin and other major financial assets. Both indicators measure the relationship between Bitcoin and currencies, commodities.

Covariance is a measure of joint variability between the returns of two assets. When two assets move to the same direction, the value of covariance is positive. A positive covariance indicates that the investments on two assets would incur profits or loss at the same period. A negative covariance indicates that two assets move in opposite direction. When one asset A incurs profit, the other asset B is likely incurring loss.

Covariance is a statistical method used to assess the relation between two asset prices movement. For modern portfolio theory, covariance is an important method used to decide what securities to put into a portfolio. In a portfolio, risk and uncertainty can be minimized by combining assets with negative covariances. Covariance assesses whether the mean values of two variables are moving together. If the return of stock A moves higher while the return of stock B moves higher and the return of both stocks decrease together, then these two stocks are said to have positive covariances. Covariances are measured in finance to help in the diversification of investment holdings.

Formula for computing covariance between two assets X and Y:

* : price of asset X at period
* : price of asset Y at period
* : return of asset X at period
* : return of asset Y at period
* : the mean of the x values
* : the mean of the y values
* *N*: the number of data points

Given this information, the formula for covariance is:

Although the covariance does measure the directional relationship between the two assets, it does not reflect the strength of the relationship between the two assets; the correlation coefficient is a more accurate measurement of the strength.

The correlation coefficient is a statistical indicator of the strength of the relationship between the returns of two assets.  Correlation value ranges from -1.0 to 1.0. The value of -1.0 correlation shows a perfect negative correlation, while 1.0 shows a perfect positive correlation. A correlation of 0.0 indicates no linear relationship between the movements of the two variables. A value of 1.0 means that there is a perfect positive relationship between the two variables. There is also a positive change in the second variable with a positive change in one variable. A value of -1.0 means that there is a complete negative relationship between the two variables. This indicates that the variables are going in opposite directions. There is a reduction in the second variable with a positive change in the first variable. A correlation value of 0 means that two variables are independent and there is not linear relationship between their movements.

Pearson correlation tests the intensity of the linear relationship between two variables and its direction. However, it cannot catch nonlinear relationships between two variables and can't distinguish between dependent variables and independents.

The strength of correlation varies in degree, depending on the correlation coefficient value. For example, a value less than 0.1 indicates that there is a weak correlation between two variables. A correlation value of 0.9 or greater suggests a very strong relationship, which is uncommon to observe. In this paper, we primarily compare the correlation coefficient between Bitcoin and other major assets. The absolute correlation coefficient value is not the focus in the paper. The paper mainly analyses which asset has the higher correlation with Bitcoin and identifies the speculative nature of Bitcoin. Because of volatility or wild price fluctuations, investors can use negatively correlated assets or securities to hedge their portfolio and reduce market risk. Most investors hedge a portfolio's price risk, which essentially decreases any capital gains or losses as they want the dividend income or the stock or bond yield.

Formula for computing correlation of two assets:

* : covariance of variables x and y
* ​: standard deviation of x
* ​: standard deviation of y​﻿

Table 2 Correlation Between Six Major Assets

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Assets | BTCUSD | EURUSD | USDJPY | SGDUSD | Gold | CrudeOil |
| BTCUSD | 1.0 | 0.056 | 0.031 | 0.025 | **-0.102** | -0.023 |
| EURUSD |  | 1.0 | 0.327 | 0.731 | 0.036 | -0.092 |
| USDJPY |  |  | 1.0 | 0.381 | 0.148 | -0.067 |
| SGDUSD |  |  |  | 1.0 | 0.119 | -0.084 |
| Gold |  |  |  |  | 1.0 | 0.065 |
| CrudeOil |  |  |  |  |  | 1.0 |

Results show Bitcoin has no strong correlation to any of other assets. Among all of the correlation values, Bitcoin price has the lowest correlation value. Currencies have stronger correlation among the asset group. EURUSD, USDJPY and SGDUSD have correlation values above 0.3. It suggests Bitcoin is treated more as a commodity asset instead of currency. Within the group of BTCUSD, Gold and Crude Oil, Bitcoin and Gold have the highest negative correlation.

## Bitcoin Fund Data

|  |  |
| --- | --- |
| A screenshot of a cell phone  Description automatically generated  Figure . Distribution of Crypto Hedge Fund AUM | A screenshot of a cell phone  Description automatically generated  Figure . Crypto Hedge Fund Launch Median AUM |

As the most liquid cryptocurrency, Bitcoin market capitalization has reached $174 billion (bitcoin.com, Feb 20, 2020). There are 582 alternative currencies, which are inspired by the idea of Bitcoin. These altcoins are catching up with Bitcoin on trading volume, capitalisation and transaction throughput. Ripple has significant market capitalisations of $11.52 billion and Litecoin has $4.47 billion. The competition arises due to shortage of Bitcoin supply and increasing computation difficulties in Bitcoin mining. Bitcoin is the primarily traded cryptocurrency, which accounts for 62.4% of all cryptocurrency capitalisation.

Over the past three years, as the primary choice of cryptocurrency, Bitcoin has begun to mature. A significant number of crypto hedge funds are set up. Most information on the fund remains unpublished and public data is inaccurate. The PWC group gathered data from the hedge fund directly. The report estimates that there are only around 150 active crypto hedge funds, which collectively hold around US$1 billion assets under management (AUM) today. This excludes crypto index funds and crypto venture capital funds.

The AUM, of crypto hedge funds follows the similar distribution pattern to traditional hedge funds. A few large funds account for a large proportion of the total AUM. The distribution has a long tail of smaller funds.

Over 60% of crypto hedge funds have less than US$10 million of AUM. The average AUM is US$21.9 million and the median is at US$4.3 million.

Table 3 Crypto Hedge Fund Management and Performance Fees

|  |  |  |
| --- | --- | --- |
|  | Average Management Fees | Average Performance Fees |
| All funds | 1.72% | 23.5% |
| Fundamental fund | 1.75% | 22.8% |
| Discretionary fund | 1.76% | 23.2% |
| Quant fund | 1.57% | 26.8% |

Median crypto hedge fund fees include 2.0% management fees and 20.0% performance fees

Table 4 Crypto Hedge Fund Return and Beta

|  |  |  |
| --- | --- | --- |
|  | 2018 Return | Beta |
| Median all funds | -46% | 0.82 |
| Median fundamental fund | -53% | 0.75 |
| Median discretionary fund | -63% | 0.74 |
| Median quant fund | +8% | -2.33 |
| Bitcoin | -72% | 1.00 |

A close up of a map

Description automatically generated

Figure . Median 2018 Crypto Hedge Fund Return

Crypto hedge funds use Bitcoin return as an investment performance benchmark. Bitcoin was down 72% in 2018. The median crypto hedge fund return was -46%, which outperformed the benchmark. The return highlights the extremely volatile and risky nature of Bitcoin.

## Bitcoin Ownership and Merchant Adoption

The paper identifies the Bitcoin population as both merchants which accept Bitcoin and Bitcoin users. Major companies have joined the support of accepting Bitcoin as payments. The population of stores which accept Bitcoin are growing steadily.

A close up of text on a black background

Description automatically generated

Figure . Major Companies Accepting Bitcoin Payments

The paper identifies 24 major companies and 63 large stores which accept Bitcoin as either direct or indirect payment methods. Those companies include Microsoft, Wikipedia and Expedia. Goods which can be purchased with Bitcoin includes Adidas and American Eagle Outfitter gift cards, flight tickets on CheapAir and Amazon groceries through Purse.io

A survey released by Hartford Steam Boiler shows one-third of U.S. small and medium-sized businesses accept cryptocurrency as payment for goods and services.

Coinmap records show there are currently 18,740 venues which accept Bitcoin.

A screenshot of a cell phone

Description automatically generated

Figure . Number of Bitcoin Wallets Created

Data published by Statista shows there are currently 44 millions of Bitcoin wallets at the end of 2019.

Table 5 Bitcoin Wallet Balance Distribution

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Balance, BTC | Addresses | % Addresses (Total) | Coins (BTC) | $USD | % Coins (Total) |
| (0 - 0.001) | 14377136 | 48.39% (100%) | 2,996 | 23,726,675 | 0.02% (100%) |
| [0.001 - 0.01) | 7412489 | 24.95% (51.61%) | 29,226 | 231,470,328 | 0.16% (99.98%) |
| [0.01 - 0.1) | 5045670 | 16.98% (26.67%) | 161,923 | 1,282,416,198 | 0.89% (99.82%) |
| [0.1 - 1) | 2084124 | 7.01% (9.69%) | 661,511 | 5,239,122,993 | 3.62% (98.94%) |
| [1 - 10) | 639317 | 2.15% (2.67%) | 1,694,730 | 13,422,139,551 | 9.28% (95.31%) |
| [10 - 100) | 138927 | 0.47% (0.52%) | 4,468,232 | 35,388,084,328 | 24.47% (86.03%) |
| [100 - 1,000) | 14060 | 0.05% (0.05%) | 3,562,039 | 28,211,096,905 | 19.51% (61.56%) |
| [1,000 - 10,000) | 2051 | 0.01% (0.01%) | 4,883,978 | 38,680,767,476 | 26.75% (42.05%) |
| [10,000 - 100,000) | 104 | 0% (0%) | 2,269,949 | 17,977,834,225 | 12.43% (15.3%) |
| [100,000 - 1,000,000) | 3 | 0% (0%) | 523,860 | 4,148,937,733 | 2.87% (2.87%) |

Table 6 Bitcoin Address Richer Than

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 USD | 100 USD | 1,000 USD | 10,000 USD | 100,000 USD | 1,000,000 USD | 10,000,000 USD |
| 21,282,819 | 6,754,859 | 2,459,445 | 592,822 | 126,529 | 11,797 | 1,283 |

The majority of the world’s digital currencies is owned by just a few thousand wallets. More than 21 millions of wallets own only a fraction of a Bitcoin.

## VisaNet

As a payment method, Bitcoin has been compared with existing infrastructure solution, VisaNet. This paper refers to Visa 2019 financial report and finds relevant information on Visa transactions, payment volume, processing time and operating expenses.

Visa has a large team of 19,500 employees in 130 offices across 76 countries. VisaNet infrastructure supports 3.4 billions of cards at over 61 millions of merchant locations.

Table 7 Annual Payment Volume and Transactions of Major Payment Systems

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Visa | Bitcoin | Mastercard | American Express | JCB | Diners Club |
| Payment Volume ($B) | 8,449 | 1,050 | 4,338 | 1,169 | 283 | 172 |
| Total Transactions (B) | 188 | 0.12 | 103 | 8 | 4 | 3 |
| Cards (M) | 3,359 | 44 | 2,022 | 114 | 127 | 63 |

During fiscal year 2019, 188 billions of transactions were processed by VisaNet, equating to an average of 515 million transactions a day. A total volume of $8,449 billions US dollars was processed by VisaNet.

Table 8 Visa and Bitcoin Operating Cost in Past Three Years

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Visa | | | Bitcoin | | |
|  | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 |
| Operating Expenses ($M) | 7,976 | 7,655 | 6,214 | 3,889 | NA | NA |

The cost of Bitcoin is primarily estimated through electricity cost. The paper does not take into account of fixed cost, for instance Bitcoin mining hardware.

## Other industry use cases

Blockchain, the technology behind Bitcoin, offers another method of record keeping. It's a distributed database, which does not allow changes to existing records. Records in the Blockchain network are irrefutable. Blockchain has initiated development of entirely new industries through smart contracts and other applications. The application of Blockchain has extended far beyond the scope of financial services. Out of the digital online world, which is currently dominated by centralized infrastructure, Blockchain establishes a distributed consensus system. Blockchain is considered disruptive technology by many existing industries and offers tremendous opportunities for developing a scalable and open economy. Blockchain is revolutionary technology for many industries to solve long-standing issues and improve efficiency. As the medium to develop innovations, Blockchain addresses some of society’s most glaring inefficiencies: cutting costs, reducing delays and upholding the integrity of data in countless important areas.

This paper analyses three industries, which are actively exploring Blockchain for reducing operating expenses.

### Healthcare

Healthcare is an example of where Blockchain is helping to improve efficiency by storing encrypted patient information that is shared across healthcare providers, removing the need for form filling. Data is stored on a Blockchain network and securely encrypted, significantly reducing the risk of a privacy breach. Healthcare professionals are better equipped to provide well-informed diagnosis and treatment using comprehensive and reliable patient records stored on a Blockchain network. Reduced wait time for patients as past records are quickly accessible, administration costs are reduced, and duplication is avoided.

Blockchain technology will significantly benefit the health-care industry. The healthcare sector has been impacted over the past 30 years by the introduction of centralized data systems, health data control and a policy to concentrate on digitizing medical data in collaboration with multiple service providers of electronic medical records (EMRs). The majority of databases that store knowledge about patients are held by healthcare providers, pharmaceutical companies and other health and medical ecosystem stakeholders. They do not communicate with each other. The lack of interoperability between most longitudinal health data systems at individual (patient) and population (public health) levels explains systemic barriers which are often encountered in the following situations:

When the patients want to seek medical assistance from other healthcare providers;

When clinical trial managers need to verify their participants’ vast medical data;

When pharmaceutical firms need to ensure the validity of medicines that circulate globally;

Due to the failure to exchange data safely and the siloed administration of medical records, patients waste precious time and money obtaining unnecessary medical services (e.g. conducting repeated blood tests or physical checks). In emergencies, doctors and other health care practitioners do not have access into the full medical history of a patient (e.g. clear reports detailed patient allergies, previous or resistant medical conditions, administration of controlled substances, etc.). As a result, the patients are not treated correctly or adequately.

### Real Estate

Blockchain is transforming the real estate industry by creating a seamless, decentralised transaction process that reduces the need for intermediaries and therefore lowers costs. Secure storage and accessibility of verified, unaltered documents and data for a purchase/sale transaction or obtain financing. Decentralised and open property market database where information is published by the public rather than a central body. Reduced transaction fees and costs in a transaction as there will be less of a need for intermediaries and time spent on consultants to broker the transaction.

### Supply Chain

Managing supply chains is a complex process. Supply chains span over international locations, go through hundreds of stages, have large numbers of documents and payments, involve multiple parties and entities and extend over a long period of time. There is growing interest in applying Blockchain technology to transform the logistics industry.

With growing global commerce, the supply chain has evolved with much complexity. Due to lack of transparency in existing system infrastructure, it’s difficult for customers and suppliers to know the value of products and detect illegal and unethical practices. Vendors and suppliers are highly inefficient to figure out who needs what and when.

Blockchain has the chain of command as built-in features and provides supply chain reliability and integrity. Since transactions on the Blockchain network cannot be altered and are distributed across all participants, Blockchain offers transparent and secure record keeping. Blockchain has been applied ultimately to increase the efficiency and transparency of supply chains and manage the process from warehousing, delivery to payment. Since Blockchain ensures every participant has the same version of the records, there is no dispute in recording transactions along the chain.

## Bitcoin Statistics

Table 9 Bitcoin Network Statistics

|  |  |
| --- | --- |
| Description (accessed on Feb 27, 2020) | Value |
| Bitcoin's current estimated annual electricity consumption\* (TWh) | 77.78 |
| Bitcoin's current minimum annual electricity consumption\*\* (TWh) | 50.61 |
| Annualized global mining revenues | $6,008,099,440 |
| Annualized estimated global mining costs | $3,889,109,037 |
| Current cost percentage | 64.73% |
| Country closest to Bitcoin in terms of electricity consumption | Chile |
| Estimated electricity used over the previous day (KWh) | 213,101,865 |
| Implied Watts per GH/s | 0.079 |
| Total Network Hashrate in PH/s (1,000,000 GH/s) | 112,331 |
| Energy footprint per transaction (KWh) | 653 |
| Number of U.S. households that could be powered by Bitcoin | 7,202,054 |
| Number of U.S. households powered for 1 day by the electricity consumed for a single transaction | 22.08 |
| Bitcoin's electricity consumption as a percentage of the world's electricity consumption | 0.35% |
| Annual carbon footprint (kt of CO2) | 36,947 |
| Carbon footprint per transaction (kg of CO2) | 310.39 |
| Market price (US$) | 8,747.05 |
| Average block size (MB) | 1.15 |
| Transactions per day | 341,910 |
| Mempool size – The aggregate size of transactions waiting to be confirmed(Bytes) | 856,300 |

Table 10 Energy Consumption of the Bitcoin Mining Facilities by Location

|  |  |  |  |
| --- | --- | --- | --- |
| Location | Power consumption (megawatts) | % of surveyed facilities | Carbon intensity (gCO2eq/kWh) |
| China | 111 | 47.60 | 711 |
| Georgia | 60 | 25.80 | 231 |
| US | 27 | 11.60 | 489 |
| Canada | 18 | 7.70 | 158 |
| Sweden | 10 | 4.30 | 13 |
| Iceland | 5 | 2.10 | 0 |
| Estonia | 2 | 0.90 | 793 |
| Total / Weighed Average | 233 | 100.00 | 475 |

Table 11 Transaction Throughput of Bitcoin and Visa (accessed on Feb 26 2020)

|  |  |  |
| --- | --- | --- |
|  | Bitcoin | Visa |
| Energy per transaction (kwh) | 653 | 1.51E-3 |
| Cost per transactions ($) | 32.42 | 0.042 |
| Annual transactions (millions) | 120 | 188,000 |
| Annual volumes ($B) | 1,050 | 11,380 |
| Expense ($B) | 3.89 | 7.98 |
| Market capitalisation ($B) | 160.66 | 402.1 |
| Transaction throughput | 27 | 17,883(estimated with 3 times of current transactions processed) |
| Transactions per second | 3.81 | 5,961 |
|  |  |  |

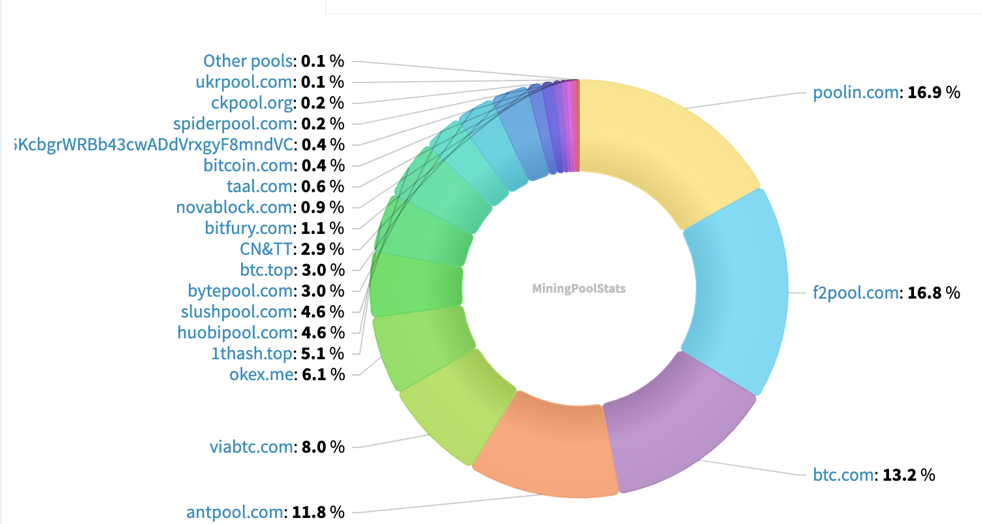


Figure . Bitcoin Mining Pool Hash Power Shares

Single Bitcoin transaction generates the carbon footprint equivalent to that of 775,987 VISA transactions or 51,732 hours of watching Youtube. Single Bitcoin transaction power consumption is equivalent to that of an average U.S. household over 22.08 days. Single Bitcoin transaction produces electronic waste equivalent to the weight of 1.39 'C'-size batteries or 1.97 golf balls.

The calculation in Table 11 includes energy consumption of VISA data centres, energy consumption of offices is not included. Due to completely different design infrastructure, a single Bitcoin transaction consumes thousands of times more energy than VisaNet. The results suggest that Bitcoin transaction cost is unrealistically high.

Table 12 Bitcoin cost breakdown. Includes cost incurred by all nodes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | at max throughput | | at *de facto* throughput | |
|  | cost/tx | percentage | cost/tx | percentage |
| Mining: proof-of-work | ~$0.8-$1.7 | ~56% | ~$3.6 | ~56% |
| Mining hardware | ~$0.6-$1.3 | ~42% | ~$2.7 | ~42% |
| Transaction validation | ~$0.002 | ~0.2% | ~$0.008 | ~0.2% |
| Bandwidth | ~$0.02 | ~2% | ~$0.08 | ~2% |
| Storage (running cost) | ~$0.0008/5years | | | |

## Electricity Consumption

The debate on Bitcoin electricity consumption has started since the beginning of Bitcoin mining. The Bitcoin network is extremely energy hungry by design. To achieve the ultimate goal of processing financial transactions without intermediaries, the Bitcoin network needs to calculate a huge amount of hash calculations. Therefore excessive electricity consumption is necessary to keep the infrastructure in operation.

A bottom-up approach (Marc Bevand, 2017) is developed to estimate the global electricity consumption by Bitcoin miners. The model starts with available mining hardware power consumption. With this model, The Cambridge Bitcoin Electricity Consumption Index (CBECI) provides lower bound and upper bound estimates. The lower bound assumes that all miners use the most energy-efficient equipment available on the market. The lower bound estimation is the absolute minimum total electricity expenditure. The upper bound assumes that all miners always use the least energy-efficient and still profitable mining hardware available in the markets. The upper bound estimation is the absolute maximum total electricity expenditure. In between lower bound and upper bound, the best-guess assumes that miners use a basket of profitable hardware rather than a single model.

Table 13 Estimated Lifetime Costs for an Antminer S9 under Various Lifetime Assumptions and a Production Cost of US$500 (Assuming Electricity Costs 5 US Cents per Kilowatt-Hour)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Machine | Expected Lifetime (Years) | Estimated Production Costs (US$) | Lifetime Electricity Use (kWh) | Lifetime Electricity Costs (US$) | Total Lifetime Costs (US$) | Electricity Costs/Total Costs (%) |
| Antminer S9 | 2 | 500 | 24,037 | 1,202 | 1,702 | 70.6 |
| Antminer S9 | 1.5 | 500 | 18,028 | 901 | 1,401 | 64.3 |
| Antminer S9 | 1 | 500 | 12,019 | 601 | 1,101 | 54.6 |

Antminer S9 was released in mid 2016, which was then the most powerful mining hardware. Table 13 calculates S9 lifetime production cost and electricity cost. Electricity price 5 cents per kWh is expected to be the average cost. Bitmain could operate in countries, where electricity is only 4 cents per kWh. With two years of expected lifetime, electricity cost could be 70.6% of total lifetime costs. Table 13 shows that Bitcoin miners spend most of their cost in electricity. The profit margin depends heavily on electricity price.

Figure . Bitcoin Electricity Consumption, TWh (annualised)

On Mar 2, 2020, the estimated electricity consumption is 92.39 Twh, lower bound 42.46 Twh and upper bound 157.06 Twh. Bitcoin consumption represents 0.35% of total electricity production and 0.40% of total electricity consumption.

A screenshot of a cell phone

Description automatically generated

Figure . Bitcoin Electricity Consumption Ranking Across Global Countries

According to the CIA factbook, if Bitcoin is considered as a country, Bitcoin electricity consumption is ranked as 38th in all countries. Bitcoin consumes more electricity than Chile and Austria. Bitcoin consumes 0.35% of world total electricity consumption.

Table 14 Electricity Capacity, Consumption and Price by Country

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Country | Capacity (Gwh) | Consumption (Gwh) | Surplus Ratio | Price ($US cents) |
| China | 14,418,960 | 5,564,000 | 61.4% | 14.6 |
| United States | 9,408,240 | 3,902,000 | 58.5% | 18.1 |
| Japan | 2,822,472 | 943,700 | 66.6% | 21.2 |
| India | 2,705,088 | 1,137,000 | 58.0% | 18.2 |
| Russia | 2,308,260 | 909,600 | 60.6% | 8.4 |
| Germany | 1,787,916 | 536,500 | 70.0% | 25.6 |
| Brazil | 1,316,628 | 509,100 | 61.3% | 17.5 |
| Canada | 1,292,976 | 522,200 | 59.6% | 12.3 |
| France | 1,132,668 | 450,800 | 60.2% | 13.6 |
| Italy | 1,024,920 | 293,500 | 71.4% | 16.8 |
| Spain | 934,692 | 239,500 | 74.4% | 26 |
| Korea, South | 902,280 | 507,600 | 43.7% | 11.4 |
| United Kingdom | 829,046 | 309,200 | 62.7% | 17.7 |
| Turkey | 640,794 | 231,100 | 63.9% | 8.9 |
| Iran | 638,954 | 236,300 | 63.0% | 5.2 |
| Saudi Arabia | 604,878 | 296,200 | 51.0% | 7.4 |
| Australia | 587,183 | 229,400 | 60.9% | 20.4 |
| Mexico | 573,342 | 258,700 | 54.9% | 16.5 |
| Ukraine | 498,619 | 133,200 | 73.3% | 6.4 |
| Indonesia | 478,121 | 213,400 | 55.4% | 10.9 |
| Taiwan | 425,824 | 237,400 | 44.2% | 11.7 |
| South Africa | 414,173 | 207,100 | 50.0% | 16.1 |

Bitcoin mining is looking for countries with electricity surplus and low electricity price. Mining activities are migrating across multiple nations. Data from CIA and World Bank shows China has the most surplus electricity production and reasonably low electricity price.

Table 15 Breakdown of Global Renewables Penetration in Bitcoin Mining

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region | Global Mining Share | Renewables Penetration | Share of Renewables for Mining | Share of Fossil/Nuclear for Mining |
| Sichuan | 48.0% | 90.1% | 43.2% | 4.8% |
| Relevant Remaining China | 12.0% | 47.1% | 5.7% | 6.3% |
| Relevant Western Regions | 35.0% | 79.4% | 27.8% | 7.2% |
| Rest of World | 5.0% | 18.2% | 0.9% | 4.2% |
| Global Total | 100% |  | 77.6% | 22.4% |
| Sources: Morgan Stanley Research (Oct 2018), EIA (Nov 2018), Natural Resources Canada (Sep 2018), R2E2 (Jul 2017), SATBA (Feb 2017), CoinShares Research (May 2019) | | | | |

Study (Bendiksen, Gibbons, 2019) estimates that 60% of global mining is happening in China. Sichuan province alone accounts for 50% of global hashrate, with the remaining 10% evenly split between Yunnan, Xinjiang and Inner Mongolia. The share of Bitcoin mining in China has been increasing over the years. Yunnan, Guizhou and Sichuan provinces provide plenty of hydropower in the rainy season. Electricity prices are among the lowest in the world during this time, making it one of the most desirable mining regions on the planet.

The study shows, out of the rest 40% of mining powers, 35% of global mining is evenly distributed between Alberta, British Columbia, New York, Washington, Quebec, Newfoundland and Labrador, Iceland, Sweden, Norway, Georgia and Iran. The reaming 5% is distributed globally.

## Hardware Evolution

A screenshot of a map

Description automatically generated

Figure . Bitcoin Mining Total Hash Rate

In 2009 Bitcoin mining was conducted by Bitcoin enthusiasts as a hobby. The first-generation miners used multi-core CPUs to generate new Bitcoin. Mining difficulty then was so low that developers could generate a few dollars a day and electricity cost was trivial. Early adopters can spend minimum investment in setting up mining hardware. CPU is the least powerful mining hardware. Nowadays CPU mining has been outdated. Compared to mainstream ASIC devices, CPUs could run for decades without earning a single coin.

The CPU could provide computation power at 10 MH/sec. The most popular graphics cards (GPU), ATI 5970, compute at rate 800 MH/sec. Graphics cards significantly increased Bitcoin mining power. Graphics cards are far more efficient than CPU in terms of power consumption per unit of work. With the introduction of dedicated hardware designed for mining, the Bitcoin mining difficulty has increased to a level that even GPU has no advantage of. GPU is not profitable with cheap electricity.

The introduction of Field Programmable Gate Array (FPGA) brought the Bitcoin mining difficulty to another level. FPGA is an integrated circuit, which is configurable after being built. The design enabled the Bitcoin mining factory to buy the chips in volume and reserve most of the computation power for Bitcoin mining. FPGA changed the Bitcoin mining industry. FPGA was the first dedicated hardware designed specifically for Bitcoin hash generation. While GPU provides a hash rate 600 MH/sec with 400 watts of power, FPGA can generate hash at 826 MH/sec at 80 watts of power. The hash rate breakthrough made the first large Bitcoin mining farms possible.

Application-Specific Integrated Circuit (ASIC) is the latest technology for mining hardware. It is specially fabricated for hash calculations only. Though the hardware is expensive and time consuming to manufacture, they provide unprecedented advantages over other mining hardware. High end ASIC provides a hash rate 118 million TH/sec (Figure 15) and is called to be the ‘end-of-the-line’ technology in Bitcoin mining. They cannot be replaced in the short term.

Dedicated mining devices were invented. A piece of hardware is designed for hash calculation. The dedicated hardware cannot be used for other purposes. Dedicated devices increased mining power five-fold, which enabled mining farms to be constructed and profitable. The Bitcoin mining industry has turned into a profitable business. Current generation of mining farms are running ASIC machines and coolers, which require excessive electricity. Having access to cheap electricity grants ASIC miners superior advantages over other competitors. It’s the cheap electricity that enables Bitcoin mining farms to be profitable and popular.

Since electricity bills are the major cost of mining farms, miners are sensitive to electricity price. Electricity costs drive miners to search for cheaper electricity. Mining companies have been looking to migrate mining farms to places like Canada and Sichuan province which offer cheaper electricity. The arbitrage over cheaper electricity incentivizes more R&D in the energy industry. Huge electricity consumption by mining farms encourages further innovation of renewable energies. Demand for low electricity costs passed down to the supply chain. With increased supply, power generators increase power plant capacity and achieve higher efficiency through economies of scale. In return the whole society is expected to benefit from innovations in the energy sector. Eventually the innovations in renewable energy will drive down the cost of the society.

# Chapter 4. Results and Discussion

## Bitcoin is a highly speculative asset

This paper compares Bitcoin with major currencies and commodities. Volatility index (Table 1) shows Bitcoin has the highest volatility among all major assets. The high volatility is reflected in daily Bitcoin price (Figure 1). The high volatility is linked directly to risk factor in portfolio management. The paper finds investment in Bitcoin is generally riskier than other assets. Table 2 shows that out of five assets, Gold has the strongest negative correlation with Bitcoin. The paper finds that Bitcoin is not a safe-haven asset, which is not consistent with Bouri, Jalkh, Molnár and Roubaud. The paper finds evidence (Section 3.1 and 3.2) that Bitcoin price has minimum correlation with either currencies or commodities. Therefore, Bitcoin is an ideal investment vehicle for portfolio diversification.

Bitcoin provides a new means of payment transfer, which assigns Bitcoin with its unique fundamental value. There are fierce debates over Bitcoin fundamental value. The volatility in Bitcoin price reflects the conflicts among these points of view. Whether Bitcoin has fundamental values, is the key factor of a good investment.

 As the Bitcoin price rose to a historical high at the end of 2017, fund data (Figure 8) shows investor interest peaked during the market rallying period. Funds which were launched in the first quarter 2018 had the highest AUM. Bitcoin price was down 72% in the year 2018 (Figure 9). It was a challenging year for investment in Bitcoin. The absolute return of the hedge fund is -46%, which performed better than the market -72%. The extremely volatile fluctuation in price highlights the high-risk nature of Bitcoin.

Starting from the second half of 2018, the fundraising environment is challenging, which reflects the panic caused by the Bitcoin price abrupt slump. Funds launched in 2019 have a smaller median AUM. Bitcoin price movements have heavily affected market sentiment over crypto hedge funds. Most funds use the Bitcoin price as a benchmark. Overall, the crypto hedge fund outperforms the benchmark and adds some alpha.

In the short term Bitcoin behaves as a speculative asset. This paper agrees that Bitcoin prices contain a substantial speculative bubble component. In the long term, investors regard Bitcoin future utility as a breakthrough medium of exchange. The long-term demand drives the Bitcoin price.

Since Bitcoin fundamentally lies in the future of revolutionary application, the fundamental value of Bitcoin should not be modelled with a typical financial pricing model. This paper disagrees with the previous claim that Bitcoin has zero fundamental value. Bitcoin price turbulence is expected due to high volume of speculation. The short-term fluctuation in price is considered a tech crash. Certain investors consider Bitcoin as a safe-haven asset and regard it as digital gold. However, Section 3.1 and 3.2 shows correlation between Bitcoin and Gold does not show any distinctive relations. This paper disagrees with the view that Bitcoin is a safe-haven asset. Bitcoin and gold have different fundamental values and they will not replace one another. This research finds that Bitcoin represents a fundamentally different investment asset class compared to existing assets. The decentralized asset shows dissimilar characteristics with other asset classes and has minimum correlation with others. Bitcoin price movements are driven primarily by speculation trading behaviours.

It can be a serious problem when cyber criminals target Bitcoin transactions. On February 28 2014, Mt. Gox announced that 750,000 of customers’ Bitcoin and 100,000 of own Bitcoins, which were worth $473 million then, were stolen. The company filed bankruptcy protection. On May 7 2019, Binance announced that 7000 Bitcoin, which were worth $40 million, were withdrawn by hackers. Through phishing and viruses, the hackers obtained a large number of user information. Hackers had gained unauthorized access to a hot wallet containing around 2% of its total Bitcoin holdings. Phishing and viruses were exploited to get user data and circumvent security measures, preventing the transactions from being blocked by Binance. Hackers might target business by infiltrating company data systems and invalidate cryptocurrency transactions. The company had set up an emergency fund which would fully cover the loss in the incident. No user funds were affected.

Since the banking system is not involved in the transaction process, no authority regulates the operations. When fraud losses occur, business owners have nowhere to turn for chargeback. Business owners should have data security and insurance measures to protect business from cyber fraud and financial loss.

## Bitcoin is not ready as a stable currency

Initially designed as a global payment network, Bitcoin is often compared with traditional payment systems. Bitcoin provides different value propositions. Bitcoin functions as an open distributed value transfer system, which anyone can join without requiring permission. Bitcoin optimists consider it as a synthetic commodity money, which can be used as a store of value in the long-term.

Fiat currencies are backed by the full faith and credit of the government that issued them and circulated within its jurisdiction. On the other hand, Bitcoin is backed by math instead of the government. Bitcoin believers thought that it would replace cash as a relatively anonymous way to pay for everything from groceries to morning coffee. To be adopted as mainstream currency, Bitcoin is faced with three main challenges: price stability, ownership and transaction cost.

Currency is defined as a medium of exchange and a store of value. Compared to major currencies, Section 3.1 shows that Bitcoin has the highest volatility in price. It’s not uncommon to observe Bitcoin daily price fluctuates up and down by 10%. The crash of Bitcoin price at the end of 2017 discourages users to store a large portion of personal assets.

The majority of Bitcoin is owned by just a few thousand wallets (Table 5). The majority of wallets own only a small fraction of Bitcoin value. Data (Coinmap) shows 18,740 venues accept Bitcoin across the globe. The ownership of Bitcoin is trivial to push Bitcoin as a global currency.

In order for transactions to be successful, Bitcoin transactions need to be processed by miners. Blockchain network can only process one block per 10 minutes. Transactions compete for space inside each block. Users of Blockchain network prefer transactions with the highest fee attached, which is awarded by Bitcoin senders. Therefore, in order to get their transactions to be processed successfully and quickly, Bitcoin senders must pay higher processing fees. To use Bitcoin as cash, users have to pay extra dollars. It would be an issue when it comes to the claim that Bitcoin would replace cash. Users are not used to paying extra dollars in daily cash transactions. Processing fees discourages Bitcoin usability and adoption. The Bitcoin’s scalability issue is discussed in Section 4.3.

## Scalability is the obstacle to wide adoption of Bitcoin as method of payment

Due to Bitcoin’s distributed infrastructure design, anyone can join the Bitcoin network as miner and process transactions. Total number of Bitcoins is capped at 21 million. The rate of Bitcoin transactions is limited at ten minutes per block. Block size is hard coded as one megabyte. These constraints impose a ceiling on the throughput of Bitcoin network transactions. With the estimation of median transaction size, the transaction processing capacity is 7 transactions per second (Table 11). Theoretically the maximum transaction throughput is 27 transactions per second. Transaction throughput of the Bitcoin network is limited by the block size, which is a hard coded parameter currently. Various solutions to this limit, and plans to remove it completely, have been proposed over Bitcoin's history. Transaction throughput is independent of the network’s electricity consumption. More participants in Bitcoin networks would certainly increase electricity consumption but does not lead to more transactions.

Section 3.5 describes VisaNet throughput and costs. Comparing to VisaNet, Bitcoin network processes 0.06% of Visa transactions and 12.4% of Visa volumes. VisaNet currently handles 5,961 transactions per second (Table 11). Taking into account redundant computation power, VisaNet could potentially handle up to 3 times of current capacity. An estimate of throughput of VisaNet is 17,883 transactions per second, which is 662 times of Bitcoin network processing capacity.

To match the performance of a mainstream payment method, a few parameters of Bitcoin networks need to be reviewed. The Bitcoin community proposes various solutions to address the scalability issue. Block size determines how many transactions could fit into one block. Bitcoin Cash is a hard fork of Bitcoin increasing the maximum block size to 8 megabytes. Interval controls the rate of new blocks created in the network. With the current interval setting to 10 minutes, a total of 21 millions of Bitcoin will be mined out by year 2140. A proposal to allow more blocks to be created is proposed, which targets to handle more transactions. It’s only first step to improve throughput and at the same time retain decentralization system infrastructure.

The lightning network implements a smart contract in the Bitcoin network which opens private payment channels between peers who participate in the transaction process. Every participant would have one channel open to the Bitcoin network. Participants would proceed transactions amongst themselves in their private channels. Only the final outcome of the transaction would be broadcasted to the Bitcoin network. This design reduces the transaction size and allows more transactions to be processed. The design proposed by lightning network has been implemented on Litecoin network. The lightning network could achieve cost efficiency and scalable networks.

The total amount of Bitcoin that will ever exist is 21 million, and as mining rigs consume more electricity, miners incur higher bills for power, and the incentive for Bitcoin mining is declining. Finally, the Bitcoin mining profits alone won't be enough to cover the energy costs. In the future, miners would have to offset their payment of electricity costs with money from the transaction fees they earn to sign a contract. Transaction fees are essential incentives for miners to verify the payment. On the other hand, high transaction fees discourage users to use Bitcoin for small value payment. Increasing transaction throughput per second would further drive down the transaction cost.

This paper shows that the main limitations to wide adoption is the low number of transactions per block. After its limitation is overcome, the Bitcoin network’s economic efficiency, operational efficiency and service efficiency are expected to increase to a level, at which it may operate as a workable global payment method.

## Bitcoin’s electricity consumption can be justified

Blockchain record keeping is secured through use of computation power. New transactions are grouped into a block. Each block contains SHA-256 cryptographic hash of the previous block and is broadcast into the network. Proof-of-work keeps Blockchain records unalterable, complete and consistent. The PoW requires miners to find a number, which is called nonce. The correct cryptographic hash is extremely time-consuming to produce, but easy for any peer in the network to verify. At the time of writing this paper (Mar 22th, 2020), mining difficulty is around 16.6 trillion.

The proof-of-work infrastructure makes it computationally infeasible to alter Blockchain records. In order for a dishonest peer to modify one block, he has to modify all subsequent blocks of the network. As new blocks are mined and added into the Blockchain network, the difficulty of modifying a block increases. With such a design, proof-of-work makes mining activities expensive. It’s exponentially expensive for a malicious miner to attack the network. An attacker would have to consume the same amount of electricity, which is used to generate historical blocks. When the Blockchain mining community has consumed electricity at the same scale with Chile (Figure 14), attackers will have a very high price to pay for the electricity bill.

To increase the chances of solving a block, miners need to increase their hash rate or hash power, which requires substantial investment on hardware and electricity. Miners with greater influence in the Blockchain network would have more to lose when they tamper with the network and fail. Proof-of-work infrastructure design benefits honest players more than attackers. Although Bitcoin electricity consumption is large in absolute value (Figure 13), it’s comparable to VisaNet operating expenses.

Bitcoin is criticised for its obvious electricity consumption. Resources consumed by the traditional banking system are far less obvious. Every transaction of VisaNet is processed by a huge data centre. Hundreds of thousand servers drive fraud detection and account clearing. Hundreds of thousand operation staffs check risk parameters and money laundering regulations. All of these costs incurred by VisaNet are reflected in operating cost (Table 8), which is twice of Bitcoin electricity bills. On the other hand, the Bitcoin network achieves a level of security for censorship resistance. Miners population does not affect transaction throughput. When transaction volume grows ten times bigger, it does not need ten times more miners.

The paper finds that electricity consumption is necessary to maintain Blockchain ledger consistency and prevent double spending issues. The electricity cost pays for keeping track of assets, reconciling them, securing transactions and fraud prevention. Although the amount of energy which mining operations consume is massive, the paper finds that benefit of Bitcoin mining outweighs the cost. Bitcoin network security is guarded by huge computation power. Electricity consumption is the price to be paid for the secure distributed ledger, which is perfect for storage and transfer of value. Blockchain is currently at experimental stage, which is necessary for future massive adoption. The infrastructure of Blockchain is sub-optimal in the beginning stage.

In the future, with the solutions to Blockchain scalability being successfully implemented, Blockchain efficiency in terms of energy consumption and transaction volume will increase significantly. As the Blockchain network infrastructure develop, electricity consumption would optimize gradually.

## Bitcoin mining is electricity buyer of last resort

A huge amount of hash calculations is necessary for its goal of processing financial transactions without central authority. Electricity is the major cost for these calculations. Bitcoin is energy-hungry by design.

Miners are actively searching for regions which produce electricity at much lower price. China-based miner, Bitmain, has publicly announced that they are setting up new mining facilities overseas in countries with low cost and surplus of electricity supply. When Bitcoin mining is using abundant supplies of renewable electricity, it is beneficial for both miners and local governments. Although local governments ban Bitcoin trading, mining activities remain legal in most countries.

Taking advantage of the cheap land, abundant electricity, low population density and cold climate, Bitcoin miners have moved to Sichuan, China, which turns Sichuan the capital of the world's Bitcoin mining industry. The Bitcoin Mining Network report (Bendiksen, Gibbons, 2019) estimates that China hosts 60% of world Bitcoin mining activities. Sichuan province contributes 50% of global mining and Yunnan, Xinjiang and Inner Mongolia share the remaining 10% of global hashrate. Sichuan, Yunnan and Guizhou are rich in hydro energy in the rainy season. As a result, electricity prices are among the lowest in the world. The lowest electricity makes Sichuan the most attractive region for Bitcoin miners. More miners are expected to migrate factories to Xinjiang and Inner Mongolia during the dry season.

Electricity is cheap in certain locations is because demand does not match up in these locations and the electricity uses in these locations are not broadly deployed, and there are no efficient distribution networks for electricity. One of the challenges with rapidly deploying and developing energy is that a power plant is not built for the demand it has today, but for the demand that develops over the next 15 years. Investment are necessarily ahead of the demand. Moving energy across countries is expensive when distribution network is not ready. China is facing an issue that the places where electricity is needed and times when electricity is needed are almost always not the places and time where electricity is available. A 50-meggawatt plant could be under construction where the present demand is only 15 megawatts.

Locations of electricity production and consumption are usually separate. Power grids and hydropower plants are built for future demands, which cost a large capital budget. Local power generators are in favour of Bitcoin mining activities. Bitcoin miners generate large cash flows for power generators, which incentivize power generators to produce at prices below average. Power plant projects could break even in much shorter period. Bitcoin mining acts as electricity buyer of last resort. Rocketing price drives demand for Bitcoin mining, which boosts the economies of areas that produce surplus electricity.

Table 14 shows China has the largest amount of excessive electricity in supply. With government subsidies, China's electricity price is maintained at the mean level of top twenty countries. Since electricity is subsidized by the government, a significant portion of Bitcoin mining is performed in China (Table 15). Bitcoin miners thrive for cheap electricity and migrate to regions that have excess power supply. China, Iran, Russia and Iceland have attracted their share of bitcoin miners. Bitcoin mining business model is power arbitrage. Bitcoin mining is not sustainable in places where electricity is expensive. Places where hydroelectric power is plentiful attracts major Bitcoin mining activities. Study (Bendiksen, Gibbons, 2019) shows that 78 percent of Bitcoin mining operations are powered by renewable energy, which would have been wasted if not used for Bitcoin mining.

Power grid and generator infrastructure are built-up to sustain future developments, which tend to be underutilised for long periods of time. Bitcoin mining changes the power generator infrastructure business model fundamentally, which could turn loss making renewable projects profitable.

Bitcoin mining is not a waste of resources. The energy consumption in mining is misrepresented. Cryptocurrency mining is one of the few industries that is completely geographically independent. It does not matter where the data centre is located. Electricity price is the dominating factor. It allows the miners to choose the location of mining system based entirely on the local cost of electricity. Essentially mining is doing market arbitrage for the cheapest source of electricity. Bitcoin mining could strengthen the economic case of such electricity plant. Instead of paying off the electricity plant in five years, the Bitcoin mining plant pays off in one year, which would be wasted otherwise. Bitcoin mining amortized power plants in a much shorter period. From the perspective of balancing energy demand and supply on a global scale without distribution networks, the decentralisation of Bitcoin is driving the decentralisation of energy production.

## Bitcoin is driving innovation initiatives

As the underlying technology of Bitcoin network, Blockchain solves the fundamental security issue of distributed ledger. It has been well exploited to solve current financial industry problems and tested on non-financial industry problems. The technology has much more to offer than just Bitcoin. A number of Blockchain projects in non-financial industries have been proven successful.

When Bitcoin miners migrate into an area and stress the grid, energy firms respond by raising fees. That might force miners to either shut down or take actions to dramatically boost their equipment’s energy efficiency. As a result, electricity bill has incentivized miners to upgrade from GPU to FPGA, recently to ASIC. This trend has been adopted by Google to redesign its data centre hardware. Operating the largest data centre network, Google has turned to ASIC, which is built for a dedicated task. ASIC can perform 30 times better than general purpose chips. ASIC can do one thing and can perform better than anything else. Bitcoin mining farms are the largest testing ground for ASIC applications. Since the introduction of ASIC into Bitcoin mining, the total mining hash rate has increased multiple fold to 120 million of TH/s (Figure 15).

The study offers an overview of Blockchain technology and a variety of its business implementations and shows how existing business models could be disrupted. Blockchain technology is demonstrated to be able to influence several aspects of business models. This paper identifies three key ways in which Blockchain technology can impact and disrupt business models: by authenticating traded products, by disintermediating, and by reducing transaction costs.

Blockchain challenges the fundamental modern infrastructures and is set to revolutionize the business models and market opportunities. A number of convincing practical applications in both financial and non-financial sectors have been implemented. Section 3.6 shows Blockchain can help non-financial industries by reducing two types of costs for business - the cost of networking and verification. Major financial companies like Visa, Mastercard, banks and NASDAQ are betting on Blockchain to test implementations of existing business models. Some of them are looking in the world of Blockchain for new business models. The purpose of early adopter is to ensure that they are ahead of the curve in terms of Blockchain's regulatory environments.

The Blockchain stands to disrupt many areas of society and hence it is important to explore its usage from as many perspectives as possible. This paper discusses developments in Blockchain technology on the diffusion of innovation curve. As the curve indicates, in terms of its use by multinational corporations, Blockchain is in the innovation stage. With major firms making investments, Blockchain may see the standardization and adoption. The insights derived from the academic literature and social media have been used to classify industries into five stages of the innovation-decision process, namely, knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). On innovation curve, adopters can be classified into five categories such as innovators, early adopters, early majority, late majority and laggards (Rogers, 2003). Blockchain has the diffusion effects on society in the economic, political and social contexts and had been implemented in multiple applications. Computer science and finance service are early adopters of Blockchain. Supply chain, medical sector and real estate have considered Blockchain to improve operation efficiency. Insurance and finance have landed at confirmation stage of the innovation-decision process. Supply chain and real estate are at implementation stage of the process. Due to regulation on medical records, healthcare is improving in persuasion stage.

Despite of the related threats, the paper envisages that Blockchain technology is exploring more adoption. For now, a few of start-ups can be winners and most of them will fail. In a decade or two, the society will be seeing substantial adoption.

It's obvious that the consequences of Blockchain technology are important for society and solve problems in the real world. The use scope of Blockchain remains to be explored by the society.

# Chapter 5. Conclusion

This paper builds a complete picture on Bitcoin and Blockchain in general. This paper builds financial models with popular financial indicators. Under these models, Bitcoin is compared with major commodities and currencies. This paper findings are that Bitcoin is not correlated with major commodities and currencies. This paper examines Blockchain transaction throughput as a payment network. To become a mainstream payment network, Blockchain should achieve the same throughput level of VisaNet.

Bitcoin is not a pure financial asset. Financial pricing model is not applicable to calculating Bitcoin fundamental value. Bitcoin price contains substantial speculative behaviours. 150 crypto hedge funds with US$1 billion assets under management, are actively investing in Bitcoin and altcoins.

Bitcoin is not ready yet as a daily currency for purchasing groceries due to a few design flaws. Bitcoin’s inability to charge back holds back both merchants and consumers of using it as payment methods. Bitcoin transaction throughput is limited by its scalability design. To be a global financial infrastructure, Bitcoin should dramatically increase its throughput, which currently processes 1 block in every 10 minutes and 250 transactions per block. Referring to Visa network, Bitcoin scalability is expected to increase to 1000 times. More aggressive scaling is being explored, which requires fundamental protocol redesign on Blockchain. The paper illustrates a variety of solutions to scalability.

Starting with software engineering and asset management, Bitcoin has diffused to a much broader range of industries. It is computationally infeasible to alter information stored within Blockchain, which requires an excessive amount of computing power. Millions of independent peer systems uphold the Bitcoin network, as a result data integrity and security of the network is guaranteed. Data integrity and security appeals industries and solves their multiple party trust issues. Blockchain offers decentralized solutions to business which require trust among multiple parties. Blockchain solves the issue of trust and intellectual property. Use cases have been discovered in industries, healthcare, real estate and supply chains.

Bitcoin mining evolves from CPU, GPU, FPGA and now primarily uses ASIC machines. Hardware evolution process boosted the IC industry and gaming industry.

With 5 mining pools accumulated to 66.7% of total mining power, the Bitcoin network is facing challenges from the community inside. Bitcoin decentralisation design has been gradually dominated by large mining farms. Although China banned Bitcoin exchange trading and many countries have raised regulation rules to tackle black market activities in Bitcoin trading, Bitcoin mining is legal in most countries and especially preferred by countries which have surplus electricity supply. Bitcoin mining activities are energy arbitrage, which are always seeking the cheapest energy. As a result, Bitcoin provides substantial cash flows to hydropower plants and in the long term stimulates power generator shift from coal or oil to clean technology. The paper findings are consistent with the view that Bitcoin mining is acting as global electricity buyer of last resort.

Bitcoin is more than another speculative and volatile financial asset. Bitcoin is the first version of decentralised cryptocurrencies and is in the early stage of publicly used payment channel. The technologies behind Bitcoin represent the medium to develop innovations that can address some of society’s most glaring inefficiencies: cutting costs, reducing delays and upholding the integrity of data in countless important areas.

The Blockchain technology drives great innovations relating to industries beyond financial services. Society benefits from significant implications of Blockchain. Revolutionary applications of Blockchain technologies are aimed at solving real-world problems on a global scale. Societies and governments play positive roles in transforming Bitcoin from money laundering into revolutionary applications.

# Chapter 6. Future Studies

The study is built on the technical profile of Bitcoin and Blockchain. Technical indicators are exploited to assess the nature of Bitcoin. The diffusion effects of Bitcoin are discussed in the context of financial assets, transaction throughput and disruptive business models of other industries. The study lacks analysis on the effects of Bitcoin on government fiscal and monetary policies. Bitcoin are expected to grow into global currency by optimists. When governments have no control over the currency’s issue and transaction authority, it posts huge challenges to the effectiveness of the fiscal and monetary policies. The decentralization nature of Bitcoin could cause central banks to predicate money demand inaccurately. Future studies can address the effects of Bitcoin on government fiscal policies and central bank monetary policies.

# References

Barber, S., Boyen, X., Shi, E., & Uzun, E. (2012). Bitter to Better — How to Make Bitcoin a Better Currency. Financial Cryptography and Data Security 399-414.

Batsaikhan, U. (2017). Cryptoeconomics - the opportunities and challenges of blockchain. IDEAS Working Paper Series from RePEc.

Bendiksen, C., & Gibbons, S. (2019). THE BITCOIN MINING NETWORK. Retrieved from https://coinsharesgroup.com/assets/resources/Research/bitcoin-mining-network-june-2019-fidelity-foreword.pdf:

Blockchain.com. (2020). Blockchain Charts. Retrieved from https://www.blockchain.com/en/charts

BOTOŞ, H. M. (2017). Bitcoin Intelligence – Business Intelligence meets Crypto Currency. CES Working Papers, IX(3).

Bouri, E., Jalkh, N., Molnár, P., & Roubaud, D. (2017). Bitcoin for energy commodities before and after the December 2013 crash: diversifier, hedge or safe haven? APPLIED ECONOMICS, 49.

BP. (2019). BP Statistical Review of World Energy. Retrieved from bp.com:

CCA. (2020). Cambridge Bitcoin Electricity Consumption Index. Retrieved from cbeci.org

Cheah, E.-T., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. Economics Letters.

Chovin, L. (2018). International Markets – Bitcoin Believers Versus Sceptics. Credit Control, 39, 52-56.

Chuen, D. L. K., & Low, L. (2018). Inclusive fintech : blockchain, cryptocurrency and ICO: New Jersey : World Scientific.

CIA. (2017). Electricity - Installed Generating Capacity. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/rankorder/2236rank.html

Cocco, L., Pinna, A., & Marchesi, M. (2017). Banking on Blockchain: Costs Savings Thanks to the Blockchain Technology. future internet.

Croman, K., Decker, C., Eyal, I., Gencer, A. E., Juels, A., Kosba, A., . . . Wattenhofer, R. (2016). On Scaling Decentralized Blockchains. Financial Cryptography and Data Security, 106-125.

Crosby, M., Nachiappan, Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). BlockChain Technology: Beyond Bitcoin. Applied Innovation Review(2).

Digiconomist. (2020). Bitcoin Energy Consumption Index. Retrieved from https://digiconomist.net/bitcoin-energy-consumption

Finance, C. C. f. A. (2019). Cambridge Bitcoin Electricity Consumption Index. Retrieved from https://www.cbeci.org/

Forsyth, R. W. (2017). 21st Century Tulips. Up & Down Wall Street.

Georgiadis, E. (2019). How many transactions per second can bitcoin really handle ? Theoretically.

Grover, P., Kar, A. K., & Janssen, M. (2019). Diffusion of blockchain technology: Insights from academic literature and

social media analytics. Journal of Enterprise Information Management.

GUPTA, R. (2017). FUTURE OF BITCOINS - A STUDY. Journal of Internet Banking and Commerce, 22(3).

Horra, L. P. d. l., Fuente, G. d. l., & Perote, J. (2019). The drivers of Bitcoin demand: A short and long-run analysis. International Review of Financial Analysis, 62, 21-34.

Inc., V. (2019). Visa Inc. Fiscal 2019 Annual Report. Retrieved from https://annualreport.visa.com/FY2019/default.aspx:

Kjærland, F., Khazal, A., Krogstad, E. A., Nordstrøm, F. B. G., & Oust, A. (2018). An Analysis of Bitcoin’s Price Dynamics. Risk and Financial Management.

Kugler, L. (2018). Why Cryptocurrencies Use So Much Energy - and What to Do About It. Communications of the ACM, 81(7).

Luther, W. J. (2018). Is Bitcoin Intrinsically Worthless? The Journal of Private Enterprise, 33, 31-45.

Ma, J., Gans, J. S., & Tourky, R. (2018). MARKET STRUCTURE IN BITCOIN MINING. NBER Working Paper, 24242.

Milewski, D. (2020). One-Third of Small Businesses Accept Cryptocurrency. Retrieved from https://www.munichre.com/hsb/en/press-and-publications/press-releases/2020/2020-01-15-one-third-of-small-businesses-accept-cryptocurrency.html

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. bitcoin.org.

Nguyen, T., Bodisco, C. d., & Thaver, R. (2018). FACTORS AFFECTING BITCOIN PRICE IN THE CRYPTOCURRENCY MARKET: AN EMPIRICAL STUDY. International Journal of Business and Economics Perspectives, 13(1).

pwc. (2019). 2019 Crypto Hedge Fund Report. Retrieved from https://www.pwc.com/gx/en/financial-services/fintech/assets/pwc-elwood-2019-annual-crypto-hedge-fund-report.pdf:

Ram, A. J. (2019). Bitcoin as a new asset class. Meditari Accountancy Research, 27, 147-168.

Rogers, E. (2003). Diffusion of innovations (5th ed.). New York: Free Press.

Ryu, H.-S., & Ko, K. S. (2019). Understanding speculative investment behavior in the Bitcoin context from a dual-systems perspective. Industrial Management & Data Systems, 119(7), 1431-1456.

Sompolinsky, Y., & Zohar, A. (2018). Bitcoin's underlying incentives. Communications of the ACM, 61(3).

Stoll, C., Klaaßen, L., & ̈rfer, U. G. (2019). The Carbon Footprint of Bitcoin. Joule, 3, 1647-1661.

Taylor, M. B. (2017). The Evolution of Bitcoin Hardware. Computer,, 50, 58-66.

Vries, A. d. (2018). Bitcoin’s Growing Energy Problem. Joule, 2(5), 801-805.

Vries, A. d. (2019). Renewable Energy Will Not Solve Bitcoin’s Sustainability Problem. Joule, 3(4), 893-898.

Xiang, N. (2017, 22/02/2017). China’s Sichuan, Known For Spicy Food, Becoming Bitcoin Mining Capital. Retrieved from https://www.chinamoneynetwork.com/2017/02/22/chinas-sichuan-known-for-spicy-food-becoming-bitcoin-mining-capital

Yelowitz, A., & Wilson, M. (2015). Characteristics of Bitcoin users: an analysis of Google search data. Applied Economics Letters, 22(13).

思二勋. (2019). 中国区块链政策现状及趋势分析报告. Retrieved from http://blockchain.people.com.cn/NMediaFile/2019/0905/MAIN201909050920000297932371328.pdf: