CRYPTOCURRENCIES AND STOCKS PORTFOLIO:

EVIDENCE FROM INDIA

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By

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CERTIFICATE

This is to certify that **Mr. Stanley James** has carried out the research embodied in the present dissertation entitled **"Cryptocurrencies and Stocks Portfolio: Evidence from India"** for the full period prescribed under M.Phil. ordinances of the University of Hyderabad.

This dissertation is an independent work and does not constitute part of any material submitted for any research degree or diploma here or elsewhere.

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DECLARATION

I, **Stanley James,** hereby declare that the research embodied in the present discussion entitled **"Cryptocurrencies and Stocks Portfolio: Evidence from India"** is an original research work carried out by me under the supervision of **Dr. S Raja Sethu Durai**, School of Economics, for the award of M.Phil., from University of Hyderabad.

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Stanley James

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Abbreviations

MPT	MODERN PORTFOLIO THEORY
NPV	NET PRESENT VALUE
MVA	MEAN VARIANCE ANALYSIS
CAL	CAPITAL ALLOCATION LINE
CML	CAPITAL MARKET LINE
BTC	BITCOIN
USD	US DOLLAR
P2P	PEER TO PEER
EFTS	ELECTRONIC FUND TRANSFER SYSTEM
MVO	MEAN VARIANCE OPTIMISATION
VaR	VALUE AT RISK

Chapter 1

INTRODUCTION

1.1 Background

Application of Information Technology in the area of finance in the last decade has led to the development of a new class of payment system called the cryptocurrencies. It suddenly caught the attention of the financial world due to unique features such as direct payment without any intermediary like banks, improved security, anonymity and an innovative bookkeeping system called block chain. Even though envisaged as new currencies, cryptocurrencies do not have the wide public acceptability to be used as a currency. Any currency is characterized by three main functions. They are: 1) medium of exchange, 2) unit of account and 3) store of value. Take for example the case of Bitcoin, the most popular cryptocurrency. How well can Bitcoin fulfill the above criteria? Over its short period of history, Bitcoin's volatility was very high.

Thus, it does not qualify to a stable store of value. Due to its limited acceptability as a payment option, it cannot be a good medium of exchange as well. The high fluctuations also prevent it from being a unit of account. Bitcoin has thus failed as a currency. The story of most of the cryptocurrencies is the same.

But cryptocurrencies suddenly became a popular investment tool. Because of the huge demand and spiraling prices, it is widely used as alternative investment tool as against the purpose it was invented for. Even though cryptocurrencies were introduced as an alternative private, decentralized currency, various factors led to its wide popularity as an alternative investment tool. The main factor was the crackdown on cryptocurrencies by various governments thereby limiting its use as an alternative currency. This was the major reason for the Bitcoin price crash

of 2013 following the US government's crackdown. Another factor is the search for a new asset class post the 2008 financial crisis. Bitcoin was seen as an alternative to conventional investment tools which exhibited high correlation in the post crisis period. Lack of popularity also limited its use as a currency as 'acceptance by all' is a major factor which determines a currency's strength. Security concerns in the cyber world was another dubious factor. In fact, there have been instances of large sums of Bitcoin being stolen and Bitcoin exchanges being hacked. People have lost large number of cryptocurrencies due to such cyber threats.

This study focuses more on the investment aspect of the cryptocurrency. As any investment asset, cryptos too have its own properties. Return, risk and volatility are some major concerns regarding all assets. But cryptocurrencies distinctly stand out. For example, the value of Bitcoin, the most popular cryptocurrency was 1000 USD in Jan 2017, but had reached nearly 19000 USD by Dec 2017. Thus, volatility is very high for cryptocurrencies. This different nature of crypto assets from conventional assets leads to difficulty for investors in taking the right decision while investing and trading cryptocurrencies. Cryptocurrency investment has substantial security risk, operational risk and exchange rate risk. Due to high unpredictability and risk, in-depth analysis is required to find the most suitable strategy for investors. There is a need to analyze in detail the factors that drive the prices as well as volatility behavior of cryptocurrencies. This is not only essential for the accurate prediction of expected returns but also efficient portfolio management of crypto assets. A lot of studies in the field are necessary to help investors frame the right strategy as investors rely on rumors and speculation to invest in cryptos.

1.2 What are Cryptocurrencies?

Cryptocurrencies are virtual digital currencies which acts as a medium of exchange directly between individuals. This is called peer-to-peer payment which does not require any

intermediaries like banks or any other financial institutions. This makes the transactions easy with minimum time and processing fees. It is called cryptocurrency because it uses the cryptographic protocol for security. Most of the cryptocurrencies are decentralized, based on distributed public ledger called blockchain. This means that no single authority is the custodian of the ledger, but the ledger is managed and maintained by all the participants in the network. The most interesting feature of cryptocurrrency is that there is no central authority like the central banks, thus making it immune to the interference of government. Cryptocurrencies are purely private currencies. Bitcoin was the first and the most popular cryptocurrency based on blockchain technology. It was introduced in 2009 by a person with pseudonym Satoshi Nakamoto. In a paper titled "*A peer to peer electronic cash system*", Nakamoto introduced a new private currency, which is entirely decentralized without government control, using peer-to-peer network to solve the problem of double spending.

Central to the functioning of cryptocurrencies is the distributed ledger technology, also called the blockchain technology. It is nothing but a ledger which is shared. It is different from the traditional ledger kept by the banks, in which a third party (bank) oversees and manages the ledger. However, in a blockchain, the ledger is public and decentralized, managed by the participants (called peers) itself, and not by any third party. The ledger has the history of all the transactions ever conducted using that cryptocurrency. Each and every peer has access to the entire history of transactions and balance of all account. For every new transaction, a user has to request for the transaction. The requested transaction is broadcast to a P2P (peer to peer) network consisting of computers known as nodes. The P2P network of nodes validates the transaction and the user's status using known algorithms. Once verified the transaction is combined with other transactions to create a new block of data for the ledger. The new block is then added to the existing blockchain in a way that is permanent and unalterable. Thus the

transaction is complete. Once the transaction is confirmed and new block added to the blockchain, it cannot be forged, reversed or manipulated.

Who verifies the transactions? Only miners can confirm transactions. Miners confirm and make the transactions legitimate, and then spread them to the network. Once miner confirms it, every node adds it to their database. Even though there a large number of miners, only one miner can legitimize and confirm a transaction. So, when a request for a transaction is made, miners compete with each other to confirm the transaction. For this, miners are given a complex mathematical problem to solve. The miner who solves the computer based mathematical problem first get to confirm the transaction. This process is called mining. Mining has huge costs involved. It requires large amount of computing power and electricity. A miner is rewarded with cryptocurrencies for the work they do. As more and more cryptocurrencies are mined, it becomes increasingly difficult to mine and the mathematical problem becomes tougher. This will require more energy and computing power. Due to this it becomes unviable for individuals to involve in mining and most of these mining are now done by large corporations by establishing mining farms.

A notable feature of cryptocurrencies is scarcity. The whole ecosystem of a cryptocurrency is designed by its architects in such a way that the supply is limited to a particular number of cryptocurrencies. For example, Bitcoin's supply is limited to 21 million, of which around 17 million is already mined. The last Bitcoin will be mined sometime in 2140. More cryptocurrencies are added (increase in money supply) by mining. This limited supply means that cryptos are deflationary in nature, unlike the conventional currencies which are inflationary in nature. Also, the total number of currencies that will be in circulation (money supply) at any future time period can be exactly predicted. Thus, there is no scope for surprises. The advocates of cryptocurrencies argue this scarce nature of cryptos solves the most important challenges of the conventional banking system – inflation and unpredictability.

Cryptocurrencies have gained wide public imagination, especially that of the investors, in this decade. Bitcoin caught global investor attention during 2013, when the first spike in value occurred. The value increased from 100 USD to 1000 USD in just a month before losing much of it in the subsequent months. A value increase of such fold would come only later in the second half of 2017, when market price skyrocketed from around 2000 USD to nearly 20000 USD. Following Bitcoin's success story, other cryptocurrencies also came up rapidly. Some of them are considered better than Bitcoin's architecture. These alternate cryptocurrencies are referred to as Altcoins. Today there are almost 1500 altcoins. Some of the successful altcoins are Ethereum, Ripple, Monero, Litecoin etc. As of February 2019, the combined market value of all cryptocurrencies stands at $120 billion, with Bitcoin representing half of it. As economies face the challenges of inflation and threat of financial recession, many believe that cryptocurrencies would serve as a hedge against these challenges and help escape capitalist controls.

1.3 Modern Portfolio Analysis

Modern Portfolio Theory (MPT) is considered to be the central theory in finance. Economist Harry Markowitz introduced MPT in his 1952 essay '*portfolio selection*', a work which transformed the area of portfolio management. The central idea is that instead of focusing on risk of individual assets, an investor should focus on the risk of a diversified portfolio. A diversified portfolio is the one which has a combination of various assets of different nature. The overall volatility of a diversified portfolio is less than the total sum of the volatility of individual elements. Even if the individual assets are volatile, the entire portfolio's volatility can be very low if properly diversified.

Before the introduction of Modern Portfolio Theory, investment decisions were centered on individual assets. Investors used to analyze individual assets to find out the sure bets. Expected

Net Present Value (NPV) was used to identify these sure bets, by discounting the future cash flows. Assets which were considered as ‘sure bets’ were those which produced a fairly good amount of return with minimum risk. Thus assets which can generate more returns at a short span of time were considered more important. Markowitz was against this idea. ‘Net Present value’ has its own shortcomings. Selecting the portfolio comprising stocks of highest NPV is riskier and a good portfolio is the most diversified one. Thus, portfolio diversification was Markowitz’s proposition.

Modern portfolio theory (MPT) deals with the selection of portfolio that maximize the returns according to the individual’s preference of risk. Using both expected portfolio risk and individual preference for risk, MPT helps to construct an optimum portfolio. The modern portfolio theory has revolutionized the approach to investment management by allowing to quantify risk and returns. The focal point of the theory is to focus on portfolio risk rather than individual risk and when more risky assets are combined, form a portfolio with lesser overall risk than individual risk. The portfolio is weighted and balanced in such a way that the overall risk is less than that of the underlying assets. An individual can hold a highly risky asset, so long as the overall portfolio risk is minimized by other less risky assets.

The Modern Portfolio Theory is based on many assumptions. It assumes that investors are rational and try to maximize their utility with a given amount of money, and also investors are risk averse who always try to minimize the risk. They choose higher returns to lower returns for any given level of risk. It also assumes that they have fair information about markets, return and risk. Another major assumption is that markets are efficient and absorb all the information perfectly and quickly.

Mean variance analysis (MVA) is the mathematical technique used to combine assets in a portfolio. Under MVA, most important properties of any investment can be summarized as

measure of expected return and the measure of dispersion around the expected return. These measures are expressed as mean and standard deviation respectively. Variance or standard deviation shows how much is the spread of numbers in a set are. Expected return tells the probability of estimated return of the asset/portfolio/investment. Through the mean-variance analysis, investors weigh the risk against the expected return. This tool helps them to find out the highest gains at any given level of risk, or the lowest risk at any given level of return. The overall portfolio risk is computed through a function of variance of individual asset along with the correlation among them. While talking about the portfolio, the portfolio return (which is portfolio mean) is the weighted average of the mean of the individual assets. But portfolio risk (which is portfolio standard deviation) is not the weighted individual standard deviations

1.4 Motivation of the study

The 2008 financial crisis marks a turning point in the way global monetary and financial institutions were looked upon and exposed major flaws in the functioning of these institutions. It all started when major US investment bank Lehman Brothers filed for bankruptcy in 2008. It was followed by a series of bank collapses. This shook people's faith in the banking system. Institutions which were perceived as 'too big to fail' went bankrupt due to mismanagement, loose supervision, and high internal risk and the inherent weakness of the whole banking system got exposed. The collapsed banks were bailed out by the government using taxpayers' money, which further angered people. The root problem of the conventional banking system is that it works on trust. The banks should be trusted to act responsibly with the investor money and central banks should be trusted not to destabilize the currency. The financial crisis was a jolt to the integrity of banking system's record keeping practices and the unquestioned faith in capitalistic financial institutions. This blind trust empowered banks to manipulate ledgers and accumulate subprime assets which led to big asset bubbles. The lesson to be learnt from the

history of trust breaches of fiat currencies is that placing trust on a third party is not a feasible model.

Cryptocurrencies emerged as a response to the financial crisis and the loss of faith in the banking system which followed. The first mention about Bitcoin, the first cryptocurrency, came just about two months after the Lehman crisis in November 2008. The creator of Bitcoin had expressed his concern over the breach of people's trust by the banking system. This trust problem is solved to an extent by cryptocurrencies by facilitating peer to peer transactions without the need for a third party like banks to enable a transaction. Historical evidences suggest that when faith in a currency is lost, people have resorted to cryptocurrencies as an alternative. While the natural tendancy for the public is to use any other country's currency, cryptocurrencies have the added advantage of easy purchase through online exchanges. For example, during the Greece economic crisis, there was a reported surge in demand for Bitcoin to be used as a currency. During the 2013 banking crisis in Cyprus, Bitcoin price reported a surge, pointing to an increased demand. Argentina is another country where people resorted to Bitcoin to escape capital controls. When the government restrained people from buying dollars in the midst of a financial crisis, it was reported that Argentina became a hotspot of Bitcoin purchase.

This recent interest showed by the pubic in cryptocurrencies motivated me to study more about them. Also, in my opinion, studies in the area of finance and banking need a relook in the post financial crisis period as some interesting observations can be made. The emergence of cryptocurrencies is one among them. While studying about the properties and behavior of cryptocurrencies, most important emphasis has to be on its investment properties. This is because in reality, even though cryptos were designed as a currency, it did not catch the attention of the public as a currency, but as an investment tool. Bitcoin, the first cryptocurrency became extremely popular within few years and was followed by other altcoins as well. Since

there were some flaws in the design of Bitcoin, some altcoins which came later provided a better design by solving those flaws. But none of those currencies gained the public confidence to be used as a currency but all are still used as investment tools. The 1500 plus cryptos which are traded in the market now thus makes an interesting study subject.

1.5 Research Gap

A lot of studies about cryptocurrencies have come up in the last decade following the introduction of the first cryptocurrency – Bitcoin. Most of these works came from law and computer science backgrounds and focused on the technical aspects of cryptocurrencies. Such papers studied about the cryptographic nature of cryptocurrencies (Rainer et al., 2015 and Nakamoto, 2008), problem of double spending (Karame et al., 2012), analysis of the cryptocurrency network (Ron and Shamir, 2013), and cyber security related aspects.

Studies analyzing cryptocurrencies from a purely economic point of view began to come up very recently. Most of these papers look at broadly two aspects, namely:

- Cryptocurrencies as a medium of transaction
- Cryptocurrencies as an investment tool

Among existing studies on the investment properties of cryptocurrencies, diverse issues are dealt with. Bouri et al (2016) studied about the safe haven and hedging properties of Bitcoin. Cesar and Estrada (2017) looked at the price volatility of Bitcoin. Dyhrberg (2015) analyzed the financial asset capability of Bitcoin using GARCH volatility analysis. Urquhart (2017) studied about the price clustering in Bitcoin. While volatility estimations using various econometric models are plenty (Katsiampa, 2017; Chu et al., 2017; Catania et al., 2018), most of the research are also centered on Bitcoin. One major reason might be the lack of availability of time series data. Data for most of the cryptocurrencies are available only from 2014 onwards

and only the data for Bitcoin is available from 2011 onwards. An overview of the literature on cryptocurrencies show that much studies about cryptocurrencies as a diversification tool has not been done. Even among the limited studies about cryptocurrencies as diversifiers, no studies have so far been conducted in the Indian context. So the contexts were research gap clearly exists are:

- Very limited studies on cryptocurrencies as diversifiers
- Studies on diversification limited to Bitcoin and not extended to other cryptocurrencies
- No such studies in Indian context

To solve this gap in the literature, this study makes an attempt to look into the diversification aspects of cryptocurrencies beyond Bitcoin to other such currencies also and that too in the Indian context. The study analyses whether including cryptocurrencies in an Indian portfolio will yield significantly better portfolio returns or not. This research can particularly be helpful for an Indian investor who is looking at ways to diversify his diversifiable risk.

1.6 Objectives of the Study

With the following background in mind and research gaps identified from the existing literature, the study proposes the following objectives

- To empirically examine the role of cryptocurrencies in portfolio selection for Indian stocks.
- To find out the optimal portfolio share composition between the cryptocurrencies and stocks

1.7 Methodology and Data

The study is entirely based on secondary sources of data. Stock prices data is collected from yahoo finance (www.finance.yahoo.com) and market rates of cryptocurrencies is collected from

www.coindesk.com. Monthly closing prices data was collected over the period of 2013 to 2018 with 60 observations for each assets. The returns were calculated as the natural logarithmic first difference.

The optimum portfolio is combined with investor's choice by imposing Capital Allocation Line. This line joins the point representing risk free rate and the optimum portfolio. In fact the point of tangency of the CAL with the efficient frontier becomes the optimum portfolio. CAL gives investor a range options to invest and a point on the CAL can be chosen based on the risk appetite of the investor. Investor can either invest entire wealth in risk free asset or in optimum portfolio with higher risk and returns. He can also consider a combination of both, which falls between both these points in the CAL. The investor can also select a portfolio beyond the optimal portfolio by borrowing at the risk free rate, if he wishes to undertake more risk. The selection of the optimal portfolio depends upon the individual choice, based on the risk appetite.

The same process is continued by adding Bitcoin to the portfolio of stocks and the efficiency frontier and CAL is plotted. The procedure is continued by adding all six cryptocurrencies to the stocks, efficiency frontier and CAL is plotted. Analyzing the efficiency frontiers give idea about the portfolio's performance. Further we also get answer about the weightage of total cryptocurrencies to be included in the portfolio. Weightage distribution among the cryptocurrencies is also found out similarly. The results of the analysis along with tables and graphs are given in the section below.

1.8 Relevance of the Study

Post 2008 financial crisis, there has been a shift of interest from traditional investment tools to new assets. Investors have started searching for alternate investment options to reap the benefits of diversification. It is around this time that cryptocurrencies emerged. News about the new

currency, its unique features, cryptographic technology etc. made it so popular within a short time period. People started investing in it without knowing about the consequences. When more people bought cryptos, the price skyrocketed within no time. This prompted more and more people to invest. Most of these investment decisions were based on rumours and half knowledge as there was no information coming from official sources or based on authentic research.

Lack of research-based analysis has led to confusions and investors not getting a clear picture of the investment prospects and related aspects of cryptocurrencies. This not only creates confusion among investors, but also leaves fund managers in doubt. They do not have a clear idea on what is the profitability of investing in cryptos, what is the risk–return trade off of cryptocurrencies, what should be the ideal share of cryptocurrencies in a portfolio of assets etc. Major reasons for the lack of research are 1) cryptocurrency is a new area of study, which is still in its infancy, and 2) lack of proper data over the time (time series data). But now it has already been one decade since the first cryptocurrency is introduced and data of more and more cryptos have started to come in. This makes it an appropriate time to conduct more studies on cryptos so that valuable information about the properties of these assets can be provided to investors.

Unambiguity over crypto assets is worsened by government's aversion to such assets. In 2018, RBI issued a notification preventing financial institutions under its control to facilitate conversion of Rupee to cryptocurrencies. This led to panic among investors and speculation that cryptocurrencies do not have any future in India. But agencies which are not under the control of RBI continued trading of cryptos. So at a time when investors knowledge about cryptos are limited and the related policies from the part of government adds to the uncertainty, the study has more relevance than ever. Even though portfolio analysis of cryptocurrencies is not entirely new, studies on the Indian context is entirely new. This study aims to help Indian

investors in taking more informed decisions while considering cryptocurrencies to be added in the portfolio. The relevance of the topic will only increase in the future as cryptos mature as an investment tool and more investors start including it in their portfolios.

1.9 Chapter Scheme

Chapter 1 provides a bird's eye view of the whole work. It starts with the background of the study and explains the basic definitions about cryptocurrencies and the modern portfolio theory. The chapter gives a brief outline about the motivation of the study, summary of the review of literature and explain the existing research gaps in the study which then develops into the objectives of the study. A small paragraph also explains about the methodology and data used for the study. The chapter ends with the current relevance of the study.

Chapter 2 explains the evolution and history of money, how money came into being, the way changes took place and when the current monetary mechanism controlled by government and central bank came into being. The chapter also gives an account of Hayek's idea of money as explained in his book *'denationalisation of currency'.* In other words, the chapter is also a criticism of the present monetary system.

Chapter 3 is the detailed review of all the literature. First part is the summary of those literature which deals with modern portfolio theory and its portfolio analysis and another part deals with the empirical works that are related to cryptocurrencies.

Chapter 4 explains about the data and methodology, the underlying theoretical framework, which is nothing but the modern portfolio theory. Modern portfolio theory and how it is helpful in analyzing portfolios are explained in detail in the chapter.

The final chapter concludes the study by giving an account of the findings, inferences and suggestions. The results are given with the help of graphs, tables and figures.

Chapter 2

CRYPTOCURRENCIES: AN OVERVIEW

2.1 A Brief History of Money

The concept of money has been around since the beginning of the civilization. Money is best described as a medium of exchange. It allows a person to trade what he has for what he needs. The concept of money has changed from time to time and has included various items. By saying that a person has a lot of money, people usually mean that he/she is rich. But economists have a specific meaning for money. They define money as *"anything that is generally accepted in payment for goods and services or in the repayment of the debts."* (Mishkin, 1992, p-G7) In an economy, money has three function: i) medium of exchange, ii) unit of account and iii) store of value. (Mankiw, 1999, pp. 155-156)

In the beginning, people exchanged goods they had for another good. This was called barter system. When people started creating agricultural wealth, i.e. farm produce and animals, they started exchanging these. Participants in the trade directly trade these items without having a common medium of exchange. Evidences suggest that bartering dates back to 9000 BCE to 6000 BCE. Goods such as cattle, salt, spices, weapons, food grains, fur, silk etc where all used for trade. With increased trade between regions and traders connecting different geographical regions, barter system also spread to different parts of the world. The system is still prevalent in some remote parts of the world. But eventually people realized the difficulties that a barter system has. Adam Smith was the first among the economists to point out the inefficiencies of a barter system. The main problems are: i) problem of double coincidence of wants, ii) no

common measure of value, iii) indivisibility of most of the goods, iv) difficulty in storing wealth, v) absence of standards for deferred payments etc.

Barter system later gave way to commodity money. This is the earliest form of present-day money. But in this form money was not made of paper or metal. Goods or tokens that were regarded in high value were widely considered as a medium of transaction. For example, cowrie shells were considered as an easy way to store and transfer than cattle or agricultural produce. Many societies had used cowrie shells as money and the first evidence dates back to 1200 BCE in china. Mesopotamians had used a system based on weight through shekel where certain amount of food grains was considered to be equivalent to certain weight of a precious metal or gold. The Chinese later modified cowries to create metal versions with flat round coins having a hole in the middle. This allowed people to do transaction with much ease and without the fear of money spoiling, as is the case is perishable money. Bronze and copper metal cowries were also introduced in the later part of the Bronze Age and can be seen as the earliest form of metal coins. The first metal coins were made out of silver and appeared in Lydia, the present-day Turkey. This method was modified and copied to other parts of the world like Greece, Persia, Rome, Macedonia etc. These new metal coins were made of precious metals like gold, silver, bronze etc. which had some inherent value.

The metal currencies eventually gave way to paper currencies. This is the basis of the paper currencies that we use in circulation today. The first signs of paper currency appeared in China. This was in circulation from 9^{th} century to 15^{th} century but later collapsed due to excess production and use leading to soaring inflation. Later paper currency system started in Europe. Banks evolve in Europe in the 16^{th} and 17^{th} centuries. Initially paper currencies were issued as a form of credit note. Traders deposited amounts of gold in banks and in return received a statement mentioning the amount of gold deposited. Or a person can pay for the goods and services at a later date by writing and signing in a paper promising future payment. These

signed papers can later be transacted as a promissory note, thus acting as a currency. Paper currency that functions as a medium of exchange had thus evolved as a result. Later governments started to issue this promissory note through a government decree (fiat) and that was the start point of modern-day fiat currency system.

Gold standard was the monetary system which was in place for a brief period between early 1800s to 1930. England officially made gold to be the standard of value in 1816. It was a system where a currency's value is directly pegged to gold. For each currency printed, there should be an equivalent amount in value of the gold kept. Paper money can be freely converted into gold the amount of which is equivalent in value. By 1900 most of the developed countries adopted this monetary system. Gold certificates which are backed by gold will be used as the medium of exchange instead of the circulation of coins. The government guaranteed that it would redeem any amount of currency for its corresponding gold value. The period between 1870 and 1914, when the First World War broke out was the golden period of gold standard.

The system of gold standard began to collapse after 1930s because of the world war and great depression, both of which destroyed the economies of the western nations. An attempt to revive the gold standard was made through Bretton woods system. Under this system US assured the world that its currency is reliable as dollar would be pegged to gold and thus USD would become the reserve currency. The problem of gold standard was that if the government wants to print more currency than its gold reserves, it is not possible. And with nations prospering with more income, production and consumption more money is required and gold standard would not work. This was the reason for the collapse of gold standard in 1971 when US stopped convertibility of dollar into gold. Since then all nations have operated using their own fiat currency without the backing of any precious metals or gold.

Today in most of the countries, currency is issued through a government decree (fiat) which is called fiat currency. The currency has to be accepted as legal tender. It neither can be converted into precious metals nor has any intrinsic value. Today's money has only token value which means the face value exceeds the intrinsic value. The value is derived from the creditworthiness of the issuer, i.e., the sovereign government. World over, currencies are issued and managed on behalf of the government by the country's respective central banks. Because paper currencies and coins can easily be stolen and are difficult to transport in large numbers, modern banking system have introduced financial instruments like cheques and demand drafts. This simplified bank transactions of large amounts. Another new mode of fund transaction/payments is through plastic money. Debit cards and credit cards allow individuals to make purchases and pay the money using the cards either instantly or later. Computer based telecommunication technologies have now facilitated online fund transfer through Electronic Fund Transfer Systems (EFTS). Money can be transferred from payer to payee account in simple steps using electronic devices like computers, smart phones etc. All these recent innovation in payments have reduced the cost, time and energy in transferring deposits or making payments in efficient and easy manner.

A new type of currency which has caught people's imagination is cryptocurrency. In the conventional monetary system that we follow now, money is created by the sovereign government. People who are unhappy with government management of monetary system are behind the cryptocurrency project. They argue that government controls the money supply and uses monetary policy in an expansionary way to its benefit. This will drive up the prices of commodities, services, healthcare, education, infrastructure, housing etc and the end result is inflation. Along with this the whole banking system controls the entire money and credit and if the banks don't act prudently, this would also result in a financial crisis; similar to the one happened in 2008. Cryptocurrencies are being developed as a solution for this problem. These

are private currencies which are totally decentralized and based on cryptographic technology. The ledger is available to the public, while at the same time protecting the identity of the participants. While this new class of currencies has become popular, still it has its problems and has not successfully gained the public trust.

2.2 Hayek's Idea of Denationalization of Currency

The first origin of the idea of a private currency, which is entirely out of the control of the government, was put forward by the famous economist Friedrich August Von Hayek (8 May 1899 – 23 March 1992). He belongs to the Austrian school of Economics. Hayek rose to fame with the publication of his famous book *'Denationalization of Money'* (1976). In this book he proposes the idea of removing government monopoly over the issue of fiat currency in order to ensure price stability. So how does government monopoly disrupt price stability? Hayek says that because of the government monopoly, central banks accommodate the financial needs of the government by keeping interest rates low and thus the central banks give their policies an inflationist bias. However, in his view, the use of money supply to achieve particular ends turns out to destroy the price mechanism equilibrium and therefore provoke major business fluctuations (Hayek, 1976:119). In fact, his criticism of the Keynesian order was based on what he refers to as arbitrary interventions in the economic order. Central banks world over are highly influenced by the political class according to him. The whole argument of Hayek's book was to avoid political interference in monetary policy. This is the same reason why he criticizes Keynesian economics.

Hayek is unhappy with the history of government management of money the world over. This, he mentions, is because of the orientation of finance ministers and central bankers towards Keynesian school of thought. In his book he mentions that "… *Ministers of finance were told by economists that running a deficit was a meritorious act, and even that, so long as there were*

unemployed resources, extra government expenditure cost the people nothing…"(Hayek, 1976: 118). The criticism here is that the reason for most products like food, healthcare, education, transportation, housing etc keep spiraling upwards is due to act of government run central banks creating more and more money through expansionary monetary policy. For instance, in 2017 alone the Federal Reserve increased the money supply by 600 billion dollars. The same view was reflected in the words of famous economist and Nobel laureate Milton Friedman who said: *"Inflation is a monetary phenomenon. It is made by or stopped by the central bank."*

According to Hayek, a stable currency is utmost important for the currency to operate at maximum efficiency, for which government intervention must be abolished. So how will a currency work in a denationalized framework, free from any government intervention? Hayek proposes the idea of different banks issuing different currencies which would pave the way for a market competition among the currencies. Banks could issue non-interest-bearing certificates and deposit accounts based on their own distinct registered trademark and this can be treated as currencies. These currencies of different banks can be traded at variable exchange rates. This effectively means a free market competition among various private currencies. Or in other words, privatizing the supply of money. According to Hayek the advantage of such a mechanism is that prices will convey to the different agents the relevant information to make decisions.

In a situation where number of currencies exists, which currency will prevail ultimately? Hayek underlines that the one currency which exhibit maximum price stability in its value as a unit of account will be the most desirable among all the competing currencies. He highlights that money should act mainly as: i) as cash purchases for goods and services, ii) as reserves for future needs, iii) as deferred payments and iv) as unit of account. Stability of currency is the most important requirement which can seamlessly facilitate all these function. (Hayek, 1976: 67). Under Hayek's framework, market forces at play will determine the relative value of

competing currencies resulting in a free-floating exchange rate between currencies. In the long run, only those currencies which ensure a stable purchasing power would exist. The stability would be measured as against a standard of wholesale prices of commodities in the market. (Hayek, 1976:76). In the long run, people would prefer to hold the currency which maintains the stable value in terms of purchasing power of goods and services. Stability becomes very important because currency devaluation hurts creditors and devaluation hurts debtors. The marginal cost of printing currency and nominal interest rate would be assumed as zero. Banks that fail to manage the stable value of its currencies would lose customers and would be forced to drive out of the business.

The current discussion about the new innovation in financial products such as cryptocurrencies is believed to have incorporated the idea proposed by Hayek and the Austrian school. Hayek's two major arguments were:

- Free competition among various currencies.
- End of government monopoly over supply of money.

The cryptocurrencies that have gained public attention recently conforms to both these ideas and has many elements of the libertarian monetary system. The world is only starting to witness a change in its payment system through cryptocurrencies. Only time will tell the fate of such monies. But interest in cryptocurrencies has caused great interest in the free market idea of Austrian school on money supply and inflation. This has put the focus on revisiting the understanding of monetary theory and how rising price level is the result of government - central bank policy mismanagement of the economy. But supporters of the new currency regime argue that having witnessed the disasters committed by central banks world over through high-expansionary monetary policies, the new products deserve a chance.

2.3 Introduction of Digital Currencies

Efforts to make private currencies which are free from government control are not something new. In fact, such a project has been going on for a while from the 1990s onwards. Before the modern-day cryptocurrencies came into existence, there were some experiments to introduce private currencies, all of which failed miserably. Some of those currencies were:

1990: DigiCash- In 1982, David Chaum, a cryptographer, in his paper titled "Blind signatures for untraceable payments" applied the idea of blind signatures to money. After eight years, he took these cryptographic protocols to market, and formed 'DigiCash', a company that ultimately went bankrupt in 1998.

Initially Digicash caught everyone's attention. Many merchants adopted it and even the Deutche bank adopted it. Digicash offered an alternative payment model based on very low transaction costs as opposed to the credit-based model of Visa and MasterCard. A currency outside the purview of any central authority was an interesting idea then.

But the battle for payment dominance was ultimately won by Visa and MasterCard, and later by PayPal.

1996: E-Gold- The idea of E-gold was that users create an account to which gold and silver can be sent. Once it is credited, this account can be used for transactions and purchase of commodities. In the late 1990s this operation was a success. But problems began to evolve by 2000. More regulations on business classified under the category of money transmitters were implemented under The US patriot Act and gaining licenses became very difficult. This along with a campaign against the E-gold made its survival difficult. A US federal court order banning E-gold marked its end in 2005.

1997: Hashcash- Hashcash was created in 1997 by Adam Back (it is cited in Nakamoto's paper). But his efforts did not become successful. There were other similar projects which were shortlived, like Wei Dai's 'b-money'(also cited in Nakamoto's paper) and nick Szabo's 'bitgold'. All these desperate efforts to create an online private currency could not stand the test of the time and ultimately failed.

1998-1999: Beenz.com and Flooz.com- Beenz and Flooz were currencies intended to reward people for internet behavior such as logging into some specific websites, shooping using some certain portals, taking some online quizzes, doing online marketing etc. But both the idea was gone by 2000 because of the dot-com crash

1999: InternetCash.com- Internet Cash was based on prepaid cards. It brought onboard a number of merchants willing to participate and the cash could be redeemed in any of the merchandise. In 2000 the company had a funding of $10 million and staff strength of around 70. The company even tried to protect its monetary system through patents. But it became just another company that was forced to close in the aftermath of the dot-com crash of 2000-2001

2.4 Financial Crisis and the Change of Thought

People store their money in banks when they have excess funds in hand. This is either to get rid of the risk of storing money or use the money in the future or both. Additionally, banks provide an interest rate for the funds parked with them making it more attractive. Banks use this money to lend to others who are in need of money as well as to invest in income generating investment. But what happens if loans taken from the banks are defaulted? Or what if the investments made by banks make losses? The depositor's money is at risk. This is what happened in the 2008 financial crisis. The banks used depositor's money to give away loans

recklessly which later became non-performing assets. This led to the collapse of the banks. This exposes a major problem of the current banking system-problem of trust. In other words, depositors trusted the banks would manage their money in a responsible manner but the banks managed the depositor's money in an irresponsible manner.

There is also a second problem. When banks started collapsing, the government wanted to take preventive action in order to arrest the spread of the contagion and thus bailed out a few banks. And the money used to bail out the new firms is the public money, collected through taxes. So effectively the banks lost the public money for behaving irresponsibly and the government bailed out the irresponsible banks again using public money. This created a serious problem – erosion of public trust in banking system. Consumer dissatisfaction and eroded trust in the government – central bank managed monetary system led to a rethinking among many to find an alternative. This rethinking was not only felt in those countries which were the epicenters of the financial crisis, but throughout the world because financial crisis affected the whole world.

Along with these two problems, there is the problem of government printing more money. In most of the countries, government spending is far more than the government revenue due to the developmental demands of the country. One-way governments deal with this is by asking the central banks to print more money. This reduces the value of currency that people hold, reduce the purchasing power of money and we call this as 'inflation'

2.5 Emergence of Cryptocurrencies

From 2001 onwards new instruments of digital money never really took off, until Nakamoto published the Bitcoin white paper in 2008. This paper led to the invention of the first cryptocurrency called Bitcoin. Cryptocurrencies are virtual digital currencies which acts as a medium of exchange directly between individuals. This is called peer-to-peer payment which

does not require any intermediaries like banks or any other financial institutions. It is called cryptocurrency because it uses the cryptographic protocol for security. Most of the cryptocurrencies are decentralized, based on distributed public ledger called block chain. This means that no single authority is the custodian of the ledger, but the ledger is managed and maintained by all the participants in the network. Cryptocurrencies are private, which, which means there is no government interference. In the subsequent years, the world witnessed the growth of many such cryptocurrencies. Currently there are about 1500 actively traded cryptocurrencies. Unlike the earlier digital coins, these new ones are built based on cryptographic programming which made it more secure. Some other well-known cryptos are Ripple, Ethereum, Litecoin, Namecoin, Bitcoin cash etc.

So why should a new system emerge when already a well-developed mechanism is in place? It is not a coincidence that Bitcoin, the first modern day decentralized private cryptocurrency was introduced just months after the worst economic crisis after the great depression. Post 2008 financial crisis, people started thinking of an alternative currency which is not controlled by any central authority and the answer was the invention of cryptocurrency. It is because financial crisis proved that a trust-based system would not work. These currencies got rid of third parties to facilitate transactions and is based on peer to peer transaction.

Supporters of cryptocurrencies argue that the conventional fiat currency system has a lot of loopholes and cryptocurrencies are the answer to many such problems. Some of the advantages that cryptos have over the present-day currency system are:

Problem of trust: in the current banking system one individual can make payments to another only through an intermediary, i.e. the banks. It is the bank which maintains the ledger book containing all the transactions of these individuals. Here arise two problems of trust. First, the participants should trust the bank that it will not manipulate the ledger.

Second, they should trust the central bank that it will not reduce the value of currency people are holding through expansionary monetary policy thereby inducing inflation. But both these are not guaranteed. There have been instances in the past where banks have indulged in fraudulent activities and central banks/government printing more currency leading to destabilization of the currency value.

With cryptocurrencies however, these problems are solved. No one can manipulate the ledger as it is available in the public and interfering in the public ledger needs majority's permission. Also, unlike central banks inflating fiat currency, no one can purposefully destabilize cryptocurrencies.

Decentralization: In the present form, creation of money, supply of money, interest rate and other policy rates etc are under the sole discretion of the government. General public is at the mercy of the monetary authorities. A single entity can decide for the whole country whether it is good or bad. But in the cryptocurrency regime, no single individual or entity can control the supply or issue of currency. Every change needs the concerted decision of the majority. This means cryptos act as a decentralized currency whereas fiat currencies are centralized in nature.

Immutability: If an individual wants to know how money was spent from his bank account, he checks the transaction history of the bank. But this means that 1) the individual trust the bank for not manipulating the transaction history and 2) individual trust the bank that no outsider is allowed to manipulate the transaction history i.e., the transaction ledger is safe. However, the banking system cannot work on the basis of trust but some foolproof mechanism to ensure that no fraudulent activities take place. In cryptocurrency ecosystem, this is ensured by the cryptographically secure nature of the cryptocurrencies. No one can interfere and manipulate the ledger because of its cryptographic nature. These records are then made public and are unchangeable.

Durability: Cryptocurrencies are not physical currencies. So it can't be destroyed. Unlike conventional currencies which can be stolen, destroyed etc, cryptos are durable. Some cryptos have reported the problem of stealing through hacking (e.g. bitcoin) but there are cryptos which claim to be proof to online stealing.

Portability: Conventional currencies need to be carried around everywhere. It becomes increasingly difficult to carry more and more currencies. Unlike these currencies, cryptos are stored in cloud. So, users can make payment anytime from anywhere with an internet connectivity.

Divisibility: Similar to currencies being divisible (eg: rupees can be subdivided to paisa), cryptos can be divided into sub units. For example, Bitcoin, the most popular cryptocurrency can be divided up to 18 decimal points. So, the divisibility is more than any other fiat currencies.

Rarity: It means the quality of being limited in supply. Governments create more currency to fund public spending if tax revenue is insufficient for meeting the expenses. This makes inflation an inherent problem with all fiat currencies. But many cryptocurrencies solve this issue by limiting the supply to a fixed number. For example, Bitcoin supply is limited by 21 million and currently some 14 million has been mined out and in circulation. This means that these currencies are not inflationary in nature.

No boundaries: Most fiat currencies are geographically limited to their respective countries. International transactions are facilitated through banks. It is affected by a number of factors such as exchange rates between the currencies, transaction charges etc. Also a significant amount of time is required for the processing of transactions. But Cryptocurrencies are universal currencies. It has no borders and making international transactions is very easy. There are no processing charges or any other fees and it is

much faster than the fiat currency system. This has great significance for the global trade and finance.

Anonymity: Another feature of cryptocurrencies is its privacy. In the current system, the government and bank authorities can access and control personal information because there is no privacy. Cryptocurrencies take this power away from banks. All transactions are made available in the pubic ledger, but the identity and personal information of participants is unknown secure.

Blockchain technology. It is a public record of information into which people can add more information. It is an entirely new way to document data on the internet. Multiple copies of the same information are kept on different locations in different devices. So even if one copy gets damaged, other copies make the ledger safe. Also, any change made only to one copy will be invalid as other unchanged copies make the change redundant. Any change can be affected only with the consent of the majority. Even though blockchain was first developed for cryptocurrencies, it has also proved its usefulness in other areas like online shopping, exchanges, social networking platforms, prediction markets, voting systems, games, public record keeping, banking systems etc.

But even though cryptocurrencies solve many issues of the conventional currency system, they also come with some other problems which are new. Those are:

Acceptability: Cryptocurrencies have till now not gained a widespread acceptance as a trustworthy currency. Partly this is due to the crackdown on cryptocurrencies by various governments including the US and Chinese governments.

Volatility: Cryptocurrencies are publicly traded in crypto exchanges. So its value/price depends on the demand and supply. This will create unpredictability in its value, making it more

volatile. As an example, Bitcoin witnessed a sudden increase in prices by the end of 2017 - around 2000% - and then fell drastically after a few months. This incident made Bitcoin infamous for its high instability.

2.6 Bitcoin: The Most Popular Cryptocurrency

Because of all the above mentioned uses and many more, cryptocurrencies soon caught the imagination of the masses. It all started with the invention of Bitcoin, the first ever cryptocurrency. Prior to the introduction of cryptocurrencies, all the previous attempts aimed at creating private online currencies didn't really take off because they all had a major problem: the requirement of a trusted third party like a bank to maintain the system in some way or the other. On 31st October 2008, Satoshi Nakamoto published a nine-page academic paper titled "Bitcoin: A Peer-to-Peer Electronic Cash System" suggested a solution. Nakamoto's paper suggested a totally transparent public ledger or 'blockchain' which is not controlled by anyone. Nakamoto laid down the problems of the existing 'trust-based model' and suggested a peer-to-peer distributed timestamp server which will facilitate two parties to transact directly without the help of a third party or banks. This paper became the basis of Bitcoin which was later introduced in 2009. Bitcoin, the first crypto currency would later totally change the perception of how a currency and an investment asset should be.

Bitcoin caught global investor and attention during the 2013, when the first spike in value occurred. The value increased from 100 USD to 1000 USD in just a month before losing much of it in the subsequent months. A value increase of such fold would come only later in the second half of 2017, when market price skyrocketed from around 2000 USD to nearly 20000 USD.

From 2013 to mid-2017 bitcoin stayed in the range of 100 USD to 2000 USD. The most important incident during this period was the collapse of Mt.Gox, a bitcoin exchange and the

first one to file for bankruptcy protection after hackers stole around $500 million of bitcoins. This is the largest Bitcoin hack in its short history and exposed the security flaws in the system. All these developments created huge concerns and doubts among the investors about Bitcoin which already gained notoriety for being a wild asset without any financial protection for its users.

Figure 1: Price movement of Bitcoin.

(source : https://coinmarketcap.com/currencies/bitcoin/#charts)

Bitcoin remained relatively calm till 2017. The year 2017 saw the largest volatility in bitcoin price with an increase from 1000 USD to 20000 USD in a matter of few months. By the end of 2017 Bitcoin price peaked at $197783.06 on 17 Dec 2017.

The Bitcoin high ride of 2017 sparked off serious debates and discussions among investors, intermediaries and governments. Many government authorities and banks, being wary of the developments declared it illegal (examples) and some governments like (examples) proclaimed that they would not be responsible for any loss that investors make by investing in Bitcoin. But

some monetary authorities were optimistic in their view about this new currency (examples). Some financial players like CME Group Inc., Chicago Board Open Exchange (CBOE) created platforms for customers to trade bitcoin futures.

But the Bitcoin glory did not last long. Just after December 2017, it began to fall and lost half the value within a couple of weeks. The fall was partly due to the fear among investors of a crackdown by the government authorities. The Bitcoin functioned outside the auspices of official monetary regulators and they saw Bitcoin as a wild bull that created financial threat as well as existential threat which needed to be tackled. Many countries including India, Russia and China have banned bitcoin for this reason.

2.7 What are Bitcoin's Shortcomings?

But Bitcoin is not without its shortfalls. We should keep in mind that Bitcoin was just a prototype of how a crypto currency should function like. It was the first experiment done by a person (or a group of people) by the name Satoshi Nakamoto and the original paper gives a direction of how a cryptographic based online currency can be. It does not mean it is a perfect model. In fact Bitcoin has many shortcomings, the basis of which later led to the formation of many other cryptocurrencies. These are referred to as alternate currencies or Altcoins. These possess all the advantages as well as solve some problems of Bitcoins. Even though Bitcoin introduced a superior technology, it has now been surpassed by protocols of new Altcoins.

The rate of money creation**:** The Bitcoin ecosystem is created in such a way that the total money supply is limited to 21 million. Currently around 15 million are in circulation. The rest are created and put to circulation through a process called 'mining' by people (or computers) called 'miners'. As more and more Bitcoins are mined, it becomes increasingly difficult to mine more Bitcoins. It is said that the last Bitcoin will be mined by the year 2140.

This feature makes Bitcoin deflationary in nature. As more and more people start using it, with the limited number of currencies in circulation, more commodities can be purchased with less currency. Economists from the Austrian school argue that allowing prices to fall in relation to the currency is a good way to tackle inflation.

But the problem is that if the amount of money is not increasing with the number of users or uses, this affects the purpose for which Bitcoin is being used by its users. Users who see that the price of Bitcoin is going up from 5 USD in 2011 to 19000 USD within six years does not think that prices of goods and services are falling with respect to bitcoin; but instead think that "If I keep my Bitcoins, they will be worth more in value after some years. So let me not spend and save it instead". This simply means that Bitcoin users don't want to use it as a payment tool but like to use it as a speculative asset.

This is a major flaw in the design of Bitcoin. This problem can be solved only by allowing the money circulation to grow by the level of how much is being used, so that the currency remains stable relatively to goods and services and other currencies. If a currency rapidly appreciates, it will be seen only as an investment tool and not as a mode of payment. Even the principle that Bitcoin follows, which rewards only creators(miners) and investors rather than promoting it as a means of payment, too has conveyed the idea that this is an investment tool rather than a currency. But there are other cryptocurrencies which don't have this problem. Those cryptos are referred to as stable coins, which are designed in such a way that they do not appreciate or depreciate too much and is more or less stable. A classic example is Tether.

Not anonymous but only pseudonymous**:** Another claim of Bitcoin is that it provides anonymity in transactions. But the digital currency is not fully effective in doing so. Transactions happen between addresses and the transaction history is publically available. So over a time many transactions are attached to a single address. Interested

parties can learn an address' transaction and buying patterns. This effectively means Bitcoin is not fully anonymous, but only pseudonymous.

Limited block size and block speed: Higher block size means higher the number of transactions that can be handled by the block. Bitcoin has a block size of just 1 MB. But Altcoins like Bitcoin cash, which came into being in August 2017, has a block size of 8 MB. This enables it to handle more transactions easily. Altcoins like Ripple, Litecoin and Ether have faster block times than Bitcoin. For example, it takes on an average 2.5 minutes for Litecoin to complete a block, whereas Bitcoin takes up to 10 minutes.

Everyone cannot participate in the mining process**:** Application specific integrated circuits (ASICs) are required for Bitcoin mining and ASICs are very expensive. This makes it possible only for big players to participate in the mining process. Majority of Bitcoin mining are dominated by large mining firms for this reason. Bitcoin gold, an altcoin which came into existence in October 2017 is designed in a more democratic way by making mining process available for wide range of processors.

High energy requirement**:** The computing power required for Bitcoin mining is so huge that it cannot be done on a single computer. Large computing farms need to be set up to mine Bitcoin viably. As more and more Bitcoins are mined, mining becomes increasingly difficult. This will only scale up the computing power requirement of Bitcoin in the future. Huge electricity is needed for these mining farms to function. This is the reason why majority of the mining are concentrated in countries where electricity is cheap.

All these shortcomings of Bitcoin forced communities to start their own project to search for alternative cryptocurrencies as an attempt to construct more refined cryptocurrencies. Some took off while some did not. Thus came all the cryptocurrencies that we see today either as an alternative to bitcoin or to tap into the possibility of a future cryptocurrency boom.

Chapter 3

REVIEW OF LITERATURE

3.1 Introduction

Even though there are much research in the area of cryptocurrencies, most of the researches are centred on the technical aspects of cryptocurrencies like the block chain technology, its safety etc. Most of these studies are from the domain of law and computer science. Majority of such papers studied about the cryptographic nature of cryptocurrencies (Rainer et al., 2015 and Nakamoto, 2008), problem of double spending (Karame et al., 2012), analysis of the cryptocurrency network (Ron and Shamir, 2013), and cyber security related aspects. But more recently researchers have been studying about the economic and financial behaviour of Bitcoin as a currency and investment tool, volatility being an important aspect among them. Since this study focuses mainly on cryptocurrency as an investment tool, most of the literature that are reviewed focus on the investment aspect.

3.2 Theoretical Review

Markowitz (1952) was the author of *'portfolio selection'*, the pioneering work in portfolio theory and introduced the Modern Portfolio Theory (MPT). MPT develops a tool that allows investors to choose a portfolio based on the prevalent market risks. This is done by creating an efficient frontier. MPT states that, assuming investors are risk averse, he will be ready to accept more risk only if compensated by a high return. To achieve higher returns, an investor should accept high risk. Thus there is a tradeoff between risk and returns. The actual tradeoff will be different for different investors based on their risk averse nature. But the implication is that, a

rational investor will not go for a portfolio if there is another portfolio with a better risk-return profile. The paper stated that an investor can achieve more returns by including more number of assets in his portfolio, instead of just holding one asset. This is termed as portfolio diversification. *The theory of Investment value* by J.B. Williams states that the investor should maximize the discounted value of future returns. Markowitz mentions that discounted value of future returns can be maximized by diversifying the portfolio. A diversified portfolio is both preferable and superior.

The paper not only emphasis on diversification, but also on the right kind of diversification. For example, a portfolio of hundred assets in the transport sector is inferior to a portfolio with some assets from transport, defense, communication etc. it is because assets within an industry is highly correlated. Assets should have very low covariance among them. If an investor diversifies between two portfolios of originally equal variance, then the resulting portfolio will have a less variance than the original two portfolios. The author also states that the returns from securities will be inter related that diversification cannot remove all the variance. Diversification helps in reducing the variance.

Before the introduction of Modern Portfolio Theory, investment decisions were centered on individual assets. Investors used to analyze individual assets to find out the sure bets. Expected Net Present Value (NPV) was used to identify these sure bets, by discounting the future cash flows. Assets which were considered as 'sure bets' were those which produce a fairly good amount of return with minimum risk. Thus assets which can generate more returns at a short span of time were considered more important. Markowitz was against this idea. 'Net Present value' has its own shortcomings. Selecting the portfolio comprising stocks of highest NPV is more risky and a good portfolio is the most diversified one. Thus portfolio diversification was Markowitz's proposition.

The Modern Portfolio Theory is based on many assumptions. It assumes that investors are rational and try to maximize their utility with a given amount of money, and also investors are risk averse who always try to minimize the risk. They choose higher returns to lower returns for any given level of risk. It also assumes that they have fair information about markets, return and risk. Another major assumption is that markets are efficient and absorb all the information perfectly and quickly.

Kiyotaki N and Moore J (2002) in their famous work titled *"Evil is the root of all money"* mentions why money is required. The famous concept is that money lubricates the lack of double coincidence of wants. It means without money people are forced to practice barter system. The problem of double coincidence of wants arises when the seller of a good does not get in return the good he wants, from the buyer. Money solves this issue. But authors say that money is not required to solve the double coincidence issue. If there is an agreement between the parties that person B will provide the good person A needs at some later time, in return for the good person A sells to B now, then the problem does not arises. Thus there is a promise given by B to A. So a promise is enough to solve the problem of lack of double coincidence of wants.

But the problem happens when person B breaks the promise. This means that there should be a written promise that can be given to person A by B, which can be redeemed when B fulfills his promise. This acts as money. So money is required so that individuals don't resort to breaking promises. Here, when an evil is done (i.e., breaking a promise) and the whole purpose of money is to prevent it. This is the reason for the statement: "Evil is the root of all money". This is explained using a Wicksell's triangle, which consists of three individuals, three goods and three time periods. This leads to the conclusion that lack of double coincidence of wants

does not explain why money is required, but lack of commitment / trust necessarily explains the need for use of money.

Hayek (1976), in his book, "*denationalization of currency*" proposes the idea of removing government monopoly over the issue of fiat currency in order to ensure price stability. So how does government monopoly disrupts price stability? Hayek says that because of the government monopoly, central banks accommodate the financial needs of the government by keeping interest rates low and thus the central banks give their policies an inflationist bias. However in his view, the use of money supply to achieve particular ends turns out to destroy the price mechanism equilibrium and therefore provoke major business fluctuations (Hayek, 1976:119). The whole argument of Hayek's book was to avoid political interference in monetary policy.

In his book he mentions that "… *Ministers of finance were told by economists that running a deficit was a meritorious act, and even that, so long as there were unemployed resources, extra government expenditure cost the people nothing…*"(Hayek, 1976: 118). The criticism here is that the reason for most products like food, healthcare, education, transportation, housing etc keep spiraling upwards is due to act of government run central banks creating more and more money through expansionary monetary policy.

According to Hayek, a stable currency is utmost important for the currency to operate at maximum efficiency, for which government intervention must be abolished. For this, Hayek proposes the idea of different banks issuing different currencies which would pave the way for a market competition among the currencies. Banks could issue non-interest bearing certificates and deposit accounts based on their own distinct registered trademark and this can be treated as currencies. These currencies of different banks can be traded at variable exchange rates. This effectively means a free market competition among various private currencies. Or in other words, privatizing the supply of money. According to Hayek the advantage of such a

mechanism is that prices will convey to the different agents the relevant information to make decisions. The one currency which exhibit maximum price stability in its value as a unit of account will be the most desirable among all the competing currencies and will eventually prevail.

William Sharpe (1994) in his paper titled *'Sharpe ratio'* proposed a measurement called 'Sharpe ratio' to measure the level of expected returns earned for undertaking each unit of extra risk. The slope of the Capital Allocation Line is referred to as 'reward to variability ratio', widely known as Sharpe ratio. It is the additional expected return that an investment provides for each additional unit of risk (ΔMEAN / ΔSTDEV). The slope represents the tradeoff between return and risk. A higher slope means greater returns for undertaking each unit of risk and vice versa. Thus higher the slope of the CAL, the better it is. The point where CAL is tangent with the efficient frontier is the portfolio with highest Sharpe ratio. That is the optimal portfolio because steeper the CAL, higher is the Sharpe ratio and CAL is the steepest at the point of tangency with efficient frontier. Steepest CAL gives the highest return for the extra risk taken.

The main aspects of Sharpe ratio are asset volatility and asset return. Historic average of the return is used as a proxy for asset return. Standard deviation of the historic return is used as a proxy for asset volatility or risk. William Sharpe also introduced two types of Sharpe ratio: ex-post and ex-ante. If the past returns data of an asset is used to analyze the past performance of the portfolio, it is ex-post analysis. When expected future returns and expected risk free rate is considered for predicting the performance of an asset, it is referred to as ex-ante analysis.

Nakamoto (2008) in his pioneering work that led to the creation of Bitcoin, *"Bitcoin: A peer to peer electronic cash system*" mentions about two problems faced by digital currencies - the problem of trust and the problem of double spending. In the conventional monetary system, banks act as the suppliers of debit and credit services as well as keep the ledger. This means

the most important factor is the trust that people place in banks. The public trust them not to debase the currency and misuse funds or to manipulate the ledger. Because banks are profit maximizing entities, this trust based model has its own problems. Number of financial crisis of the past exposes the inherent problems of the trust based model, when banks have acted irresponsibly. Nakamoto solves this issue of trust based model by ruling out the possibility of human intervention in the monetary system. The white paper suggests a public ledger, where all the transactions will be publicly recorded and placed as the solution. Any change in the public ledger needs the verification from the majority. So in this new model, it is the public which is the custodian of the ledger rather than the banks.

The problem of double spending occurs if the same currency is spent twice. Physical currencies don't face this problem as it is handed over to the seller of goods and services by the buyer. But digital currencies face this problem as there is a threat of digital currencies being duplicated. Since every digital currency is a digital file, there is a risk that it can be duplicated and send to multiple people. This will lead to unlimited number of money being created. The solution that Nakamoto suggested in this paper to prevent double spending problem was blockchain technology. This is a public ledger which records all the transactions in the Bitcoin network. These transactions are validated by miners, which is then successfully added to the ledger. Since every transaction is verified in the network, this makes sure that a Bitcoin is not spent twice and each transaction is legitimate. The more confirmations a transaction gets, more difficult it is to double spend. If someone tries to double spend simultaneously, then both the transactions get cancelled because the functions will show the network that it is counterfeit. Most of the cryptocurrencies formed since then uses the same blockchain technology to prevent double spending.

3.3 Empirical Review

Glaser et al tries to find out the intention behind people buying cryptocurrencies. They analyzed whether people obtaining Bitcoin is for the transactionary purpose of buying goods and services or with a speculative mentality in order to make profits at a later date. This is understood by collecting both Bitcoin exchange data and Bitcoin transactions data and analyzing whether the volume of exchange of Bitcoin is succeeded by a similar volume of Bitcoin transactions. A daily time series data for the period 2011 to 2013 is used and the methodology adopted is the Autoregressive Conditional Heteroskedasticity (ARCH) estimation. The results indicate that users are attracted towards Bitcoin with an aim of trading those in the exchanges, hoping to make profits at a later date, rather than using it as a currency. The study verifies this result by also finding out that Bitcoin returns react to news and events related to the cryptocurrency.

Dyhrberg (2015) looks at what kind of a financial asset is Bitcoin. By analyzing which statistical properties Bitcoin shares with gold and currencies, it is understood whether Bitcoin behaves like an asset or like a currency. A GARCH (1, 1) model is used to analyze how Bitcoin price volatility reacts to various variables. An exponential GARCH is used to understand how Bitcoin reacts to good and bad news. Among the explanatory variables, except dollar-euro exchange rate, in all other variables, the variance equation shows that a positive volatility shock decreases the variance of the Bitcoin returns. It suggests Bitcoin has risk management capabilities and may be preferred by risk averse investors. The eGARCH results showed that positive and negative shocks affect Bitcoin returns asymmetrically i.e., no leverage effect. Thus Bitcoin can be used as a good investment in anticipation of bad news for risk averse investors.

Overall the study concludes that Bitcoin is something in between currency and gold, on a scale with one extreme being pure medium of exchange, and the other extreme being pure store of

value, as it shares many similarities with both gold and the dollar. Thus a risk averse investor can combine the advantages of both the instruments by including Bitcoin in the portfolio.

Camilla Law and Marja Vahlqvist (2017) analyze whether Bitcoin can be used as a diversification tool. A linear regression analysis is used to understand whether there is a significant relationship between Bitcoin and a host of other assets like the Swedish stock market index (OMXS 30), Dow Jones index, Nikkei225 index, oil and gold. The idea is that a significant zero correlation means Bitcoin can be used as a diversifier. The initial result suggested a zero correlation, but insignificant. It was further analyzed by using the Modern Portfolio Theory's Mean Variance Optimization (MVO) method. The result gave two minimum variance frontiers – one with Bitcoin and the other without Bitcoin. The portfolio without Bitcoin yielded a significantly higher return for the same risk, compared to the portfolio without Bitcoin. This suggest that Bitcoin can be used as a diversifier.

Eisl et al analyzed how the inclusion of Bitcoin affect the asset allocation of an already well diversified portfolio i.e., whether including Bitcoin improves the risk-return profile of a well-diversified portfolio. Assets in the portfolio included commodities, stocks, money market, fixed income etc. The research uses portfolio optimization approach built on the Conditional Value-at-Risk (CVaR) method. Also applied is portfolio back testing technique to calculate monthly out-of-sample returns and risk return ratios based on the CVaR. CVaR is used because Bitcoin returns are not normal. The results show that a small share of Bitcoin in portfolio can make Bitcoin investments more feasible. Also Bitcoin can contribute to the risk return ratios of optimal portfolios. Including Bitcoin in the portfolio from the range 1.65% to 7.69% increases both the expected return as well as the risk of the portfolios. However the returns outweigh the risks faced by the investor.

Chen and Vivek (2014) study whether Bitcoin is helpful in enhancing the performance of a well diversified portfolio. Diversifying feature of Bitcoin is compared with that of Euro, Yen, Pound, Dollar and gold. The daily closing price of all these instruments is taken for the period July 2010 to Dec 2013. The currency behavior of Bitcoin vis a vis other assets is studied by analyzing the distributional properties of all the instruments. Similarly, investment property is understood by examining the correlation of returns of Bitcoin and the other assets. Second objective of whether addition of Bitcoin improves the productivity of a well diversified portfolio is analyzed by creating various portfolios and adding Bitcoin to the portfolio to see if there is an improvement. Sharpe ratio and Sortino ratio are used to see if there is a significant reduction in risk or increase in returns. In the final part of the study, Black-Litterman approach is used to study whether Bitcoin remains in the portfolio even after negative news about the portfolio. This is done by quantifying historical and forecast news and incorporating into the model.

The results state that Bitcoin is a poor currency because it is not widely accepted and also a poor investment tool due to its high volatility. Individual investors can make their portfolio better by including a small proportion of 2.83% of Bitcoin to their portfolio. Using the Black-Litterman approach, the study predicts that Bitcoin will lose 50% value in the following years and that the optimal share of Bitcoin will fall to 1.71% from 2.83%.

Briere et al (2015) studies the effect of including Bitcoin in a well-diversified investment portfolio from the viewpoint of an American investor. Using weekly data from 2010 to 2013 a well diversified portfolio is first created using traditional assets such as stocks and bonds, as well as alternative investments such as commodities, hedge funds etc. The study shows that the correlation between Bitcoin and other assets are very week, which is a strong case to further study by including Bitcoin in the portfolio. To understand whether Bitcoin improves the

portfolio performance, mean-variance spanning test proposed by Huberman & Kandel (1987) and Ferson et al. (1993) is used.

The results indicate that Bitcoin included portfolios show better risk-return profile than the portfolios without Bitcoin. Including Bitcoin increases the Sharpe ratio from 1.39% to 2.83%. Similarly, sortino ratio improves from 2% to 6.1% upon inclusion of Bitcoin in the portfolio. While plotting the minimum variance frontier, Bitcoin included portfolio is much steeper than Bitcoin free portfolio, indicating that for a fixed measure of volatility, Bitcoin included portfolio provides better returns. At the same volatility level of 12%, including 6% Bitcoin in the portfolio share improves the average annual return from 13.1% to 32.5%.

Wu and Pandey (2014) assess whether there is any positive or negative effect while adding Bitcoin to an investment portfolio. While examining whether Bitcoin behaves as a currency or not, distributional properties of the historic returns were analysed. To understand whether if Bitcoin exhibits properties of an investment asset, correlation of returns with other major asset classes were analysed. The study also see whether Bitcoin can be used as a diversification tool or not. This is done by first creating a portfolio of the various asset classes and analyzing the behavior of the portfolio with and without adding Bitcoin. Optimum portfolios were created by random simulation of over a thousand times. In the final analysis, Black-Litterman approach is used to find out whether Bitcoin continue to be in investors' portfolio even after all the pessimistic views and confusions about Bitcoin.

The findings suggest that Bitcoin is still in its infancy stage and is not used as a medium of exchange. In fact Bitcoin does not conform to the other basic characteristics of a currency as well. It is also found that the correlation of cryptocurrencies with other asset classes are negligible, which suggest that Bitcoin has the potential to be a diversifier. They also conclude that portfolio effectiveness improves when Bitcoin is added to the portfolio. The results of the

Black-Litterman analysis shows that after incorporating the negative and pessimistic news about Bitcoin, share of Bitcoin in an optimal portfolio drop by around 60%. Despite this, the overall conclusion of the study is that including Bitcoin improves the portfolio performance.

Campbell et al (2001) says that choosing the traditional mean-variance optimization process to construct efficient portfolio is not the best strategy for optimizing returns and minimizing risk. Most of the financial data are non-normal, whereas mean-variance analysis assumes it to be normal. The best methodology will be to incorporate the non-normality of returns into the model. The paper develops a model for portfolio selection which is based on maximizing the expected return subject to a downside risk constraint, instead of standard deviation alone. Downside risk is taken in terms of portfolio Value at Risk (VaR) so that the additional risk arising from the non-normality of returns can also be accommodated. This allows a generalized framework, with a distributional assumption suiting the type of financial data. The performance of the portfolio is measured by creating a performance index similar to the Sharpe ratio. Thus an alternative index to Sharpe ratio and an alternative method to mean-variance approach is constructed.

The study took eight years daily data of US bond and stock markets and portfolios are created which maximizes performance index. Efficient VaR frontiers are then plotted as against the minimum variance frontiers used in conventional methodology. At 95% confidence level, the optimum portfolio is obtained as 64% in bonds and 36% in stocks. By choosing a VaR level, the investor's degree of risk aversion can be captured. This is an advantage of the model because the investor can very well determine the risk-return tradeoff. The investor wants to maximize the return and minimize the return, subject to a downside risk constraint.

Tsao and Liu analyze different methods to incorporate the Value at Risk (VaR) framework in portfolio selection. VaR is most commonly used if the aim is to measure the downside risk.

Three main methods analyzed are delta normal method, historical simulation method and monte-carlo simulation method. Delta normal method assumes that the asset returns follow a multivariate normal distribution. Historical simulation method assumes that the distribution of the future returns is exactly similar to its historical realization. Monte-carlo simulation is similar to historical simulation except the assumption that instead of historical realization as a proxy for future distribution, a statistical process which is believed to adequately capture the possible change in the assets is used.

It is concluded that the efficient frontier can be more efficiently created by using the Non-Dominated Sorting GA (NSGA) II method. In the empirical analysis result, it is found that the portfolios in the VaR frontier are different from that of portfolios in the traditional mean-variance frontier at 99% confidence interval. This means that when confidence interval rises, i.e., when the investor is risk averse, it can lead to inefficient allocation of resources if mean-variance framework is used. Also it is concluded that results of mean variance analysis and mean VaR analysis are similar only if the returns follow a normal distribution. Thus it can be inferred from the study that mean VaR analysis gives more robust results if i) data is not normal and ii) investor is highly risk averse regardless of the distribution of the data.

Baur et al (2017) tried to analyze the return and risk nature of Bitcoin as well as the correlation of Bitcoin with sixteen other assets like stocks, metals, bonds, currency etc. The study analysis empirically about the explosive nature (or volatility) of Bitcoin, the safe haven properties of Bitcoin, and its correlation with different assets classes. A user analysis is also done to find out whether investors use Bitcoin to invest or as a currency. Results indicate, in line with the expectation, that Bitcoin had the highest return as well as volatility of all the asset classes examined. The study also concluded that between Bitcoin and the other assets, there is no

significant correlation and provides diversification benefits. Regarding user analysis, the study confirmed that majority of Bitcoin users use it as a speculative asset, and not as a currency.

3.4 Conclusion

This chapter covers a short review of the researches that are considered as the most important works in the area. The theoretical part covers mainly the pioneering works that led to the development of modern portfolio analysis. These works are mainly the books and research papers which forms the basis of the theoretical framework of our study. This section also includes the pioneering study which led to the creation of cryptocurrencies.

The empirical section consists of the main works related to cryptocurrencies. Most of these works are either econometric analysis of the volatility of cryptocurrencies or portfolio analysis of including cryptocurrency in a portfolio. Since Bitcoin is the first and the most commonly known cryptocurrency, and also the one which provides the maximum historical data, majority of the studies are centered on Bitcoin. Studies related to other cryptocurrencies is rare. The research problem that most of the studies try to address is whether including cryptocurrencies will benefit the portfolio or not. The conclusion of majority of these papers is that inclusion of cryptocurrencies, especially Bitcoin, is beneficial for an investor and improves portfolio performance.

Chapter 4

METHODOLOGY AND DATA

4.1 Methodology

Portfolio analysis is first done by creating a portfolio, which serves as a benchmark for comparison. Stock price returns of BSE 30 firms were considered to create the portfolio. 24 stocks were selected out of this, whose shape ratio was positive. The solver function in excel is used to find out the optimum weight of each stock to be included in the portfolio. Various combinations of stocks are combined, and the returns and risk are calculated. This is done by: 1) changing the weights to minimize the risk while holding the return constant or 2) changing the weights to maximize the return by holding the risk constant. Plotting these various risk – return combinations of different portfolios will give the efficiency frontier. Efficiency frontier gives all the possible combinations of assets / all possible portfolios. The optimal portfolio among all these portfolios in the efficient frontier is found out using Sharpe ratio. The portfolio with the highest Sharpe ratio is the optimum portfolio.

The optimum portfolio is combined with investor's choice by imposing Capital Allocation Line. This line joins the point representing risk free rate and the optimum portfolio. In fact the point of tangency of the CAL with the efficient frontier becomes the optimum portfolio. CAL gives investor a range options to invest and a point on the CAL can be chosen based on the risk appetite of the investor. Investor can either invest entire wealth in risk free asset or in optimum portfolio with higher risk and returns. He can also consider a combination of both, which falls between both these points in the CAL. The investor can also select a portfolio beyond the optimal portfolio by borrowing at the risk-free rate, if he wishes to undertake more risk. The

selection of the optimal portfolio depends upon the individual choice, based on the risk appetite.

The same process is continued by adding Bitcoin to the portfolio of stocks and the efficiency frontier and CAL is plotted. The procedure is continued by adding all six cryptocurrencies to the stocks, efficiency frontier and CAL is plotted. Analyzing the efficiency frontiers give idea about the portfolio's performance. Further we also get answer about the weightage of total cryptocurrencies to be included in the portfolio. Weightage distribution among the cryptocurrencies is also found out similarly. The results of the analysis along with tables and graphs are given in the section below.

4.1.1 Mean variance analysis

Under the mean variance analysis (MVA), most important properties of any investment can be summarized as measure of expected return and the measure of dispersion around the expected return. These measures are expressed as mean and standard deviation respectively. Variance or standard deviation shows how much is the spread of numbers in a set are. Expected return tells the probability of estimated return of the asset/portfolio/investment. Through the mean-variance analysis, investors weigh the risk against the expected return. This tool helps them to find out the highest gains at any given level of risk, or the lowest risk at any given level of return. The overall portfolio risk is computed through a function of variance of individual asset along with the correlation among them. While talking about the portfolio, the portfolio return (which is portfolio mean) is the weighted average of the mean of the individual assets. But portfolio risk (which is portfolio standard deviation) is not the weighted individual standard deviations.

Variance of each asset is calculated using the formula:

$$\delta^2 = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \mu)}{n - 1}}$$

Where *x* is the return on the asset at time *t*

Variance of the portfolio is calculated using the following formula:

$$\delta^{2(r_p)} = \sum_{i=1}^{n} w_i^2 \times \delta^2(r_{i)} + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2 \times w_i \times w_j \times cov(r_i, r_j)$$

Where *w* is the weight of an asset *i* in the portfolio *p*, and *r* is the return of asset *i*

OR

Portfolio Variance $= W^T S W$

Where $S \rightarrow$ variance – covariance matrix

$W \rightarrow$ Weight matrix

$W^T \rightarrow$ Transpose of weight matrix

The **expected portfolio return** is calculated as the sum of the weighted expected returns for each asset:

$$E(r_p) = E(r_1) \times w_1 + E(r_2) \times w_2 + E(r_3) \times w_3$$

Where $w_1 + w_2 + w_3 = 1$

OR

Expected portfolio returns $= W^T R$

i.e., the matrix multiplication of the weighted average of individual expected returns

4.1.2 Sharp Ratio

The slope of the Capital Allocation Line is referred to as 'reward - variability ratio', widely known as Sharpe ratio. It is the additional expected return that an investment provides for each additional unit of risk (ΔMEAN / ΔSTDEV). The slope represents the tradeoff between return and risk. A higher slope means greater returns for undertaking each unit of risk and vice versa. Thus, higher the slope of the CAL, the better it is. The point where CAL is tangent with the efficient frontier is the portfolio with highest Sharpe ratio. That is the optimal portfolio because steeper the CAL, higher is the Sharpe ratio and CAL is the steepest at the point of tangency with efficient frontier. Steepest CAL gives the highest return for the extra risk taken.

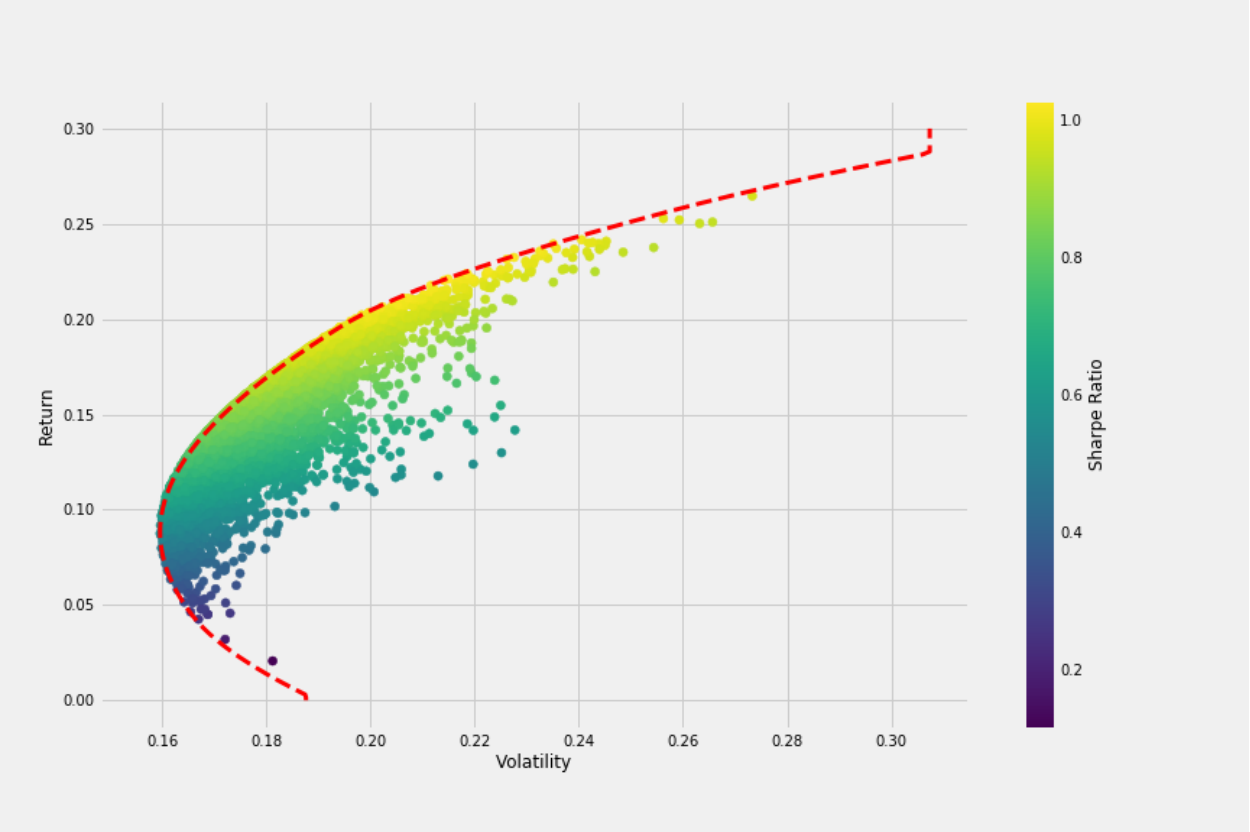
The main aspects of Sharpe ratio are asset volatility and asset return. Historic average of the return is used as a proxy for asset return. Standard deviation of the historic return is used as a proxy for asset volatility or risk. William Sharpe also introduced two types of Sharpe ratio: ex-post and ex-ante. If the past returns data of an asset is used to analyze the past performance of the portfolio, it is ex-post analysis. When expected future returns and expected risk-free rate is considered for predicting the performance of an asset, it is referred to as ex-ante analysis.

4.1.3 Efficiency Frontier and Capital Allocation Line

The aim of the Mean-Variance analysis is to construct an efficient frontier. An efficient frontier is a set of most optimum portfolios that gives the highest expected return for every given level of risk. Each point on the frontier also depicts the portfolio with least risk for that particular level of expected return. In other words, efficient frontier consists of portfolios in which expected returns can be further increased only at the cost of higher risk. After identifying the frontier, MVA addresses the problem of how an individual investor will choose a portfolio among various efficient portfolios. This depends on the investor's willingness to trade-off return and risk, or the risk appetite of the investor. The frontier shows the different ways in

which investor is able to make the trade-off. Hence it is very important to know the risk – return preferences of the investor in order to choose the best portfolio for each individual. MVA also introduces a risk free asset. This allows the investor to choose the best portfolio without having to deal with the question of risk preferences.

Figure 2: efficiency frontier

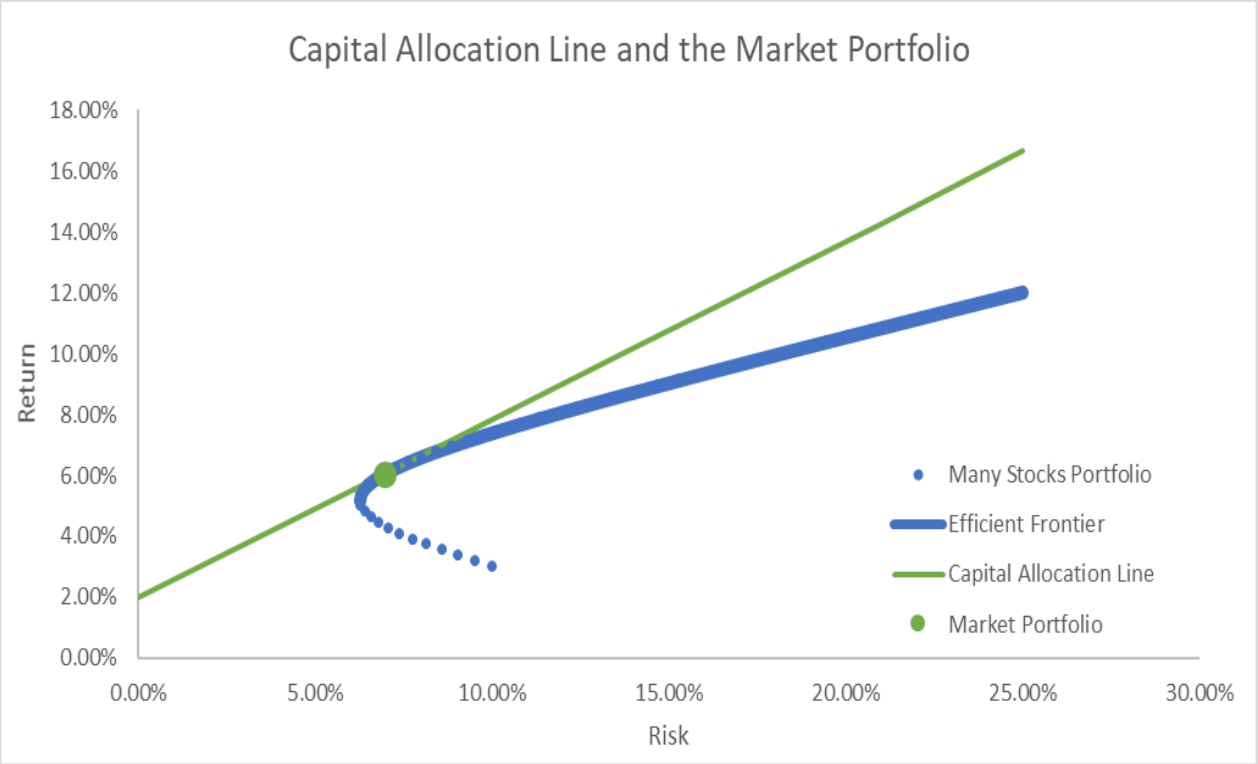


The red line in the figure shown above depicts an efficient frontier. It is called efficient frontier because each point in the frontier represents the portfolio with the highest return (for a given level of risk) or least risk (for a given level of return). Thus an investor would want to choose only the portfolios in this line as it is the most efficient points. Portfolios to the right of the efficient frontier are inefficient because a more efficient and better point is available for a given level of risk and return. Portfolios to the left of the frontier are not available. Which portfolio along the efficient frontier should the investor choose depends upon the individual risk appetite. If the risk appetite is high, an investor can choose a portfolio towards the upper right portion

of the curve where both return and risk are high. A risk averse investor can settle at the lower left portion of the efficient frontier.

What happens if a risk free asset is introduced into the portfolio? Risk free asset and risky portfolio can be linearly combined to create a new portfolio. What will be the risk – return characteristics of the new combination? This is represented by Capital Allocation Line (CAL). Capital allocation line, also called Capital Market Line (Capital Market Line) is a locus of points representing various combinations of risky assets and risk free assets.

Fig. 3: Capital allocation line



The straight line depicted in the above figure is the capital allocation line. It connects the point representing risk free asset and runs all the way to be tangent to the efficient frontier. The vertical intercept of the line represents the portfolio in which 100% assets are risk free and the point tangent with the hyperbola represents the portfolio of 100% risky assets. Between these two points lies various portfolios representing positive combinations of both risky and risk free

assets. Points to the right of the tangency point represent portfolios involving negative holdings of risk-free assets, meaning at this point the investor borrows at risk free rate and invest in the risky assets. The introduction of the CAL by choosing risk free asset as a part of the portfolio increases the risk-return combinations available to the investor to choose from because except the tangency point, CAL provides better returns than all other points in the efficient frontier. The formula for CAL can be shown as

$$\boldsymbol{E(R_C) = R_F + \sigma_C \frac{E(R_P - R_F)}{\sigma_P}}$$

Where P is the portfolio of risky assets, F is the risk-free asset, and C is the combination of both asset groups P and F

The slope of the Capital Allocation Line is referred to as 'reward to variability ratio', widely known as Sharpe ratio. It is the additional expected return that an investment provides for each additional unit of risk (ΔMEAN / ΔSTDEV). The slope represents the tradeoff between return and risk. A higher slope means greater returns for undertaking each unit of risk and vice versa. Thus, higher the slope of the CAL, the better it is. The point where CAL is tangent with the efficient frontier is the portfolio with highest Sharpe ratio. That is the optimal portfolio because steeper the CAL, higher is the Sharpe ratio and CAL is the steepest at the point of tangency with efficient frontier. Steepest CAL gives the highest return for the extra risk taken.

4.2 Data

The primary step is to collect the historical price data of the assets used in the analysis. The study is entirely based on secondary sources of data. Stock prices data is collected from yahoo finance (www.finance.yahoo.com) and market rates of cryptocurrencies is collected from www.coindesk.com. Monthly closing prices data was collected over the period of 2013 to 2018 with 60 observations for each asset. The returns were calculated as the natural logarithmic first difference.

Stock prices of BSE 30 companies were used. BSE companies were used for the analysis because of the importance they have in terms of market capitalization, and performance. From those, data of 24 companies whose Sharpe ratio is positive (based on historical returns) is used for the analysis. These companies are ADANI PORTS, ASIAN PAINTS, AXIS BANK, HDFC, HDFC BANK, HERO MOTOCORP, HINDUSTAN UNILEVER, ICICI BANK, INDUSIND BANK, INFOSYS, ITC, KOTAK BANK, L&T, MAHINDRA & MAHINDRA, MARUTI, NTPC, POWERGRID CORP, RELIANCE INDUSTRIES, SBI, TATA STEELS, TCS, WIPRO and YES BANK. Portfolio of stocks were selected because equities are the most common instruments Indian investors use in portfolios.

The six cryptocurrencies used for the analysis include Bitcoin, Dash, Litecoin, Stellar, Ripple, and Monero. These six currencies were selected particularly because data is not available for most of the other cryptocurrencies. Proper returns data from 2013 to 2018 is available for only these many cryptocurrencies. The data was available in US Dollars, and was converted into Indian Rupee by using the prevalent exchange rates at that time.

Chapter 5

EMPIRICAL RESULTS

5.1 Introduction

As mentioned in the previous chapter, Mean Variance Analysis allows us to combine different assets as a portfolio and examine the properties of the portfolio to make appropriate decisions. In the first part of this chapter, the data and methodology used for the analysis is mentioned in detail. There are 30 variables used in total. Every detail like the source of data, transformation of data, and the portfolio analysis is described. Then descriptive statistics is computed and given, which give a brief understanding about the nature of the variables used. The chapter then gives the result of the analysis. The analysis is done using the solver function in Microsoft Excel which helps in optimization. The results are displayed as graphs for easy understanding. Five graphs depicts the efficiency frontiers and the respective capital allocation lines. Findings of the study can be easily be understood form the graph which shows that including cryptocurrencies in the portfolio improves the performance of the portfolio.

Further, the optimal portfolios are found out using Sharpe ratios. The weight of cryptocurrencies to be included in an optimal portfolio is also found out. Along with that, the optimal weight within cryptocurrencies are also given, which will help the investor while choosing which cryptocurrency to invest. The chapter ends with a concluding note on the brief findings.

5.2 Analysis and Results

5.2.1 Summary statistics:

Table 1: Summary Statistics of all assets.

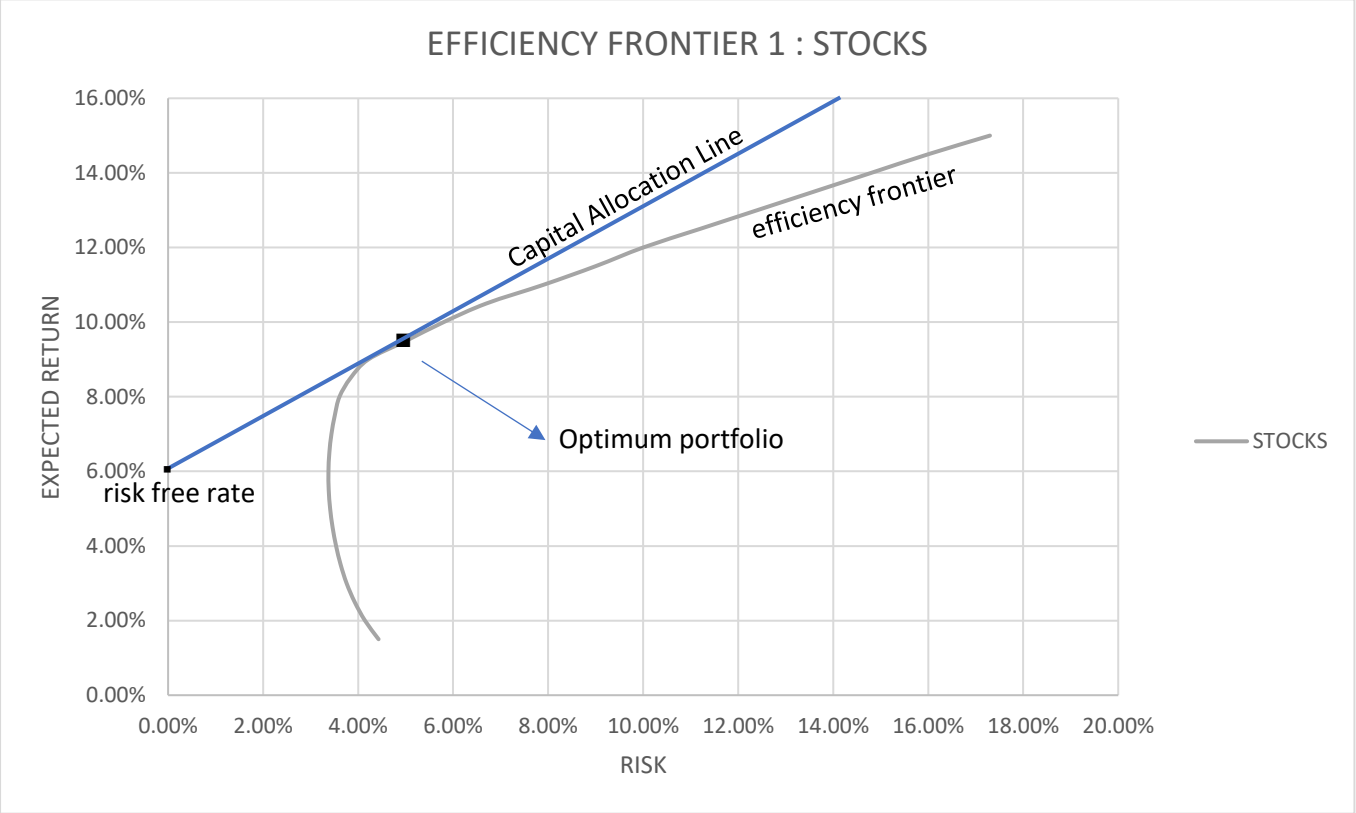
	Mean	Std. Error	Median	Std. Dev	Variance	Kurtosis	Skew	Range	Min	Max	Sum	Count	Confidence Level - 95%
ADANI	0.01	0.01	0.00	0.10	0.01	-0.16	-0.16	0.45	-0.21	0.23	0.29	60	0.03
ASIANPAINT	0.02	0.01	0.00	0.06	0.00	-0.27	0.49	0.26	-0.10	0.16	0.77	60	0.02
AXISBANK	0.01	0.01	0.01	0.07	0.00	-0.15	0.25	0.29	-0.12	0.17	0.51	60	0.02
BAJAJ AUTO	0.00	0.01	0.01	0.06	0.00	-0.08	0.34	0.28	-0.11	0.17	0.18	60	0.02
HDFC	0.01	0.14	0.02	0.97	0.94	24.32	-0.13	9.58	-4.82	4.76	0.62	60	0.28
HDFC BANK	0.02	0.01	0.01	0.05	0.00	-0.80	0.12	0.20	-0.08	0.12	0.86	60	0.01
HERO MOTORS	0.00	0.01	0.00	0.06	0.00	0.09	0.36	0.29	-0.13	0.16	0.12	60	0.02
HIND.UNILVR	0.02	0.01	0.02	0.05	0.00	0.46	0.17	0.24	-0.10	0.13	0.88	60	0.01
ICICI	0.01	0.01	0.00	0.09	0.01	-0.14	0.15	0.41	-0.19	0.22	0.37	60	0.02
INDUSIND BANK	0.02	0.01	0.02	0.06	0.00	1.28	-0.47	0.32	-0.17	0.15	0.93	60	0.02
INFOSYS	0.01	0.04	0.01	0.26	0.07	5.03	0.09	1.54	-0.73	0.81	0.60	60	0.07
ITC	0.00	0.02	0.00	0.14	0.02	6.45	0.57	0.92	-0.44	0.48	0.22	60	0.04
KOTAK BANK	0.02	0.01	0.02	0.05	0.00	-0.08	-0.16	0.26	-0.12	0.14	0.84	60	0.02

L&T	0.01	0.02	0.01	0.15	0.02	4.20	-0.20	0.96	-0.49	0.47	0.46	60	0.04
M&M	0.00	0.03	0.00	0.21	0.04	8.61	0.02	1.49	-0.73	0.76	0.15	60	0.06
MARUTI	0.02	0.01	0.02	0.08	0.01	2.09	-1.19	0.37	-0.23	0.14	0.92	60	0.02
NTPC	0.00	0.01	0.00	0.06	0.00	0.34	-0.40	0.28	-0.17	0.11	0.16	60	0.02
POWERGRID	0.01	0.01	0.01	0.05	0.00	-0.28	-0.23	0.24	-0.13	0.12	0.37	60	0.02
RELIANCE	0.02	0.04	0.02	0.25	0.06	4.60	0.03	1.47	-0.69	0.78	0.91	60	0.07
SBIN	0.00	0.01	0.00	0.09	0.01	0.43	0.08	0.44	-0.22	0.22	0.18	60	0.03
TATA STEEL	0.01	0.01	0.00	0.09	0.01	0.22	0.03	0.46	-0.21	0.25	0.30	60	0.03
TCS	0.01	0.04	0.01	0.25	0.06	5.07	-0.44	1.43	-0.76	0.67	0.41	60	0.07
WIPRO	0.00	0.03	0.00	0.20	0.04	8.63	-0.14	1.36	-0.70	0.66	0.11	60	0.06
YES BANK	0.01	0.08	0.03	0.57	0.32	5.27	-0.17	3.28	-1.63	1.65	0.72	60	0.16
BITCOIN	0.05	0.03	0.00	0.25	0.06	0.67	0.72	1.14	-0.45	0.69	2.58	60	0.07
DASH	0.08	0.05	-0.04	0.38	0.14	0.21	0.69	1.72	-0.59	1.13	3.75	60	0.11
LITECOIN	0.04	0.05	-0.04	0.34	0.12	0.51	0.85	1.47	-0.50	0.98	2.14	60	0.10
STELLAR	0.08	0.08	0.00	0.55	0.31	3.32	1.50	2.82	-0.69	2.13	4.15	60	0.16
RIPPLE	0.09	0.08	-0.04	0.54	0.29	4.58	1.87	2.89	-0.70	2.20	4.71	60	0.15
MONERO	0.08	0.07	0.02	0.46	0.21	1.15	0.86	2.23	-0.70	1.53	4.03	60	0.13

The above table provides the basic statistic summary of the assets used for the analysis, such as Mean, Std. Error, Median, Standard Deviation, Variance, Kurtosis, Skewness, Range, Minimum, Max, Sum, Count etc. There are total 30 variables of which 24 are stocks and six cryptocurrencies.

5.2.2 Efficiency frontiers:

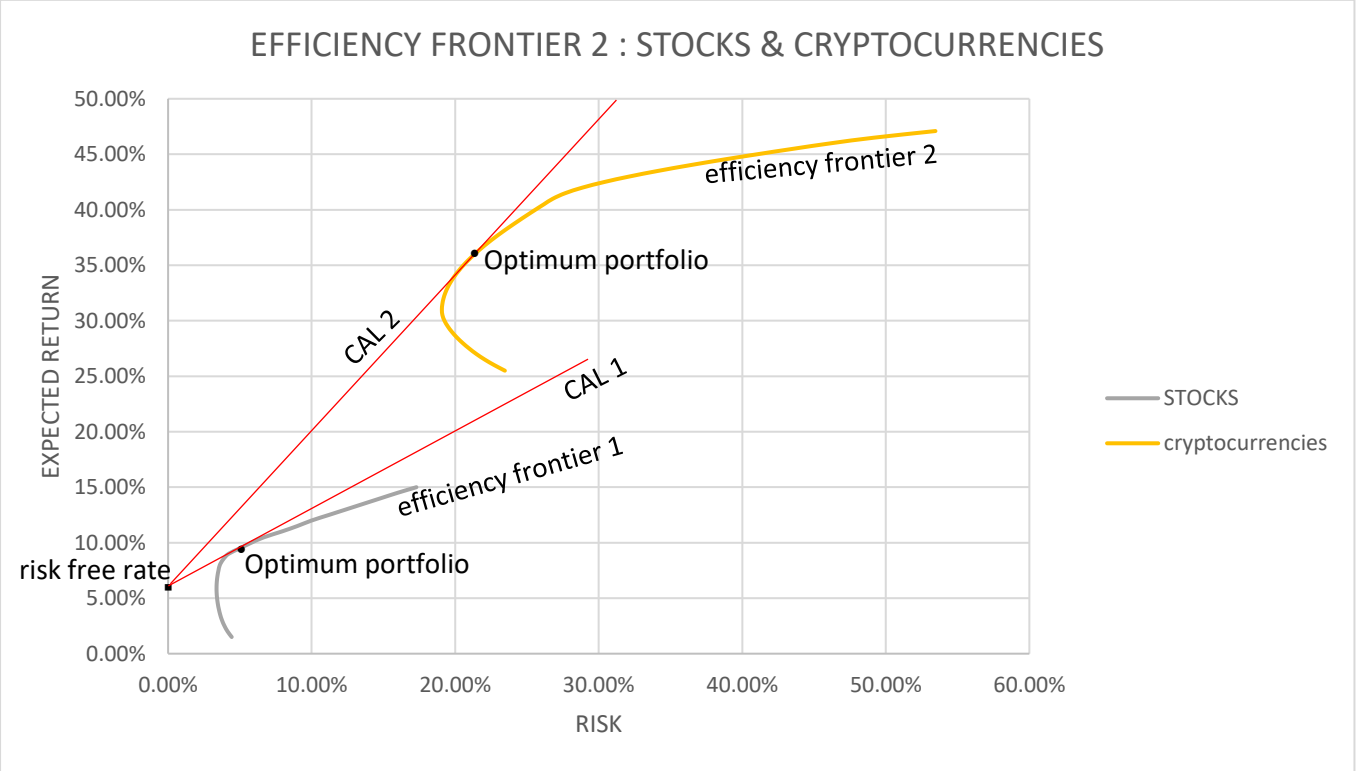
Figure 4: Efficiency frontier of portfolios containing only stocks



The above depicted graph shows the efficiency frontier of the portfolio containing exclusively stocks. It shows the return and risk level of portfolios containing various combinations of the same stocks. Similar to normal efficiency frontier behaviour, when there is an initial increase in returns at lower level of returns, the risk falls. But after a certain point the risk increases with increase in return. The optimal portfolio would be the point shown in the black colour dot, where the Sharpe ratio is the highest. It is the same point in which the Capital Allocation Line is tangent to the efficiency frontier. The return at this point is 9.6% and risk is 5%. A rational investor would be advised to choose the portfolio with the highest Sharpe ratio because it is the better option out of all the portfolios. Sharpe ratio is the additional expected return that an investment provides for each additional unit of risk undertaken (ΔMEAN / ΔSTDEV). While

fitting the CAL, risk free rate is taken as 10 year government bond, which is around 6%. An investor can choose any point on the CAL based on the risk appetite. Either he can invest the total money in the risk free rate, or at the optimum portfolio, or a combination of both in between. A risk lover can go beyond the optimum portfolio by borrowing at the risk free rate and investing at appoint beyond the optimum portfolio.

Figure 5: Efficiency frontiers of stock-only and crypto-only portfolios



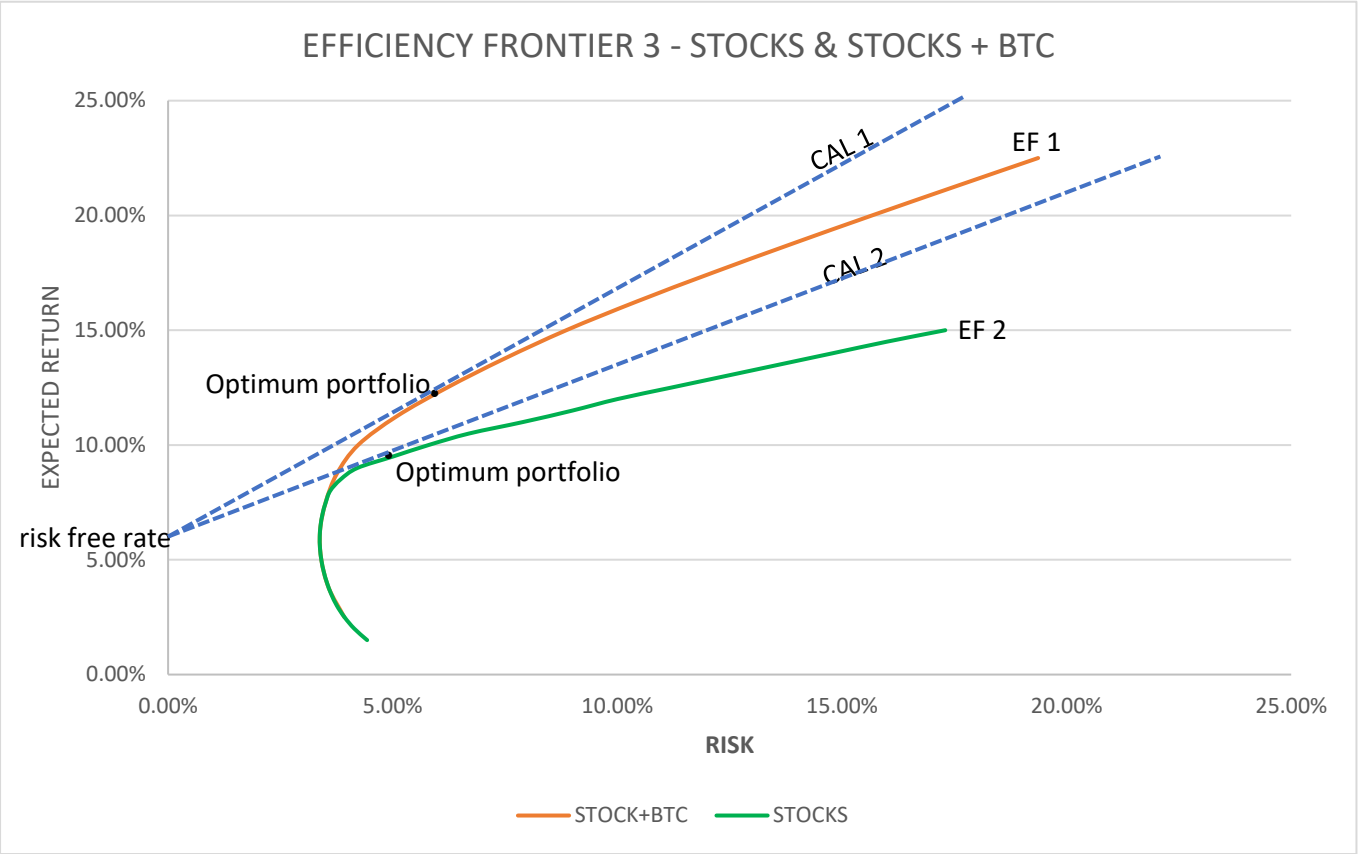
This graph plots both the efficient frontier of stocks-only portfolio and cryptocurrency-only portfolio. Both the frontiers can be easily compared and understood from the above plot. It is evident that cryptocurrencies have higher risk and return than equities. They are a risky class of assets and at the same time provide higher returns. This points to the fact that volatility of cryptocurrencies is very high which is already established by existing literature.

Capital Allocation Line of cryptocurrencies, which joins the risk-free rate and the optimal portfolio, is also marked in the figure. Based on the analysis, the optimal portfolio turns out be

the one marked with black dot. At this point, the returns is 37.5% and risk is 22%. This point is the one with the highest sharpe ratio and is also the point tangent to the Capital Allocation Line (CAL 1)

Since the portfolio on the cryptocurrency frontier is highly risky, it is not advisable to invest in any of the frontier on the efficiency frontier, not even in the optimal portfolio. The optimal portfolio here just gives the best option out of many risky portfolios. So, a risk averse investor can consider the lower efficient frontier, the one which provides portfolio of only stocks with 9.6% return and 5% risk (figure 2). But these portfolios provide less returns as well as risk. So an investor who is willing to take some more risk in order to increase the returns can optimize the portfolio by including some risky cryptocurrencies. According to Modern Portfolio Theorem, including more risky assets to a portfolio can even lead to an overall reduction in total portfolio risk. These combinations are depicted below.

Figure 6: Efficiency frontier of portfolios containing only stocks and stocks + Bitcoin

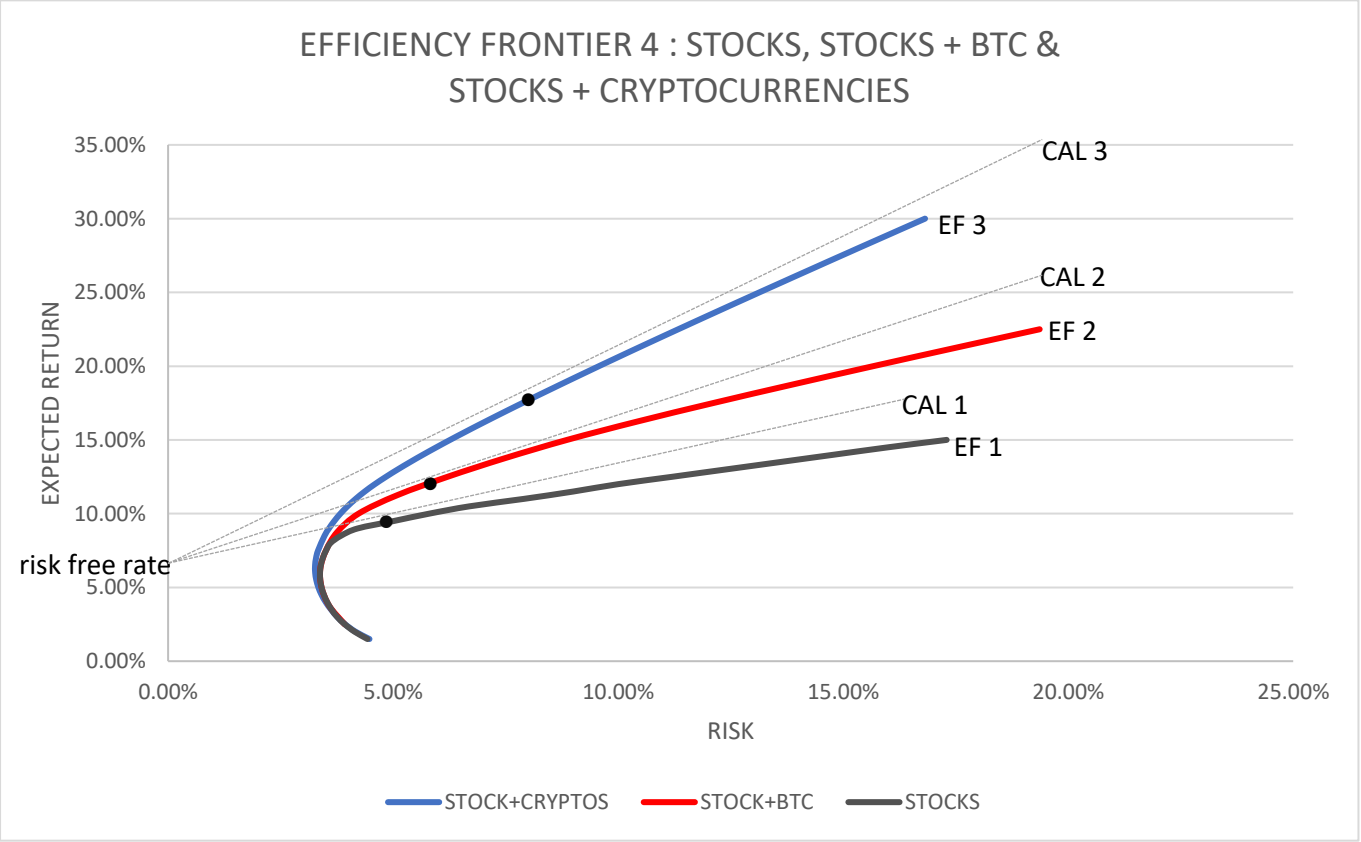


The above graph is the comparison of both efficient frontiers of portfolio including and excluding Bitcoin. The green efficient frontier below is the portfolios representing various combinations of only stocks and the red one above is when Bitcoin is included with stocks. It is clearly evident that at lower levels of return, risk is also low and both the efficient frontiers follow the same path. However, after a certain point, both the frontiers start taking different path, that is, when return and risk together increase. But at the same time, the frontier with Bitcoin included along with stocks provide a higher returns for every point of risk. For instance, at the point where the standard deviation is 10%, return provided by the stocks-only portfolio is around 12% whereas the return when Bitcoin is included is around 16%. This provides answer to the long-time question of whether adding Bitcoin improves the portfolio performance or not. The reason for selecting Bitcoin in this case is due to the fact that Bitcoin is the first,

most famous and largest traded cryptocurrency, with 50% of cryptocurrency share. And a large majority of investors are aware only about Bitcoin and have not even heard other alternate currencies.

At the optimum portfolio point among stocks, the return is 9.6% and risk is 5%. At the optimum portfolio among stocks plus Bitcoin, the return is 12.5% and risk is 6.1%. In the higher performing frontier, the optimum weight of Bitcoin in the excel solver function at the optimal point where sharpe ratio is the highest came out to be 7.2% with shares taking up rest 92.8%. This is marked at the point of tangency of Capital Allocation Line with the efficiency frontier.

Figure 7: Efficiency frontier of portfolios containing only stocks, stocks + Bitcoin and stocks + all cryptocurrencies



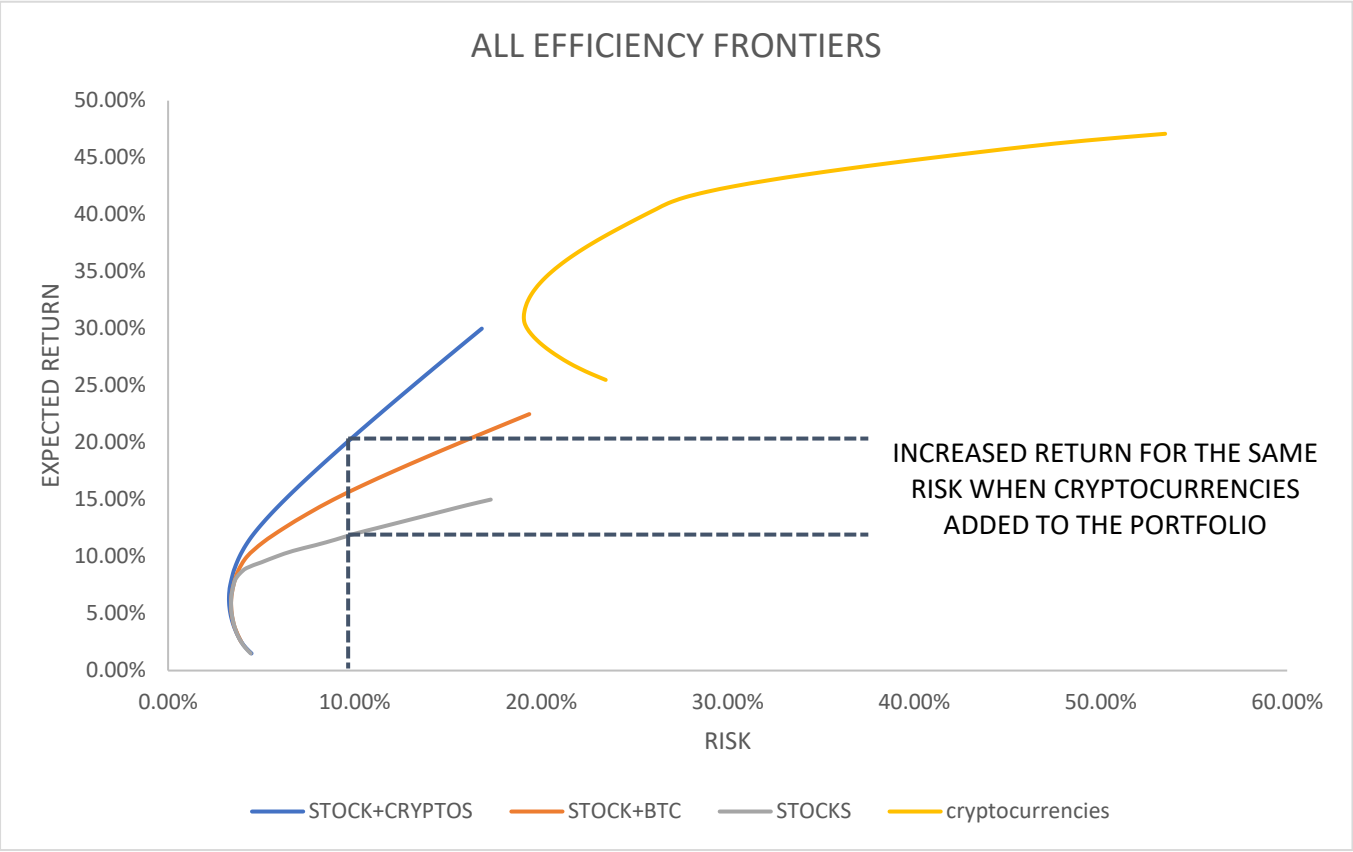
The above graph is the comparison of three efficient frontiers of 1) portfolios of only stocks, 2) portfolios of stocks combined with Bitcoin, and 3) portfolios of stocks combined with all

cryptocurrencies. The black efficient frontier below is the portfolios representing various combinations of only stocks and the red one above is when Bitcoin is included with stocks. The blue frontier is obtained when six cryptocurrencies are combined with the stocks. Initially after overlapping together, the three frontiers start to take different paths. It is evident that the frontier in which all cryptocurrencies are included provides much better returns for the same risk than the other two frontiers. So when only Bitcoin is included with stocks, the portfolios perform better and when all the cryptocurrencies are added, portfolios are much more superior in terms of returns. This provides the answer for the basic question of the research, that adding cryptocurrencies provide better portfolio performance.

Including Capital Allocation Line provides the optimal portfolios in the three efficient frontiers. It is the point of tangency of CAL with efficient portfolios. That is also the point where sharpe ratio is the highest. In the stocks + cryptocurrency efficient frontier (EF 3), which is tangent to CAL 3, the optimum portfolio provides a return of 17.7% and risk of 8%. This is significantly higher than the other two optimum portfolios of EF 1 and EF 2. So EF 2 is better performing than EF 1 and EF 3 is better than both EF 1 and EF 2.

In the highest performing frontier EF3, the optimum weight of cryptocurrencies at the optimal point, where sharpe ratio is the highest came out to be 9.87% with shares taking up rest 90.13%. Also, among cryptocurrencies, only three currencies registered positive weight in the portfolio – Bitcoin, Monero and Ripple. The rest three – Dash, Litecoin and Stellar registered zero in the optimized portfolio. Bitcoin takes up 49.7%, Monero has 41.4%, and Ripple has 8.7% in order to get the most optimized portfolio.

Figure 8: All the Efficiency frontiers



This graph compares all the efficiency frontiers. It is clear from the graph that by including cryptocurrencies in a portfolio of stocks, expected returns are much higher. Even while adding just Bitcoin, portfolio performs better, and when all other cryptocurrencies are added, the result is the best portfolio performance. For instance, at 10% risk, portfolio of stocks gives 10% returns, when Bitcoin is included, returns increase to 15%, and when all cryptocurrencies are added, the returns become 20%.

The risk and returns of the four optimal portfolios of the respective four efficient frontiers are given below as a table:

Table 2: Return, risk and Sharpe ratio

	STOCKS	STOCKS + BITCOIN	STOCKS + CRYPTOCURRENCIES	CRYPTOCURRENCIES
RETURN	**9.6%**	**12.5%**	**17.7%**	**37.5%**
RISK	**5%**	**6.1%**	**8%**	**22%**
SHARPE RATIO	**1.92**	**2.04**	**2.21**	**1.70**

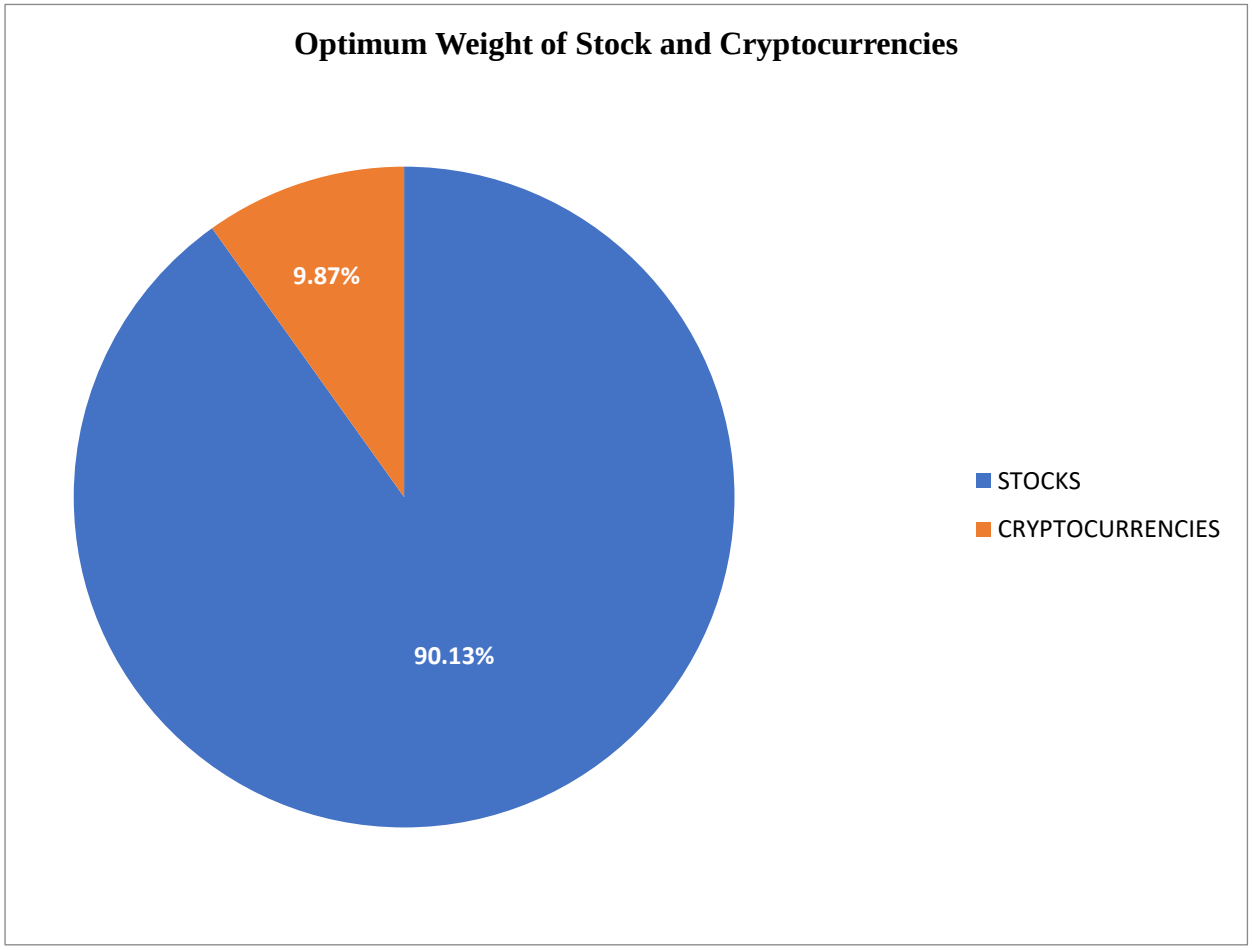
It is clear from the above table that, as portfolio is diversified by adding cryptocurrencies, return increases, so is the risk. But the rate of increase in return is far higher than the rate of increase in risk, which means the Sharpe ratio is higher when portfolio is diversified with cryptocurrencies. Higher the Sharpe ratio, the better it is as Sharpe ratio is the increase in return for a unit of extra risk that the investor takes. Also the portfolio with only cryptocurrencies gives much higher returns of 37.5% and very high risk of 22%. But the Sharpe ratio is less because the rate of increase in return is less than the rate of increase in risk which does not make investing in the optimal cryptocurrency-only portfolio a good option. A Sharpe ratio of one or greater is considered to be good, whereas two or greater is considered to be very good and a Sharpe ratio above three is excellent. It is not advisable to have a Sharpe ratio less than one.

5.2.3 Optimal weight of cryptocurrencies

Optimal weight of cryptocurrencies is found using the excel solver function. This is the weight distribution at the optimum portfolio of the efficient frontiers. Two optimum weights are found. The first one is the weight of cryptocurrencies and stocks in total. The second one is the weights of different cryptocurrencies within.

Stock – Cryptocurrency weightage:

Figure 9: Stock – Cryptocurrency weightage

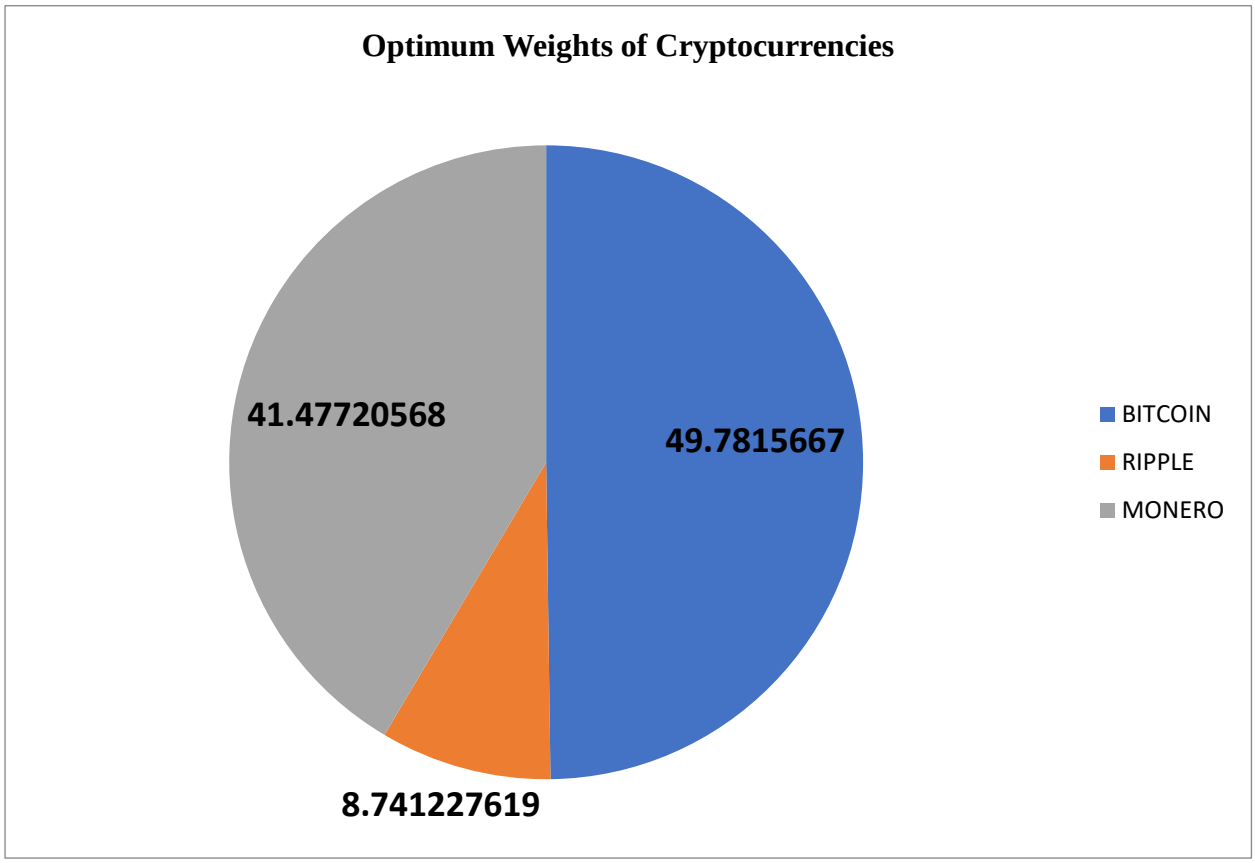


The above figure represents the optimum share of cryptocurrencies and stocks within the optimum portfolio. The optimum portfolio is obtained at the point of tangency of efficient frontier (EF 3 of figure 4) with Capital Allocation Line (CAL 3 of figure 4). This is the point

where sharpe ratio is the maximum and provides the best option to the investor as at this portfolio, the investor get the maximum returns to a unit of risk undertaken. The study proposes that an investor wishing to include cryptocurrencies into his portfolio gets the best performance **when cryptocurrencies are given 9.87% weightage in the portfolio and the rest 90.13% to stocks.** At this optimum portfolio, investor can earn a return of 17.7% and a risk of 8%. This portfolio provides the maximum increase in return for a unit of extra risk that the investor wishes to take, with a portfolio Sharpe ratio of 2.21 (see table 4 above).

Weightage within cryptocurrencies:

Figure 10: Weightage within cryptocurrencies



Earlier graph shows that cryptocurrencies should be 9.87% of the total portfolio. But which among the six cryptocurrencies used for the analysis should get the largest weight? Which

should get the least share? This is analyzed and the results provided in the above graph. It shows that out of the six cryptocurrencies considered for the study – Bitcoin, Dash, Litecoin, Stellar, Ripple and Monero, only three cryptos – Bitcoin, Monero and Ripple should be included in an optimal portfolio and the rest three cryptos – Dash, Litecoin and Stellar should be assigned zero weightage for optimal performance. Bitcoin gets the highest weightage of 49.8% (nearly half), Monero gets next highest weightage of 41.47% and Ripple gets the least weightage of 8.74%.

The result is shown in the table given below:

Table 3: Weightage within cryptocurrencies

CRYPTOCURRENCY	OPTIMUM WEIGHTS
Bitcoin	**49.8%**
Monero	**41.5%**
Ripple	**8.7%**
Dash	**0%**
Litecoin	**0%**
Stellar	**0%**

5.3 Conclusion

This analysis is done to understand whether adding cryptocurrencies to an Indian investor's portfolio will lead to a significantly improved portfolio performance or not. For this purpose, a portfolio containing only stocks were created. Cryptocurrencies were then added to the portfolio and new portfolio optimized using the simplex method is obtained. Properties of this new portfolio is compared to that of the old portfolio to find out whether including cryptocurrencies will improve the portfolio performance or not.

The chapter mentions about the secondary data collected and about the methodology of the study. A brief summary statistic is presented in the table which gives the basic details about the variables used for the study. All the efficient frontiers obtained from the study are presented. There are four efficient frontiers – 1) the one with only stocks, 2) with only cryptocurrencies, 3) stocks combined with Bitcoin, 4) stocks combined with all cryptocurrencies.

The results point that adding Bitcoin to the portfolio of stocks improves the performance of the new portfolio in terms of risk and return. Also adding all cryptocurrencies to the stock portfolio further increases the portfolio performance by improving the Sharpe ratio. The final results also show the optimum weights of the cryptocurrencies which should be added to the portfolio

Chapter 6

SUMMARY AND FINDINGS

6.1 Introduction

The study deals with the question of whether including cryptocurrencies in a portfolio of assets will improve the performance of the portfolio or not. In other words, can cryptocurrencies act as a diversifying tool or not. The topic has importance in the post financial crisis period as the trust in the existing monetary framework is fast eroding. Failure of central banks to control inflation, using depositors' money carelessly by the banks leading to creation of NPA's, political misuse of banking system etc. all led to collapse of the system in many instances. This led to a mistrust in the banking system and a search for an alternative currency which can be used replace the fiat currency system. This process gained momentum after the 2008 financial crisis. Thus all the cryptocurrencies that we see today is born. But against the purpose for which cryptos were created, it was seen by the public as an investment tool rather than a currency. It soon caught the attention of the general public, especially the investors as a new investment option, at a time when traditional investments were losing its lustre.

Because of the reasons mentioned above cryptocurrencies were considered for studying a portfolio analysis. This will be helpful for investors who wish to invest in cryptocurrency and make it a part of the portfolio. The study is all the more important because of two reasons. One, such a study has not been done in the Indian context. Two, Indian investors don't have much knowledge about cryptocurrencies, its characteristics etc. This study will not only reveal some of the properties of cryptocurrencies, but also answer the question of whether adding cryptocurrency is better for the portfolio or not.

6.2 Chapter wise summary

Chapter one deals with the introduction to the study. Background of the study is briefly given. This part explains about cryptocurrency, origin of cryptocurrencies, the reasons which led to its invention, technical aspects of how a cryptocurrency function etc. The chapter also explains the theories behind the framework which is the Modern Portfolio Theory and the Mean Variance Analysis. A small paragraph about the literature review is given which then proceeds to the gaps in literature and how this study is going to fill the gap. Objectives of the study is clearly laid out. The chapter also has a brief mention on the data and methodology used. The chapter concludes by mentioning the relevance of the study and the chapter schemes order of the study.

Second chapter explains the evolution and history of money, how money came into being, the way changes took place and when the current monetary mechanism controlled by government and central bank came into being. Right from barter system to the modern fiat currency system, the chapter gives a detailed history of money. Also explained is the time when the trust problem in the banking system started. The chapter gives an account of Hayek's idea of money as explained in his book *'denationalization of currency'.* In other words, the chapter is also a criticism of the present monetary system. Citing the book, the section explains what the problem of the modern monetary management is, which is fully controlled by the governments. The section also explains the problems as well as the advantages associated with cryptocurrencies. A small summary is also given about Bitcoin, the first and the most popular cryptocurrency.

Chapter three covers a short review of the researches that are considered as the most important works in the area. The theoretical part covers mainly the pioneering works that led to the development of modern portfolio analysis. These works are mainly the books and research

papers which forms the basis of the theoretical framework of our study. The empirical section consists of the main works related to cryptocurrencies. Most of these works are either econometric analysis of the volatility of cryptocurrencies or portfolio analysis of including cryptocurrency in a portfolio.

Chapter four explains briefly the underlying theoretical framework, which is nothing but the modern portfolio theory. Modern portfolio theory and how it is helpful in analyzing portfolios are explained in detail in the chapter. Mean Variance Analysis, which is the mathematical tool used in the Modern Portfolio Theory is explained with formulas. The chapter also deals with portfolio diversification. Efficiency frontier and capital allocation line are mentioned because those are the main tools in the analysis.

The fifth chapter is all about the data and methodology, and the analysis used in the study. A brief summary statistic is presented in the table which gives the basic details about the variables used for the study. All the efficient frontiers obtained from the study are presented. There are four efficient frontiers – 1) the one with only stocks, 2) with only cryptocurrencies, 3) stocks combined with Bitcoin, 4) stocks combined with all cryptocurrencies. The whole explanation is given with the help of graphs, tables and figures for easy understanding. The final chapter concludes the study by giving an account of the findings, inferences and suggestions.

6.3 Summary and Findings

The study found out that adding cryptocurrencies to a portfolio of stocks can improve the performance of the portfolio significantly. In other words, cryptocurrencies act as a diversifying tool in the Indian context. Adding Bitcoin improves the portfolio's risk – return profile and adding other cryptocurrencies further improves the portfolio's performance. It was found that before adding cryptocurrency, the Sharpe ratio of the portfolio was 1.92. After adding Bitcoin to the portfolio, Sharpe ratio improved to 2.04. When all the six

cryptocurrencies were added to the portfolio, the Sharpe ratio further increased to 2.21. Whereas portfolio containing only cryptocurrency has a lower Sharpe ratio of 1.7. The higher the Sharpe ratio, the better it is as Sharpe ratio is the extra expected return that an investor can gain for a unit of extra risk undertaken. The inference from the study is that when cryptocurrency is added to the portfolio, both risk and returns increase, but increase in returns is much higher than the increase in risk, thus raising the Sharpe ratio. Whereas for a portfolio containing only cryptocurrencies, both risk and return is very high, but the increase in risk is much higher than the increase in return. This gives a low Sharpe ratio.

The study helps investors in familiarizing with the characteristics of cryptocurrencies while adding those to a portfolio. It gives more clarity about investment options using cryptocurrencies as investors investing in cryptocurrencies were guided by doubts, rumours and misconceptions rather than credible research. The study guides the investing community in framing portfolio strategy while investing in cryptocurrencies or including it in the portfolio. It also helps fund managers while designing investment options for customers when the investment includes cryptocurrencies.

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