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PORTFOLIO MANAGEMENT: WILL HODLING CRYPTOS MAXIMIZE INVESTOR RETURNS?

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Abstract

Background and Objectives
This thesis aims to investigate whether adding cryptocurrencies to a portfolio of traditional assets enhances the portfolio performance. Moreover, the previous research conducted in this area focused only on Bitcoin. This study devotes to examine the benefits of 18 cryptocurrencies together, which have been selected based on their market capitalization. Out of these 18 cryptocurrencies under study, we also aim to analyze the effects of the more recent additions in the crypto market, which is a stable coin and a utility coin, thereby making our study relevant to the present-day innovations in the crypto space. In addition to this, since the Blockchain and Cryptocurrency technology are newly founded ideations in the financial ecosystem, we scheme to provide a brief overview of this technology by taking into consideration aspects such as their advantages, disadvantages, types of blockchain and cryptocurrencies along with their working and the market players involved for their functioning.

Data and Methodology
The times series data was obtained from Coinmarketcap and Yahoo Finance. The time period of research was from 01st January 2014 to 28th February 2020. We employ the Mean-Variance analysis of Markowitz (1952) and Sharpe-ratio of Sharpe (1964) and calculate the mean returns, standard deviation, and Sharpe-ratio and optimize three sets of portfolios: Maximization of Sharpe-ratio (with no short sale), Maximization of Sharpe-ratio (with short sale) and a Minimum Variance portfolio.

Results
Results showcase that including cryptocurrencies in a portfolio of traditional assets, provides an improved Sharpe-ratio in comparison to the standard portfolio, which consists of traditional assets only.
Moreover, on the construction of the correlation matrix, overall there is no significant correlation among the cryptocurrencies and traditional assets. Results also state that despite Bitcoin being the leader in the crypto space with a market dominance of 62%, it shows lower benefits in the portfolios constructed. However, on the other hand, we found exceptional results by the inclusion of other altcoins and Utility coins (Binance Coin). Furthermore, it should also be noted that cryptocurrencies are risky assets where, although they provide high returns than traditional assets, but they also exhibit extreme volatility. Moreover, the results are based on the limited availability of historical data for most of the cryptoassets, due to which conclusion from the results must be drawn with caution.
However, cryptocurrencies have the potential to be analyzed and included for diversification benefits.

Keywords	
Blockchain, Cryptocurrency, Mean-Variance, Sharpe-ratio, Bitcoin, Traditional Assets, Altcoins	
Additional information	

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1   INTRODUCTION

The financial markets have steadily evolved over the past few decades, where the medium of exchange; money has experienced tremendous advancement (Bunjaku, Trajkovska & Kacarski, 2017). Money plays a crucial role in the lives of every individual as it enables the satisfaction of our daily needs and wants and facilitates economic exchange. The primary feature of money is to function as a medium of exchange – *where buyer and seller accept it as means of payment*, as a unit of account – *enabling price comparison for the things we buy*, and as a store of value – *to maintain the value of an asset without depreciation in its value* (Yermack, 2015). The financial markets of our economy embarked on a journey with the digital world to produce the Fintech industry, which ventured into a couple of new inventions that have revolutionized our lives (e.g., credit cards, digital payments). The "newest fintech fad," as described by Mazer (2017), are cryptocurrencies. These digital currencies have grown immensely in recent years and received vibrant attention from various corporations and the public. These groundbreaking innovations in the financial space have challenged the political, social, and economic foundations of our society (Mazer, 2017). However, they remain a topic of debate between various institutions and academic communities. Famous American Economist Paul Krugman describes cryptocurrencies as "evil," and Warren Buffet calls it a "mirage" (Mazer, 2017).

But, cryptocurrencies have come a long way since its fruition. The transformation and development it has experienced have made many academic groups examine their effectiveness. It was until recently that the focus of this industry has shifted to the finance and economic perspective, where a large number of academic writers have started examining their effectiveness. However, the literature provides contrasting views. Some argue that they are speculative investment vehicles (Glaser, Zimmermann, Haferkorn, Weber & Siering, 2014; Baek & Elbeck, 2015; Cheah & Fry, 2015) while others state that Bitcoin provides significant diversification benefit in a portfolio of traditional assets and alternative assets (Brière, Oosterlinck, & Szafarz, 2015; Gangwal, 2016; Kajtazi & Moro, 2019). Since the argument of Bitcoin providing diversification benefit holds weightage to us. We, therefore, tend to analyze in this thesis if the addition of not only Bitcoin but also other altcoins (see

Appendix A) enables us to enhance portfolio performance. The following section intends to unfold the evolution of cryptocurrencies and also formulates the research question this thesis aims to investigate.

1.1 The Crypto Space

Digitization and Automation are foundational pillars of technology that have been embedded in our daily lives. The combination of these pillars has changed the way we live, produce, and work. They are the backbones which helped to create platforms such as online payment system, like PayPal, MoneyGram, to manage our finances. The introduction of A.I. (Artificial Intelligence) and robotics in the automobile and industrial sectors, the use of websites and applications for booking transportation, hotel rooms, and eateries. Digitization and Automation also laid a founding stone in the field of finance, where a new class of asset was born that works as a medium of exchange in the Fintech world called crypto-assets, which are generally referred to as Cryptocurrencies in the crypto space.

The financial market crash of 2008 triggered the rise of crypto-assets, with Bitcoin being the first cryptocurrencies to be launched in 2008 (Nakamoto, 2008). It is often mentioned that the 2008 market collapse laid the groundwork for the introduction of bitcoin (Bambrough, 2019). The catastrophic reaction of the market crash remains fresh and can be recalled easily, as its consequences cannot be forgotten. The disaster, which began due to the crisis in the mortgage market sector, later spread across globally, resulting in massive government bailouts and an economic downturn. The repercussion of this not only affected the economies globally but also had a direct impact on investors, which include the working class and retired people. They lost their trust in the banking system, and its regulation as the crisis made the markets turn violent, and the banks to declare themselves bankrupt, which hit them directly. American Economist Ben Bernanke mentions that "September and October of 2008 was the worst financial crisis in global history, including the Great Depression" (Worstall, 2014).

Due to the effects it had on the economies, it sparked a revolutionary change in the financial space with investors looking to avail alternative options where they could

keep their investments safe and have a means to store value. It was an anonymous group named under Satoshi Nakamoto, who introduced the first crypto-asset called Bitcoin in the crypto space in 2008. Since then, there has been an uproar increase in the number of cryptos active in the crypto platform. Till the time of writing this thesis, there are almost 5,232 cryptocurrencies in circulation operating in around 20,968 markets (Coinmarketcap, n.d).

Moreover, bitcoin was conceptualized in 2008 as an alternate towards fiat currencies, and this can be ascertained from a hidden script from the first block of bitcoin, also called the "Genesis Block." Bitcoin Wiki (n.d.) states that the script reads as "03/Jan/2009 Chancellor on brink of second bailout for banks". This script was the headline of the U.K. Times published, which emphasizes on a bank bailout of that particular day. This cites the importance that the developers of bitcoin were dissatisfied with issues in the financial system and the fragility it would bring with it. Motivating them to provide alternative investment options to investors that can be sorted both as a store of value and as a medium of exchange. And bitcoin came as a first possible choice of investment as it functions on a more stable and trusted network that runs on cryptography (Nakamoto, 2008). After which other cryptoassets joined in with individual variations in their features and properties, which we will discuss in chapter 4.

The modus operandi of bitcoin has been mentioned in a white paper "Bitcoin: A Peer-to-Peer Electronic System," released by Satoshi Nakamoto in the year 2008. Until the time of writing this thesis, the existence of Satoshi Nakamoto is unknown, whether it is a group of people, hackers, or even a real person. Bitfortune (n.d.) mentions, "So far, we have only referred to Satoshi Nakamoto as an individual. However, another likely scenario is that Bitcoin was created by a group of people, financial institution, government agency, or business." Moreover, the awareness around cryptocurrencies was not that prevalent in its initial days, and for the very first time, it was used by a Florida based programmer, to buy two pizzas in exchange for 10,000 Bitcoins (Hankin, 2019). Bitcoin witnessed marginal growth in its value until 2012, and in 2013 its price made progress where it rose to $100. However, in 2014 it lost its reputation due to the hack on Japanese cryptocurrency exchange Mt.Gox (Bitcoin Wiki, n.d.).

However, over the years, there has been substantial advancement in the awareness around cryptocurrencies as major universities have started, including cryptocurrency and blockchain technology curriculums in their syllabus.

Coinbase (2019) states that,

> Uniting the top 10 schools on the list — which in the U.S. include MIT, New York University, Stanford, and the University of California-Berkeley — is a deep commitment to crypto and blockchain at both the student and faculty level. Cornell offers 14 classes on cryptocurrency and blockchain.

> Last year, Stanford held the mantle of teaching the largest number of courses on crypto and blockchain (10), followed by Cornell (9) and University of Pennsylvania (6). In 2019, Stanford is offering 8 courses and University of Pennsylvania is offering 2.

The introduction of these courses implies that institutions in the United States are cognizable of the importance this new technology holds and are leaving no stone unturned to impart and build upon this knowledge further. Institutes in countries like China, Japan, Denmark, Switzerland, and Singapore also have curriculums that include cryptocurrency topics. In addition to this, an article published on Bloomberg by journalist Patterson and Tan (2018) state that the CFA Institute, which provides professional certification in investment and finance to professionals through the qualification of Chartered Financial Analyst; have started including topics on cryptocurrencies and blockchain technology to their Level 1 & 2 curriculums. These journalists speculate that this signals the adoption of cryptocurrencies and other crypto assets to be traded in Wall Street in the nearest future.

In spite of receiving widespread attention and being attributed as an innovative and marvelous approach toward digitizing our financial economy, cryptocurrency, however, have not been widely adopted in our economy. Predominantly due to the widespread criticism they received soon after their launch, where they were and even now being used as a medium of exchange by illegal market participants to buy and

sell illicit products over the darknet marketplace. Whereas, some others found opportunities in them for money laundering and tax evasion activities, and some even duped people under some Ponzi schemes. All these activities are being carried out due to their feature of pseudo-anonymity, which we will address in section 3.3.

However, in spite of the criticism and controversies they are surrounded, the entire crypto-space grabbed headlines after 2017, when the value of bitcoin skyrocketed from $1,000 to $20,000 by the end of December 2017 (Bitcoin Wiki, n.d.). The excitement with the sudden rise of bitcoin prices, caused it to become a financial phenomenon, where market players started viewing it as a digital currency. However, many researchers attribute bitcoin as a speculative asset, that is prone to bubble-like conditions (Baek & Elbeck, 2015; Cheah & Fry, 2015; Corbet Larkin, Lucey, Meegan, & Yarovaya, 2018b). Equivalently, Yermack (2015), who analyzed bitcoin from an economic perspective, argued that bitcoin does not satisfy the criteria of a currency. He states that the founding features that describe money are its functions as a medium of exchange, a unit of account, and as a store of value. Where bitcoin does meet the first criterion, however, not on a global scale, on the other hand, he argues that it fails to meet the second criteria, as it is impractical to quote prices up to four to five decimal place as it will likely make it difficult for consumers to use it as a medium of exchange, as comparing prices in decimals is confusing and complicated. Whereas, with regard to the third criterion, he points out that, as a store of value, cryptocurrencies possess a challenge due to the risks of frequent attacks of hacking and thefts.

But, as we previously mentioned, cryptocurrencies have come a long way, and there have been new developments in their ecosystem. These advancements lay the baseline for our thesis, where we aim to examine cryptocurrencies are a source of money or as a financial asset. Furthermore, there is a very thin line difference between money and financial asset where the money is a financial instrument, which is highly liquid, which pays very little or sometimes no interest, whereas other types of financial assets are less liquid but have the potential to pay higher returns. Since cryptocurrencies are less liquid due to their existence on a virtual medium, we intend to explore the opportunities they have from the perspective of being a financial asset.

In addition to this, the current academic literature in portfolio management has favored only Bitcoin in their analysis, but with the ever-growing addition of other crypto-assets called alternative coins (altcoins), there is an opening of diversification benefits from these new financial innovations in the crypto space. Where some of the most famous ones, Ethereum, Ripple, Dash, Litecoin, received widespread acceptance in the crypto world due to significant changes in them that gave them an upward edge over Bitcoin. Bitcoin, which is considered as the father of the crypto space; however, contains certain flaws that sprung the growth of these altcoins, who have modified their crypto coins to gain from the pains of bitcoin so that they can be deemed better. Some of the refinements include features such as their transaction speed as in for Litecoin, which has a faster block generation, which results in faster transaction confirmations (Reiff, 2020b), different methods of mining the coins, which we will cover in section 4. Thus, it is essential to analyze the potential competitors of Bitcoin and how they perform in relation to traditional financial instruments (assets).

This thesis aims to explore the investment opportunity of the 18 largest cryptocurrencies that have been selected on the basis of their market capitalization and how they enable investors to maximize returns. Out of these 18 cryptocurrencies, two are the new introduction in the crypto space, where one was conceptualized to curb the high volatility in the crypto market that is a stable coin USDT (Tether). The other one is a utility token (see Appendix A) (Binance coin), which not only provides generic functionality of being a medium of exchange but also allows investors to gain from its other services, which we will explore more in chapters 3 and 4.

1.1.1   Research Question

The aim of this thesis is to evaluate portfolio optimization combining cryptocurrencies hodlings (see Appendix A) and traditional assets, which formulates the following research question

- *Will diversification in cryptocurrencies maximize investor return?*

In answering the research question, this thesis will take a perspective of a U.S. individual investor. This is mainly because the U.S. crypto market is more well developed than the other markets.

1.1.2   Research Objectives

Moreover, with the formulation of our central research question, we also set the objective of understanding the blockchain technology and functioning of the cryptocurrency market.

- *Fundamentals of the blockchain technology and its working*
- *Understanding the concept of cryptocurrencies and its types*

1.2   Background and Motivation

" "I think that the Internet is going to be one of the major forces for reducing the role of government. The one thing that's missing, but that will soon be developed, is a reliable e-cash, a method whereby on the Internet you can transfer funds from A to B without A knowing B or B knowing A. The way I can take a \$20 bill hand it over to you and then there's no record of where it came from."

-   **Professor Milton Friedman**[1]

There are three reasons why the topic of cryptocurrency holds significant importance. First and foremost, the concept of "currency" has been undergoing tremendous progress during the last few years (Wesley, 2018). We started from commodity money, coins, paper money to plastic cards, and now digital currencies (Ekne, 2018). These digital currencies, also called cryptocurrencies, function on a more straightforward and trustable algorithm called the blockchain. Another important feature it holds is its decentralized platform, where payment settlement

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[1] (Hanke, 2014)

takes place through its peer-to-peer network, without surveillance from any third party (Heller, 2017). As a result of which the governments are being challenged by the rise of these decentralized currencies. Inclusion of these digital assets has disintegrated the government-backed currency marketplace, who sometimes use their power to manipulate and print fiat currency to boost economic progress, such as hyperinflation problem in South America which is peaking to 500,000% in Venezuela (Lookingforastory, 2020), devaluation of Yuan which is the official currency of China and the recent financial crisis of Greece and the Brexit (Gangwal, 2016). The emergence of Bitcoin and other cryptocurrencies are challenging the concept of currency, giving people alternatives to surpass governmental dominance (Heller, 2017).

Secondly, we are currently in the third industrial revolution, which can also be referred to as the digital world, where more and more people, businesses, and governments are conquering the digital space and becoming dependent on digitalization. This widespread adoption of digitization also needs a medium to overlook the security and transparency of operations. Blockchain technology easily fits in the requirement due to its unique features, such as decentralization, open-source, easy to code, and facility for large database storage. Blockchain makes use of cryptographic coding, which makes its secured and tamper-proof, allowing it to be flexible for use in any kind of business. It has the ability to record every kind of information from marital, medical, land dealings (Wesley, 2018), to its current use in the financial industry.

Additionally, blockchain technology is currently being experimented with by a number of food and retail companies. It is estimated that the use of blockchain in food and agriculture sectors is expected to reach $1.4 billion dollars by 2028 (ResearchAndMarkets.com, 2018). Moreover, many banks have already started, including blockchain technology in their operations, due to its lower transaction cost and speedy transactions. Such as Western Union, which uses the Stellar (XLM) blockchain platform for its payment operations (Huillet, 2019).

And, thirdly, blockchain and cryptocurrencies became global phenomena when the bitcoin price surged to an all-time high of $20,000 in 2017, which created hype and

grabbed attention from the media and the public. Ever since then, individuals have been piqued to capitalize and earn huge profits from these decentralized virtual assets. The total market capitalization of cryptocurrencies increased by over 300% from 2016 to 2017 (Wesley, 2018). Moreover, from the period of 2017 till 2018, the markets increased additionally by 800% (Wesley, 2018). Another interesting factor is that some countries are pitching in for the wide adoption and legalization of cryptocurrencies as means of payment method, such as in the case of Japan and Brazil. Febrero (2019) mentions that the Central Bank of Brazil has officially recognized Bitcoin and other cryptocurrencies as a medium of exchange.

Furthermore, high net worth banks have been banking as well to adopt these innovative instruments in their business models. J.P Morgan is working out a plan to launch its cryptocurrency called the JPM coin (J.P. Morgan, 2019). Goldman Sachs has been conducting "extensive research on asset tokenization and stable coins" (Palmer, 2019). Social Media networking site Facebook is also making efforts to launch its own digital currency Libra (Lopatto, 2019). Equivalently, some of the major companies have also started accepting bitcoins as viable sources of payment options such as Microsoft, Wikipedia, BMW, AT&T, and subway, as we already mentioned in the previous section. Where Microsoft is accepting payments in Bitcoin to purchase games, movies, applications on the Appstore, and for Xbox as well as for purchasing license for Windows 10. Wikipedia, NordVPN, and AT&T also allow its subscription payments through Bitcoin. CoinsCapture (2019), describes that "apart from trading, cryptocurrency is also accepted by many companies as a source of payment for different goods and services like buying pizzas or various household goods, booking flight tickets or movie tickets, VPN services and many more."

But at the same time, as we know, fiat currencies face issues such as price instability, economic volatility. The cryptocurrencies also suffer from high price volatility (Brière et al., 2015). Furthermore, due to this extreme volatility crypto market tanked in December of 2018, where it fell by almost 70% (Ouimet, 2019). In spite of knowing that cryptocurrencies are intended to be seen as a vehicle of innovation in the financial space, it still scumbles to debates, due to the disadvantage it carries in terms of price volatility where discussion range from its widespread adoption.

Cryptocurrencies as an alternative source of finance? And some even argue that cryptocurrency is just a bubble (Corbet, Lucey, Urquhart, & Yarovaya, 2018a).

On the contrary, with time, new developments being materialized in the crypto space, which has tended to make it a robust system, motivating us to see how these developments would enhance the cryptocurrency performance and provide any additional returns to investors.

1.3 Road Map

The roadmap to this thesis is structured as follows: Chapter 2 provides a relevant literature overview on portfolio selection models we undertake to conduct our analysis, and then we conclude this chapter by looking at the previous research work undertaken in portfolio selection using cryptocurrency. Chapter 3 intends to provide a comprehensive overview of the blockchain and cryptocurrency technology to our readers. Chapter 4 provides an overview of the assets under study and what differentiates them from each other. Chapter 5 discusses the sources of data the research methodology to be employed in detail. Chapter 6 explains the empirical results obtained from the various strategies we employ. And Chapter 7 provides the conclusion for the study undertaken. Furthermore, the references and the appendices are listed thereafter.

2   LITERATURE REVIEW

This section aims to provide a theoretical background on which this thesis is based. We will first cover the literature on the mean-variance analysis of the portfolio selection theory, which is based on the model of Markowitz (1952), along with the Sharpe ratio of Sharpe (1964). And we end this section by looking into earlier research focusing on portfolio selection, including cryptocurrency.

2.1   Literature on Modern Portfolio Theory and Sharpe Ratio

Miguel Cervantes, in 1605 mentioned a very famous piece of advice in his book titled "Don Quixote," where he mentions of not laying all investments in one basket but instead to diversify investments for better returns (Grammarist, n.d.). This famous quote received widespread attention to this modern-day through the work of Harry Markowitz.

Fund allocation in assets be it the conventional (such as stocks, bonds, and cash) or the alternative class (such as hedge funds, real estate, commodities), is a problem that every individual face, who tries to gauge a balance between the risks and the returns of each asset class. Due to which Markowitz (1952), in his seminal work of "Portfolio Selection," established a framework to assist investment decisions.

Markowitz (1952), in his theory, highlights the concept of diversification and how investors can construct an efficient portfolio that maximizes expected return (mean) for a given level of risk (variance). He states that the expected risks and returns of an asset should not be weighed individually, but rather the individual assets contribution to the overall risk and return of the portfolio should be assessed. The main essence of Modern Portfolio Theory revolves around the elimination of idiosyncratic risk, the risk associated with a particular asset that can be avoided by diversification. This further enables one to maximize returns and lower the risk of the portfolio by holding a mix of negatively correlated/uncorrelated assets. Where, the overall return of a portfolio is the weighted average of negatively correlated assets, which then enables the construction of the efficient frontier. The formation of the efficient frontier represents a choice to the investor, where the selection of a preferred optimal

portfolio can be derived depending on the risk appetite of the investor. Harry Markowitz, due to this theory of his, is also called the father of portfolio theory (Elton & Gruber, 1997).

Over the years there were further refinements made to the Portfolio Theory mentions (Elton & Gruber, 1997) such as Litzenberger and Kraus (1976) who in the portfolio theory added moments such as skewness and excess kurtosis, (Fama & French, 1989; Campbell & Shiller, 1988) examined effects using a multi-period model. However, the portfolio theory of Markowitz (1952), still is the backbone for much of the analysis conducted today, because, the alternatives by (Litzenberger & Kraus, 1976; Campbell & Shiller, 1988; Fama & French, 1989) showed no further additions of improvements to the portfolio performance and instead make the analysis process more cumbersome. (Elton & Gruber, 1997). Portfolio Selection theory has, therefore, revolutionized the way of investing by providing a method that allows the construction of a portfolio that not only consists of risky assets but also where the overall risk is less than the combined risk of each individual asset.

Findings of Markowitz were later advanced by William F. Sharpe to measure the risk-return of the portfolio. Under his method, he proposes that none of the prior authors considered investor behavior under conditions of risks. Adding risk factor makes it all the more effective, as an investor has all the investment options choices available, including the risk, where he can opt for the one that maximizes his utility.

The Sharpe-ratio is formulated as,

$$max \; SR_p \; = \; \left(\frac{E[rp] - r_f}{\sigma_p} \right)$$

Where,
- $E[rp]$ = expected return on portfolio,
- r_f = the risk free rate,
- σ_p = standard deviation of Portfolio P.

Sharpe (1964, 1994) shows how the portfolio performs when a risk-free rate is added that measures the excepted return per unit of risk. Thus, we can combine the Sharpe-ratio with the Portfolio Theory to find the optimal portfolio, which maximizes the Sharpe-ratio.

2.2 Literature on Portfolio Management in Cryptocurrency

Cryptocurrencies aspire to be widely adopted digital currencies, and since they are relatively recent additions in the financial ecosystem, there is a limited amount of prior literature available. However, they have been under the microscope since their inception in early 2009, and therefore last few years has seen a plunge in the literature surrounding them, with previous literature more dedicated towards computer science. The financial literature available on cryptocurrency dates only from 2013 onwards (Corbet et al., 2018a), with available research mainly devoted only towards Bitcoin (Corbet et al., 2018b). This is mainly because it is one of the most popular cryptocurrency and also due to it being the first cryptocurrency to be launched in the crypto space. In this section, we provide a comprehensive overview of the previous research undertaken in cryptocurrency performance.

Cryptocurrencies are digital currencies that work on a technique called cryptography, which caters to provide security, transparency, ownership, and authenticity for the currency under exchange. They were introduced to function as a medium of exchange and to imitate features of physical currencies. However, studies performed on Bitcoin (Wu & Pandey, 2014; Yermack, 2015) suggest that it poorly functions as a currency. In addition, Yermack (2015) highlights that volatility involved within Bitcoin ceases its use as a unit of account and store of value, thereby concluding that Bitcoin is more like a speculative investment. However, Pagano and Seduno (2018) mention that Bitcoin has a true form of money. Whereas, Eichengreen (2019), in his study, analyzed the evolution of conventional currencies and argued that cryptocurrencies do not provide the functionality of money. Likewise, bitcoin is a speculative bubble with zero fundamental value (Cheah & Fry, 2015).

However, further studies were undertaken to understand the properties of Bitcoin as a diversifier or as a speculative (hedge) asset. Beck and Elbeck (2015) analyzed bitcoin

and Dyhrberg (2016a) analyzed bitcoin using GARCH methodology. Both indicate that it has hedging capabilities. In addition to this, Dyhrberg, also mentions that bitcoin is a financial asset that possesses features of both a currency (dollar) and as a commodity (gold). On similar grounds, Selgin (2015) states it has combinable features of the fiat and commodity currencies. Brière et al. (2015) examined the benefits of bitcoin from a U.S. investor perspective. They analyzed the effects of bitcoins in a portfolio consisting of traditional assets consisting of worldwide developed and emerging markets of stocks and bonds, alternative assets such as commodities which include oil and gold, along with hedge funds, currencies (Euro and Yen) and the world real estate data from FTSE global market. They find that bitcoin exhibits extremely high returns of 404% annually, but also volatility as high of 176%. They further also evaluated the performance of bitcoin in a mean-variance analysis, where two portfolios are constructed, one with a volatility of 6% and another with a volatility of 12%. They find that the portfolios, which include bitcoin, surpasses returns as there is an additional 8% and 19% increase than the portfolio excluding bitcoin. Thus, concluding that adding small proportions of bitcoin does provide a significant increase in returns. Furthermore, Dyhrberg (2016b) examined bitcoin against the FTSE Index (Financial Times Stock Exchange Index) and the U.S. Dollar and states that bitcoin has hedging capabilities and can be used as a tool for minimizing risk.

More studies, analyze characteristics of cryptocurrency from an investment point of view, where Klabbers (2017) mentions, bitcoin tends to provide attractive returns when included in a well-diversified portfolio. Similary Baur, Hong and Lee (2018) also mention that diversification in bitcoin has benefits not only during normal conditions but also during turbulent times. Baur et al. (2018), furthermore, also find that Bitcoin is unrelated to the traditional asset class. A more comprehensive review of bitcoin was conduced by Kajtazi and Moro (2019), who studied the effectiveness of bitcoin in a diversified portfolio consisting of conventional and alternative assets of the U.S., European and Chinese markets and concluded that adding bitcoin increases the returns and also improves the risk-return ratio. Similar results were found (Platanakis & Urquhart, 2018), where bitcoin enhances Sharpe, Omega, and Sortino ratios. Guesmi, Saadi, Abid and Ftiti (2019) mention, bitcoin proves to provide diversification and hedging benefits when selected as an alternative

investment for traditional investors due to its high average return and low correlation with conventional financial assets. Gangwal (2016) furthermore, mentions that since bitcoin enables to provide improved returns, investors should start considering investing in bitcoin as it shows opportunities as an alternative class of asset. A similar stance has been mentioned by Wu and Pandey (2014) and Brière et al. (2015), who mentions that investors can avail benefits by holding small amounts of weights in bitcoin.

Taking into consideration, the recent additions in the number of cryptocurrencies introduced in the crypto space, studies have undertaken the new altcoins under examination as well. Where, Andrianto and Disputra (2017) evaluated the performance of bitcoin, along with ripple and litecoin in two methods, one including in a portfolio of foreign exchanges (Forex) and commodities (Metal, Gold, and Silver) and other involving stocks. They report that the inclusion of cryptocurrencies in both methods outperforms an individual portfolio of Forex and Commodities and that of stocks. Andrianto and Disputra, further also mention that portfolios, including cryptocurrencies in their analysis, have exceeded the index performance of S&P 500 and Dow Jones. Additionally, Anyfantaki, Arvanitis, and Topaloglou (2018) mention that investment strategies that include cryptocurrencies outperform the conventional asset class, which includes stocks, bonds, and cash. Likewise, Bitcoin, along with alternative coins such as Ripple and Ethereum, are uncorrelated to equities, bonds, currencies, and precious metals, mention (Liu & Tsyvinski, 2018). Ketelaars (2018) examined the diversification benefits of Bitcoin and four other cryptocurrencies and found that these digital assets, when included with other financial instruments, provide significant diversification benefits and a higher Sharpe-ratio.

This thesis aims at studying the risk and return of cryptocurrency included in a portfolio of traditional assets by utilizing the portfolio theory of Markowitz (1952) and Sharpe-ratio of Sharpe (1964).

3   CLOSER LOOK IN THE CRYPTO SPACE

"The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value."

-   **Don & Alex Tapscott[2]**

3.1   Blockchain 101: What is Blockchain Technology?

The blockchain technology is the main crux behind the cryptocurrencies and their working. As a result, it would be crucial to understand this magnificent structure before we dive deeper to provide a comprehensive review of the cryptocurrencies.

Yaga, Mell, Roby, and Scarfone (2018) mention that blockchains are "tamper-evident" and "tamper-resistant" distributed digital ledgers that operate without any intervention from the government or central authorities. The term Blockchain can be traced back to 1979, where Ralph Merkle introduced it for the first time. So, the early day blockchain is also called the "Merkle tree" or "Hash tree." Merkle (1990), in his paper titled "A Certified Digital Signature" introduced a method of verifying data that would enable computers to work much faster. Under this method, he proposed that large amounts of data can be easily identified and verified. Narayanan, Bonneau, Felten, Miller, and Goldfeder (2016) mention that in 1991, Haber and Stornetta schemed this idea and created a digital signature called "time-stamping documents" which provides an idea of when the document came in existence. This method of time-stamping helps to convey the order of document creation accurately, and any modifications made to the data makes the entire document invalid. In the year of 2008, Satoshi Nakamoto took forward this concept of creating a distributed blockchain, which contains a secure history of data exchanged by making use of the P2P (Peer-to-Peer) network to stamp the time and verify each transaction or data transferred, without the intervention of any central authority. Professor Campbell

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[2] (Bawa, 2019)

Harvey at the CFA Institute annual conference enumerates, "To tamper with a blockchain by correctly guessing a hash would take roughly the same number of guesses as there are atoms in the known universe — and that's for just one block" (Duke Fuqua Insights, 2017).

To put in simple words, we can say that blockchain is a decentralized digital ledger, also called as decentralized ledger technology (DLT) that inputs records in chronological order for each transactional entry that takes place. These entries are then copied and sent across every other computer node in its network while ensuring security and transparency. The nodes here imply a cluster of computers that are not owned by a single entity or person, but by thousands of users around the globe who keep a record of all transactions across the network. This record-keeping is referred to as "ledger" in the cryptocurrency ecosystem.

So, every time a transaction takes place, it is time-stamped, verified, and added to the ledger as a "block," and these blocks of data are secured and bound to each other using cryptographic code called "chain." Chain implies bonded by previous transactions. In the case of Bitcoin, its first block is called the "Genesis Block," which is attached to all the new blocks created. Also, it is important to remember that in this process, once the transaction is verified, it cannot be altered or reversed in any possible manner. Reiff (2020a) states that "When we say the words "block" and "chain," we are actually talking about digital information (the "block") stored in a public database (the "chain")." And to make sure the true state of the ledger is verified and updated, each node in the network identifies and communicates with each other to see if all the copies are the same. This secured decentralized network publicizes every single transaction that takes place, and even if one of the copies is not the same, due to manipulation of a transaction record, the network rejects that transaction. This security protocol obstructs people from manipulating the ledger to spend the cryptocurrency more than once or send some other persons digital funds to themselves. Thereby making the blockchain technology a truly revolutionary innovation within itself. The World Economic Forum survey states that by the year 2027, 10% of global GDP will be stored on blockchain technology (TrustBar, 2018).

3.2 Blockchain 101: Working of Blockchain

The concept mentioned above would seem confusing and complicated, but the idea of this technology can be simplified with a practical approach. Due to which we try to provide an example to make it easy for our reader to understand how blockchain technology works. We demonstrate this practical example in lines with the approach used by Skella (2017) and Brenyah (2018).

To keep things simple, we replace the words "blockchain" and "block" and make use of a "shared document" and "page." Moreover, in this shared document, every new addition to this shared document would be a new page. We can think of this shared document as google docs, which we all mostly use when we work in a group or want to instantly share data with a large number of people since it becomes easy to read and write data on this shared platform provided by Google Inc. However, to add an exception, we know that to write and edit on the google docs is only possible if the main author or admin who created the google docs shares the rights by which it makes it centralized. However, in case of our example since we understand the process in terms of blockchain we do not have a centralized location of this shared document; instead, there are thousands of copies of our shared documents stored on computers and servers all across the globe making it available to all, thereby making it decentralized. Since there are several uses of this shared document, we shall limit its use to function only to remit and receive money.

Now, for instance, Person A (Steve) wants to remit (send) money to his father, Person B (Paul). Let us also use Figure 1, provided below, to get a better understanding of this process. Steve remits the funds to Paul; this enters stage 1, which will create a new page with details of the entire transaction and will be sent across all the locations of our shared document with a copy of this new page along with all the previous transactions attached (Stage 2). All the computers across the locations would then process this new transaction through some authorization/verification process of acceptance or rejection of this transfer page from Steve to Paul (Stage 3). Once the transaction is authorized as legitimate by some computers (Stage 5), it outputs the page with a tick (Stage 7).
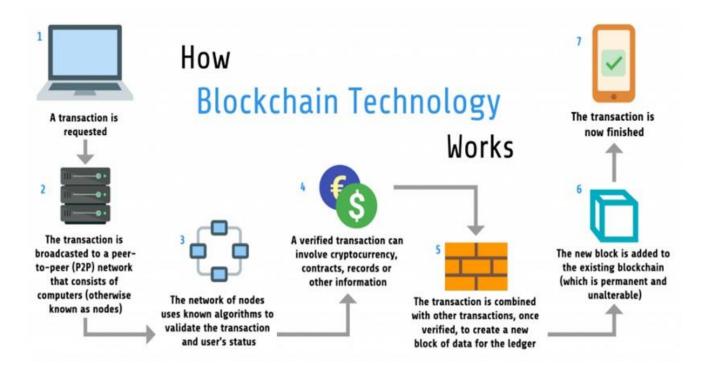
Figure 1: Working of a Blockchain [reprinted] from "How Blockchain Technology Works," by IPSpecialist. (2019). Retrieved May 11, 2020, from https://ipspecialist.net/how-blockchain-technology-works/

Now, let us assume, Steve realizes he sent more money than required and thinks of reversing the transfer, but the page of the transfer has already been added to our shared document. So, now what makes our shared document interesting is the one essential feature it comprises is once a page has been attached to our shared document, there is no possible way to reverse it and remove the transaction from our shared document. The only possible option available would be that Paul agrees to remit back the extra funds he received to Steve, which would then create a new page of this transaction of the extra funds transferred back to Steve and again the computers across all the locations would process this new transaction through an authorization process and once found to be legitimate will output this transfer with a tick and add the page globally to our shared document. Another essential factor that makes the blockchain process unique is that it will continue working as long as the internet lasts in the world.

Most of us would also have a question about how is this different than our banking system? Although we can yes, it is similar. However, what makes the concept of shared document different is it does not authorize or instruct any bank to do the

transfer on behalf of Steve or Paul for which a bank would typically charge him a minimum transfer fee. Instead, the shared document cuts off the reliance on any middleman. Moreover, one crucial aspect of the shared document is that it is not owned or controlled by any individual or bank. It is owned by all the users involved who have a copy of the shared document, where every user can keep track of what information is being shared. Furthermore, even if one Person lets say Clark holds more than one copy and falsely tries to alter the shared document, it would provide him no gain as every newly added page needs to be approved and authorized by a global network of computers where all the copies are stored. So even if Clark alters some pages and tries to add them to the shared document, the computers across various locations will reject these pages.

3.3   Blockchain 101: Elements of Blockchain

The blockchain technology consists of individual components which are necessary for its functioning, which is mentioned below.

- **Decentralized –**

One of the elementary features of blockchain technology is that it is an autonomous decentralized network, where the bureaucracy of any middleman or government is cut-off. This primary feature enables storing, recording, and updating data on multiple systems in multiple locations, which makes it easy for every user to have a copy of the data (Niranjanamurthy, Nithya, & Jagannatha, 2018). The network also tends to be useful due to three primary reasons; firstly, they are fault-tolerant, that is, the network is less prone to failure, due to their reliance on several nodes with which there are fewer chances of a breakdown at the same time. Secondly, they are attack resistant; in a way, due to the large number of participants within the network, the decentralized platform lacks failure due to the disappearance of any central node, thereby making this technology more expensive and less feasible for intrusions. As typically, central nodes are more prone to attacks and have the capacity to disengage the entire system. And thirdly, they are collision-resistant, in a way that it is less likely for participants to form unison that will benefit them at the expense of other participating agents. (Buterin, 2017).

- **Transparent –**

Transparency is the most spectacular features of the blockchain technology, where the data across all the networks can be viewed by all users who join in, by making use of the necessary encryption and control mechanism it provides the users a fully auditable and valid ledger of transactions. In addition to this, blockchain technology is designed in a way that enables the storage of information that cannot be altered or changed. Users can easily track and inspect their data and witness the transaction that takes place. (Kritikos, 2018).

- **Open Source –**

Open source blockchain systems are freely accessible for public use, where every user who joins the network can analyze, distribute, and modify the software. These open-source blockchain networks are not owned or managed by one single entity or central authority. Instead, they are collectively managed by a group of users who join the network. Every information published on the blockchain network is freely shared and is transparent for all to benefit. There are numerous advantages of having an open-source network, such as collective innovation, where users from all across the globe can develop and manage the software, without the need to be centrally located in one particular place or location. Secondly, the security features of the code can be enhanced and addressed immediately if in case any errors or defects are detected, such as Bitcoin, where its code had to be upgraded 48 times, and blockchain network of Ethereum network was upgraded 61 times. (Aziz, 2019).

- **Autonomy –**

Blockchain technology is structured in a way that allows not only executing transactions but also to store the cryptocurrencies. And it addresses the investor psychology of "trust" in the system through the use of cryptographic coding, where validation of transactions is done only through valid codes, which assures the users that everything on the blockchain system works on the basis of trust. And this manifestation of trust eliminates the need for any third-party surveillance. Nakamoto

(2008) states, "What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party."

- **Immutable –**

Taçoğlu (n.d.) defines Immutability as "unchangeability." The framework of the blockchain technology is designed in such a way that the data that has been stored lasts forever, and it cannot be manipulated, tampered, or falsified by any party. However, this feature suffers from one drawback, where a user or group of users, who gain 51% or more can take control of the network and can tamper the data by preventing new transactions or reversing the previous ones. Hence, it is imperative for more users to be active on the network so that there is an equal distribution of power to avoid such attacks.

- **Pseudonymity –**

Pseudonymity is associated as a disguised identity or as a false name. In blockchain technology, users transact with others using their pseudo-identity. Pseudo-identity is referred to as a wallet address where each user has their own public key address that allows them to interact with the system without revealing their real name or identity. This mechanism, however, as we addressed in section 1.1, provides an opportunity for illegal market players to take advantage of this process to conduct illegal activities.

- **Hashing –**

Hashing is one of the unique features of blockchain technology. A hash function makes use of strong mathematical codes with three following properties: An inputted string of data can be made up of single character or multiple characters, but the outputted data always remains a 256-digit character. Secondly, even the slightest change in input data, the entire output changes, and thirdly, hashes function go only one way; that is, the inputted code can never be decoded from the output of the data.

(Harvey, 2014). Including these, there are additional properties that are essential in the hashing function, which are collision-resistance, hiding, and puzzle friendliness (Narayanan et al., 2016). Collision-resistance is where it is highly impossible to find two hash function inputs that give the same hash output. Hiding implies that the generated output has no feasible way for any adversary to figure out the input data. Moreover, the Puzzle friendliness function of hashing states that there does not exist one particular strategy of solving the puzzle, then trying to guess the values randomly. (Narayanan et al., 2016). Majority of Bitcoin protocols function on a hash function called as SHA-256, which stands for a secure hash algorithm (Harvey, 2014) Furthermore, there are many hashing algorithms used by different companies, such as Ethereum uses KECCAK-256, Ripple (XRP), uses RPCA hashing, Litecoin uses Scrypt. But since these are out of scope from our topic of discussion, we will limit our study only to understand the concept behind hashing. Below is an example of how the hash function looks[3].

Example 1:

Input data – Steve remits 25 dollars to Paul

Output data - 6a1533cf1b4a09109cd081c8bdf9c675130291949049bb076d70f4279ad8f4b5

Example 2:

Input data – Steve remits 5 dollars to Paul

Output data - 2b26e42b5c6e02f8a66b31c77c5b40157aacbf68d5b5c9007270ddac9074b395

Here, we can see that in the first example, Steve remits 25 dollars to Paul, but soon he realizes he was supposed to send 30 dollars and not 25 dollars. If we recall from our previous section on the working of blockchain, the transaction, once done in a blockchain network, cannot be reversed, so instead, Steve had to make another

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[3] https://xorbin.com/tools/sha256-hash-calculator

transaction of 5 dollars. So, each time a new transaction is created, there will be a new hash function generated.

- **Double Spending –**

Blockchain Technology received the much-awaited awareness only after the introduction of Bitcoin by an entity named Satoshi Nakamoto. There were previous attempts made to introduce digital currencies; however, the ideas failed due to non-existence of any mechanism to avoid double-spending. The developers behind Bitcoin made sure they addressed this issue. So, in simple words, we can say that double spending is to avoid spending the coin twice. This can be avoided by the process of verification and broadcasting each transaction in each network node. Verification of transactions takes place through a process called mining, which we will discuss in the next section. Nevertheless, mining in simple terms is the verification of each block. The miners make sure to verify each block of transactions to avoid double-spending.

3.4   Blockchain 101: Types of Blockchain

- **Permissioned –**

These are private blockchains, which work in a controlled setting that is a closed network. (Anwar, 2020). Where the issuing body limits the access for verification and alteration of data to some authorized users only. This type of blockchain is mostly used by organizations, who need to protect and control the number of people accessing their blockchain network. (Yaga et al., 2018). The permissioned blockchain network differs from the public blockchain in a way, where the network is centralized in private blockchains, where the issuing authority or body overlooks the network data. These tend to be fast due to the limited number of participants allowed in the network, due to which the transactions are processed faster than in public blockchains. (Anwar, 2020).

- **Permissionless –**

These are public blockchains, which are open to all users and do not need any permission to publish blocks from any issuing body, unlike the permissioned blockchain network. The users just need to download the required software to publish their blocks. Moreover, since these are open-sourced, anyone can read and issue transactions. (Yaga et al., 2018). All they need is an internet connection. The first-ever public blockchain released was the blockchain of bitcoin. The transaction is verified by the process of mining, which involves solving complex mathematical problems to keep the blockchain functional. Each miner, who solves the block to verify the transactions are incentivized. However, these public blockchains suffer from some drawbacks such as transaction speed, and it takes from a couple of minutes to sometimes hours to complete a transaction in the bitcoin network, this is mainly due to the heavy use of mathematical coding. In contrast, in the case of VISA, it can handle 24,000 transactions per second. Another problem with them is the excessive use of electricity, which is utilized to manage each node and to solve the mathematical algorithm. Examples include Corda, Multichain. (Anwar, 2020).

- **Consortium Blockchain –**

These are also called as Federated blockchains, which is a crossbreed between the private and public blockchain and contains attributes of both. In these, the authority controlling them has a right over which data needs to be made public and which to keep as private. This type of blockchain is not open to the public as well but still hold a decentralized operation due to the large number of organizations controlling them, so no one authority has direct control over the network. These are well-situated for organizations that work in a partnership business. Examples include IBM food trust, Energy Web Foundation. (Anwar, 2020).

3.5 Blockchain 101: Blockchain in Crypto Space

Blockchain is a technology that uses cryptographic coding, which ensures that data stored is secured and distributed across all nodes in the network. Cryptocurrency is a part of this ecosystem, which uses this platform for sending and receiving coins.

Cryptocurrencies are digital assets that are not tangible in the real world. They exist only in their digital world, which works through a mechanism of the P2P network (Peer-to-Peer). For someone to create a cryptocurrency, all they need is to create a shared document with the first page of the shared document, which we explained in the previous section and notify the number of crypto coins that would be in circulation. Using our example again, we now say that Clark has created his cryptocurrency coin named Clarkcoin and creates a shared document with its first page labeled as "10,000 Clarkcoin now exist".

Clark now decides to give out some of the Clarkcoins to his family and friends and creates a new page for each transaction. So, every time a new transfer is initiated, a new page, along with the transaction details previously executed along with the first page of the 10,000 Clarkcoin, is attached, which then needs the new initiated page to be validated and authorized. Where-in after its validation, an updated copy of this page to whom Clark remitted his Clarkcoins is saved across all the network nodes.

Now let us assume that Clarkcoin is actual money trade, but only that it exists in a digital world, so how can one receive these Clarkcoin? For someone to withdraw or exchange these, they need to set up a digital wallet. Digital wallet functions similar to a bank account, where a public and a private key is generated, which is similar to a bank account number. Clark now decides to send 100 Clarkcoins to his father Bruce in his digital wallet. Clark logs into his digital wallet account and feeds in public key wallet address of Bruce, where he instructs to send 100 Clarkcoin to Bruce. Bruce will then receive these 100 Clarkcoins, but he can use these only when he validates it with his private key. This entire process of validation will then create a new sheet of the transaction, which will then be copied across all network nodes—enabling each and every user on the server to have a copy of every transaction that is executed.

3.6   Blockchain 101: What is Cryptocurrency?

Cryptocurrencies do not have any intrinsic value as that of the fiat currencies, which are backed by central authorities. Cryptocurrencies are a set of virtual digital assets which gained massive popularity in recent years. They aspire to be a set of new currencies in our economy, which promises to deliver stability and trust in its value

through the technology it uses. The terms blockchain and cryptocurrencies go hand in hand; however, it is crucial to examine them separately to gain a better understanding of them. This section, hence, provides an overview of cryptocurrency.

Cryptocurrency is planted on a technology called cryptography. Cryptography facilitates the design of procedures, such as encoding rules of the cryptocurrency scheme within the system that can achieve set objectives and prevent any kind of invasion or duplicity (Goldwasser and Bellare, 1996; Narayanan et al., 2016). These cryptography codes also contain the mathematical protocol, which controls the creation of new units of the cryptocurrency. (Narayanan et al., 2016).

Lansky (2018) proposes that Cryptocurrencies consist of three essential characteristics, which are pseudo-anonymity, autonomy from central authority, and prevention of double-spending attack. Chaum (1983), in his dissertation titled "Blind signatures for untraceable payments," introduced the concept of digital currency through his ambitious project e-cash under his flagship company Digicash Inc. E-cash implemented by Chaum consisted of a concept of digital notes, which contain a series of unique codes. Consumers could use them for offline and online payments, and the merchant accepting them simply had to deposit these notes in the banks accepting e-cash payment, and their accounts would be credited. E-cash employed a function called "blinding," which eradicates the double-spending problem and maintains the privacy of the consumers. However, this theme entirely relied on banks than its successor bitcoin and other cryptocurrencies, who eliminate the need for centralized surveillance. E-cash of Chaum faded due to complications within the company and the rise of momentum in credit cards. It was Nakamoto (2008) who further built on this concept of Chaum and was also able to connect all the three features and form the first-ever cryptocurrency Bitcoin in 2008. Narayanan et al. (2016) mention that it took nearly 25 years to make this concept a reality.

Conjointly, another essential trait of cryptocurrencies is that they have a similar, yet a different value-based mechanism to fiat currencies. Unlike fiat currencies, cryptocurrencies have a finite supply, which states that they cannot be exploited and minted by their developers to boost prices artificially (Wesley, 2018). Cryptocurrencies also have no intrinsic value of their own, unlike the fiat currencies,

who derive value from the government issuing them, or through the exchange for another commodity. Instead, their values are derived by the number of people who buy and sell them.

3.6.1 Merits of Cryptocurrency

According to Ivashchenko (2016), some of the merits of cryptocurrencies are as follows:

- **Decentralized –**

Cryptocurrency ecospace has no central surveillance in its network, meaning that the central authorities or government do not dictate the rules in this ecosystem. Every individual computer mining cryptocurrency is a part of the network. Furthermore, even if some part of the network goes offline, the system still continuous working, due to the large number of distributed networks connected to each other.

- **No boundaries –**

Cryptocurrencies are structured in a way to be immutable and to avoid double-spending problems. Thus, making it impossible to counterfeit, replicate, and double-spend them. This guarantees integrity in the entire system.

- **Lower Cost –**

Executing transactions using cryptocurrencies is a cheaper alternative, as the need for paying commissions or taxes is completely eliminated, than in the case of fiat currencies for which banks charge commission and brokerage fees. Also, the transaction under cryptocurrencies takes place on a real-time basis, and transactions are confirmed within a short span of time.

- **Easy to use –**

In comparison to the traditional methods of sending and receiving money, where a bank account is needed, and opening a bank account is cumbersome and time-consuming. In the case of cryptocurrency, the process of opening a crypto account is far easier, simple, and straightforward and only requires the user access to the internet.

- **Unlimited possibilities of transactions –**

Each owner enjoys freedom with the number of cryptos they own and are at liberty to use their assets for any purpose they deem fit. They can transfer, receive, pay anyone across the globe.

3.6.2   Demerits of Cryptocurrencies

According to Bunjaku et al. (2017), some of the demerits of cryptocurrencies are as follows:

- **Strong Volatility –**

There are a number of reasons for extreme volatility in the crypto market. Firstly, the market size of the overall crypto space is less than the developed global markets, such as in case of the world stock market, which in 2017 was around $76.3 trillion dollars (Baccardax, 2017), whereas cryptocurrency market capitalization was around $800 million dollars (Marshall, 2018). Due to this, smaller markets are more prone to fluctuations in supply and demand. Secondly, they suffer from announcements made by new events surrounding the crypto market, where the negative events drop the price instantly, and the positive news events spike the prices (Letra, 2016). Thirdly, the prices for these coins also suffer from sensitivity to news and announcements from the government and other regulatory bodies of various countries. Where for some time now, governments of various countries have been imposing restrictions and regulations on the unregulated crypto market, which have impacted the overall market share of cryptocurrencies. All these factors accounted together directly

impact investors due to which Warren Buffet and Economist Nouriel Roubini state that cryptocurrency markets are like a bubble.

- **Tech Savvy –**

Investments in cryptocurrencies are yet more for tech-savvy users since the process is still cumbersome as not many people understand how to use it. lansiti and Lakhani (2017) state that an experiment conducted at Bitcoin Club of MIT Institute in 2014 where students were provided $100 each to invest in Bitcoin, out of the 4,494 students, 30% did not sign up for the event and another 20% converted the bitcoins to cash within a few weeks. The preliminary reason was that many found it complicated to understand where and how to use Bitcoins. Similar result was found by Parashar and Rasiwala (2018). They conducted an analysis regarding the awareness and perception around cryptocurrencies and found that out of the 114 respondents they interviewed, around 74% mentioned that investment in Bitcoin requires expertise.

- **Scalability –**

Scalability is another issue for cryptocurrency, where scalability refers to the processing and speed of transactions. Due to which cryptocurrencies have been facing fierce competition from VISA and Mastercard. As we already discussed in section 3.7 that cryptocurrencies are verified through the process of mining. And mining is a very complicated process, where the transaction processing can take from a couple of minutes to sometimes even hours. Whereas in the case of VISA and Mastercard, they can process more than 1,000 transactions per second, whereas in the cryptocurrency ecosystem to verify one block, Bitcoin sometimes takes around 10 minutes and Ethereum around 15 seconds.

- **Money Laundering –**

Cryptocurrencies, since their introduction, have always had a reputation for money laundering activities; this is mainly due to their pseudo-anonymity feature due to

which illicit market players have taken advantage of this and escaped with millions of fund. Chainalysis, a blockchain analysis company, which provides services in compliance-related issues, states that in 2019, around $2.8 billion in bitcoin were transferred by illicit traders (Chainalysis Team, 2020).

- **Lack of central issuer –**

Cryptocurrencies also often stumble due to the issues of not having any regulatory surveillance. Since reversal of transactions and the identity of the sender and receiver are hidden even if someone mistakenly sends some crypto coins to some unknown recipient, there is no way for its reversal, and the unknown recipient can walk away with the cryptos. Whereas, in the case of banks, such issues can be addressed immediately. Another reason for not having a central authority causes instability in the crypto market as all the prices depend only on the demand and supply, which in return causes volatility issues in their prices.

Moreover, the lack of regulation has also tarnished the image of cryptocurrencies due to their explicit use for buying and supplying illegal goods and services. The feature of anonymous payment mechanism they consist has facilitated the growth of the online "darknet" marketplace. Foley, Karlsen, and Putniņš (2019) state that around 27 million bitcoin users were using it for illegal trading activities on the darknet.

- **Risk of Hacks –**

Cryptocurrencies or blockchain technology, as such, are less prone to hacks or data breaches (Ryan, 2019). The most common types of hacks that have occurred over the past several years are mainly due to the exchange and wallet service provides where the private and public keys are stored. The main reason for this is that most of the exchanges or wallet providers may have a security flaw in their network. Other reasons, as argued by Ryan (2019), include; most of the crypto trading platforms allow using weak passwords, fail to use two-way authentication, or most of them are centralized and have inadequate wallet protection. Moreover, there are thefts that occur due to Ponzi scheme on some exchanges. Dreyfuss (2020), states that losses

from cryptocurrency hacks for the year 2019 were around $4.52 billion dollars, which were 160% more than in 2018.

3.7   Blockchain 101: Market Player in Cryptocurrencies and Blockchain

- **Initial Coin Offering –**

Initial Coin Offerings (ICOs) resemble the IPO (Initial Public Offerings) platform, with the main difference being that ICOs are unregulated. Rosic (2017b) narrates it as, "ICOs are blockchain crowdsales, the cryptocurrency version of crowdfunding. The ICOs have been truly revolutionary and have managed to accomplish many amazing tasks." ICO is also affiliated as "token sales" or "token launch" (Deloitte, 2017), which is an approach usually utilized by start-up companies or companies who are creating new products with an associated utility. These companies specify the need for ICO by publishing a white paper or make announcements through crypto forums, which explain the type of the project, its purpose, future goals, and the amount of funds it wants to raise. Based on which investors can look for potential opportunities in these projects and make investments. When investors invest in these companies, they receive tokens of the project, and in return to build the project, the funding is done through cryptocurrencies such as Bitcoin (BTC), Ether (ETH), and sometimes even in Fiat currencies. Bitcoin Magazine (n.d.) mentions several projects used a crowdsales model to try and fund their development work in 2013. Ripple, during its ICO launch, had pre-mined 1 billion XRP tokens, which it sold to willing investors in exchange for bitcoin and other fiat currencies. Ethereum had also raised over $18 million in early 2014. CoinDesk analysis states that ICOs helped raise more funds in the first few months of 2018 than in 2017 (Floyd, 2018).

- **Crypto Mining –**

To make this process simple and easy to understand, we would use Bitcoin as an example, so that the readers get a clear picture of what exactly is cryptocurrency mining.

Cryptocurrency mining is not like the regular printing of fiat currencies, where central banks print notes for the functioning of the economy. The process of mining in cryptocurrency is a method used to validate transactions that have been executed over a blockchain network (Karamat, 2018). It is a method where transactions between users are verified and added to the public ledger of the blockchain. Any user who has access to the internet and wants to earn additional bitcoins (or other cryptocurrencies) can participate, provided he has the required hardware configuration. Each time a bitcoins are purchased and sold, a record is made in the blockchain ledger, where the transaction needs to be validated to maintain the integrity of the network and avoid the double-spending issue, due to which the network nodes (users/miners) validate these transactions when each block is filled with worth 1MB of transactions. The block is verified randomly, as there are no set rules for verifying the block. Each miner has to guess the hash function that is the 64-digit hexadecimal number.

The two types of models used for validation; the Proof-of-Work (PoW) and the other is Proof-of-stake (PoS). Under the PoW model, individuals, groups, or business entities compete with one another to validate each block. They usually make use of high-end computers with specialized hardware and software configuration, which enables them to solve the complex mathematical algorithms. The first person who guesses the mathematical code and validates the accuracy of the transaction is given a block reward. A block reward is simply incentive paid out to the miner for validating the block. Payment of incentives is usually made via the particular cryptocurrency, which was being validated or digital tokens of the currency that is being validated. However, there are certain drawbacks of using the PoW model; firstly, it is extremely expensive due to the heavy use of electricity to mine the coins. Williams (2018) states that there are varying costs of mining in different countries, he analyzed the cost of mining in Venezuela and South Korea and points out that, Venezuela is the cheapest country in terms of mining, where each bitcoin can be mined at just $531 dollars, whereas in the case of South Korea, mining each bitcoin would cost nothing less than $26,170. The difference in mining prices is due to variation in their electricity contracts, where the electricity contracts in Venezuela are highly subsidized, whereas, in South Korea, charges add on as the consumption units increase.

Secondly, another issue with PoW model is that the security interface is vulnerable to intrusions and hacks, mainly due to the reason that is if any individual or group that gains a 51% control of the networks computing power, they could essentially hold the network and the digital currency and create substantial hindrances on the network.

Another model that has been receiving some attention is the PoS model. This model does not rely on high-powered computers and mining farms to validate the transactions on its blockchain network. Instead, it is a method where the various stakeholders of cryptocurrency receive the right to validate transactions. This means the more cryptocurrencies are held by a person, the more likely it is that he would be chosen to validate a block of transactions, the apparent advantage of this platform is that it is considerably lower in cost. Also, this model has no issues of hackers gaining 51% control of the computing power of the network because to do so; the hackers would need 51% control of all the virtual coins in circulation, which is expensive and infeasible. But again, this model also suffers from some drawbacks. In the PoS model as we mentioned already, the crypto holders have a right to validate the block, so the crypto holder who has a more substantial stake would ultimately make all the decision in the network, this in a way deviates the actual purpose of the cryptocurrency ecosystem since it was developed to remove the centralized method of transacting digitally.

- **Crypto Exchange –**

Cryptocurrency exchanges are online platforms that allow investors to trade or buy and sell cryptocurrencies against each other or through fiat currencies in exchange for a specific fee (brokerage) (Hansen, 2018). Also, not all exchanges allow trading using fiat currency or trade all cryptocurrencies such as in the case of Binance, which allows users to only trade cryptocurrencies for one another, whereas in case of Coinbase it allows users to buy and sell cryptos via fiat currencies and the other way round. Also, it does not support trading in some particular range of coins, such as Binance coin. There are three major types of exchanges; a trading platform – these are online websites which allow trading and act as a bridge between buyer and sellers (e.g., Coinbase, eToro), Direct Trading Platforms – these allow direct trading

between users from any country and they do not have a fixed market price; instead the sellers set their selling price (.i.e., exchange rate) and finally there are the brokers – these are also online websites where buyers and sellers can trade cryptos but at a price set by the broker themselves. (Rosic, 2018a)

- **Crypto Wallets –**

Cryptocurrency wallets are usually used as a tool of communication with various blockchain networks, which facilitate users to exchange cryptocurrencies and manage their balance. The usual notion is that these wallets store the cryptocurrencies, but that is not the case. These wallets do not enable the storage of crypto assets; instead, they act as a medium of exchange by generating the necessary information for their buying and selling. (Binance Academy, n.d.; Rosic, 2017a). The wallets make use of cryptography technology; that is the private and public key. These keys are issued to the user when he/she signs up for any cryptocurrency wallet services. Here, both the private and the public key are linked explicitly to the user, with no personal information encrypted in them. The public key can be considered as an email I.D. address, but this does not showcase any of the personal details; it only facilitates the exchange of cryptos.

- **Crypto Nodes –**

Cawrey (2014) states that in the course of understanding how Bitcoin functions, we often tend to ignore the excessive amount of machinery needed to maintain this globalized infrastructure. To simply explain what nodes mean; we can think of these any electronic device which has an internet connection and an IP address, which enables us to send and receive data on our devices. In a similar stance, crypto nodes (usually laptops, computers) function, which acts as an intermediary point of communication to transmit, receive and create messages. The main primary feature of a node in the cryptocurrency ecosystem is to make a copy of every transaction that takes place; this ensures that the integrity is retained and there is no alteration or reversal of data available (Heal, 2019). These nodes are connected to each other and exchange data and information on a real-time basis so that each node on the blockchain network is up to date. There are two important types of nodes in a

blockchain network; a full node; which keeps a complete record of the entire blockchain database and runs 24/7, a light node; these do not keep a database of the entire blockchain database but just provides information on a specific block on request on clients, and these interact with the full nodes block for this information retrieval.

3.8 Blockchain 101: Types of Cryptocurrencies

Corbet et al., (2018b) states that studies have focused so much on bitcoin, that there has been an ignorance towards its competitors. Moreover, as our analysis also examines the 18 largest cryptocurrencies, it would be important to review the types of cryptocurrencies. Hence, this section covers the types of cryptocurrencies.
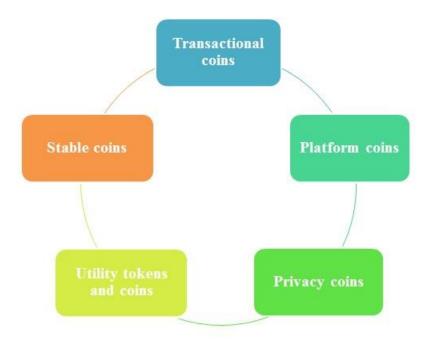
Figure 2: Types of Cryptocurrencies

- **Transactional coins –**

Transactional coins, also called Financial token/coins, are the conventional cryptocurrencies which were introduced to eliminate the use of fiat-based currencies

and transition to a self-governing decentralized digital currency, which can be used to transact for goods and services. These cryptocurrencies function similarly like traditional currencies without a traditional intermediary or central authority, such as a bank or a payment gateway, their sole purpose is to act as a medium of exchange similar to gold and cash. These coins can be used online to buy anything from a cup of coffee to transfer funds to someone in another country. There are even ATMs being set up to transact with these coins for fiat currencies such as the US dollar or Euro. (Davis, 2018). Some of the most popular payment coins are Bitcoin, Ethereum, Monero (CoinBundleTeam, 2018).

- **Platform Coins –**

As the name suggests, platform coins are natives of their blockchain network, which provide users multiple other services than to function as a medium of exchange merely. Such as Ethereum, which uses smart contract protocols, which allows its users and other enterprises to build their own blockchain networks over its own blockchain. This, in a way, cuts costs for the developer, as they do not need to spend time building a new blockchain and just create their codes to provide their services. Some examples include OmiseGo, which is a decentralized blockchain-based company that provides financial services to its users where they can execute financial transactions such as payments, remittance, payroll deposits, and asset management functions. Kyber Network is another project built over the Ethereum network, which allows its users to exchange and convert digital assets with instant liquidity. (Adams, 2018). Moreover, all the decentralized applications developed are built over the ERC-20 (see Appendix A), which is an essential requirement to build and develop apps on the network of Ethereum.

- **Privacy Coins –**

Privacy coins are next-generation cryptocurrencies which come with high encryption techniques which allow users to transact anonymously (Shilov, 2019). The founders of these privacy coins use such methods of coding which makes it impossible to trace the source and destination of the transactions such as Monero (XMR), while some enable a "mixing mechanism" which is same as scrambling several transactions into

one single group and publishing on the blockchain network such as in DASH. Verge coin (XVG) makes use of encryption data, which makes the IP addresses of the users untraceable, which makes it challenging to know the source from where the transaction was executed and their destinations untraceable. The primary purpose of these cryptos is to transfer the power in the hands of the users to maintain their privacy. But these cryptocurrencies have caused a rise in criminal and fraudulent activities due to the leverage of anonymity being prevalent in them. (ShapeShift, 2020).

- **Utility Coins –**

These cryptocurrencies differ in their functionality than the payment coins, where their primary purpose is not as a medium of exchange but to provide utility to the users. Utility, as such, refers to the provision of services or products. The significant use of utility token is that it gives the token holder right to use the network and assistance in developing their own blockchain ecosystem within the blockchain of the company. Filecoin raised $257 million dollars through its crowdfunding sale and enabled these token holders to access its decentralized cloud storage platform (Katalyse.io, 2018). Nexo token is a native of the Nexo platform, which provides cryptocurrency loans to its users either in fiat currencies or Bitcoin and Ethereum (Nexo, n.d.). The other is Binance coin, which is a native coin of the Binance exchange, where it provides rebates to the holders of the coin when they transact over its platform (Garner, 2018).

- **Stable Coins –**

Stable coins were created in the cryptocurrency space for the sole purpose of providing reliable storage value. They came in existence, due to the extreme volatility associated with the standard or traditional cryptocurrencies (such as Bitcoin, Ethereum). (Kovačević, 2020). This can be compared with ECB (2019) who makes the comparison of the volatility in the crypto market to that of other assets and states that the volatility of cryptocurrencies in 2017 and 2018 was so high that it peaked the combined volatility not only the European stocks and bonds but also, oil and gold prices. Moreover, due to the fluctuations in prices, investors were gaining

and losing money rapidly than expected. Thereby, the criticism the crypto space was facing, made some developers and entities introduce these coins. Moreover, there are various types of stable coins, from fiat collateralized, commodity collateralized, crypto collateralized to non-collateralized. Fiat collateralized, and commodity collateralized is the most commonly used stable coins. Fiat collateralized are the ones that are pegged to fiat currencies such as the U.S. Dollar or Euro or GBP. Whereas, in the case of commodity collateralize, these are backed by commodities such as gold, oil real estate, and sometimes even a basket of different commodities. (CBInsights, n.d.).

4   SELECTION OF ASSETS

"The process of selecting a portfolio may be divided into two stages. The first stage starts with observation and experience and ends with beliefs about the future performance of available securities. The second stage starts with relevant beliefs about the future performances and ends with choice of portfolio."

-    **(Markowitz, 1952, p. 77)[4]**

4.1   Cryptocurrencies

- **Bitcoin (BTC) –**

Bitcoin is the first decentralized cryptocurrency introduced in the crypto space. In August of 2008, a website titled bitcoin.org was registered, which bore the descriptive status of Bitcoin. As previously mentioned, a whitepaper titled "Bitcoin Peer-to-Peer Electronic Cash System" published by Satoshi Nakamoto (2008) keys in the functionality of Bitcoin. The network was operational with the issuance of the first bitcoins, which were mined by Satoshi Nakamoto called the "Genesis Block." (Wikipedia, n.d.). Moreover it functions much like any other fiat currency or digital payment systems such as PayPal, Visa, or Mastercard, with the only difference being that Bitcoin operates in a digital world through the blockchain network which is not regulated by any central authority. (Bittiraha.fi, n.d.)

- **Ethereum (ETH) –**

Ethereum project was launched by Vitalik Buterin in 2013, and it went live in 2015 with 72 million pre-mined coins, out of which 65% are in circulation (Olszewicz, 2020). Ethereum is the second biggest cryptocurrency. The project provides services in three major sectors; firstly, its use as a digital asset, secondly as a platform for

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[4] (Markowitz, 1952)

other developers, companies, and start-ups to build their own blockchain and issue their own tokens. And thirdly, it provides a decentralized platform for running "Smart Contracts." Similarities between Ethereum and Bitcoin is that both mine their coins and use the PoW stake protocol. But the significant difference is that blocks of Ethereum network are created every 15 seconds, unlike in Bitcoin, which is created after every 10 mins and also that it does not have a predetermined supply limit in the circulation of its coin ETH. (Mezni, 2019). At the moment, there are about 109 million coins in circulation (Olszewicz, 2020).

- **Ripple (XRP) –** ✕

Ripple is a profit-building technology platform that also has its own coin called XRP, developed by its parent company Ripple Labs. The company provides real-time payment and currency exchange service settlements to financial institutions and banks for any value and at a marginal fee. More than 100 companies worldwide have adopted Ripple protocol such as MoneyGram, Western Union, Barclays, Bank of England, and Merill Lynch, to name a few. Ripple not only allows transactions in cryptocurrencies but also in fiat currencies. Ripple differs from bitcoin and other cryptocurrencies, as in case of its transaction processing time, it settles transactions in 4 to 5 seconds and processes 1500 transactions per second, whereas Bitcoin takes more than 10 mins and Ethereum around 15 seconds. Another factor that differentiates, Ripple is that Bitcoin is based on a PoW consensus algorithm, but Ripple does not rely on the process of mining to verify its transactions; instead, it makes use of a consensus protocol, where each block is verified by specially selected nodes/servers to add the block in the network. It is important to note that Ripple and XRP are not the same, XRP is a native currency of the Ripple labs and the currency was introduced not as an alternative or as a store of value, but to act as a medium of exchange, where, in case there is a lack of exchange available between two trading pairs of currency, users can use XRP for conversion. (Tahiri, 2019). The supply of XRP coins is finite where during its conceptualization, 100 billion of XRPs were created, and no new XRPs will be ever created. (XRP, n.d.).

- **Bitcoin Cash (BCH) –**

As we know, Bitcoin was the first-ever conceptualized cryptocurrency to be launched in 2008. One problem associated with Bitcoin was that the developers limited the block size to 1MB, and as the user increased on the network of Bitcoin, the block size limit caused the blocks to pile up and, in turn, affected the transaction time and increased the transaction fee. This caused a rift between the Bitcoin users, where one group was favoring Bitcoin unlimited and the other preferring a Segregated Witness Solution (SegWit). Bitcoin unlimited is a method of eradicating the block size limit, and SegWit is a method of storing data and information in separate files outside the blockchain. However, these solutions still caused a dispute as no conclusion could be reached on adopting one. This conflict finally came to an end on 1st August 2017, when Bitcoin Cash was created with a block size of 8MB and all those who held Bitcoins before the split (fork) received the same amount of Bitcoin Cash. (Cointelegraph, n.d.). Bitcoin Cash is a continuation of the Bitcoin Project, but the only difference pertains to faster transaction processing and cheaper transaction fees (Bitcoin Cash, n.d.).

- **Litecoin (LTC) –**

Like Bitcoin, Litecoin is also one of the initial cryptos and came in existence around October 2011. Litecoin offers its users high speed payments to anyone across the world with comparatively lower transaction fees than the traditional payment options (SWIFT, ACH, and FedWire Systems). Litecoin was launched by a former Google executive Charlie Lee. It gained momentum when concerns over processing time and confirmation of block transactions started becoming an issue for Bitcoin. Litecoin also uses the (PoW) consensus algorithm to validate its transactions. However, the significant difference between Bitcoin and Litecoin is that the former uses SHA-256 Algorithm, due to which mining of Bitcoin is expensive and requires custom hardware equipment called ASICs (Application – Specific Integrated Circuits) which are superior to the standard CPUs of daily life (see Appendix A). Litecoin, on the other hand, makes use of the Scrypt algorithm, which eradicates the use of ASIC packed computers and allows mining to be done on regular CPUs. Litecoin processes

block at a rate of 2.5 minutes, whereas Bitcoin processes each block at a rate of 10 minutes. (Litecoin wiki. n.d.).

- **EOS (EOS) -**

EOS token is a cryptocurrency owned by the EOSIO network. It was launched in 2017 with an ICO funding of $4 billion dollars. The main aim of EOS platform is to provide users with a decentralized operating system to build decentralized applications which can scale millions of transaction per second, along with other facilities such as cloud storage, user authentication, and server hosting. The EOS platform is administered by block.one, a team who has previous experience in the cryptocurrency and blockchain network. EOS works on an ownership model where it enables users to create applications on their platform with no transaction fees, and this works as a result of costs of running an application being covered through inflation in its tokens in circulation, where each blockchain working on the EOS platform needs to generate 5% inflation per year, where these funds are circulated within the platform for the smooth running of its network and to be self-reliant. Another essential feature of EOS is it runs on a PoS mechanism, where the outcome of attack and intrusion in the network is eliminated due to the ability of the PoS system to freeze the block, in case any fault is detected. (Kauffman, 2018; Rosic, 2018b).

- **Binance Coin (BNB) -**

Binance coin is a native currency of the Binance platform. It was launched in 2017 with an ICO of 100 million, on the Ethereum platform, but it migrated to its own built-in blockchain in late 2019. Binance coin has the same standard functionality, such as the other cryptocurrencies for trading against other cryptos. However, one crucial function it solely consists of is that it provides discounts while trading on its exchange platform, giving users additional benefits of lower transaction fees. Also, an added benefit it has Binance follows a mechanism of burning its coins in circulation. Till now, it has attempted it eight times. The reason for doing this is to

make the coins scarce in the crypto market, which will, in turn, raise its prices and benefit the holders of their coin. (Musser, 2019).

- **TEZOS (XTZ) -**

Tezos (XTZ) is a digital token linked to the blockchain network of Tezos company, which was introduced in the year 2014. However, the project went live only after 2018. Tezos project is based on two very unique features, which the founders deemed fit given how the issues bitcoin was facing, which we already mentioned above, about the fork (split) of the bitcoin network, into BTC (Bitcoin) and BCH (Bitcoin Cash). The two features are; "On-Chain governance" and "Michelson." On-chain governance is a concept, which is similar to the standard corporate governance policies which companies follow. In terms of Tezos, it is a process that allows its developers to come up with new ideas and projects that can help for the improvement of the network. The developers submit their proposals for network protocol upgrades in return for compensation, where this proposal is passed on the stakeholders, who vote if they consider the proposal acceptable. After which the proposal is tested, and a vote call is rolled out again, where the stakeholders make the final decision of the proposal, if it is passed, a legitimate upgrade is initiated with the new version of the protocol. This, in a way, ensures that the network of the company also improves with the passage of time and also ensures that each stakeholder approves the proposal, as this avoids centralization. Tezos also allows the use of smart contracts similarly as Ethereum; however, Tezos uses functional programming language, where it combined codes in one single function, this enables to read and understand how the code will function mathematically. It is deemed better than Ethereum, because, in Ethereum, smart contracts are written in another program called Viper or Solidity, which are then compiled in the Ethereum blockchain network, whereas in Tezos, Michelson codes are directly run on the Tezos blockchain. (Mitra, 2019).

- **Cardano (ADA) -**

Cardano is a multi-layered blockchain technology introduced in 2015 by a company called IOHK, which stands for Input-Output Hong Kong. It also allows developing

smart contract apps, much like Ethereum. With the difference lying that each system has its own platform. Hence, called as multi-layered because it has different application software for each platform, such as one for its financial transactions and one for its distributed computing network. Cardano project is still undergoing development, and only a part of its project is available to use, which is its settlement layer. (BitDegree, 2019a)

- **Stellar (XLM) -**

The Stellar project evolved due to the difference between the founders of Ripple, where Jed McCaleb, wanted to provide financial services to the masses and those who had inadequate access to financial literacy. It came into existence in the year 2014. Stellar is a platform that allows cross-border transactions, where it enables one to send and receive any type of currency. Its own native token XLM also acts as a mediator and provides conversion assistance between other currencies. Stellar is currently in partnership with various companies who use their cross border functionality to conduct their business. Such as IBM, which uses its services to settle payments in British pounds and Fijian dollars. ICICI Bank, a private bank in India, also uses Stellar networks services within India and outside India for payment settlements. (Tahiri, 2020).

- **Monero (XMR) -**

Monero is a type of cryptocurrency which uses a special kind of cryptographic coding to ensure that all transactions that take place on its network are secure, private, and untraceable. It was launched in 2014. Monero is different from the generic cryptoassets such as Bitcoin and Ethereum, who use an approach of pseudo-anonymity where wallet addresses are published on their blockchain network, making it easy to track and trace. Whereas on the other hand Monero, makes use of ring signatures, where the wallet address of each user is mixed with other wallet addresses, thereby making it difficult to trace the originator of the transaction. This project also uses the same mechanism of mining to mint new coins, but the major difference lies on its hardware equipment, which is not as expensive as the ones

required for bitcoin mining, rather Monero can be mined using any platform such as Windows, Andriod, Linux, and Mac OS. It also validates each block in less than two minutes. (Admiral Markets, n.d.)

- **TRON (TRX) -**

TRON project, token TRX stands for Tronix, is the 10th largest cryptocurrency with a market capitalization of $1.5 billion. TRX was launched in 2017 on Ethereum networks ERC 20 protocol, but soon it launched its own independent blockchain and minted its own new coins, now called TRX coin. TRX facilitates as a medium of exchange, where users can use it to pay for goods and services. It can also be used as an investment instrument as its value has sizably increased since its launch. Furthermore, it also provides its owners with voting rights in the company. The number of TRX that can be minted is limited to 100 billion, out of which 40% were dispensed during its ICO launch, 15% is retained for private offerings, 35% reserved by TRON project itself and the remaining 10% are held with a chat platform based company called "Peiwo." Furthermore, another factor what differentiates TRX from standard cryptocurrencies such as Bitcoin, is that TRX cannot be mined further, it was pre-mined with a total of 100 billion of TRX, out of which 65% are already in circulation. (Davies, 2019).

- **Dash (DASH) -**

Dash was launched in 2014. It traces its roots to Bitcoin, because Litecoin was forked from Bitcoin, and from Litecoin, Dash was forked. Dash functions similarly to Bitcoin and Litecoin, in terms, of sending and receive money. However, it also allows some advanced functionalities than Bitcoin and Litecoin. It enables to maintain privacy and offer higher transaction speed, and this works through the process of master nodes. Master nodes, which we will discuss in the following chapter, refers to miners. Miners are the ones who verify transactions on the blockchain network. In the case of Dash, to maintain privacy and faster transactions, it makes the use of master nodes. These master node miners need to keep a minimum deposit of 1000 DASH in order to become master nodes miners. These miners then

perform essential functions, such as verifying private transactions, instant transactions. (BitDegree, 2019c).

- **Neo (NEO)** -

AntShares was launched in 2014, and later in 2017, it was rebranded to its current name Neo. Neo enables the creation of smart contract platforms due to which it is also called as the Ethereum of China. Neo also does not require smart contracts to be written in complex programming languages such as Ethereum who uses Solidity; instead, it allows codes to be developed using common programming languages such as C++, Javascript, and Python. It is also not mineable like its peers; there were only 100 Neo tokens launched during its conceptualization, out of which 65 million tokens are in circulation that is 65% of its total tokens. Neo project also has its own token called NEO, which is used as a medium of exchange and also to create and manage blocks. (BitDegree, 2020b).

- **IOTA (MIOTA)** -

IOTA was launched in 2015, with an aim to provide data transfer and financial transactions transfers in a fast, cheaper, and secure process. IOTA, like most other cryptocurrencies, does not use blockchain technology; instead, it relies on a process called "Directed Acyclic Graph," which IOTA associated as "Tangle." Tangle is a distributed ledger technology which is structured in a method, where it flows in just one direction where the information cannot be reversed or split. This basically means, unlike bitcoin, who has two groups, miners and users. IOTA users are only its miners, where every user who wants to transact with another person needs to verify and confirm transactions for two other people, this in a way, eliminates transaction fees and also increases transaction speed. (BitDegree, 2020a).

- **Zcash (ZEC)** -

Zcash is a fork of bitcoin, which was conceptualized in 2016. It also has the same finite supply 21 million tokens. It was introduced to provide complete privacy to its users through some special cryptographic coding. Where, if users choose to make their transactions private, only the date and time of transaction is published and secures the rest of the information. Zcash is mostly similar to Monero, with significant difference relying on that privacy is a default feature of Monero, whereas, for Zcash, users have to opt for it. Zcash is intended to be better than bitcoin as it not only makes transactions private but also has a faster transaction speed where blocks can be confirmed in less than 2.5 minutes. It also eliminates the need for complicated hardware equipment like the ASIC hardware used in bitcoin and allows mining through simple CPUs and computers that we use in our daily life. (BitDegree, 2019d).

- **Vechain (VET) -**

The Vechain project was not launched initially to allow its token to function as a medium of exchange. Instead, its primary aim is to bring blockchain-based technology to enhance supply chain management and quality control processes. It was developed in 2018 on the Ethereum blockchain network with an ICO launch of $20 million worth of ETH. (Analyst Team, 2018). It later developed its own blockchain network and rebranded its token as VET coin, which stands for the name of project VeChain Thor. Vechain plans to achieve an ecosystem of secured supply chain management process through the method of asset digitization. Where they aim to create a unique identity for products through the process of hashing, which will allow all the participants to track the progress of the products, as this will enable easy tracking and prevent frauds and maintain the authenticity of the products. Vechain currently has partnerships with PwC, Microsoft, Renault, to name a few. (Asolo, 2018).

- **Dogecoin (DOGE) -**

Dogecoin is an open-source platform, which was introduced in 2013. Dogecoin is different from most of the other crypto assets due to it being an inflationary coin,

where each time coins lost or misplaced can be mined to get the supply back to 100 million tokens. Dogecoin is not usually seen as an instrument for investment; rather, it is mostly used as a medium of exchange. Moreover, Dogecoin has gained massive popularity due to its community support, where it donated $50,000 to the Jamaican Bobsled Team to make it to the Sochi Winter Olympics. It also raised and donated $30,000 to build wells in Kenya. (BitDegree, 2019b).

- **USDT –**

USDT is a stable coin launched by a company called Tether, which is pegged to the US Dollar. It came into existence due to the criticism in the cryptocurrency ecosystem, where all the currencies faced extreme volatility, where-in investors made significant gains and huge losses at the same time. The main feature of USDT is to provide stability in the cryptocurrency market. It was created on the Omni platform, which is based on the blockchain network of bitcoin. Each USDT is worth $1 U.S. dollar, due to the reserves held back in USD by the exchange platforms. (Blockgeeks, n.d.; Hay, 2019).

4.2   Traditional Assets

- **TLT –**

iShares Barclay 20+ Year Treasury Bond ETF (TLT), tracks the index composed of U.S. treasury bonds with maturities greater than 20 plus years (Blackrock, n.d.). TLT is also attributed as a high-quality ETF due to its credit risk being zero and having an expense ratio of 15 basis points. But it also suffers from an increase in interest risk. The main reason for selecting this bond ETF is because it has a negative correlation with assets such as VNQ, SPY, and DJCI, which can be seen in the correlation matrix in figure 4 as well.

- **VNQ –**

Vanguard Real Estate ETF (VNQ) tracks the MSCI US Real Estate market. It a 25/50 index, which tracks the performance of large, mid, and small-cap real estate sector companies based in the U.S (Vanguard, 2020).

- **SPY –**

The SPDR S&P 500 is an ETF index that is managed by the State Street Global Advisors, which mirrors the S&P 500 index performance. Since the S&P 500 index consists of a basket of 500 largest U.S. based companies operating in different sectors, it is used as a performance indicator of the U.S. economy. (State Street Corp, 2020).

- **IAU –**

iShare Gold Trust mirrors the daily movement of gold prices. It is a standard tool used by investors to protect against periods of inflation. It provides an easy and cost-effective access to gold investments. The shares of the trust (iShares Delaware Trust Sponsor) are backed by physical gold held by a custodian (JP Morgan Chase Bank, London). (Blackrock Inc, 2020).

- **DJCI –**

The DJCI (Dow Jones-UBS Commodity Index) was purchased by Swiss Bank UBS AG in 2009 (Reuters, 2009). Since then, the Index is called as ETRACS Bloomberg Commodity Index Total Return ETN, which mirrors the performance of Bloomberg Commodity Index. It is a broad-based index consisting of a basket of commodities diversified in holdings such as natural resources, live cattle, metals, oil, natural gas, and grains. There are in total 23 commodities held in this index. (Gunzberg, 2014).

- **VT –**

Vanguard Total World stock represents the performance of the FTSE Global All Cap index, which covers investments in both U.S. and foreign markets and in developing

and developed markets. As of 31st October 2019, there were a total of 8,936 stocks comprised of 49 markets. Out of these largest markets covered include 55% of U.S. markets, 8% of Japan, and 5% of the United Kingdom. (Vanguard, 2020). The reason for including this index is to represent global stocks held by a U.S. individual investor[5].

4.3 Risk-free rate

For the computation of the Sharpe-ratio, we require the risk-free rate. Hence the three months US Treasury Bill rate was selected as a proxy for the risk-free rate. The rate taken into consideration is 1.55%[6], which is the risk-free rate as of 21st Feb 2020.

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[5] (Moore, 2018)

[6] (U.S. DEPARTMENT OF THE TREASURY, n.d.)

5   RESEARCH FRAMEWORK

5.1   Data

The study is undertaken for the period from 1st January 2014 to 28th February 2020. One issue that we encountered while obtaining the data is that the closing prices quoted across each exchange was different. The main reason for price discrepancy is based on the different methods used for calculating the market capitalization values, due to which we obtained the daily price information for the cryptocurrency from Coinmarketcap.com. As its price is a quoted basket price computed using a weighted combination of closing prices from other exchanges (Corbet et al., 2018b). Moreover, each cryptoassets is selected based on its market capitalization ranking, which is a common approach employed in most of the previous studies undertaken (Fry & Cheah, 2016; Bernyah, 2018; Corbet et al., 2018b). Market capitalization ranking of cryptoassets is calculated based on its current trading price times its current circulating supply. We also limit our study only to cryptocurrencies traded in USD as our thesis aims to examine portfolio holding of a typical individual U.S. investor and also to prevent issues from price conversion inconsistencies. The daily closing prices were collected from the first available date until the last observation date. Due to which the total number of observations varies depending on when the cryptocurrency was introduced.

Daily price information for the traditional assets was retrieved from Yahoo Finance on 2nd March 2020. And there are a total of 2250 observations for each asset. The traditional assets selected are spread across a wide range of asset classes to represent investment opportunities that would arise by investing in a diversified portfolio. On the basis of this, we have selected two stock markets, one a U.S. index and another one, a global stock market index. A commodity index with 33.8% holding in the energy sector, along with holding in various commodity markets such as oil and natural gas, metals, grains, and cattle. Along with a U.S. real estate market index and a treasury bond. Moreover, we have also selected an alternative asset, which is a gold fund index. For the risk-free rate, we obtained the daily data from the U.S. treasury website. And the risk-free rate is considered as 1.55%, which is the 3 month U.S. Treasury bill rate as of 21st February 2020.

Also, cryptocurrencies are traded all seven days of the week, including holidays, whereas the traditional assets are traded only on weekdays. As the number of cryptocurrencies under examination is larger than the traditional assets, we, therefore, use the average function in Microsoft Excel to calculate the prices for traditional assets on the weekends and holiday periods.

5.1.1 Presentation of Assets

Table 1 below summarizes information of the selected cryptocurrencies, which includes its market capitalization values, the first and the last observational data periods along with and the total number of observations for each crypto-asset.

Name (Ticker)	Category	Market Capitalization (USD)	First Observation	Last Observation	Total no. of Observations
Cryptocurrencies					
Bitcoin (BTC)	Virtual currency	$142,484,153,393	01-01-2014	28-02-2020	2250
Ethereum (ETH)	Decentralized Platform	$ 21,604,074,880	06-08-2015	28-02-2020	1667
Ripple (XRP)	Financial Platform	$ 9,065,629,558	01-01-2014	28-02-2020	2250
Bitcoin Cash (BCH)	Virtual currency	$ 4,826,238,704	01-08-2017	28-02-2020	942
Litecoin (LTC)	Virtual currency	$ 3,107,624,134	01-01-2014	28-02-2020	2250
EOS (EOS)	Decentralized Platform	$ 2,795,734,415	01-07-2017	28-02-2020	973
Binance Coin (BNB)	Utility token	$ 2,543,232,346	25-07-2017	28-02-2020	949
Tezos (XTZ)	Decentralized Platform	$ 1,768,658,686	04-07-2018	28-02-2020	605
Cardano (ADA)	Utility and Decentralized Platform	$ 1,047,254,156	02-10-2017	28-02-2020	880
Stellar (XLM)	Financial Platform	$ 1,027,594,229	05-08-2014	28-02-2020	2034
TRON (TRX)	Virtual currency	$ 983,254,364	13-09-2017	28-02-2020	900
Monero (XMR)	Privacy coin	$ 946,007,827	20-05-2014	28-02-2020	2112
Dash (DASH)	Virtual currency	$ 676,734,744	08-02-2014	28-02-2020	2213
Neo (NEO)	Decentralized Platform	$ 659,177,740	15-07-2017	28-02-2020	960
IOTA (MIOTA)	Virtual currency	$ 535,684,358	13-06-2017	28-02-2020	992
Zcash (ZEC)	Privacy coin	$ 369,695,663	29-02-2016	28-02-2020	1219
Dogecoin (DOGE)	Virtual currency	$ 265,708,666	23-01-2014	28-02-2020	2229
Vechain (VET)	Utility token	$ 245,014,205	03-08-2018	28-02-2020	576
Tether (USDT	Stable coin	$ 6,376,183,665	02-03-2015	28-02-2020	1826

Table 1: Summary of Cryptocurrency Assets, including Market Capitalization and number of observations

Also included in table 1, are the various categories each crypto-assets falls under depending on the area of function. There are a total of six categories that have been identified: Firstly, the most generic function of cryptocurrencies as a virtual financial currency, that is to function as a medium of exchange. Secondly are the decentralized applications (dApp) platform providers, which provide a platform for developers and entities to run and develop decentralized blockchain networks. Thirdly, are the financial platforms which aim to provide instant and secure global financial services. Fourthly, we have utility tokens, which provide users services other than merely as a financial currency. Next, we have privacy coins, which enable a high level of encryption to make the transactions anonymous. And finally, we have the stablecoins, which aim to hold a constant price by being pegged to real-world assets, so that they can provide a store of value.

Name (Ticker)	First Observation	Last Observation	Total no. of Observations
Traditional Assets			
iShares 20+ year Treasury Bond (TLT)	01-01-2014	28-02-2020	2250
Vanguard Total World Stock (VT)	01-01-2014	28-02-2020	2250
Vanguard Real Estate (VNQ)	01-01-2014	28-02-2020	2250
SPDR S&P 500 (SPY)	01-01-2014	28-02-2020	2250
iShares Gold Trust (IAU)	01-01-2014	28-02-2020	2250
Dow Jones Commodity Index (DJCI)	01-01-2014	28-02-2020	2250

Table 2: Summary of Traditional Assets

Table 2 above summarizes information of the selected traditional assets. In the table, we have the first and the last observational data periods for each asset class along with the total number of observations for each asset. Assets selection has been made on the basis of a diversified global portfolio held by a typical U.S investor.
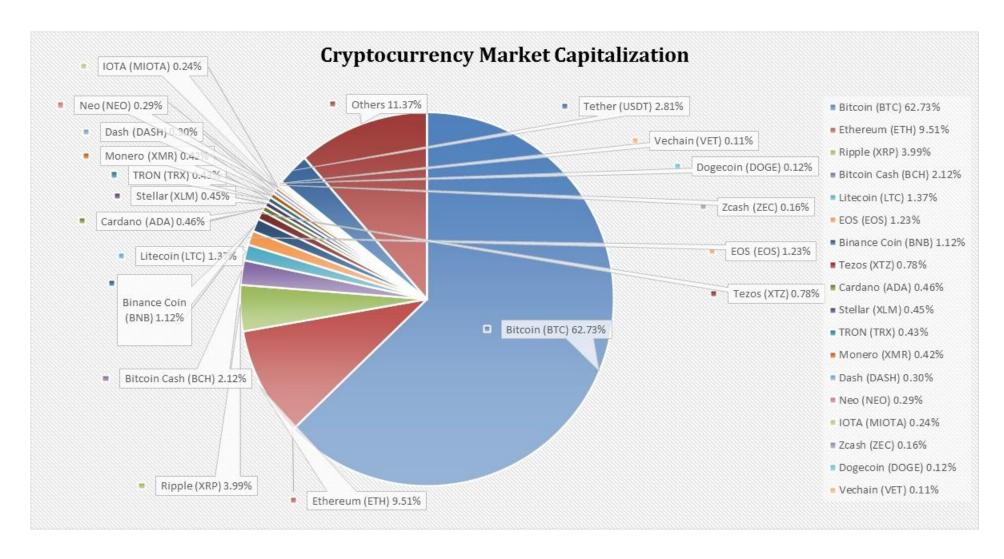
Figure 3: Cryptocurrency Market Capitalization

Moreover, figure 3 above represents the market capitalization values for each cryptocurrency. The market cap values have been calculated based on the total market capitalization value of all cryptocurrencies as on 2nd March 2020, and each individual cryptocurrencies market capitalization value. The data has been collected from Coinmarketcap.com. From the figure below, we can see that bitcoin has the highest stakeholding with a market share dominance of 62.73%. Following it is Ethereum, Ripple and Bitcoin Cash. Most of the other cryptocurrencies have a lower stakeholding with their market share of less than or equal to 1%.

5.2   Method of Analysis

In this section, we examine the analysis to be undertaken for the research question of our thesis. We aim to study the diversification benefits of including cryptocurrencies by employing the mean-variance analysis of the Portfolio Theory of Markowitz (1952), along with the Sharpe-ratio of Sharpe (1964) by focusing on the construction of an optimal portfolio of traditional assets and cryptocurrencies.

In line with the purpose of our thesis, we focus exclusively on the maximization of Sharpe-ratio (without short sale), maximization of Sharpe-ratio (with short sale), and a minimum variance portfolio. We also enhance the study by choosing a basket of cryptocurrencies (18 cryptoassets under examination). The motivation is based due to the growing development in the cryptocurrency ecosystem (Corbet et al., 2018b). And with the launch of various cryptoassets which have been altered to meet the criticism the generic cryptoassets face. We study the benefits of not only the generic cryptocurrencies such as (Bitcoin, Ethereum, Ripple) but also new inclusions such as utility tokens, stable coins to examine how they perform. Moreover, the previous academic research carried out on the topic "portfolio optimization," including cryptocurrency, was solely conducted on bitcoin predominantly due to its widespread popularity (Baek & Elbeck, 2015; Klabbers, 2017; Kajtazi & Moro, 2019). But as the crypto market is experiencing substantial growth in its value, some even examined altcoins such as Ethereum, Ripple, Litecoin, Dash (Cheah & Fry, 2015; Dodebier, 2017; Ketelaars, 2018) however, the study is finite to only a few altcoins. The study conducted on a vast number of cryptocurrencies that is more than six or seven is

limited, due to which we enhance this limitation by taking into consideration of such an extensive study. Furthermore, as previously mentioned, we strictly focus only on the U.S market for constructing the efficient frontier due to the U.S cryptocurrency market being a well-developed one than in comparison to the other markets and also to avoid conversion rate inconsistencies.

5.2.1 Portfolio Construction

The construction of the efficient frontier and analysis is done using Microsoft Excel by employing the approach used by Markowitz (1952).

First, to construct an efficient frontier, we need to formulate the equation for the expected return for all the "N" daily returns. N stands for the number of years under observation. In our study, $N = 5$, as we use five years of data from 2014 until 2020. Furthermore, "k" stands for the number of assets under analysis, we will study more about "k" in section 5.4.

We first start by converting the daily prices into log returns to calculate the daily returns for each data series. Equation 1, below presents the method of calculation, where $P_{i,t}$, stands for the current day closing price and $P_{i,t-1}$ is the previous day closing price.

$$r_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \qquad\qquad Equation\ 1$$

For the traditional asset returns, calculations are computed using the split-dividend adjusted prices, but these are directly available from Yahoo Finance.

After we calculate the daily return, each data series is then summed up to together to get the average daily returns, as shown in equation 2 below, where μ_1, μ_2 up to μ_n are the log returns for the entire data series.

$$\mu = E\,[r] = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_n \end{bmatrix} \qquad\qquad Equation\ 2$$

Once we compute the average daily returns, using the average function in Microsoft Excel, we then annualize these returns to calculate the descriptive statistics for each asset. Moreover, since the log-returns are additive, annual returns can be easily calculated by simple multiplication, as shown in equation 3. Here, we simply multiply the number of days by the average daily returns to get the annualized returns.

$$r_{annual} = (no.\,of\ trading\ day) * E[r]_{daily} \qquad Equation\ 3$$

Also, it is important to note that for the traditional assets, the number of trading days were assumed to be 252 and for cryptocurrencies, since they are traded for all 7 days of the week, the trading days are considered to be 365.

$$E(R_p) = w_i E(R_i) + w_j E(R_j) + w_k E(R_k) + \cdots\cdots + w_n E(R_n)$$

Next, we compute the portfolio returns by using the method mentioned above, where,

- R_p = expected return on the portfolio,
- R_i = return on the asset i,
- w_i = weights held in asset i,
- n = Number of assets in the portfolio.

Since we have many assets under study, we employ the matrix function in excel, by which we can also express the above method in a equation form, as shown in equation 4.

$$E(R_p) = \sum_{i=1}^{N} w_i E(R_i) \qquad\qquad Equation\ 4$$

Equation 4 states that the return on Portfolio (R_p) consisting of "N" assets is equal to the sum through all the individual assets weights times the sum of their individual returns. Also, it is important to note that the weights of the portfolio should sum up to be 1. That is the set of weights, w_i for each asset from $i = 1$ …... n should be as ($\sum_{i=1}^{N} w_i = 1$).

Next, we need to calculate the covariance matrix, which is used to create the minimum variance portfolio and the optimal portfolio.

The variance of the portfolio is calculated as $\sigma_p^2 = \boldsymbol{W^T S(W)}$

Where, $\boldsymbol{W^T}$ are the weights of each asset transposed, multiplied by $\boldsymbol{S}$ which is the variance-covariance matrix and then again multiplied by ($\boldsymbol{W}$) which are the weights of each asset.

Furthermore, the standard deviation of the portfolio is calculated as

$$\sigma_p = \sqrt{\boldsymbol{W^T S(W)}} = \left[\begin{bmatrix} W_i \cdots & W_j \end{bmatrix} \begin{bmatrix} \sigma_{ii} & \cdots & \sigma_{ij} \\ \vdots & \ddots & \vdots \\ \sigma_{ji} & \cdots & \sigma_{jj} \end{bmatrix} \begin{bmatrix} W_i \\ \vdots \\ W_j \end{bmatrix} \right]^{1/2}$$

Here, $\boldsymbol{S}$, as mentioned previously, refers to the variance-covariance matrix, which is the covariance between each of the assets returns in the portfolio. Also, the covariance of each asset return with itself is the variance of that asset returns such as σ_{ii}.

$$\sigma_p^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \qquad\qquad Equation\ 5$$

Moreover, we can also express the above variance computation in a matrix form, as shown in equation 5. Where i and j represent each asset and σ_{ij} is the covariance between the return of assets i and j.

5.3   Portfolio Diversification Strategies

The literature on portfolio diversification does not consist of one particular method as the best method to diversify a portfolio. We, therefore, analyze different sets of portfolios by enabling them in a table format so that it becomes easy for our readers to follow. There are in total 9 portfolios constructed which aim to maximize Sharpe ratio (without short sale), maximization of Sharpe (with short sale), and a minimum variance portfolio. In the previous section, we had mentioned "k," so it stands for the number of assets included, as shown below.

Type of Portfolio	Number of Assets included (k =)	Minimum Variance	Max Sharpe (no short allowed)	Max Sharpe (short allowed)
Traditional Asset	7	Yes	Yes	Yes
Cryptocurrency (1)	19	Yes (including USDT)	-	No
Cryptocurrency (2)	17	Yes (excluding BNB & USDT)	-	No
Cryptocurrency (3)	19	-	Yes (including BNB)	No
Cryptocurrency (4)	18	-	Yes (excluding BNB)	No
Traditional Assets and Cryptocurrencies	24	Yes	Yes	Yes
Traditional Assets and Utility Token	8	Yes	Yes	Yes
Mixed Portfolio	26	Yes	Yes	Yes

Table 3: Portfolio Diversification Strategies

Portfolio 1: Equally Weighted Portfolio

In this portfolio, each asset has an equal weight. Weights are derived by dividing 100% by the total number of assets. Moreover, we would like to inform our readers that we do not intend to study diversification benefits using this portfolio constructed. The significance of equally-weighted portfolios is far from being true (Brière et al., 2015) but we still build it because it is elementary and guides us for the construction of optimized portfolios, we aim to study in this thesis.

Portfolio 2: Minimum Variance Portfolio

Six sets of minimum variance portfolios are constructed. We compare the results of each to our base portfolio, which is a portfolio consisting of traditional assets only. For portfolio consisting only of cryptocurrencies, we run two sets of minimum variance portfolios. One including stable coin (USDT), which is a cryptocurrency portfolio (1), and another one excluding (USDT), which is a cryptocurrency portfolio (2). The reason for constructing two variants is to identify if stable coin controls the volatility issues within the other generic cryptocurrencies. Portfolio optimization on this data set was structured as ($min\ \sigma_p^2 \mid w_i \geq 0\ for\ all\ i$).

Portfolio 3: Max Sharpe (without short sale)

In this portfolio strategy, six sets of portfolios are constructed. Each portfolio is again compared to the base portfolio consisting of traditional assets only. For a portfolio consisting only of cryptocurrencies, we run two sets of Max Sharpe strategy. One including utility coin (BNB) that is cryptocurrency portfolio (3), and another one excluding (BNB), cryptocurrency portfolio (4). Portfolio excluding (BNB) although provided high expected returns but also was loaded with high volatility. Due to which another portfolio was constructed to identify the benefits of (BNB). Portfolio optimization on this data set was structured as ($max\ SR_p \mid w_i \geq 0\ for\ all\ i$).

Portfolio 4: Max Sharpe (with short allowed)

For this set of portfolios, four sets of portfolios are constructed. We again compare the results of each to our base portfolio, which is a portfolio consisting of traditional assets only. It is important to note that for portfolios consisting of cryptocurrencies, we do not run a short-selling constraint, as the crypto market has no facility to short sell for now. Due to which all the short-selling constraints prevail only for the traditional assets. Portfolio optimization on this data set was structured as ($max\quad SR_p \mid w_i \geq 0\quad for\quad all\quad i\quad consisting\quad of\quad cryptocurrencies \mid w_i \leq 0\ for\ all\ i\ consisting\ of\ traditional\ assets$).

5.4   Descriptive Statistics

Name (Ticker)	Mean Return	Standard deviation	Skewness	Kurtosis	Sharpe Ratio
Cryptocurrencies					
Bitcoin (BTC)	39.12%	73.93%	-0.47	5.50	0.51
Ethereum (ETH)	70.96%	116.05%	1.83	98.88	0.60
Ripple (XRP)	34.87%	125.66%	3.55	40.39	0.27
Bitcoin Cash (BCH)	-3.39%	96.32%	-0.11	22.41	-0.05
Litecoin (LTC)	14.05%	109.15%	0.89	12.54	0.11
EOS (EOS)	20.35%	102.01%	0.60	61.89	0.18
Binance Coin (BNB)	84.68%	95.40%	2.66	34.60	0.87
Tezos (XTZ)	6.32%	58.90%	0.32	18.78	0.08
Cardano (ADA)	9.83%	92.46%	0.32	73.80	0.09
Stellar (XLM)	51.25%	135.52%	1.13	19.02	0.37
Monero (XMR)	60.46%	128.87%	1.41	7.32	0.46
TRON (TRX)	28.30%	106.03%	0.80	54.08	0.25
Dash (DASH)	88.19%	144.29%	2.81	45.43	0.60
Neo (NEO)	71.59%	118.64%	1.81	29.44	0.59
IOTA (MIOTA)	-16.40%	92.89%	-0.53	15.03	-0.19
Zcash (ZEC)	-60.42%	117.34%	-1.54	123.29	-0.53
Vechain (VET)	-16.14%	57.66%	-0.84	27.91	-0.31
Dogecoin (DOGE)	26.36%	124.47%	2.63	12.30	0.19
Tether (USDT)	0.17%	9.69%	0.05	21.74	-0.14
Traditional Assets					
iShares 20+ year Treasury Bond (TLT)	4.57%	10.27%	-0.57	2.18	0.29
Vanguard Total World Stock (VT)	2.64%	11.59%	-0.95	5.75	0.09
Vanguard Real Estate (VNQ)	3.52%	12.52%	-1.03	4.28	0.16
SPDR S&P 500 (SPY)	5.42%	11.64%	-0.16	6.13	0.33
iShares Gold Trust (IAU)	2.87%	11.31%	0.76	3.90	0.12
(EEM)	0.11%	16.03%	-1.12	2.51	-0.09
Dow Jones Commodity Index (DJCI)	-6.19%	11.17%	-1.66	3.41	-0.69

Table 4: Descriptive Statistics for all assets

Table 4 above presents the descriptive statistics for cryptocurrencies and traditional assets. The mean and standard deviation have been annualized, as described in Equation 3. From the statistics computed above, we can see that cryptocurrencies exhibit extreme price movements than in comparison to the traditional assets. Moreover, stable coin USDT, showcases return much more similar to the returns of the traditional assets. The statistics further confirm that cryptocurrencies are very risky assets, and there are higher chances of big wins and losses at the same time. This is due to their extreme price fluctuations, and this can be confirmed with their

kurtosis values, which have a large tail-risk associated. Moreover, with an increase in prices, cryptocurrencies also exhibit a higher percentage of volatility, which further decreases their Sharpe-ratio values than in comparison to the traditional assets.

5.5 Correlation among assets

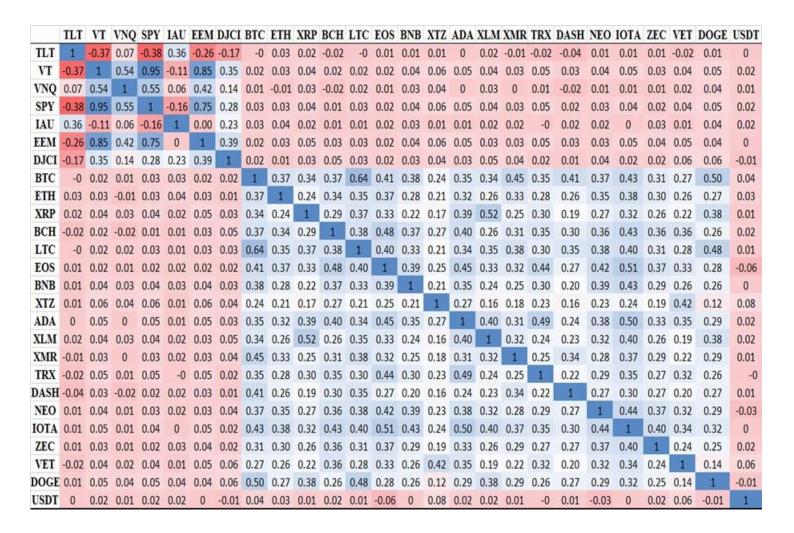|	TLT	VT	VNQ	SPY	IAU	EEM	DJCI	BTC	ETH	XRP	BCH	LTC	EOS	BNB	XTZ	ADA	XLM	XMR	TRX	DASH	NEO	IOTA	ZEC	VET	DOGE	USDT
TLT	1	-0.37	0.07	-0.38	0.36	-0.26	-0.17	-0	0.03	0.02	-0.02	-0	0.01	0.01	0.01	0	0.02	-0.01	-0.02	-0.04	0.01	0.01	0.01	-0.02	0.01	0
VT	-0.37	1	0.54	0.95	-0.11	0.85	0.35	0.02	0.03	0.04	0.02	0.02	0.02	0.04	0.06	0.05	0.04	0.03	0.05	0.03	0.04	0.05	0.03	0.04	0.05	0.02
VNQ	0.07	0.54	1	0.55	0.06	0.42	0.14	0.01	-0.01	0.03	-0.02	0.02	0.01	0.03	0.04	0	0.03	0	0.01	-0.02	0.01	0.01	0.01	0.02	0.04	0.01
SPY	-0.38	0.95	0.55	1	-0.16	0.75	0.28	0.03	0.03	0.04	0.01	0.03	0.02	0.04	0.06	0.05	0.04	0.03	0.05	0.02	0.03	0.04	0.02	0.04	0.05	0.02
IAU	0.36	-0.11	0.06	-0.16	1	0.00	0.23	0.03	0.04	0.02	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.02	-0	0.02	0.02	0	0.03	0.01	0.04	0.02
EEM	-0.26	0.85	0.42	0.75	0	1	0.39	0.02	0.03	0.05	0.03	0.03	0.02	0.04	0.06	0.05	0.03	0.03	0.05	0.03	0.03	0.05	0.04	0.05	0.04	0
DJCI	-0.17	0.35	0.14	0.28	0.23	0.39	1	0.02	0.01	0.03	0.05	0.03	0.02	0.03	0.04	0.03	0.05	0.04	0.02	0.01	0.04	0.02	0.02	0.06	0.06	-0.01
BTC	-0	0.02	0.01	0.03	0.03	0.02	0.02	1	0.37	0.34	0.37	0.64	0.41	0.38	0.24	0.35	0.34	0.45	0.35	0.41	0.37	0.43	0.31	0.27	0.50	0.04
ETH	0.03	0.03	-0.01	0.03	0.04	0.03	0.01	0.37	1	0.24	0.34	0.35	0.37	0.28	0.21	0.32	0.26	0.33	0.28	0.26	0.35	0.38	0.30	0.26	0.27	0.03
XRP	0.02	0.04	0.03	0.04	0.02	0.05	0.03	0.34	0.24	1	0.29	0.37	0.33	0.22	0.17	0.39	0.52	0.25	0.30	0.19	0.27	0.32	0.26	0.22	0.38	0.01
BCH	-0.02	0.02	-0.02	0.01	0.01	0.03	0.05	0.37	0.34	0.29	1	0.38	0.48	0.37	0.27	0.40	0.26	0.31	0.35	0.30	0.36	0.43	0.36	0.36	0.26	0.02
LTC	-0	0.02	0.02	0.03	0.01	0.03	0.03	0.64	0.35	0.37	0.38	1	0.40	0.33	0.21	0.34	0.35	0.38	0.30	0.35	0.38	0.40	0.31	0.28	0.48	0.01
EOS	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.41	0.37	0.33	0.48	0.40	1	0.39	0.25	0.45	0.33	0.32	0.44	0.27	0.42	0.51	0.37	0.33	0.28	-0.06
BNB	0.01	0.04	0.03	0.04	0.03	0.04	0.03	0.38	0.28	0.22	0.37	0.33	0.39	1	0.21	0.35	0.24	0.25	0.30	0.20	0.39	0.43	0.29	0.26	0.26	0
XTZ	0.01	0.06	0.04	0.06	0.01	0.06	0.04	0.24	0.21	0.17	0.27	0.21	0.25	0.21	1	0.27	0.16	0.18	0.23	0.16	0.23	0.24	0.19	0.42	0.12	0.08
ADA	0	0.05	0	0.05	0.01	0.05	0.03	0.35	0.32	0.39	0.40	0.34	0.45	0.35	0.27	1	0.40	0.31	0.49	0.24	0.38	0.50	0.33	0.35	0.29	0.02
XLM	0.02	0.04	0.03	0.04	0.02	0.03	0.05	0.34	0.26	0.52	0.26	0.35	0.33	0.24	0.16	0.40	1	0.32	0.24	0.23	0.32	0.40	0.26	0.19	0.38	0.02
XMR	-0.01	0.03	0	0.03	0.02	0.03	0.04	0.45	0.33	0.25	0.31	0.38	0.32	0.25	0.18	0.31	0.32	1	0.25	0.34	0.28	0.37	0.29	0.22	0.29	0.01
TRX	-0.02	0.05	0.01	0.05	-0	0.05	0.02	0.35	0.28	0.30	0.35	0.30	0.44	0.30	0.23	0.49	0.24	0.25	1	0.22	0.29	0.35	0.27	0.32	0.26	-0
DASH	-0.04	0.03	-0.02	0.02	0.02	0.03	0.01	0.41	0.26	0.19	0.30	0.35	0.27	0.20	0.16	0.24	0.23	0.34	0.22	1	0.27	0.30	0.27	0.20	0.27	0.01
NEO	0.01	0.04	0.01	0.03	0.02	0.03	0.04	0.37	0.35	0.27	0.36	0.38	0.42	0.39	0.23	0.38	0.32	0.28	0.29	0.27	1	0.44	0.37	0.32	0.29	-0.03
IOTA	0.01	0.05	0.01	0.04	0	0.05	0.02	0.43	0.38	0.32	0.43	0.40	0.51	0.43	0.24	0.50	0.40	0.37	0.35	0.30	0.44	1	0.40	0.34	0.32	0
ZEC	0.01	0.03	0.01	0.02	0.03	0.04	0.02	0.31	0.30	0.26	0.36	0.31	0.37	0.29	0.19	0.33	0.26	0.29	0.27	0.27	0.37	0.40	1	0.24	0.25	0.02
VET	-0.02	0.04	0.02	0.04	0.01	0.05	0.06	0.27	0.26	0.22	0.36	0.28	0.33	0.26	0.42	0.35	0.19	0.22	0.32	0.20	0.32	0.34	0.24	1	0.14	0.06
DOGE	0.01	0.05	0.04	0.05	0.04	0.04	0.06	0.50	0.27	0.38	0.26	0.48	0.28	0.26	0.12	0.29	0.38	0.29	0.26	0.27	0.29	0.32	0.25	0.14	1	-0.01
USDT	0	0.02	0.01	0.02	0.02	0	-0.01	0.04	0.03	0.01	0.02	0.01	-0.06	0	0.08	0.02	0.02	0.01	-0	0.01	-0.03	0	0.02	0.06	-0.01	1

Figure 4: Correlation Matrix

Figure 4 above showcases the correlation matrix between all the assets; that is, cryptocurrencies and traditional assets. It can be seen that generally, most of the traditional and crypto assets are uncorrelated, further suggesting that there might be diversification opportunities present. This is consistent with earlier research (Baur et al., 2018; Corbet et al., 2018a; Guesmi et al., 2019). Moreover, within the crypto space, they generate a high correlation to each other. There is are no confirmed finding for this, but the reason might mainly be due to market dominance of bitcoin,

which creates sensitivity amongst the prices of other altcoins. And another major reason is that most of the investors follow prices of bitcoin very closely, so any price fluctuations noticed in bitcoin, affects the entire market, as this relates more to investor sentiments and investor behavior notion to a particular market. The only exception is with regard to Tether (USDT), which was introduced to curb volatility within the crypto space and provide price stability; therefore, it showcases very little to no correlation to other crypto assets.

Moreover, we can see that most of the traditional assets showcase correlation, but with an exception to TLT (bonds), IAU (gold), and DJCI (commodity index). iShare 20+ Years Treasury bond (TLT) was selected due to it being a safe haven investment, which balances out the equity risk.

6   RESULTS

6.1   Optimal portfolio of Traditional Assets

Name (Ticker)	Equally Weighted Portfolio	Minimum Variance	Max Sharpe – ratio (no short sale)	Max Sharpe – ratio (with short sale)
TLT	14%	39.90%	45.25%	49.65%
VT	14%			-80.79%
VNQ	14%			-16.12%
SPY	14%	31.57%	43.99%	158.02%
IAU	14%	10.83%	10.75%	30.30%
EEM	14%			-10.00%
DJCI	14%	17.69%		-31.07%
Total	**100%**	**100%**	**100%**	**100%**
Return	**3.40%**	**4.30%**	**6.31%**	**12.47%**
Standard deviation (Volality)	**7.18%**	**5.34%**	**5.79%**	**8.81%**
Sharpe Ratio	**0.49**	**0.79**	**1.09**	**1.41**

Table 5 – Optimal Portfolio of Traditional Assets

Table 5, above and Figure 5, below represents the standard portfolio, which can be considered as a proxy for investors investing in the traditional asset class. The standard portfolio is analyzed to make comparisons of how the portfolio comprised of a combination of traditional assets and cryptocurrencies when optimized perform and do they provide any additional benefits to the investors, as our thesis revolves around this central question.

In table 5, we can see that when weights are allocated equally amongst each asset, it provides an annual return of 3.40% with a volatility of 7.18%, and a Sharpe-ratio of 0.49. The equally weighted portfolio performs poorly, and as mentioned previously, we construct it only for demonstration purposes and to guide on the further portfolio strategies.

In the case of minimum variance portfolio, larger weights are held in bond funds (TLT), due to it being a low-risk investment fund, along with weights held in SPY, IAU, and DJCI. This depicts that weights are allocated across different markets to

control for volatility associated with each asset class. The returns from this set of the portfolio provide returns of merely 4.30%, whereas, in the case of volatility, it is still high and of 5.34%. Furthermore, in spite of DJCI (Commodity Index) providing negative annual returns of -6.20%, it still holds larger weights in the Minimum variance portfolio. This is mainly because the DJCI index is diversified in many sectors, so although it exhibits negative returns, but it protects against inflation, and moreover, it demonstrates low to negative correlation with other traditional assets.
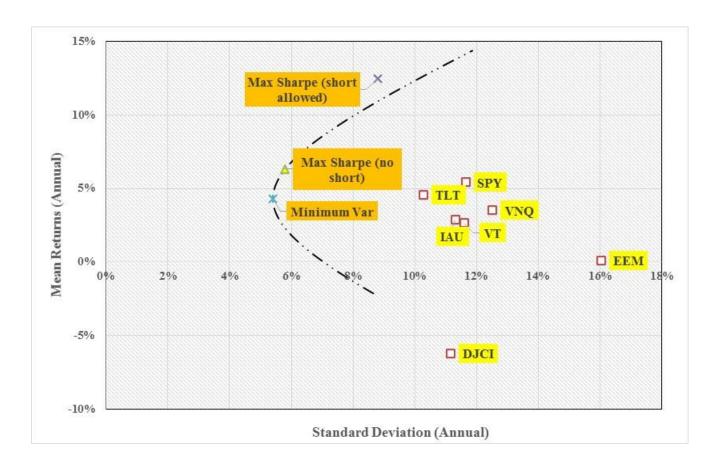

Figure 5: Efficient frontier constructed for Optimal portfolio of Traditional Assets

In portfolio maximizing Sharpe-ratio, larger weights are held in the S&P 500 fund (SPY) this is mainly due to the performance of some of the stocks which amplified the S&P 500 returns since 2014, which includes Amazon, Netflix and Abiomed to name a few. Along with weights in the bonds fund (TLT) and small amounts of weights in (IAU). In the case of the short-sale portfolio, larger weights are held in S&P 500 (SPY), allowing for a leveraged position in it, whereas other than TLT and

IAU, each asset takes a short position. The annual returns from this portfolio are 12.47% with a volatility of 8.81%.

6.2   Optimal portfolio of Cryptocurrencies

Name (Ticker)	Equally Weighted Portfolio	Minimum Variance (without BNB and USDT)	Minimum Variance (with USDT)	Max Sharpe ratio (no short sale) (without BNB)	Max Sharpe ratio (no short sale) (with BNB)
BTC	5.26%	19.26%		12.73%	
ETH	5.26%	0.13%		27.35%	17.05%
XRP	5.26%	0.86%			
BCH	5.26%				
LTC	5.26%				
EOS	5.26%		0.94%		
BNB	5.26%		0.20%		52.17%
XTZ	5.26%	36.43%	0.49%		
ADA	5.26%	1.85%			
XLM	5.26%			3.55%	0.25%
XMR	5.26%			7.18%	3.46%
TRX	5.26%	0.48%	0.04%		
DASH	5.26%			23.65%	18.43%
NEO	5.26%		0.29%	25.53%	
IOTA	5.26%	1.21%			
ZEC	5.26%	1.89%			
VET	5.26%	36.60%	0.61%		
DOGE	5.26%	1.29%	0.19%		
USDT	5.26%		97.24%		
Total	**100%**	**100%**	**100%**	**100%**	**100%**
Return	**28.40%**	**5.19%**	**2.28%**	**71.24%**	**82.50%**
Standard deviation (Volality)	**49.69%**	**37.91%**	**7.93%**	**68.13%**	**64.47%**
Sharpe Ratio	**0.57**	**0.13**	**0.28**	**1.04**	**1.27**

Table 6: Optimal Portfolio of Cryptocurrencies

In table 6 above and figure 6 below, we analyze the performance of cryptocurrencies individually to see how they perform and to find interesting cryptoassets that tend to perform better than the others. Here in table 6, we have separated the portfolio in 4 sets, where there are two minimum variance portfolios constructed: one excluding BNB and USDT and another one, including both. We get to see amazing results in this scenario, as the portfolio excluding these two cryptoassets we get a return of 5.19% but with excessive volatility of 37.91%. This demonstrates the extreme volatility of cryptocurrencies as one of its significant weaknesses. Due to which the

crypto market has experienced extreme bullish and bearish trends in the past, where investors have gained and lost massive amounts in a very short span of time. However, to counter this criticism, stable coins were launched in the crypto space, and USDT is one of the leading stable coins. And from our analysis, we can see that the portfolio, which includes USDT (Tether), the volatility sharply decreases by 79%. Higher weights of 97.24% are allocated to USDT. This provides us results as expected, where newer additions to the crypto market, such as stable coins, do help to curb extreme volatility in the crypto space.
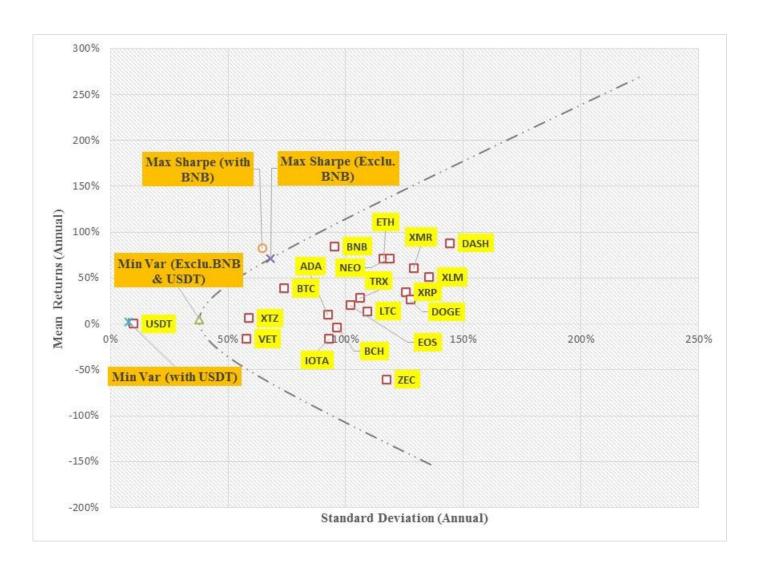

Figure 6: Efficient frontier constructed for Optimal Portfolio of Cryptocurrencies

The other two portfolios constructed include the maximization of the Sharpe-ratio. Here we want our readers to know that short selling is not allowed in the cryptocurrency market, so we do not perform optimization in the short-selling

scenario. The two portfolios represent one without BNB and another one with BNB. It is also important to note that USDT, although included in the portfolio optimization but has no weights allocated because the role of stable coin is only to curb volatility in the crypto ecosystem and not to provide any additional benefits in terms of returns. The reason being that these coins are pegged or tethered to other assets (such as US Dollar, Euro, Gold), and in the case of USDT, it is pegged to the US dollar. And the price of the peg hovers around 1 USDT is equal to 1 Dollar, so there will never be an extreme spike in the prices of USDT. But there are always chances of the price to drop due to the price fluctuations in the U.S. Dollar, due to internal and external factors surrounding U.S. Dollar, which are out of scope from our thesis topic.

From table 6, we can see that portfolio of cryptocurrencies that excludes Binance coin (BNB), although it provides us an exorbitant return of 71.24%, it also has massive volatility of 68.13%, these are instances where investors can quickly lose their invested amounts in a span of time. Whereas, when we add Utility token Binance coin (BNB), our returns amplify by 15% and stands at 82.50%. BNB holds weights of 52% in this portfolio. Moreover, in the case of the volatility, it decreases by 5.37%, which has a substantial difference than the portfolio excluding Binance coin (BNB).

6.3   Optimal portfolio of Cryptocurrencies and Traditional Assets

Name (Ticker)	Equally Weighted Portfolio	Minimum Variance	Max Sharpe ratio (no short sale)	Max Sharpe ratio (with short allowed)
Traditional Assets				
TLT	6%	39.73%	43.91%	47.20%
VT	6%			-81.86%
VNQ	6%			-13.10%
SPY	6%	31.00%	40.42%	151.46%
IAU	6%	10.65%	8.22%	26.59%
EEM	6%			-9.23%
DJCI	6%	17.46%		-29.76%
Cryptocurrencies				
BTC	6%	0.21%	0.98%	0.97%
ETH	6%	0.22%	1.89%	2.00%
BCH	6%	0.12%		
XTZ	6%	0.22%		
XLM	6%		0.05%	0.10%
XMR	6%		0.58%	0.84%
DASH	6%	0.10%	2.00%	2.28%
NEO	6%		1.94%	2.50%
VET	6%	0.51%		
Total	**100%**	**100%**	**100%**	**100%**
Return	**25.38%**	**4.36%**	**11.24%**	**18.05%**
Standard deviation (Volality)	**30.13%**	**5.37%**	**7.58%**	**10.39%**
Sharpe Ratio	**0.84**	**0.81**	**1.48**	**1.74**

Table 7: Optimal Portfolio of Cryptocurrencies and Traditional Assets

Table 7 above presents us with the optimal portfolio of Traditional assets and Cryptocurrencies. We also want to inform our readers that the portfolios constructed above, exclude USDT and BNB. The cryptocurrency portfolio optimized comprises of only Bitcoin and other altcoins. The reason for this segregation is to get a better insight of how the standard cryptocurrencies (**note:** there is no concept called as standard cryptocurrency, we utilize this term for enabling the readers to get a better understanding of the motive of our analysis that relies on the return maximization in terms of Bitcoin and altcoins and new versions of altcoins such as Utility and Stable coins) perform versus the newer versions of cryptocurrencies which evolved recently.

Another essential thing to note is, as previously mentioned, the cryptocurrency market does not allow for short selling, so in the optimal portfolio of maximizing Sharpe-ratio with short selling, we added a constraint in excel solver for the weights of the cryptocurrency ≥ 0. With regard to the Minimum Variance portfolio, there is an increase of 1.39% in the returns, then in the case of our standard portfolio. Weights are being held in 6 cryptocurrencies ranging from 0.12% to 0.51%. Totaling to 1.38% weights held in crypto assets.

Furthermore, we find better results in the case of maximizing Sharpe-ratio (without shorting) where there is a 78.12% increase in our returns than the standard portfolio and stands at 11.24%. Although there has been an increase in the volatility by 30%, the overall return still remains better than the overall volatility.
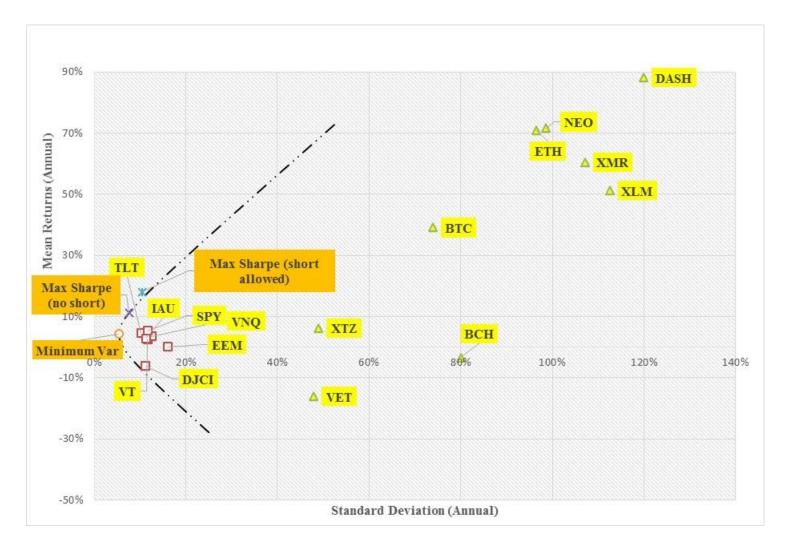

Figure 7: Efficient frontier constructed for Optimal portfolio of Traditional Assets and Cryptocurrencies

Whereas, portfolio allowing for short-selling, increases the overall annual return by more than 44%, than in comparison to our standard portfolio.

6.4 Optimal Portfolio of Traditional Assets and Utility Token

Name (Ticker)	Equally Weighted Portfolio	Minimum Variance	Max Sharpe ratio (no short sale)	Max Sharpe ratio (with short allowed)
Traditional Assets				
TLT	12.50%	39.87%	43.45%	47.32%
VT	12.50%			-77.63%
VNQ	12.50%			-15.66%
SPY	12.50%	31.51%	40.58%	151.13%
IAU	12.50%	10.80%	9.15%	28.13%
EEM	12.50%			-10.77%
DJCI	12.50%	17.68%		-30.53%
Cryptocurrencies				
BNB	12.50%	0.14%	6.82%	8.02%
Total	**100%**	**100%**	**100%**	**100%**
Return	**13.75%**	**4.41%**	**11.77%**	**18.78%**
Standard deviation (Volality)	**12.02%**	**5.39%**	**7.82%**	**10.66%**
Sharpe Ratio	**1.14**	**0.81**	**1.50**	**1.76**

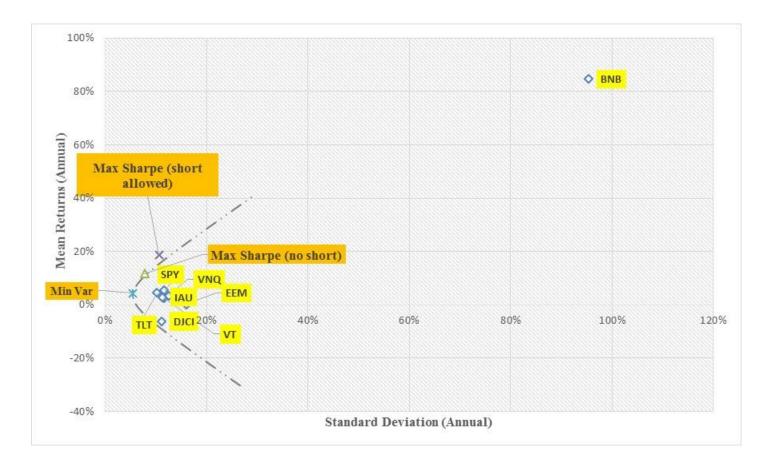**Table 8: Optimal Portfolio of Traditional Assets and Utility Token**

Figure 8: Efficient frontier constructed for Optimal portfolio of Traditional Assets and Utility Token (BNB)

As can be seen in Table 8, Utility token, Binance coin (BNB) will be included in the standard portfolio that we analyzed in section 6.1, table 5. Here, we construct three sets of an optimal portfolio, which will examine the optimal portfolio of traditional assets and utility token Binance coin (BNB) in relation to our standard portfolio.

In the Minimum Variance portfolio, return increases by 2.55% and stands at 4.41%, with a smaller amount of weights held in the Binance coin at 0.14%. In comparison to table 5, there is an 86.52% increase in returns, which is enormous when we optimize the portfolio for maximization of Sharpe-ratio with short sale restriction and the standard deviation increases by 35%, which is still less than in comparison to the standard portfolio consisting of traditional assets.

Whereas, in comparison to the portfolio allowing short selling, there is a 50% increase in the total return, with weights of 8.02% held in Binance coin (BNB).

6.5 Mixed Portfolio

Name (Ticker)	Equally Weighted Portfolio	Minimum Variance	Max Sharpe ratio (no short sale)	Max Sharpe ratio (with short allowed)
Traditional Assets				
TLT	3.85%	28.08%	43.99%	49.64%
VT	3.85%	8.45%		-130.20%
VNQ	3.85%			-17.67%
SPY	3.85%	13.62%	38.66%	209.67%
IAU	3.85%	6.93%	4.69%	33.43%
EEM	3.85%			-8.27%
DJCI	3.85%	12.41%		-53.53%
Cryptocurrencies				
BTC	3.85%			
ETH	3.85%		1.97%	2.26%
XRP	3.85%			
BCH	3.85%	0.02%		
LTC	3.85%			
EOS	3.85%	0.28%		
BNB	3.85%		6.71%	8.90%
XTZ	3.85%			
ADA	3.85%			
XLM	3.85%			
XMR	3.85%		0.42%	0.80%
TRX	3.85%	0.04%		
DASH	3.85%	0.05%	2.51%	3.22%
NEO	3.85%		1.04%	1.75%
IOTA	3.85%			
ZEC	3.85%			
VET	3.85%			
DOGE	3.85%			
USDT	3.85%	30.05%		
Total	**100%**	**100%**	**100%**	**100%**
Return	**20.00%**	**0.90%**	**14.54%**	**27.56%**
Standard deviation (Volality)	**36.52%**	**4.52%**	**9.88%**	**15.67%**
Sharpe Ratio	**0.54**	**0.19**	**1.47**	**1.75**

Table 9: Optimal Portfolio of all Assets

Table 9 above presents us with the optimal portfolio of Traditional assets and all Cryptocurrencies combined together. Comparing the results of this portfolio to our standard portfolio, we can see that for the Minimum Variance portfolio, the returns have decreased substantially, with an annual return of 0.90%. So, we do not get the desired return in this portfolio strategy. Moreover, there is no big difference in volatility when compared to the standard portfolio.

However, we find that adding cryptocurrencies increases the overall returns by 130% in the portfolio, maximizing Sharpe-ratio, which provides a return of 14.58%. Furthermore, the volatility also is less compared to the standard portfolio, and this depicts that adding cryptocurrencies does maximize return. In total, 12.65% of weights are held in cryptocurrencies.
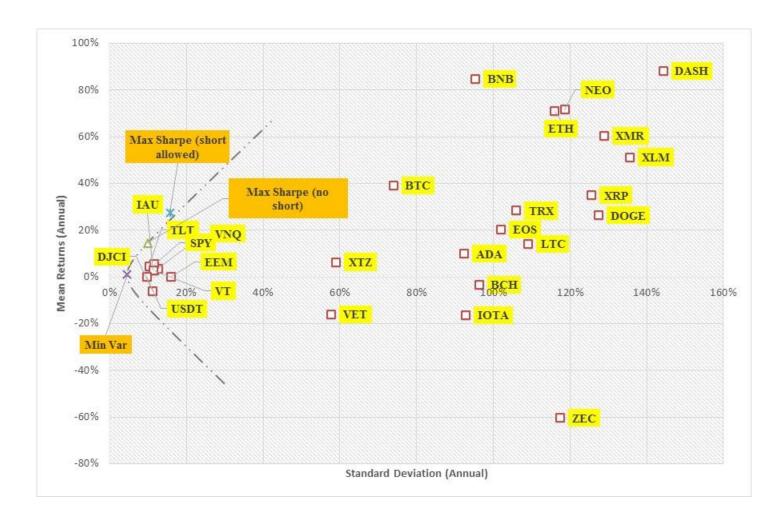

Figure 9: Efficient frontier constructed for Optimal portfolio for all Assets

Whereas, in the case of a portfolio, allowing for short selling, the returns increase by 121%. With larger weights held in Binance coin and Dash. Moreover, the S&P 500 (SPY) takes on a more leverage position with weights held at 210%.

7 CONCLUSION

7.1 Results

In this final chapter of our thesis, we answer the findings of our research question and the research objectives and sum up the most important findings of our research. The empirical findings are combined to present relevant answers to the designated research questions. Moreover, the reliability and validity of the research, along with the recommendations for further research, are presented.

In this thesis, our purpose was to examine the benefits of holding cryptocurrencies along with providing a complete overview of the blockchain technology and the functioning of cryptocurrencies. Cryptocurrencies and blockchain network are a recent innovative inclusion in our financial economy. Hence, we formulated an overall understanding of how the blockchain and cryptocurrency markets function by exploring the working of both the blockchain and cryptocurrencies and how they are interrelated to each other. Moreover, we also studied the various elements that enable the implementation of blockchain. Furthermore, exploring the advantages and disadvantages associated with cryptocurrencies and the types it consists. In addition to this, we also analyzed the market players involved in this digital space.

 In order to examine the potential benefits of cryptocurrencies when added in a portfolio of traditional assets, we utilized the "Portfolio Selection" theory of Markowitz (1952), by employing the mean-variance analysis and the Sharpe-ratio of Sharpe (1964). The results of the study suggest that adding cryptocurrencies in a portfolio consisting of traditional assets not only boosts the overall return but also overshadows the volatility issues within the cryptocurrency community. Moreover, it also provides a better risk-to-return ratio, which is the Sharpe-ratio.

Furthermore, we studied the recent additions of new types of cryptocurrencies, which include Utility coin and Stable coin. Stable coin (USDT), when included in a portfolio of cryptocurrencies, curbs the volatility to some extent, thereby demonstrating its purpose to act as a store of value and reducing the volatility issues within the crypto market. Addition of Utility token (Binance coin) provides

surprising results, where in spite of its recent introduction in the crypto space in 2017, it has demonstrated exceptional performance in comparison to the other cryptos understudy. Findings from our study state that the exceptional performance Binance coin has been able to provide is due to its function as a utility platform. This is mainly because Binance coin is the crypto-asset of the largest cryptocurrency exchange in the world that is the Binance exchange, where its value appreciates more in comparison to other cryptocurrencies because, as users start trading on its exchange its value appreciates and moreover, users are also provided trading fee discounts if they hold Binance coin, this leads to an appreciation in its price. These are the major reasons for the surge in its value, which enhances the overall performance of the portfolio even when added individually to the portfolio of traditional assets.

Moreover, our analysis also comprised of the periods of the subsequent boom (2017) and downfall (2018) of the crypto market for the time period we studied. Analysis conducted also states that the significant correlation between cryptocurrencies and traditional assets does not exist as most of the cryptocurrencies exhibit negative to minimum correlation values. Overall results from the maximization of Sharpe-ratio provide improved results when we include cryptocurrencies in both the portfolio, the one excluding Binance coin and the other one, including it.

7.2   Limitations of the Study

As the historical data on many cryptocurrencies included in the study is limited, our results are also based on this limited data periods. This means that the annual returns, standard deviation, and Sharpe-ratio results would provide less likely results in future studies. Moreover, our analysis has been conducted at a time when the cryptocurrency market is yet evolving due to which the crypto market is very sensitive to market news and also follows bitcoin price closely. This could also lead to incorrect results from our analysis. Furthermore, results from the inclusion of utility coin (Binance coin) provided us exceptional results, but it has been less than four years since these crypto-assets was launched. Hence, future studies should take this perspective into consideration. Moreover, we only focused on the mean-variance analysis strategy, and this would also tend to provide higher returns. Hence

recommended that future studies look into measures that accurately examine portfolio performance, including cryptocurrencies.

7.3 Risks

We already discussed the risk associated with cryptocurrencies in section 3.6.2. However, we would like to elaborate more on this as for cryptocurrencies to be widely adopted in our financial economy; they need to address such challenges effectively and efficiently. Cryptocurrencies have been facing criticism since their launch due to their use by illicit market players. However, in spite of the growing cases of fraudulent and money laundering activities, there is still a rapid growth in the number of privacy coins being introduced. These cryptocurrency projects are coming up with mechanisms to privatize the transactions where users initiating the transaction and the receiver cannot be traced. Such as Monero, which uses a "ring signature," keeping no transaction history of its coin. And Dash, which utilizes a mechanism of "PrivateSend," which combines various transactions into a single transaction, making it difficult to trace each individual transaction. These cryptos are a threat to society at large as these projects are only offering an opportunity for such illegal activities. And, moreover, restricting their base in our financial economy.

Also, crypto markets players such as the wallet and exchange providers have been victims of cyber frauds. Where intruders and hackers, who on finding loopholes in the system, break-in and drain the network. They not only damage all the computer nodes with malware but also disrupts further operations. The core reason for such breaches are that most of these market players are unregulated and they build their systems on loosely held controls, which are more prone to theft and fraud, and since they are unregulated prior checks do not fit in the criteria of investors, who due to limited knowledge, of how cryptocurrency operate, make lump sum investments in such exchanges and later fall as the victims.

Furthermore, Disparte (2018), mentions that another factor which creates risk in the crypto space is their correlation. Cryptocurrencies tend to be highly correlated to each other, and we can see this even in figure 4 of the correlation matrix. Due to this, they are highly sensitive to price changes within their ecosystem. Moreover, the high

correlation is directly linked to Bitcoin, and this is mainly because of two reasons, one being Bitcoin has a market dominance with a 62% stakeholding in the entire crypto space, and secondly, it is due to investor perception or investor sentiments. As bitcoin was the first cryptocurrency to be launched, investors follow the price trends of bitcoin strictly, making the entire market sensitive to its price. So even a slightest fall or rise in bitcoin impacts the entire market.

7.4 Future Adoption and Discussion

Professor Morris Perlman enumerates that "Money is like a myth that requires only imagination for its creation, but faith for its effectiveness" (Campbell, 2018). However, the opinions surrounding cryptocurrencies seem to be of a split as Bill Gates calls bitcoin a technological masterpiece. Whereas, Jamie Dimon states that cryptocurrencies have no future value and not a smart choice to invest. The same opinion is provided by Warren Buffet, who calls it a modern-day scam. While these discussions have no end, cryptocurrencies will remain a topic of debate in the coming few years as well. Moreover, the extensive growth crypto market is facing is uncontrollable; however, its fate only time will tell us. And in spite of the legal barriers each country is facing in regulating these assets, investors are keeping no stone unturned to dive into the vast pool of opportunities they can tap on to profit for these assets.

One crucial factor that puts cryptos in the front-line is that investments in the traditional asset, in times of crisis or recessions, always disappoint investors as they have no option but to exit the market with whatever profits or gains they have in order to avoid further losses. However, in the case of digital assets like the cryptocurrencies, investors do not need to exit the market entirely; instead, they just transfer funds to a stable coin, which acts as a store of value and halts losses in invested amounts. Furthermore, what adds more benefit is that there are minimal transaction costs of transferring to these stable coins and re-transferring back to the crypto assets, which make it even more cost-effective and simple to transact. However, cryptocurrencies suffer from volatility issues that hinder more investors from investing in them, but with the advent of stable coins, this stance has reduced to

a greater extent. Moreover, a well-informed investor can always rely on well-informed studies and researches surrounding sound investments in cryptos.

Furthermore, the awareness around the utility that cryptocurrencies hold is expanding as more and more companies have engaged in partnerships to include them in their business operations such as IBM, Western Union, J.P Morgan, to name a few companies. However, for cryptocurrencies to be deeply rooted in our financial economy, they have to undergo certain changes where there should be a proper regulatory framework that oversees the operations within the crypto space. The lack of awareness and extensive knowledge of digital space is another hindrance to their inclusion. Furthermore, in spite of the increase in the number of money laundering and illegal activities carried on by using crypto assets, there are still a large number of cryptoassets project which are developing privacy coins to enhance anonymity while transacting. Such cryptos are not only complicating the process of tracing back transactions but also providing opportunities for such crimes to breed on. These coins need to have some regulation behind their working or a mechanism to allow regulatory bodies to keep track of their use.

Finally, we would like to conclude with a quote mentioned by lansiti and Lakhani (2017), who mentions that,

> True blockchain-led transformation of business and government, we believe, is still many years away. That is because blockchain is not a "disruptive" technology, which can attack a traditional business model with a lower-cost solution and overtake incumbent firms quickly. Blockchain is a *foundational* technology: It has the potential to create new foundations for our economic and social systems. But while the impact will be enormous, it will take decades for blockchain to seep into our economic and social infrastructure. The process of adoption will be gradual and steady, not sudden, as waves of technological and institutional change gain momentum.

7.5   Suggestions for Further research

As the cryptocurrency environment is still undergoing research and developments, and as per our analysis conducted, the parent cryptocurrency Bitcoin has seen substantial volatility in its prices, whereas, in contrast, other cryptocurrencies (altcoins) have had tremendous growth in their value. Hence, as the other altcoins are maturing and creating their mark in the crypto space, exploring their benefits would be crucial from an investment point of view. Moreover, our research was based on the traditional mean-variance analysis, which did provide us significant results. However, further research should examine the benefits by using analysis techniques such as Mean-Cvar, or statistical models such as spanning tests, GARCH methodology.

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APPENDICES

Appendix A

Altcoins: All alternative cryptocurrencies other than bitcoin are termed as altcoins.

ASIC: Stands for "Application Specific Integrated Circuit," these PCs consist of specially designed chips that can accomplish the designated task at a significantly faster speed than any regular PC and are nowadays exclusively manufactured for cryptocurrency mining.

ERC-20 – are a set of rules for all the token created on the Ethereum platform, which explicitly states how each token will function.

Fork – Forking is splitting of codes or blockchain protocols. Example from our thesis is Bitcoin and Bitcoin Cash. As we previously mentioned block limit of bitcoin caused its split where bitcoin cash was created.

HODL – HODL means to buy and hold. It was derived from a misspelling of hold back in 2013. Thereafter "hodl' became a terminology used for holding cryptoassets in the crypto space.

Token: Tokens are crypto assets, which represent a unit of value or usage rights developed by a company but on top of an existing blockchain network.