Assessing the attractiveness of cryptocurrencies in relation to traditional investments in South Africa

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by

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ABSTRACT

The dissertation examined the effect of cryptocurrencies on the portfolio risk-adjusted returns of traditional and alternative investments using daily arithmetic returns from August 2015 to October 2018 of traditional assets (South African stocks, bonds, currencies), alternative assets (commodities, South African real estate) and cryptocurrencies (Cryptocurrency index (CRIX) and ten other individual cryptocurrencies). This is worth investigating as cryptocurrencies have been performing well while the listed equities in South Africa and most alternative investments have been underperforming (Srilakshmi & Karpagam, 2017). The mean-variance analysis, the Sharpe ratio, the conditional value-at-risk (CVaR) and the mean-variance spanning techniques were employed to analyse the data. The spanning test carried out was the multivariate ordinary least squares (OLS) regression Wald test. The research findings showed that the inclusion of cryptocurrencies in a portfolio of investments improves the efficient frontier of the portfolio of investments and the portfolio of investments risk-adjusted returns. Moreover, the findings suggested that cryptocurrencies are good portfolio diversification assets. However, investments in cryptocurrencies should be made with caution as the risks of investments are high in relation to traditional and alternative investments. The findings of this study advocate for individual and institutional investors to include cryptocurrencies within their South African portfolio of traditional and alternative investments.

Keywords: Alternative assets; CRIX; Cryptocurrencies; Efficient frontier; Portfolio optimisation; Traditional assets

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GLOSSARY OF TERMS

Bitcoin is one of the more widely used forms of cryptocurrencies (Dandapani, 2017)**.**

Bitcoin Cash is the cryptocurrency that was formed from the hard fork of Bitcoin on 1 August 2017, which resulted in a faster blockchain for Bitcoin Cash (S. Kim, Sarin, & Virdi, 2018).

Blockchain is a "digitised system of accounting records which records in detail all transactions according to a mathematical set of rules to prevent illegal interference" (Nguyen, 2016, p. 51).

Cryptocurrency is a "decentralised peer-to-peer digital currency based on computer cryptography for security" (Dandapani, 2017, p. 615).

Cryptography is "the art of writing or solving codes" (Hornsby, 2010, p. 355).

Digital currency "is electronic money that serves as an alternative currency in digital or online transactions" (Dandapani, 2017, p. 614).

Ethereum is a commonly used cryptocurrency that is used for smart contracts (S. Kim et al., 2018). Smart contracts allow for the automation of the implementation of the contract terms and conditions.

Fiat currency is currency that derives its value from being backed by the government and it is produced by the government, through the central bank (Danielsson, 2018).

Litecoin is a peer-to-peer digital currency that allows global and prompt near zero cost payment, that can process settlements four times faster than Bitcoin (Dandapani, 2017; S. Kim et al., 2018).

Martingale is the anticipated variance between two consecutive prices, this difference is zero. "The martingale process implies that price differences are serially uncorrelated and that univariate linear time series models of prices have no forecasting value" (Mills & Markellos, 2009, p. 340).

Proof of Work (PoW) is the computational power of a network of computers being used to solve mathematically complex problems in order to maintain cryptographic links and validate transactions (S. Kim et al., 2018).

Pure overlay is a an investment management strategy that produces “excess returns through intentional active deviations in sector, countries, or asset classes” (Carhart, 2003, p. 458).

Risk premium or premia is the difference between the market rate of return or expected return and the risk-free rate (Fama & French, 2004; “Risk premia,” 2018).

LIST OF ACRONYMS

AMH:	Adaptive Market Hypothesis
BFT:	Behavioural Finance Theory
BPT:	Behavioural Portfolio Theory
BTC:	Bitcoin
CAPM:	Capital Asset Pricing Model
CPT:	Cumulative Prospect Theory
EMA:	Exponential Moving Averages
EMH:	Efficient Market Hypothesis
ETH:	Ethereum
FRED:	Economic Research Federal Reserve Bank of St. Louis
FREDA:	Federal Reserve Economic Data
GARCH:	Generalised Autoregressive Conditional Heteroscedastic
GBM:	Geometric Brownian Motion
LTC:	Litecoin
MPT:	Modern Portfolio Theory
OLS:	Ordinary Least Squares
PT:	Prospect Theory
US:	United States of America

CHAPTER 1: INTRODUCTION

1.1. Background of the study

Cryptocurrency is a form of digital currency (Dandapani, 2017) that is based on cryptography. Digital currency is "electronic money that serves as an alternative currency in digital or online transactions" (Dandapani, 2017, p. 614) while cryptography is "the art of solving codes" (Hornsby, 2010, p. 355). Therefore, cryptography is the use of encryption and decryption of data and information. Moreover, one can view cryptocurrency as digital currency that is built using encryption and decryption. Therefore, cryptocurrency is currency secured in its own vault using electronic puzzles and codes. Nonetheless, the concept of cryptocurrency and cryptography has been around for several years.

In 1983, Chaum (1983) suggested the use of cryptography within payment systems. This was to protect the user of electronic payment systems from their payment data being used by third parties. He proposed an untraceable payment system using blind signature systems. The object of these untraceable payment systems was to prohibit third parties from tracking the payment details, including the time, payee and amount of payments made. This was done to enable the disclosure of the payee and proof of payment only if necessary and to stop the theft of payment information while blind signatures refer to the use of passwords to encrypt and decrypt information so that the information is never compromised between the creation, transportation and delivery of the information between two parties (Chaum, 1983). This led to the creation of Digicash on 21 April 1990. Digicash was a combination of untraceable payment systems and digital currency. However, due to bad management, the entity that built Digicash went bankrupt in 1998. This resulted in the demise of Digicash (Abrar, 2014; "How DigiCash blew everything," 1999).

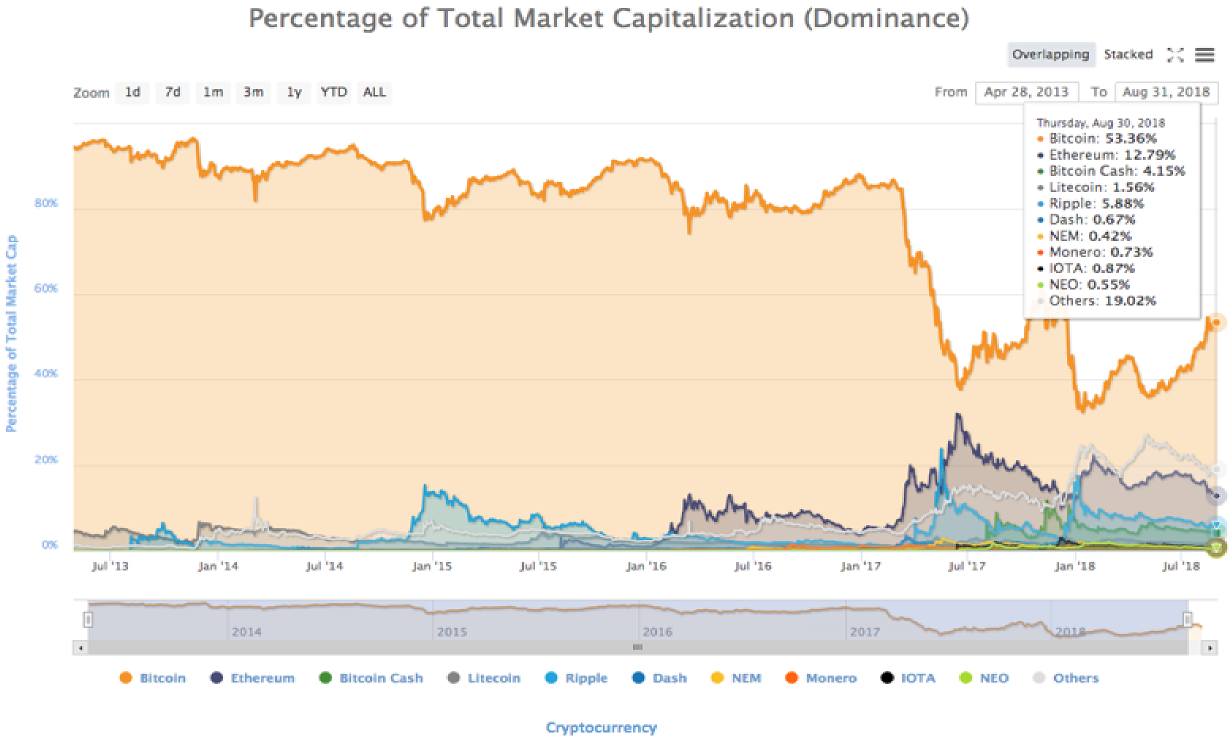
In 1998, Dai (1998) proposed the concept of b-money, which is an untraceable digital currency that uses proof of work (PoW). B-money was not minted by the government or regulated by a central bank (S. Kim et al., 2018) while PoW refers to the computational power of a network of computers being used to solve mathematically complex problems in order to maintain encryption and validate transactions (S. Kim et al., 2018). However, no actual digital currency was created directly from this theory.

Szabo (2005) proposed Bit Gold in 2005. Bit Gold was similar to b-money except that Bit Gold theorised that cryptocurrencies should be timestamped to provide evidence of the time at which the cryptocurrency was built. Nevertheless, Bit Gold did not materialise into a functional cryptocurrency, as it was not fungible.

In 2008, Satoshi Nakamoto, an unknown person or group of people, theorised that “a purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution” (Nakamoto, 2008, p. 1). Peer-to-peer refers to computers that are connected within a computer network. Nakamoto (2008) postulated that this digital currency could be timestamped and that it could use PoW.

Satoshi Nakamoto created Bitcoin in 2009 (Brière, Oosterlinck, & Szafarz, 2015; Osterrieder & Lorenz, 2017; Taylor, 2018) that has become one of the more widely used forms of cryptocurrencies (Dandapani, 2017). Figure 1 shows that, as at 30 August 2018, Bitcoin formed 53.36% of the total market for cryptocurrencies (CoinMarketCap, 2018). Figure 1 also reveals that, on 1 August 2017, the market capitalisation of Bitcoin decreased due to the creation of Bitcoin Cash from Bitcoin and the entrance of other cryptocurrencies into the market. Cryptocurrencies allow for a payment system that is based on encryption rather than trust (S. Kim et al., 2018). This means that cryptocurrency transactions are fully encrypted and cannot be breached unlike conventional financial transactions that can be hacked and breached.

Figure 1: Percentage of total market capitalisation from April 2013 to August 2018



Source: Data from CoinMarketCap Global Charts (2018).

1.1.1. How cryptocurrencies work

Cryptocurrencies, including Bitcoin, are not fixed to a country and are not regulated unlike traditional currencies such as the South African Rand. Therefore, cryptocurrencies are not linked to any specific country's economy (Dandapani, 2017; Scott, 2016). Moreover, unlike traditional currencies, cryptocurrencies are not regulated by a central bank nor are they backed by a government. They self-regulate using blockchain (Brière et al., 2015; Taylor, 2015). (Blockchain is discussed in detail below). Many shops do not quote their prices in cryptocurrencies therefore Bitcoin is not used in those shops however, there is a possibility of cryptocurrencies, such as Bitcoin, being accepted and used in the mainstream economy in the future in the same way as traditional currencies. It has been suggested that Bitcoin can be used to replace traditional currencies, particularly in countries with volatile national currencies (Dandapani, 2017; Scott, 2016). In some countries, Bitcoin has been classified as a digital asset rather than a currency (Scott, 2016). The Chicago Mercantile Exchange (CME) Group trades in Bitcoin futures as a commodity (CME Group, 2019).

Cryptocurrencies are volatile; they are also not a widely-accepted medium of exchange. However, Bitcoin, Ether and Litecoin have gained popularity in terms of being used to make payments. Microsoft's online store, Expedia, Overstock.com and Newegg.com accept Bitcoin as a method of payment. There have been improvements in the transaction speed of cryptocurrencies, for instance, Bitcoin, Ethereum, Litecoin and XRP's blockchains that can process 7, 20, 56 and 1,500 transactions per second, respectively whereas Visa and Paypal can process 1,700 and 193 transactions per second, respectively. From the above, it can be seen that cryptocurrencies are not yet seen as a medium of exchange (S. Kim et al., 2018).

Investments in shares and commodities, such as silver and gold, can be compared to cryptocurrency investments (S. Kim et al., 2018). Cryptocurrencies can be seen as an asset class determined by how much is invested in the asset and how the performance of the asset is measured (Brown, 2017). Bitcoin is seen as an asset class, a commodity and a security that is ripe for speculation purposes, however, it is not defined as a security by the Financial Markets Act in South Africa (Nieman, 2015). The early purchasing of cryptocurrency can also be likened to making an investment in an early stage business venture, similar to a venture capital or an angel investment. Therefore, these investments can be likened to investments in equity (Catalini & Gans, 2016).

The value of cryptocurrencies is increased by the demand for the coins that is related to the acceptance of the coins; the liquidity of the tokens; the fungibility of the coins; the risk of the coins becoming obsolete; and the speed at which the coins are used (S. Kim et al., 2018). The valuation of cryptocurrencies in 2018 was misleading because of the speculation surrounding cryptocurrencies (George et al., 2018). Investments made in cryptocurrencies increased in value due to the increase in the usefulness of cryptocurrencies (Catalini & Gans, 2016). However, there was a significant decline in cryptocurrency values in December 2017 that may have signalled that cryptocurrencies are not a good long-term investment (P. Kim, 2017). The greater the number of users of cryptocurrencies, the more useful and secure they become and the higher the value of their coins or tokens become (Catalini & Gans, 2016).

Cryptocurrencies are built on a system called the blockchain[1] that is defined as a distributed public ledger that is used to record cryptocurrency or digital asset transactions (Catalini & Gans, 2016). Blockchain has also been defined as “a public ledger in which Bitcoin transactions are recorded every 10 minutes” (Cascarilla, 2015, p. 19). De Meijer (2016) describes it as a decentralised network of computers and a trusted value-transferring mechanism that also acts as an archive. Therefore, it is the underlying technology behind cryptocurrency that defines what and how attributes are stored, updated, verified and utilised (Catalini & Gans, 2016; S. Kim et al., 2018; Nguyen, 2016). Blockchain is made up of blocks on a chain. Each block consists of several records and their characteristics. The security of these blocks is caused by the blocks being connected by encrypted links that utilise the previous block’s contents to establish the next block’s characteristics using a special code. As a result, the blocks are very difficult to change and are essentially unalterable because each block is a timestamp and an unchangeable audit trail (Catalini & Gans, 2016; S. Kim et al., 2018).

Blockchain operates in a specific fashion. The “miners” in the blockchain are responsible for performing complex mathematical computations that produce additional cryptocurrencies and preserve the encrypted links between the blocks. This is done in exchange for incentives that are a payment for the miners’ services. These payments consist of cryptocurrencies or tokens earned. Blockchain miners are likened to gold miners who mine for cryptocurrencies instead of gold. Their payment is in cryptocurrencies instead of cash. The payment is in the form of a part or a whole cryptocurrency and in transaction fees.[2] This process results in tokens or coins on the blockchain.

Blockchain is the first true example of how a safe network was built by the individuals transacting on the network and not the traditional financial institutions or network providers. Therefore, blockchain has created a market that does not require the use of traditional intermediaries, such as commercial and investment banks. An increase in the number of transactions that take place over the blockchain results in a more secure blockchain and thus it

[1] There is a difference between blockchain and Blockchain. Blockchain with a capital “B” refers to the name of the Bitcoin digital distributed public ledger. Whereas blockchain refers to a non-specific digital distributed public ledger.

[2] The transaction fees are only added by the market if it wishes to obtain a faster service from the miners.

makes the cryptocurrency more valuable (Catalini & Gans, 2016; S. Kim et al., 2018; Taylor, 2015). Moreover, blockchain allows for increased transparency as it has an open and transparent audit trail that can be viewed non-discriminately by the public (Cascarilla, 2015; de Meijer, 2016).

Some entities have made their own private blockchains that require contributors to be given access to the network in order to make any changes therefore no mining is involved but these are not as secure as the public ledger blockchains. These private ledger blockchains can be altered as they merely maintain the status quo of existing company ledgers and systems (Catalini & Gans, 2016; S. Kim et al., 2018). There are also consortium blockchains, which are the combination of private and public blockchains (Guo & Liang, 2016).

Blockchain has multiple uses. It can be used for clearing purposes in investments, for storing Know Your Customer (KYC) information and for anti-money laundering monitoring purposes (de Meijer, 2016). Blockchain can also be used in financial services, particularly in investment services, to improve processes and operations and decrease costs. Furthermore, blockchain has reduced the settlement and processing time of several securities' value chains and increased the safety of financial services (de Meijer, 2016; Guo & Liang, 2016; Tranquillini, 2016). In addition, the Bitcoin Blockchain has reduced the settlement process time of transactions from two days to 10 minutes for conventional financial systems settlement process times (Cascarilla, 2015). However, each cryptocurrency has its own blockchain, for instance, the blockchain for Bitcoin is Blockchain[3] (S. Kim et al., 2018).

Cryptocurrencies can be created using forks, which refers to improving and modifying the existing blockchain. There are hard forks and soft forks that are used for the creation of additional cryptocurrencies on an existing blockchain. Hard forks occur when significant improvements are made to the blockchain and this blockchain is no longer compatible with the older blockchain. Hard forks necessitate the need for two separate blockchains and coins or tokens. Soft forks occur when insignificant improvements are made to the blockchain, but it remains compatible with the older blockchain. Soft forks do not necessitate different blockchains or coins. An example of a hard fork is Bitcoin Cash from Bitcoin in 2017. Bitcoin Cash is the cryptocurrency that was formed from the hard fork of Bitcoin on 1 August 2017,

[3] See footnote 1.

which resulted in a faster blockchain for Bitcoin Cash (S. Kim et al., 2018). After discussing the blockchain, which is the underlying technology of cryptocurrencies and tokens, crypto-equity offerings are explained.

Crypto-equity offerings or Initial Coin Offerings (ICOs), which are also known as crowdsales, are offerings made for a stake in private companies' equity in exchange for payment in cryptocurrencies. The company doing the ICO offers shares in the entity for payment in the new cryptocurrency instead of in cash. This is done to raise funds for the company and increase the demand for the new cryptocurrency. It also involves the direct sale of the company's coins to investors and the mining of the company's cryptocurrency in the same way that Bitcoin is mined. ICOs are carried out for private companies' software development and for fund raising purposes. Before ICOs take place, Simple Agreements for Future Tokens (SAFTs) are initiated. SAFTs are investments made for future tokens or coins by investors in exchange for finance (Greebel, Moriarty, Callaway, & Xethalis, 2015; S. Kim et al., 2018). ICOs became very popular in 2017 due to the increased use of Bitcoin and other cryptocurrencies. This resulted in ICOs surpassing Venture Capital (VC) and business angel financing by the middle of 2017 for funding of early stage start-ups. The more prominent ICOs that have taken place include Bancor tokens for US$153 million; DAO tokens for US$152 million; EOS coins for US$185 million; Filecoin for US$257 million; and Tezos coins for US$232 million (S. Kim et al., 2018). However, many ICOs do not provide clarity about how and when payments will be made, nor do they state how and when the ICOs will be redeemed.

The next section discusses some of the advantages and disadvantages of cryptocurrencies.

1.1.2. Advantages and disadvantages of cryptocurrencies

Cryptocurrencies have some benefits. The first benefit is that cryptocurrencies are issued through a transparent network unlike other financial institutions or banks which are not transparent. Financial institutions and banks do not disclose to their clients how their deposits in the banks are funding other clients, nor do they disclose to their depositors how much of their deposits are currently being held in the bank as cash (Cascarilla, 2015; Hickey, 2017; Smith & Rosevear, 2017). However, with cryptocurrencies, the holder of the cryptocurrency can independently trace each movement in their funds and deposits.

A second advantage of cryptocurrencies is that they have a low barrier of entry in terms of transaction costs, documentation required and the verification process to open an investment account. This is an advantage for the poor who are currently unable to open bank accounts due to high costs and their lack of documents.

The third benefit is that it is easy to transact globally using cryptocurrencies because cryptocurrencies are readily available globally on exchanges through the internet. Thus, there is no need to buy foreign currency and incur foreign exchange costs. The fourth and fifth benefits are that there are no regulatory restrictions on cryptocurrency transactions and that these transactions occur anonymously (Brière et al., 2015; Hickey, 2017; Smith & Rosevear, 2017). The lack of regulatory restrictions and anonymity allows for the privacy of transactions. The caveat is that they can also be exploited for illegal transactions. For example, cryptocurrencies have been used to purchase stolen goods, illegal substances and hire contract killers (Foley, Karlsen, & Putnins, 2018). The sixth benefit is that cryptocurrency and token platforms and exchanges are open 24 hours for seven days of the week. Therefore, the cryptocurrency market is always available.

Cryptocurrencies, however, also have disadvantages. The following are some of the disadvantages of cryptocurrencies:

The first disadvantage is that the regulations surrounding cryptocurrencies are currently weak. Weak cryptocurrency regulations mean that some countries do not know how to tax cryptocurrency transactions resulting in limited tax collections from cryptocurrency transactions. Another weak regulation of cryptocurrencies is that, in many countries, cryptocurrencies are not yet bound by asset forfeiture laws and regulations. This means that, where cryptocurrencies are involved, those in the wrong may not be held accountable (Nieman, 2015; Scott, 2016). The lack of regulation of anonymous cryptocurrency transactions, may result in money laundering (S. Kim et al., 2018).

The second disadvantage is that there is a high risk in investing in cryptocurrencies because they are volatile, susceptible to sudden changes in their prices and vulnerable to implosions or bubbles, for example, the volatility of Bitcoin was 176% per annum and the average return per annum was 404% between 2010 and 2013 (Brière et al., 2015; Hickey, 2017; Taylor, 2015). The third disadvantage is that the anonymity of transactions could result in untraceable illegal transactions and activities. The fourth disadvantage is that the exchange upon which the cryptocurrency is traded can be hacked despite cryptocurrencies being built on secure blockchain technologies. A breach of a cryptocurrency exchange called Bitfinex took place in 2016 where US$72 million worth of Bitcoins were stolen (S. Kim et al., 2018). In 2016, Reuters reported that one third of Bitcoin trading exchanges had been hacked (Chavez-Dreyfuss, 2016). In instances where cryptocurrency investors suffer losses, there are no cybersecurity laws surrounding cryptocurrencies, there is no depositors' insurance and there is not much that can be done from a legal perspective to prosecute the perpetrators (P. Kim, 2017; S. Kim et al., 2018; Taylor, 2015). This lack of recourse between buyers and sellers is a matter of concern.

There are other disadvantages. One disadvantage is that, as at 2014, Bitcoin could only handle seven transactions per second, while Visa could handle 56 582 transactions per second, therefore, Bitcoin has significantly less capacity than Visa (Catalini & Gans, 2016). Thus, there is a lack of market depth in cryptocurrency markets and the costs of moving currencies between many exchanges is an issue (Dandapani, 2017). Many cryptocurrencies have not been thoroughly tested and many are not well understood.

The next section discusses one of the most well-known cryptocurrencies – Bitcoin –

in detail.

1.1.3. Bitcoin

Bitcoin was the first mainstream and most widely used cryptocurrency. The use of Bitcoin is illustrated in Figure 1 that shows that Bitcoin held 53.36% of the total market for cryptocurrencies as at 30 August 2018 (CoinMarketCap, 2018). Bitcoin is a cryptocurrency that is created using computer programming algorithms that are processed in encrypted blocks that then become Bitcoins when they are decrypted. Like any other cryptocurrency, Bitcoin miners are the network users who allow for the transfer and ownership of Bitcoin by verifying these transactions on the network. This allows users of Bitcoin to remain anonymous. The aforementioned process of Bitcoin allows for a payment system that is based on encryption rather than trust. Bitcoin was released after the financial markets' collapse of 2008 in order to allow parties in a transaction to transact without middlemen, which are the traditional financial service providers, banks or brokers (Dandapani, 2017; S. Kim et al., 2018). This release and creation of Bitcoin came at a time when the market had collapsed and there was little trust of the intermediaries within the financial market.

Bitcoin has four characteristics that suggest that it should be in its own asset class. The first characteristic is a politico-economist feature which means that it is different from other assets in terms of governance, its underlying value and use. The second characteristic is investability which means that investments can be made in Bitcoin as it has a reasonable liquidity. The third characteristic is that Bitcoin has low correlations to other assets as its prices move independently of other asset prices. The fourth characteristic is risk-reward, where Bitcoin was found to have, on average, good Sharpe ratios and thus its return relative to risk was revealed to be better than those of traditional and alternative assets (Burniske & White, 2017).

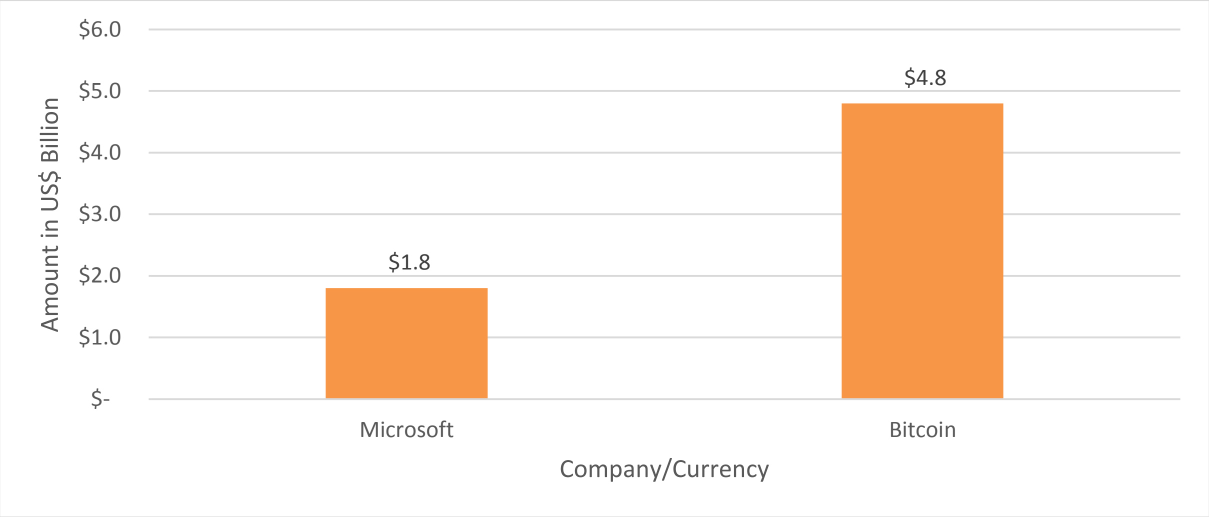
According to Cascarilla (2015, p. 19), although Bitcoin is similar to currency, it should not be considered as a currency but it should instead be seen as "an open ledger within which there is value". In the past, currencies were backed by assets such as salt, seashells and gold. However, in recent times, currencies are backed by governments (Cascarilla, 2015). Only 21 million Bitcoins in total will be circulated and, as at the third quarter of 2015, approximately 14 million Bitcoins had been circulated. Therefore, not all the Bitcoins created have been circulated, mined and distributed yet.

Bitcoins do not have physical coins from which change can be issued. To make up for this lack of change, each Bitcoin can be divided up to eight decimal places. This allows for adequate change to be released from Bitcoins, even with high Bitcoin values (Cascarilla, 2015). Even though there are a limited number of Bitcoins, this has not deterred Bitcoin from being used broadly.

Although Bitcoin is deemed to be a digital currency in some countries, it has a market price in comparison to traditional currencies like the Rand and can be traded for such currencies. Digital currency "is electronic money that serves as an alternative currency in digital or online transactions" (Dandapani, 2017, p. 614). In addition, Bitcoin tokens are digital tokens that can be exchanged between two parties, just like other currencies (Dandapani, 2017; Scott, 2016). Bitcoin can be used for retail purchases, remittances and the underbanked markets. More stores are accepting Bitcoin on a regular basis. There are 100 000 online stores in the US that accept Bitcoin and in excess of 5 000 physical stores that accept Bitcoin as a form of payment in the US (Cascarilla, 2015). Moreover, there are approximately 30 000 online stores that accept Bitcoin in South Africa (Maloumby-Baka & Kingombe, 2015).

Although there are six million Bitcoin wallets in the market, Bitcoin is not yet widely used in the markets globally (Cascarilla, 2015). Bitcoin wallets are like conventional wallets that store money. But because Bitcoin is electronic, these are online wallets that use encryption to store Bitcoin (Bitcoin Magazine, 2019). Many people do not use Bitcoin because of its volatility and many have stayed clear of the currency because of breaches in security, although over time, Bitcoin security has improved (Dandapani, 2017; Scott, 2016). Nevertheless, Bitcoin was utilised in approximately 62 million transactions as at 18 May 2015 (Taylor, 2015).

Figure 2: Average daily volume of Bitcoin and Microsoft for 3 months up to 13 December 2017



Source: Data from Kim et al. (2018) and Microsoft Excel output.

The study performed by Kim et al. (2018) found that Bitcoins were the most liquid of the cryptocurrencies in 2017. The average daily volumes of Bitcoin were US$4.8 billion for three months up to 13 December 2017. In comparison, Microsoft had an average daily volume of US$1.8 billion for the same three months up to 13 December 2017. The stark difference between the Bitcoin and Microsoft average daily volumes is reflected in Figure 2. This comparison has been made as both Microsoft and Bitcoin are traded on exchanges. Kim et al. (2018) found that, even though Microsoft's market capitalisation was over 3.5 times that of

Bitcoin, Bitcoin's average daily volume was over 2.6 times that of Microsoft's average daily volume. Furthermore, Kim et al. (2018) found that there was a significant increase in the average daily volume, market capitalisation and price of Bitcoin in 2017. However, it should be noted that Bitcoin's average daily volume, market capitalisation and price increased in line with the increase of cryptocurrencies that were added on the cryptocurrency exchange platforms. Therefore, there is an indication that some Bitcoin average daily volumes, market capitalisation and prices were driven up because Bitcoin was used as a gateway currency to purchase other cryptocurrencies across multiple exchanges. The most liquid cryptocurrency exchanges globally were Bitfinex, Bitmex and Bithumb which had average daily volumes of US$3.5 billion, US$2.4 billion and US$2.2 billion respectively in 2017 (S. Kim et al., 2018).

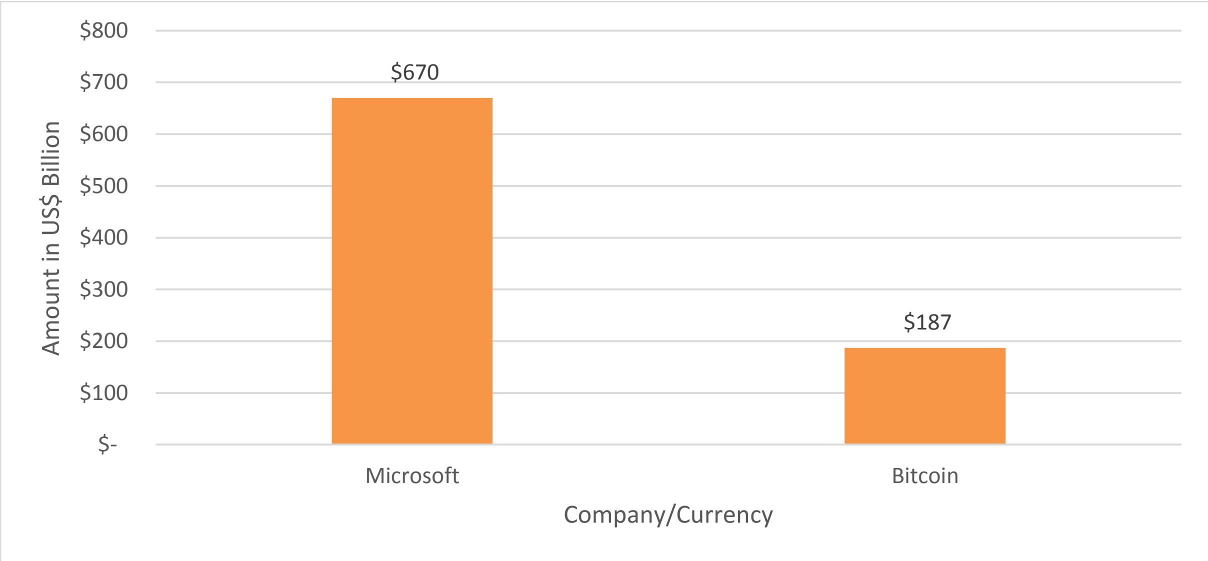
Figure 3: Bitcoin price and market capitalisation from 2013 to 2018

Source: Data from CoinMarketCap Global Charts (2018).

The value of Bitcoin has increased over most of the years since its creation. The price of Bitcoin in July 2010 was US$0.05 (Maloumby-Baka & Kingombe, 2015). During 2013 and 2014, the value of Bitcoin moved between US$13.40 and US$1,203.42 (Dandapani, 2017). The price of Bitcoin on 2 September 2017 increased greatly to US$4,780.15 (Lee, Guo, & Wang, 2017). This price fluctuation of Bitcoin is reflected in Figure 3. As at November 2016, Bitcoin had a market capitalisation of US$12 billion (Catalini & Gans, 2016). As per Figure

4, and according to Kim et al. (2018), as at 3 December 2017, the price of each Bitcoin was US$11 000 and had a market capitalisation of US$187 billion while Microsoft, which is listed on NASDAQ, had a market capitalisation of US$670 billion as at 3 December 2017 (S. Kim et al., 2018).

Figure 4: Market capitalisation of Bitcoin and Microsoft as at 3 December 2017



Source: Data from Kim et al. (2018) and Microsoft Excel output.

The next section discusses the South African market.

1.1.4. South African market

South Africa operates within a global economy and it is therefore influenced by cryptocurrencies. In South Africa, there are two main cryptocurrency exchanges, Luno and Ice3X (Ice3X, 2018; Luno, 2018).

The South African government has had a slow response in regulating cryptocurrencies. As at 2015, no legislation had been put into place regulating cryptocurrencies. The South African Reserve Bank (SARB) also does not regulate cryptocurrencies therefore all the risks lie solely with the users of cryptocurrencies. The SARB has concluded that cryptocurrencies pose no risk to the financial stability, price stability and the national payment system (NPS) (Neiman, 2015). The SARB has also issued a warning that cryptocurrencies are not legal tender, that they are not secure and that investors may lose their money (Mckenna, 2017).

The South African financial market has numerous participants including individuals, insurance companies, investment banks, retail banks, listed companies, non-listed companies, the government and the regulators. South Africa has one financial exchange, the Johannesburg Stock Exchange (JSE), which is the largest African exchange and the 19th largest exchange globally. The JSE consists of the derivative, debt and equity markets. The derivative market allows for the trading of bonds, currencies, interest rates, equities and commodity derivatives. The debt market provides for the trading of government and corporate bonds. In addition, the debt market has the JSE Repo market where banks, corporations or asset managers can speculate on the bond market and borrow short-term loans. The JSE also includes the equity market which has both the Main Board exchange market and the Alternative Exchange market (JSE, 2019a). The Main Board is where the primary listing occurs for larger companies and the Alternative Exchange Board consists of riskier investments. It is therefore easier for small to medium companies to list on the Alternative Exchange Board (Brownlee & FSP Invest, 2016).

In the next section, the problem statement will be defined.

1.2. Problem statement definition

Since the market crash of 2008, investors have sought out investments, such as alternative assets, that are not correlated to the stock market, to further diversify their portfolio investments. However, most of these alternative investments have underperformed (Srilakshmi & Karpagam, 2017). Listed equities in South Africa have also been underperforming on the Johannesburg Stock Exchange (JSE), which is the largest African exchange and the 19th largest exchange globally (JSE, 2019a). The JSE's Top 40 index and the JSE's All Share index had a return of -5.40% and -4.93% for the 12-month period ended 5 October 2018, respectively (Trading Economics, 2018). This reflects the underperformance of listed shares in South Africa. Consequently, this poor performance motivates investors to seek alternative investments to the underperforming traditional investments. Possible solutions to the problems are multifaceted. The market capitalisation of Bitcoin and over 1 000 cryptocurrencies was more than US$400 billion in January 2018. The market capitalisation of over 1 000 cryptocurrencies excluding Bitcoin in January 2018 was more than US$250 billion. Various cryptocurrency exchanges have daily volumes of US$50 billion and Bitcoin futures have been created in places like Chicago so that institutional investors can hedge and trade Bitcoin. Additionally, between January 2009 and April 2017, 606 million transactions of US$1 trillion were performed (Taylor, 2018).

The question is whether cryptocurrencies can assist in alleviating the illiquidity of many African financial markets as the cryptocurrency market has had good returns in the past even though these returns have declined in recent times. Perhaps cryptocurrencies can tackle the problem resulting from the underperformance of listed shares in South Africa.

The focus of this study is on the South African stock exchange because it is the most developed stock exchange in Africa (Demirgüç-Kunt & Klapper, 2012) and bitcoin is more widely used in South Africa than in other countries on the continent. The purpose of this study is to assess the performance of cryptocurrencies in relation to traditional investments in South Africa. Therefore, the research seeks to assess whether the incorporation of cryptocurrencies into the pool of available South African investments would be beneficial to investors. The research questions are listed below.

To assess the impact that cryptocurrencies might have on improving investment performance in South Africa, four critical questions are asked:

1. Do cryptocurrencies outperform South African traditional and alternative assets?
2. Should cryptocurrencies be included in South African investment portfolios?
3. Do cryptocurrencies have diversification advantages in South African portfolios under the conditional value-at-risk (CVaR) analysis?
4. Should individual cryptocurrencies be included in South African investment portfolios?

1.3. Statement of research objectives and hypotheses

This study seeks to answer the four research questions mentioned above. It does so by meeting four objectives. Each question has a related objective and hypothesis.

The four research objectives are:

1. To compare the return relative to risk derived from cryptocurrencies and South African traditional and alternative assets.
2. To compare the performance of South African investment portfolios with cryptocurrencies to portfolios without cryptocurrencies.
3. To contrast the performance of South African investment portfolios under the conditional value-at-risk (CVaR) analysis and mean-variance (MV) analysis.
4. To assess whether each cryptocurrency improves the performance of South African investment portfolios.

The four hypotheses tested by this investigation are as follows:

1. Cryptocurrencies generate higher returns in relation to risk than South African traditional and alternative assets.
2. Cryptocurrencies have diversification advantages in South African investment portfolios.
3. Under the conditional value-at-risk (CVaR) analysis, cryptocurrencies have diversification advantages in South African portfolios.
4. Individual cryptocurrencies have diversification advantages in South African investment portfolios.

The next section discusses the research assumptions that have been made in relation to this study.

1.3.1. Research assumptions

Secondary data were used for this study. The data for cryptocurrencies were obtained from publicly available websites being the CoinMarketCap and http://crix.hu-berlin.de. The South African government bonds data were obtained from investing.com, which is another publicly available website. It is assumed that the data are reliable and accurate. CRIX is a cryptocurrency index that consists of cryptocurrencies based on their market capitalisation (Härdle, Trimborn, et al., 2018). As CRIX is an index that is made up of multiple cryptocurrencies, it is assumed that CRIX represents cryptocurrencies within this study. This study seeks to fill knowledge gaps that are discussed below.

1.4. Justification of the study

With an increase in data, data-mining methods and statistical software surrounding market transactions and the flows of funds, there are prospects to offer fresh platforms in interpreting and investing in the financial markets. In addition, the following question was asked by researchers and financial practitioners at the Human Computer Interaction (HCI) Google Researchers Workshop: "What role is technology playing in building financial services?" (Kaye, Vertesi, Ferreira, Brown, & Perry, 2014).

The academic literature on the investment features of cryptocurrencies in general and Bitcoin in particular is not extensive, nor are studies that assess the extent to which developing countries are utilising Bitcoin (Brière et al., 2015; Scott, 2016). Moreover, most studies that have been performed on Bitcoin relate to the legalities of money laundering, income taxation and trading safety (Brière et al., 2015). Therefore, there is a need to assess the extent that Bitcoin has been utilised in developing countries. This study assesses Bitcoin's use in South African investments.

There have been numerous advancements that have occurred in financial technology, such as Blockchain and cryptocurrency that are recent concepts but not much data have been collected and analysed about them. Cryptocurrencies have the potential of having extremely high returns, volumes and liquidity as their prices and values have increased over time. The volatility of cryptocurrencies has declined as they mature. This decline is due to the increased stability and liquidity of the cryptocurrency exchanges, increased regulatory approvals for cryptocurrencies and increased ownership of cryptocurrencies (Srilakshmi & Karpagam, 2017). Cryptocurrencies have the potential of producing good returns on investments in relation to their risk and they have been found to do well in diversifying traditional investment portfolios (Lee et al., 2017). This study assesses cryptocurrencies in creating returns on investments, in relation to traditional investments in South Africa and compares the returns on investments of cryptocurrencies to traditional investments in South Africa. The subject is useful, not only for South Africans, but for the government, policy makers, businesses, academics, financial markets, and financial service institutions.

This study will be useful to those who seek to create and amend policies, laws and regulations that relate to investments in cryptocurrencies and to those in the financial service institutions, such as hedge funds, asset managers and banks. This study will assist them in reframing their financial investment products, addressing the diversification of portfolios adequately and potentially improving their clients' returns on investments. The study compares the performance of cryptocurrencies in relation to listed shares in South Africa. The study also seeks to inform financial institutions and individuals of an alternative method of investments using cryptocurrencies. An overview of the organisation of the thesis is given below.

1.5. Organisation of the study

The dissertation consists of five chapters. The first chapter is the introduction, the second chapter is the literature review, the third chapter is about the research methodology and the fourth chapter is on the discussion of the findings of the empirical study in relation to the theoretical literature. The last chapter offers conclusions and recommendations for future studies.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

An investment is made in order to derive returns (Cowell, 2013). Therefore, the objective of an investment is to maximise returns, while keeping risks as reasonably low as possible. Returns are normally the income derived from an investment and the capital appreciation of an investment (Bines & Thel, 2004). Moreover, investing is a form of buying assets in order to gain foreseeable income such as interest, dividends and rental income and/or capital appreciation of the asset over a long period of time (Malkiel, 2015). The theoretical and empirical literature of assessing returns and risks related to investments will be reviewed in this chapter.

The modern portfolio theory (MPT), capital asset pricing model (CAPM), efficient market hypothesis (EMH), behavioural finance theory (BFT) and adaptive market hypothesis (AMH) are investigated in more detail within the theoretical literature review. Additionally, the study examines the empirical studies that assess the performance of traditional assets as well as those that compare traditional assets to alternative assets. This literature review is then concluded by assessing the empirical literature where cryptocurrencies are compared to traditional and alternative investments.

2.2. Theories that guide the assessment of returns on assets

2.2.1. Modern Portfolio Theory

Markowitz (1952) proposed the Modern Portfolio Theory (MPT) in an article named *Portfolio Selection.* He suggested that investors should maximise their discounted estimated future returns and minimise their risk on securities (Fama & French, 2004; Litterman, 2003c; Malkiel, 2015; H. M. Markowitz, 1991). Markowitz (1952; 1991) further stated that, in doing so, the investors must ensure that they diversify their portfolio investment in securities by investing across multiple industries, particularly in entities which have smaller covariances or correlations than those within the industries being invested in. These industries are various industries with economically diverse characteristics. Therefore, securities should not be selected in isolation but they should be selected while bearing in mind how the fluctuations of other securities within the portfolio impact the chosen securities (Elton & Gruber, 1997). Furthermore, an increased diversification of the portfolio decreases the risk of the investment, but does not eliminate all the risk. Therefore, a correlation coefficient (CC) of -1.0 is where all the risk is removed, -0.5 is where the majority of the risk is removed, 0 is where a substantial risk reduction is likely, +0.5 is where moderate risk removal is likely and +1.0 is where risk removal is not likely (Malkiel, 2015).

In deriving the MPT, the expected returns-variance (E-V) rule was analysed and assessed. The E-V rule states that, in selecting a portfolio, the combination of the returns (E) and variance or risk (V) should be efficient. Therefore, E should be maximised for V or less than V, and V should be minimised for E or more than E (H. Markowitz, 1952). Consequently, V is the driver of E (Litterman, 2003d; Malkiel, 2015). The V of the portfolio needs to be taken into consideration when assessing the E for every investment made (Litterman, 2003d). Markowitz postulates that an optimal portfolio is one that lies on the efficient frontier (Harvey, Liechty, Liechty, & Peter, 2010). The efficient frontier is the amalgamation of securities within a portfolio that maximises returns for a specific risk level of the portfolio (Mangram, 2013; Pfiffelmann, Roger, & Bourachnikova, 2016).

There are limitations in the derivation of the E-V rule (H. Markowitz, 1952, p. 79). The limitations are that the results are not gathered from analysing an unlimited number of securities, instead, a geometric presentation of three and four securities is made. The MPT makes the following assumptions: all investors have all the necessary information to make decisions with regards to their investment; the investors have indefinite access to investment funds at a risk-free rate; the market is efficient; there are no transaction costs and taxation is not considered (Mangram, 2013). Moreover, the MPT does not consider the correlation between the asset price and risk of an asset (Sharpe, 1964). High returns of a portfolio tend to mask possible problems within the portfolio. These problems may be due to the underperformance of specific assets within the portfolio that might not be spotted due to the overall superb performance of the portfolio (Cowell, 2013). Additionally, although the risk specific to an asset can be diversified away and reduced, the risk that pertains specifically to the asset has yet to be understood (Sharpe, 1964).

2.2.2. Capital Asset Pricing Model

Sharpe (1964, p. 427) published *Capital Asset Prices: A theory of market equilibrium under conditions of risk*, where the "equilibrium theory of asset prices under conditions of risk" was analysed for the first time and the Capital Asset Pricing Model (CAPM) was introduced. In assessing the attractiveness of an investment, the expected value, risk, in the form of standard deviation, and other investment prospects are considered. It is inferred that an investor prefers a higher future value, rather than a lower future value of an investment (Sharpe, 1964). However, the investor dislikes risks and prefers to invest in risk-free assets but this can result in the investor receiving a lower value for their investment (Baltussen, 2009; Sharpe, 1964). The CAPM posits that assets that are not correlated to the market have expected returns that are equal to the risk-free rate (Fama & French, 2004). This part of the theory only looks at the individual investors' perspectives of risk (Sharpe, 1964). The circumstances under which the equilibrium capital market arises are dealt with below.

The equilibrium capital market arises under two circumstances: that all investors make investments or borrow money using the same terms and that, in assessing an investment, the expected value, risk in the form of standard deviation and other investment prospects are considered. Risk is measured using the standard deviation (Sharpe, 1964) which is the measure of the spread of a group of numbers (Leacock, Warrican, & Rose, 2015). Risk can also be measured using beta (Karceski, 2002) which measures the market or systematic risk. Beta is the difference between "the movements of an individual stock and the movements of the market as a whole" (Malkiel, 2015, p. 210). The theory states that once the asset price is at a point where the investors will receive the largest return for their risk, then the price will increase and the expected returns will decrease (Sharpe, 1964). The reason for the price increase is the result of the attractiveness of the return on investment but, unfortunately this, in turn, will lead to lower returns on the asset (Litterman, 2003c; Sharpe, 1964). The theory also states that, should the asset not be at a point where the investors will receive the largest return for their risk, the asset price will decrease, while the expected return will increase (Cowell, 2013; Sharpe, 1964). Consequently, the price will decrease as a result of a lack of attractiveness to the return on investment, but this will result in larger returns on the asset (Litterman, 2003c; Sharpe, 1964). The risk and expected return have a linear relationship in the form of the capital market line and they are positively correlated (Sharpe, 1964).

The theory has not yet considered the risk specific to an asset that is known as “unsystematic risk”. This cannot be diversified away like the market or systematic risk (Easterling, 2005; Malkiel, 2015; Mills & Markellos, 2009; Sharpe, 1964) that arises from movements in the market. Unsystematic or unique risk is the risk that relates to a specific security or asset. There is a correlation and a linear relationship between the expected return and unsystematic risk (Bines & Thel, 2004; Litterman, 2003d; Malkiel, 2015; Sharpe, 1964).

Overall, the CAPM postulates that the risk premium is the risk that cannot be diversified away. This risk is the excess between the expected rate of return and the risk-free rate (Bollerslev, Engle, & Wooldridge, 1988; Fama & French, 2004; “Risk premia,” 2018). The CAPM notes that there is a linear relationship between risk and return, and risk is denoted using beta. Consequently, this linear relationship leads to arguments that beta is ineffective (Karceski, 2002) and that beta is not useful for investments with returns over numerous periods. Accordingly, the market fails to incorporate risk differently across various assets' prices (Dempsey, 2013). Even though the CAPM accounts for the equilibrium market and expected returns, it does not account for the market's efficiency. These market efficiencies are analysed by Fama (1970).

2.2.3. Efficient Market Hypothesis

Fama (1970) analysed the efficient market hypothesis (EMH). He stated that “the primary role of the capital market is allocation of ownership of the economy's capital stock” (Fama, 1970, p. 383). He postulated that the perfect market is one where prices “fully reflect available information” at a given time. Such a market is known as an efficient market (Fama, 1970, p. 383). Lim and Brooks (2011) state that an efficient market is where present market prices absorb recent information speedily and accurately (Dempsey, 2013; Smith & Rosevear, 2017). However, Lo (2004) states that economists are not yet convinced that markets are efficient. The EMH mentions three categories of information in the market, the weak form, semi-strong form and the strong form. The weak form is where prices are based on historical information (Cowell, 2013; Fama, 1970; Lim & Brooks, 2011). The semi-strong form is where prices are based on information that is freely accessible to the public while the strong form is where prices are based on publically accessible information, as well as information that is controlled by only a few parties with access to private insider information (Cowell, 2013; Fama, 1970; Malkiel, 2015; Mobarek, Mollah, & Bhuyan, 2008). Moreover, there are four theories that encompass the EMH, these are: the expected return or “fair game” models, the submartingale model, the random walk model and the efficient market conditions (Fama, 1970, p. 387). These four theories that encompass the EMH are discussed below.

The first theory is the expected return or fair game models, which observes that expected returns reflect equilibrium market conditions. In applying this expected return model, information is used to determine the price at a given time. This information is also applied in calculating the equilibrium expected return. This theory means that information that results in expected returns being larger than equilibrium returns will not be used in the trading systems (Fama, 1970) and should prices get out of equilibrium, they will soon revert back to equilibrium to more reasonable levels (Cowell, 2013; Lo, 2004).

The second theory is the submartingale model which posits that the current price is less than or equal to the expected value of the price in the following period. In the case where the expected returns and the changes in price are equal to nil, the sequencing in pricing is a martingale. A martingale is the anticipated variance between two consecutive prices whose difference is zero. These prices are so uncorrelated that the difference between the prices results in zero. In essence, the numbers are mirror images of each other, except that one is positive and the other is negative. “The martingale process implies that price differences are serially uncorrelated and that univariate linear time series models of prices have no forecasting value” (Mills & Markellos, 2009, p. 340). Furthermore, the expected returns are based on information that is fully reflected in the price. This implies that the trading rules, where the information is wholly used to determine the price, will have lower expected returns than buying-and-holding securities in future (Fama, 1970). The third and the forth theories of EMH are now analysed.

The third theory of EMH is the random walk model, which hypothesises that the consecutive changes in price and returns are independent and they are equally distributed (Fama, 1970). Consequently, price fluctuations are random and cannot be forecasted (Lo, 2004; Malkiel, 2015). The sequence of historical returns is irrelevant but historical information is critical in analysing future returns. The random walk model relates to the fair game model in that changes in the investors’ preferences and the methods of producing new information form equilibria, where return distributions continuously occur over time (Fama, 1970). However, multiple studies conducted on the random walk theory have led to empirical studies that refute this theory (Lo, 2004).

The fourth theory relates to efficient market conditions where it is simple to establish enough conditions for capital market efficiency. These conditions state that there are no transaction costs, all accessible information is free, and there is an agreement as to how existing information affects existing prices and distributions of the prospective prices of securities. However, these conditions are not a requirement for an efficient market (Fama, 1970). There have also been numerous gaps and inconsistencies that cannot be explained by the MPT, CAPM and EMH (Shiller, 2003; Subrahmanyam, 2007). Furthermore, the MPT, CAPM and EMH do not assess the capital markets and investors from a psychological and sociological point of view (Fama, 1970; Lo, 2004; Shiller, 2003).

2.2.4. Behavioural Finance Theory

The behavioural finance theory (BFT) arose in the 1990s (Shiller, 2003). This theory assesses the capital markets and the investors from a psychological and sociological perspective. It assesses the investors' behaviour in the financial markets. The traditional finance theories, such as the MPT, CAPM and EMH, assess the decisions of the investors as being rational and seeking to maximise their returns and minimising their risk (Baltussen, 2009; Lo, 2004; Malkiel, 2015; Subrahmanyam, 2007). However, investors are not always rational (Baltussen, 2009; Lo, 2004; Malkiel, 2015; Pfiffelmann et al., 2016; Subrahmanyam, 2007) as not all market participants digest information properly and make the correct decisions using this information. Furthermore, not all investors have the same ability to absorb, interpret, synthesise and utilise information. Moreover, some investment decisions are based on moral grounds, rather than on the maximisation of profits. These decisions made on moral grounds are reflected in investors not choosing to invest in the tobacco industry and other industries that are frowned upon by the public (Baltussen, 2009). BFT is now discussed in more depth below.

There are several theories within the BFT. The first theory is that investors prefer marginal distributions of investments and they also prefer not to consider the individual weights of assets in assessing the performance of their portfolios but instead choose to assess each asset with an equal weighting. This contradicts the MPT and the CAPM theories, as the E-V rule and diversification are not applied efficiently. The second theory is referred to as "mental accounting" and "narrow bracketing". Mental accounting and narrow bracketing refer to the way individuals make decisions – in that they cluster specific decisions and allow those decisions to influence their ultimate decision. In doing so, they ignore all other decisions (Baltussen, 2009; Gumede, 2018). Therefore, mental accounting and narrow bracketing relate to compartmentalised decisions. An example of mental accounting is where investors focus on the individual assets' volatility, rather than the portfolio's volatility, which results in less than adequate returns. Mental accounting also results in investors compartmentalising their money into separate accounts, for different uses, such as holidays, investments, spending and living expenses. Mental accounting can result in high returns in the market but there is also a slim probability of huge losses arising. Nevertheless, investors invest using a short-term time horizon rather than a long-term time horizon, for example, investors are more likely to invest in stocks, rather than invest in bonds, if the investment is over a longer period (Baltussen, 2009).

There are more theories within the BFT. The third and fourth theories of the BFT are the judgmental heuristic and representativeness heuristics. Judgmental heuristic occurs when investors "reduce the complex task of forming expectations and assessing probabilities to simpler judgmental operations" however, these judgmental heuristics cause biases and defects (Baltussen, 2009, p. 13). The fourth theory is representativeness heuristics that causes investors to base the primary characteristics of a sample size on the population size. Furthermore, this theory relates to investors believing that they are in control of their investments and that they can forecast future prices based on historical prices (Malkiel, 2015). A disadvantage of this theory is that they also base the population size on the sample size. The problem with this is that it can result in too much dependence on new weights, rather than base rates or previous probabilities. It also has unrealistic forecasts and it disregards information within a process and the sample size while it overstates the sample size information (Baltussen, 2009). One of the examples of the aforementioned is the expectation of the continuation of random patterns and historical price fluctuations (Baltussen, 2009; Shiller, 2003).

Representativeness heuristics have shown that prices can rally upwards or downwards over a period of time and this contradicts the random walk theory within the EMH (Shiller, 2003). It has been found that representativeness heuristics further influences returns after earnings announcements in that fair earnings result in large returns and poor earnings result in smaller returns. Furthermore, representative heuristics influences employees to invest in the entities they work for in a manner that is inefficient for the diversification of their investment portfolios (Baltussen, 2009). Representative heuristics have influenced several individuals to invest in Ponzi schemes based on previous sample size patterns and not on realistic forecasts (Shiller, 2003).

The fifth, sixth, seventh and eighth theories within behavioural finance are availability, overconfidence, perseverance and emotions. The fifth theory, availability, refers to individuals estimating the possibility of a certain outcome. However, this human estimation can be flawed, as people tend to recall recent events unequally to older events (Baltussen, 2009). The sixth theory, being overconfidence, refers to investors being too confident in foretelling the future better than others and viewing their skills and intelligence as superior to others (Baltussen, 2009; Gumede, 2018; Malkiel, 2015; Subrahmanyam, 2007). Overconfidence leads to investors blaming circumstances rather than their mismanagement of their investments when things go wrong (Baltussen, 2009; Subrahmanyam, 2007). Moreover, overconfidence leads to the underestimation of risk and the overestimation of possible returns on investments. It also results in over-trading and the lack of diversification. The seventh theory refers to perseverance, which is the lack of willingness of investors to change their thoughts. This is can be disadvantageous, particularly when share prices are declining, as it is difficult for the investor to acknowledge a declining investment (Baltussen, 2009). The eighth theory relates to emotions, particularly fear, joy, pride and regret (Baltussen, 2009; Malkiel, 2015). When investors are fearful, they assign a lower value to investments and thus returns are lower; when they are joyful, investors assign a larger value to investments and thus returns are greater (Baltussen, 2009). Investors find it difficult to admit that they have made a poor investment due to pride but they may acknowledge that they regret what they have done (Malkiel, 2015).

The ninth theory that relates to behavioural finance is the Prospect Theory (PT) or the Cumulative Prospect Theory (CPT). The PT can be broken down into four behavioural patterns as follows: (1) individuals care more about the actual change in their wealth, in relation to some reference point, than the actual absolute value of change in wealth; (2) investors dislike losses more than they value gains; (3) investors shy away from gains but are more reactive towards losses; and (4) more credibility is given to movements in smaller probabilities than movements in larger probabilities (Baltussen, 2009; Subrahmanyam, 2007). However, microscopic probabilities are normally disregarded. The disliking of losses explains the reason for shares achieving better returns than bonds. The PT explains why investors sell shares that have risen in value and hold onto shares that have lowered in value. The PT also means that investors have a risk appetite for low probabilities on high returns and high probabilities for minor losses. However, investors who do not have a risk appetite prefer higher probabilities on lower returns and lower probabilities for larger losses. Individuals prefer to make investments in companies and countries with which they are more conversant; they also prefer to discount returns more than losses and discount minor amounts more than higher amounts (Baltussen, 2009).

The tenth and final theory of behavioural finance is herding, which posits that groups are superior decision makers compared to individuals. This is due to the consideration of multiple view points and more input and information available to the collective than to an individual. The disadvantage of herding is group thinking, where the members of the collective convince each other that an incorrect decision is correct (Malkiel, 2015).

There is criticism of viewing the BFT in isolation and this has resulted in the emergence of the adaptive market hypothesis (AMH), discussed below, which is a combination of EMH and the BFT (Lim & Brooks, 2011; Lo, 2004).

2.2.5. Adaptive Market Hypothesis

Lo (2004) posits that the Adaptive Market Hypothesis (AMH) states that prices reflect information that is determined by the environment and the participants in the economy. For instance, where there is a high demand for financial instruments in the market, the price will absorb the information quickly and the market will be efficient as limited information is in high demand and is sought avidly by many market participants. This increased competition makes the market efficient. However, where there is little demand for a financial instrument and plentiful information that is sought out by a small number of market participants, this will take time for the market to absorb. This lack of competition makes the market inefficient.

Moreover, emotions impact market participants' behaviour and the efficiency of the market. They also underpin the environment and previous positive and negative experiences (Lo, 2004).

There are several implications of the AMH. The first implication is that the correlation between risks and returns is not steady over time; this is due to the market sentiment, taxation and the regulatory systems. The second implication is that arbitrage often takes place, unlike in the EMH, where it does not. The third implication is that investment strategies will be suitable in one setting and unsuitable in another setting. For example, risk arbitrage is unsuccessful in times of decreased investment banking undertakings but is successful once the investment banking activities increase. The fourth implication is that the key to consistent returns is adaptability to the surrounding conditions and needs. The fifth and last implication is that AMH affects all market participants. This implies that, ultimately, market participants are primarily occupied with survival rather than profit optimisation (Lim & Brooks, 2011; Lo, 2004).

In the next section, the empirical literature is addressed and reviewed.

2.3. Empirical literature review

2.3.1. Techniques used for assessing the performance of traditional investments

Traditional assets are defined as equities, fixed income instruments, cash and cash equivalents, real estate and commodities (Lee et al., 2017; Srilakshmi & Karpagam, 2017). However, Lee et al. (2017) do not include real estate and commodities in their definition of traditional assets. Brière et al. (2015) also include currencies in their definition of traditional assets. Fixed income instruments refer to debt or bonds that are made as an investment in an entity or a government. Cash and cash equivalents refer to money that is saved as an investment. Real estate investments are investments made in tangible property. Commodities are investments made in tangible goods, such as natural resources that include gold, silver and uranium (Srilakshmi & Karpagam, 2017).

Empirical studies prior to 1970 used serial correlation and trading rule tests and discovered that information in stock markets is weak (Lim & Brooks, 2011). Lintner (1965) carried out a study on 301 companies' shares using regression analysis where annual returns of the entities were regressed in relation to the Standard and Poor's 425 industrial stock price index (S&P 425) over 10 years, from 1954 to 1963. In examining the variance, the study found that less than 25% of the total variance was explained by 103 of the 301 companies. Moreover, over 75% of the total variance was explained by 34 companies and over 90% of the total variance was explained by two companies. These results are valuable for assessing risks relating to individual stocks held by investors.

Another study was performed by Lintner (1965) on 70 mutual funds from Weisenberger's Investment Trust, for a period of 10 years, from 1953 to 1963. It was found that the average annual rate of return from the S&P index was 18% and the standard deviation was 22.44% over 10 years while the mutual funds' average annual rate of return was 9.6% to 21.5% and the standard deviation was between 10.5% and 22.4% per annum over 10 years. Therefore, the study showed that the S&P index had a higher annual rate of return and a higher risk over the period of study. Only six mutual funds' average annual returns exceeded that of the S&P index, while 57 mutual funds had a high average return to risk ratio. It was also found that the systematic risk was explained by standard errors of the estimate and the risk-free rate was less than the residual risk in 60 of the mutual funds. These results indicate that the investors' risk after diversification is significant. It also finds that diversification and cautiously selecting assets within a portfolio cannot significantly reduce the market and residual risk (Lintner, 1965).

Jensen (1969) performed a study on the performance of 115 mutual funds from 1955 to 1964 utilising the risk-return framework, where the Standard and Poor's 500 (S&P 500) was used to represent the market portfolio. He calculated returns as the compounded nominal 10-year rate and he used historical compounded nominal one-year rates to approximate risk. It was found that, for 89 of the 115 mutual funds, the net returns in relation to the risk-return amount for 10 years, after deducting all expenses, was below that of the market. It was also found that the investors' mutual funds after 10 years were 14.6% less than those held in market indexed investments (Fama, 1970). Additionally, Jensen performed a study where the net returns were calculated net of all expenses, excluding transaction costs. It was found that, within 72 of the 115 mutual funds, the net returns in relation to the risk-return combination were below that of the market. Moreover, the investors' mutual funds after 10 years were 8.9% less than those held in market indexed investments. Jensen also performed a study where gross returns, less interest, taxes and brokerage commissions, were calculated and assessed. This investigation found that, for 58 of the 115 mutual funds, the net returns in relation to the risk-return amount was below that of the market. It was also discovered that the investors' mutual funds after 10 years were 2.5% less those held by market indexed investments (Fama, 1970; Jensen, 1969).

A study over a period of 20 years, from 1959 to 1979, showed that various measures based on the United States of America (US) government securities interest rates could predict the risk premiums of the 20-year government bonds, New York Stock Exchange (NYSE) shares and Treasury bills (Keim & Stambaugh, 1986). Keim and Stambaugh (1986) examined the predictability of the risk premium and the seasonality of the expected returns based on asset prices over 50 years from 1928 to 1978. Risk premium, or premia, is the difference between the market rate of return or expected return and the risk-free rate. It is, in essence, the premium paid for taking a risk in making an investment (Fama & French, 2004; "Risk premia," 2018). The forecastable variables, one from the bond market and two from the stock markets, were used to predict the actual risk premiums of the NYSE shares. These variables were also utilised to forecast the returns of similar shares and bonds. Moreover, these variables were positively correlated to prospective returns. Using regression analysis, this study established that returns are at their greatest level in January, following years of a slump in asset prices for small companies and low rated bonds. Therefore, this might suggest a greater risk at the end of the year (Keim & Stambaugh, 1986).

An exploration was carried out by Bollerslev et al. (1988) that used a multivariate generalised autoregressive conditional heteroscedastic (GARCH) procedure to approximate returns for 20-year Treasury bonds, six-month Treasury bills and the NYSE value-weighted shares with expected quarterly returns, that are comparative to the conditional covariance of a diversified portfolio. The quarterly returns explored were from the first quarter of 1959 to the second quarter of 1984 for a sample size of 102. The outcome was that the conditional covariance changed over the period and is a major determinant of the time-varying or time-dependent risk premium. Furthermore, beta was also found to be time-dependent and predictable (Bollerslev et al., 1988).

A utility function and mean-variance estimates investigation of 149 investment funds from

1958 to 1967, 97 US shares from 1948 to 1968, and five and six randomly selected shares from the afore-mentioned was performed. Ninety-seven US shares were investigated instead of 100 US shares due to technical issues. Annual and monthly rates of return were used. It was determined that investors do not need assured returns where they stand to gain the greatest amount overall. There is no return that would make investors accept an assured return where they stand to gain a greater amount overall. It was also determined that, had the investors known the utility function, they would have been able to predict the relationship between the mean value and the variance (H. M. Markowitz, 1991). Utility refers to the gains derived from an investment portfolio (*Utility Theory: Describing investors' relationship with risk*, 2019).

The investigation was performed using the time-series regression. Pre-ranking beta for the NYSE from 1923 to 2003, American Stock Exchange (AMEX) from 1963 to 2003 and NASDAQ from 1972 to 2003 were the data used. By utilising compartmentalised three to five years of previous monthly betas, 10 value-weighted portfolios were constructed. The data were then used to estimate expected rates of return for the following year. This study reflected that returns were too low for investment portfolios with high betas and returns were too high for investment portfolios with low betas. For instance, a high beta portfolio with an anticipated return of 16.8% had an actual return of 13.7% while a low beta portfolio had an actual return of 8.3% instead of the anticipated return of 11.1% (Fama & French, 2004).

Cross-sectional studies performed by Subrahmanyam (2007) revealed that there is indeed a relationship between security forecasted returns and betas. However, other studies have shown that this relationship is inconsequential. Some studies have indicated that quantity and the book-to-market ratio determine prospective returns while other studies show that the determinants of projected returns are historical returns, accounting ratios and trading volumes (Subrahmanyam, 2007).

Pfiffelmann et al. (2016) performed a study on 1 452 US share prices and dividends from the Center for Research in Security Prices' (CRSP) database for 1995 to 2011. They argue that the behavioural portfolio theory (BPT) that is 70% based on the MPT has high returns, high risks and positive skewness. The study explains that the BPT attracts investors who are seeking high rewards and who are willing to take high risks but when the risk is too great, the investor opts to select no portfolio at all (Pfiffelmann et al., 2016). Nonetheless, alternative assets will now be defined, so that the alternative empirical literature can be reviewed.

2.3.2. Literature that compares risks and returns of alternative assets to traditional assets

Alternative assets have returns that do not move in the same patterns as traditional assets (Srilakshmi & Karpagam, 2017). As stated by Lee et al. (2017), alternative assets have a lower correlation to traditional assets. Examples of alternative assets or non-traditional assets are hedge funds, private equity, other overlay strategies, currencies and works of art (Easterling, 2005; Lee et al., 2017; Litterman, 2003b; Srilakshmi & Karpagam, 2017). However, Brière et al. (2015) include hedge funds, commodities and real estate in their definition of alternative assets. Pure overlay or overlay is an investment management strategy that produces “excess returns through intentional active deviations in sectors, countries, or asset classes” (Carhart, 2003, p. 458). However, Lee et al. (2017) view real estate as an alternative investment.

Now that alternative assets have been discussed, empirical literature that compares the risks and returns of alternative assets and traditional assets will now be assessed. An examination of the monthly cash flow data from the Investment Company Institute (ICI) from January 1984 to September 1996 was carried out by Karceski (2002). This examination utilised cash flows of equity funds for aggressive growth, growth, growth and income, equity income and income options. The examination was carried out using panel and time-series ordinary least squares (OLS) regression models. The outcome revealed that the beta of the weighted equity fund was 5.02 and that of the S&P 500 was 4.66. This illustrates that, within managed investment portfolios, the equity portion of the funds managed is mostly made up of high-beta shares. Furthermore, the market beta of the weighted equity mutual fund portfolio was 1.05 and that of the weighted equity mutual fund portfolio that includes cash was 0.95. The Fama-MacBeth test revealed that there was a weak relationship between the equity risk premium and the miniscule mutual funds held in US shares. There is no quantitative indication that the ownership of larger mutual funds reduces the beta risk premium but it should be noted that the Fama-MacBeth test is not robust. Additionally, market returns exceed funds flowing from stocks. The examination also revealed that aggressive growth of total net assets is greater than that of income equity funds (Karceski, 2002).

A Bayesian probability model was used to investigate joint distribution of asset returns (Harvey et al., 2010). This investigation utilised four daily share returns, 10-year Treasury bonds, crude oil futures and gold from July 2001 to June 2006. The shares were from the Russell 1000, Russell 2000, Morgan Stanley Capital International (MSCI) Europe, Australasia and the Far East (EAFE) and MSCI Emerging Markets Free (EMF) (Harvey et al., 2010). The investigation resulted in Harvey et al. (2010) arguing that skewness greatly impacts a portfolio selection.

The next section touches on empirical studies pertaining to the performance of cryptocurrencies relative to traditional and alternative assets.

2.3.3. Literature that assesses risks and returns of cryptocurrencies

Brière et al. (2015) performed a study on weekly returns of Bitcoin in relation to traditional and alternatve assets from 23 July 2010 to 27 December 2013 using the OLS regressions and the Generalized Method of Moments (GMM) estimation. The assets considered were those of Bitcoin prices in USD from Bitcoincharts and money market investments. The study also considerd the Euro, Japense Yen and emerging and developing economies’ government bonds. In addition, it looked at equities and corporate and globally linked inflation bonds. Lastly, it assessed listed real estate, oil, hedge funds and gold indices. The returns in USD of the assets were assessed and obtained from Datastream. The study found Bitcoin to be very volatile and risky at 176% per annum, however, it had high average returns of 404% per annum. The Bitcoin returns were significantly different to those of hedge funds, gold and oil. Moreover, they had a very low correlation to both traditional and alternative assets returns. It was also discovered that Bitcoin is a good diversifier of investments. The inclusion of Bitcoin in an investment portfolio, at a small level, greatly increases the risk-return utility of a well-diversified investment portfolio. However, there is a caveat: as Bitcoin is still in its early stages of development, these results might change in the medium to long term (Brière et al., 2015).

Utilising univariate extreme value analysis and tail risk characteristics, an examination was done on the Group of 10 (G10) currencies and Bitcoin exchange rates. The examination was performed from September 2013 to September 2016. The results showed that Bitcoin had a larger volatility than G10 currencies. It also revealed that Bitcoin has “stronger non-normal characteristics and heavier tails” (Osterrieder & Lorenz, 2017, p. 1). This means that Bitcoin does not have a normal distribution and it has extreme cases of risk (Forsberg, 2019). Additionally, the loss from Bitcoin every 20 days was 10% on average, more than that of G10 currencies. Thus, Bitcoin was riskier than G10 currencies. The data utilised in the examination was sourced from the Baverage and CurrFX database from Quandl. This data consisted of global price indices for Bitcoin and G10 currencies (Osterrieder & Lorenz, 2017).

Rohrbach, Suremann and Osterrieder (2017) performed a study using the momentum signal, which is based on three crossovers of exponential moving averages (EMA) over numerous periods and the geometric Brownian Motion (GBM) from 1971 to 2017. The data utilised were daily exchange rates of cryptocurrencies, emerging market currencies and G10 currencies. This data were obtained from the Economic Research Federal Reserve Bank of St. Louis (FRED), Eurostat and the BNC2 database from Quandl. This study observed that G10 currencies fared worse than cryptocurrencies and emerging market currencies (Rohrbach et al., 2017).

An investigation was conducted by Lee et al. (2017) on the price and trading volume of cryptocurrencies from CoinGecko and data from Bloomberg from 11 August 2014 to 27 March 2017. The investigation analysed the co-movements between the traditional assets and cryptocurrencies using the multivariate dynamic conditional correlation (DCC) model and the Fama-MacBeth regression. The outcome was that traditional investments do not perform as well as cryptocurrencies on an average daily return. There was a low correlation between cryptocurrencies’ returns and traditional investments’ returns. The annualised Cryptocurrency Index (CRIX) return was 30.24% while that of the stock market was 0.12%. However, CRIX has a higher risk than the S&P 500. CRIX also has a high volatility and a negative skewness; this shows that the returns rise quickly but decline at a slow pace. Therefore, cryptocurrencies are a potentially reasonable investment. Cognisance must be taken of the fact that cryptocurrencies have been found to be unpredictable but they were also found to do well in diversifying traditional investment portfolios (Lee et al., 2017).

Kim et al. (2018) undertook a panel study using key summary statistics over a period of four years from 2013 to 2017. The study utilised data from the circulating supply, daily prices, volume and market capitalisation of 20 cryptocurrencies from 169 cryptocurrency exchanges. It also used the fiat currency exchange rates from Federal Reserve Economic Data (FREDA) and various countries' inflation rates from inflation.eu. The study discovered that there was an upswing in the Bitcoin (BTC) and Ethereum (ETH) price, market capitalisation and trading activities. This upswing was due to BTC and ETH being used to buy other cryptocurrencies in 2017. BTC is one of the more widely used forms of cryptocurrencies (Dandapani, 2017). While ETH is a commonly used cryptocurrency for smart contracts, cryptocurrencies were found to be volatile and unpredictable, with BTC showing a daily price volatility of 4.99% in 2017 and 8.76% in December of the same year. Commodities, on the other hand, were found to be less volatile than cryptocurrencies with gold and silver reflecting daily price volatilities of 0.68% and 1.17%. The daily price volatilities of BTC, ETH and Litecoin (LTC) outstripped those of the countries under study. With the annual inflation of Japan, US, Britain, South Africa and Mexico being 1.57%, 2.13%, 0.55%, 5.26% and 5.97% respectively, Litecoin is a cryptocurrency that can process settlements four times quicker than Bitcoin. Nevertheless, the aforementioned percentage comparisons means that BTC, ETH and LTC's purchasing power is less certain than that of the aforementioned fiat currencies. Lastly, this study illustrated that cryptocurrencies are too volatile to be considered as currencies (S. Kim et al., 2018).

There are some similarities and differences that were found between the findings of the aforementioned empirical studies on cryptocurrencies. The first similarity between the studies is that BTC is very risky and that it is riskier than G10 currencies. Cryptocurrencies were also found to be more volatile than traditional and alternative investments. Another similarity found was that there was a low correlation between cryptocurrencies, including BTC, and traditional and alternative investments, including G10 currencies. Cryptocurrencies, including CRIX and BTC, had better returns than traditional and alternative investments, including G10 and emerging market currencies (Brière et al., 2015; Lee et al., 2017; Osterrieder & Lorenz, 2017; Rohrbach et al., 2017). Cryptocurrencies were found to be a good diversifier of investments and reasonable investment (Brière et al., 2015; Lee et al., 2017). There are notable findings from the aforementioned empirical cryptocurrency studies. The first notable finding was from a study performed by Brière et al. (2015) who discovered that Bitcoin returns differed greatly from those of hedge funds, gold and oil. S. Kim et al. (2018) carried out a study comparing country annual inflations and cryptocurrency volatility but none of the other studies carried out this analysis. The study found that cryptocurrencies were more volatile than the annual inflation of Japan, US, Britain, South Africa and Mexico. Bitcoin was found not to have a normal distribution and it that it has extreme cases of risk (Forsberg, 2019).

2.4. Conclusion and knowledge gap

The MPT, which was started in 1952, captures and computes the risk and return of an investment. It also reflects the way risk relates to returns on investments. Risk, returns and the relationship between risk and returns were explored further within the CAPM in 1964 and the EMH in 1970. Furthermore, the MPT postulates that risk can be reduced by combining non-correlated securities. It also postulates that there are two types of risks, market risks and unique risks. Market risk is the risk related to the inescapable fluctuations in the market while unique risk is the risk that pertains uniquely to a specific security (Bines & Thel, 2004). In the 1990s, behavioural finance theory (BFT) went against the grain of the MPT, CAPM and EMH to follow a more sociological and psychological view (Baltussen, 2009; Lo, 2004; Malkiel, 2015). However, Lo (2004) posits that the adaptive market hypothesis (AMH) combines BFT and EMH. There were also numerous outcomes from the empirical studies.

The empirical studies were done in three parts. The first empirical studies assessed the techniques utilised in assessing the risks and returns of traditional investments. Overall, these found that the systematic risk was explained by standard errors of estimate and the risk-free rate was less than the residual risk; diversification of a portfolio cannot significantly reduce the market and residual risk; net returns of mutual funds in relation to the risk-return amount was below that of the market; and mutual funds are overall less than those held in market indexed investments. Moreover, the empirical studies showed that returns are at their greatest level in January for small companies and low rated bonds; risk was found to be time-dependent and predictable; investors do not need assured returns; returns are too low for investment portfolios with high betas; returns were too high for investment portfolios with low betas; and, where risk is too great, the investor will not make an investment (Bollerslev et al., 1988; Fama, 1970; Fama & French, 2004; Jensen, 1969; Keim & Stambaugh, 1986; Lintner, 1965; H. M. Markowitz, 1991; Pfiffelmann et al., 2016).

The second empirical studies comprised the comparison of traditional and alternative investments. These studies showed that there is a weak relationship between the equity risk premium and the miniscule mutual funds held in US shares; market returns exceed funds flowing from stocks; and skewness greatly impacts a portfolio selection (Harvey et al., 2010; Karceski, 2002).

The third and final set of empirical studies was those of cryptocurrencies in comparison to traditional and alternative assets. These studies revealed that Bitcoin is highly volatile and risky; it has high average returns and a very low correlation to both traditional and alternative assets; cryptocurrencies are a potentially decent investment; cryptocurrencies and emerging market currencies performed better than G10 currencies; Bitcoin is riskier that G10 currencies; and cryptocurrencies are too volatile to be considered as currencies (Brière et al., 2015; S. Kim et al., 2018; Lee et al., 2017; Osterrieder & Lorenz, 2017; Rohrbach et al., 2017). Nonetheless, very few of these empirical studies focused on emerging economies, let alone Africa. Some of the empirical studies included the Rand as a currency however, they did not focus on comparing the performance of African or South African listed shares to cryptocurrencies. Herein lies a gap to study South African assets.

Bitcoin was too volatile but it also had high average returns. Since Bitcoin is still in its early stages of development, these results will most likely change over the medium term (Brière et al., 2015). There is limited empirical research on Bitcoin being used as an investment. There are also limited studies on its ability to diversify an investment portfolio (Brière et al., 2015). The empirical literature has not compared the performance of South African listed shares to cryptocurrencies. This study seeks to address this gap in knowledge. The research methodology pertaining to addressing this knowledge gap is discussed below.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

Leacock et al. (2015) state that research papers should consist of a theoretical framework that drives the research project. Therefore, the methodology is structured to meet the objectives and test the hypothesis of this study. Overall, it seeks to assess whether cryptocurrencies improve the portfolio of traditional and alternative investments and assesses whether cryptocurrencies outperform alternative and traditional assets in South Africa. This chapter's layout begins with the research approach and strategy, which is followed by the explanation of the data collection, period and sampling. Thereafter, a discussion of the analytical framework is followed by the research reliability and validity. The research methodology then concludes with the limitations encountered during the study.

3.2. Research approach and strategy

This study used the quantitative research approach and strategy. The empirical research performed was statistical modelling, computer simulated studies and secondary data analysis. The research design used was multifaceted, in that it consisted of the mean-variance (MV) analysis, the Sharpe ratio, the conditional value-at-risk (CVaR) analysis and the regression test. The MV analysis and Sharpe ratio were used to assess whether cryptocurrencies had greater returns in relation to risk than South African traditional and alternative assets. The MV analysis was also used to assess whether cryptocurrencies are a good diversifier of portfolios of South African investments. The efficient frontier with and without the Cryptocurrency index (CRIX) and the optimal portfolio are analysed as part of the MV analysis. The Sharpe and Sortino ratios are also used to enhance the analysis of the efficient frontier with and without the CRIX. While the Sharpe and Sortino ratios both measure the performance of investments, the Sortino ratio differs from the Sharpe ratio as it measures the downside of risk. This means that, while the Sharpe ratio focuses on both upside and downside risks, the Sortino ratio measures the risk should an asset not reach its target returns (Rollinger & Hoffman, 2013). The CVaR analysis, calculated at a specific significance level, was performed to assess whether a portfolio of investments that consisted of cryptocurrencies still produced an efficient frontier that was not too different from one of a MV analysis. The spanning test was used to assess whether cryptocurrencies have diversification benefits individually. The research design utilised in this investigation was based on studies by Brière et al. (2015), Kan and Zhou (2012) and Lee et al. (2017).

The data collection and period of study are discussed below.

3.3. Data collection and time period

Secondary data were used in this study. This data were numeric time series data (Mouton, 2015). The units of analysis are financial assets and cryptocurrencies. The data are used to assess these units of analysis. The data sourced consisted of time series data being the daily historical closing prices of financial assets and cryptocurrencies from 10 August 2015 to 31 October 2018. The data were extracted from 10 August 2015, as this was the date that the daily historical closing price of Ethereum was available from the very beginning of the trading week of traditional assets. Ethereum was only released to the public from 31 July 2015 (Coinmama, 2019). Referring to Table 9, Ethereum had to be included within the testing as it was the second largest cryptocurrency on 1 October 2018 and it formed 13.28% of the market capitalisation of 10 cryptocurrencies that were included in the Cryptocurrency index (CRIX) on 1 October 2018. The data were sourced from the Iress Expert database for South African financial assets, the investing.com website for 3-Year South African government bonds, the CoinMarketCap website for cryptocurrencies and http://crix.hu-berlin.de website for the CRIX. Iress is an Australian company that houses an electronic financial asset database and it has footprints in South Africa, Australia, Canada, New Zealand, the United Kingdom, Hong Kong and Singapore (Iress, 2019). CoinMarketCap is a well-known online cryptocurrency trading database that provides access to trading data for 289 cryptocurrencies from numerous cryptocurrency exchanges from across the globe (Coinguides, 2019; CoinMarketCap, 2018). CRIX is a German based cryptocurrency index that was constructed and is maintained by various academics, technologists and economists from Humboldt University, Singapore Management University and CoinGecko (Härdle, Trimborn, et al., 2018). CoinGecko is a financial trading web based database (CoinGecko, 2019). Data were sourced by accessing electronic databases and websites. There is however, a caveat in relation to secondary data, as their validity and reliability had to be determined. The data that were sourced was available for most periods under analysis, if not all, for most financial assets and cryptocurrencies. The following section will focus on sampling and the choice of data.

3.4. Sampling and choice of data

As there were two units of analysis in this study, there were two populations that were analysed. The two sets of populations that were studied were cryptocurrencies and financial assets from a South African investors' perspective. Traditional and alternative assets have been categorised under one unit of analysis, as financial assets, similar to the categorisation of the studies carried out by Brière et al. (2015) and Lee et al. (2017). The period of study was in days from 11 August 2015 to 31 October 2018. However, weekends and South African public holidays during this period were excluded, as trading of traditional assets does not occur during this period (JSE, 2018a, 2018c, 2018b). A non-probability sampling technique, being purposive sampling, was used. This technique allows for the selection of specific samples in order to test the constructs of the study (Gay, Mills, & Airasian, 2012; Leacock et al., 2015). The financial assets selected consisted of both traditional and alternative assets that would realistically be included in an investment portfolio. The traditional assets consisted of South African listed shares and government bonds while the alternative assets selected were gold, oil, platinum and South African listed property and resources. These alternative and traditional assets were classified in a similar manner, as per the research carried out by Brière et al. (2015) and Lee et al. (2017). Gay et al. (2012) posit that, with a large population, a 400 sample size would suffice, but a 500 sample size would add credence (Leacock et al., 2015). However, Lee et al. (2017) had a sample size that spanned the daily prices from 11 August 2014 to 27 March 2017, which is far greater than 500. Therefore, the sample size for this study was 800. As some samples had missing values, using the listwise deletion technique, eight of the observations with missing values were deleted to get to the sample size (Alhassan, 2017). The analytical framework will now be discussed.

3.5. Data analysis methods and analytical famework

3.5.1. Description and measurement of variables

The description and measurement of the variables articulates the reasoning behind the selection of independent and dependent variables. It also reflects on the measurement of the variables. The data collected were daily asset prices. However, daily asset returns were required for testing in the study. The calculation of arithmetic returns is represented as follows:

$$r_{i(t)} = \frac{P_{i(t)} - P_{i(t-1)}}{P_{i(t-1)}} \quad (1)$$

where r_{it} is the arithmetic rate of return for the period for ith financial asset or cryptocurrency, P_t is the price of the ith financial asset or cryptocurrency for period t and P_{t-1} is the price of the ith financial asset or cryptocurrency for period t-1.

Historical asset returns have a downward bias. Therefore, arithmetic returns, rather than geometric returns, have been used because they balance this out with their upward bias (Levy & Sarnat, 1970). Downward bias refers to the fundamental judgment in which the returns move downwards in the market ("Downward bias," 2019). These returns were calculated using Microsoft Excel, after the US dollar denominated financial asset and cryptocurrency prices were converted into South African Rands. This resulted in the calculation of the variables of the study, being the daily arithmetic return of each asset. Cryptocurrency and alternative asset returns have been found to be uncorrelated to traditional assets. However, Brière et al. (2015) found that cryptocurrencies have different statistical characteristics from oil, gold and other assets. They have also been found to be more volatile but often result in greater returns than traditional assets (Brière et al., 2015; Härdle, Lee, Nasekin, & Petukhina, 2018; Srilakshmi & Karpagam, 2017).

The study seeks to determine whether cryptocurrencies will improve the portfolio of traditional and alternative assets. It also seeks to assess the diversification benefits of cryptocurrencies in a portfolio of traditional and alternative investments. Moreover, the study also assesses the performance of cryptocurrencies in relation to traditional and alternative assets. Similar investigations, performed by Brière et al. (2015), Kan and Zhou (2012) and Lee et al. (2017), classified independent and dependent variables, as well as benchmark and test assets based on the potential diversification benefits of either cryptocurrencies or international financial assets. The alternative, traditional and domestic assets were classified as independent variables and benchmark assets, while cryptocurrencies and international assets were classified as dependent variables and test assets. Therefore, this study followed the same mode of classification from a South African investor's perspective. Refer to Table 1 below for more details as to how these assets are classified and to Appendix 2 for the definitions of each type of individual variable and asset.

Table 1: Variable description, asset names and types

Asset types	**Asset names**	**Variables descriptions**
Traditional assets	JSE All Share, JSE Top 40, JSE Alternative Exchange and South African government bond.	Daily returns of the assets.
Alternative assets	JSE SA Listed Property, JSE SA Resources, gold, Platinum, Brent Crude oil and South African Rand.	Daily returns of the assets.
Cryptocurrencies	CRIX, Bitcoin, Ethereum, XRP, Dash, NEM, Stellar, Litecoin, Dogecoin, Tether and Monero.	Daily returns of the assets.

Source: Data from author's computations.

3.5.2. Empirical model and estimation approach

3.5.2.1. Mean-variance analysis and Sharpe ratio

The strength of the MV analysis is that it assesses the return in relation to the risk of each asset, while considering the risk and return of the other assets within the portfolio of investments. This is done to optimise the portfolio of investments (Litterman, 2003d; Malkiel, 2015). Its weaknesses are that it is restricted as it does not account for high moments risks due to skewness and kurtosis, and it results in large asset weights for unconstrained mean-variance optimal portfolios (Lee et al., 2017; Litterman, 2003a).

The approach used for the MV analysis was the expected utility function that was utilised to construct the mean-variance efficient frontier, is represented as follows:

$$E\left[u\left(r_p(\omega)\right)\right] = E\left[r_p(\omega)\right] - \lambda E[(r_p(\omega) - E[r_p(\omega)])^2] \quad (2)$$

and the MV was optimised using:

$$\max_{\omega \epsilon \Omega} \Phi(\omega) := \omega_{p(\omega)} - \lambda \sigma_p^2(\omega) = \alpha^T \omega - \lambda \omega^T \Sigma \omega \quad (3)$$

where ω is the weight of the funds invested in asset i, r_p is the total return of the portfolio, $u\left(r_p(\omega)\right)$ is the utility function that measures $r_p(\omega)$, λ is the risk-aversion coefficient that accounts for the deviation of the returns from the mean, Φ is the risk-adjusted expected return function and σ_p^2 is the standard deviation of the portfolio (Tutuncu, 2012). Utility refers to the gains derived from an investment portfolio (*Utility Theory: Describing investors' relationship with risk*, 2019). During the analysis, either the Sharpe ratio was maximised or a particular risk rate was targeted (Jorion, 1992; Kan & Zhou, 2012). The MV analysis was computed using Matlab and there was no shorting of investments.

The Sharpe ratio is a performance measurement technique that is represented using the following formula:

$$SR_i = \frac{\mu_i - R_f}{\sigma_i} \quad (4)$$

where μ_i is the mean or the return of the investment or portfolio, R_f is the risk-free rate of return and σ_i is the investment or portfolio volatility (Cowell, 2013; Howard & Lax, 2003).

The Sharpe ratio determines how much excess return an investment provides above the risk-free rate for each unit of volatility. Although the Sharpe ratio is a performance measurement technique that is often used, it does have some weaknesses. The first weakness is that it only considers asset risks and returns and does not account for liabilities. It does not differentiate between downside and upside volatility. Another weakness is that extremely high returns result in a greater increase of σ_i than of $\mu_i - R_i$. It does not perform well for returns that have non-normal distributions (Howard & Lax, 2003; Rollinger & Hoffman, 2013).

3.5.2.2. Conditional Value-at-risk analysis

The auxiliary function used to construct the CVaR efficient frontier is as follows:

$$F_\alpha(\omega, \gamma) := \gamma + \frac{1}{1-\alpha} \int_{f(\omega,r) \geq \gamma} (f(\omega, r) - \gamma) p(r) dr \quad (5)$$

which allowed the study to set a target risk for the efficient frontier for a portfolio of investments with n-dimensional vector below:

$$\min_{\omega_t \epsilon R^P} CVaR_\alpha(\omega_t) = \min_{\omega_t \epsilon R^P, \gamma} F_\alpha(\omega, \gamma)$$

(6)

$$\min_{\omega_t \epsilon R^P} CVaR_\alpha(\omega_t) \qquad (7)$$

$$s.t. u_{p,t}(\omega_t) = r_{Target} \qquad (8)$$

$$\omega_t \, 1_p = 1 \qquad (9)$$

$$\omega_{i,t} \geq 0 \qquad (10)$$

where r is the returns of the assets, $p(r)$ is the probability density function of r, $\varphi(\omega, \gamma) := \int_{f(\omega,r)\geq\gamma} (f(\omega, r) - \gamma) p(r) dr$ is the cumulative distribution function of ∫, α is the probability level, r_{Target} is the target risk or significance level, R^P is the constraints of the portfolio, α is the probability level, $\omega_{i,t} \geq 0$ represents no shorting of assets and $\omega_t \, 1_p = 1$ represents investing 100% of the funds in the portfolio. CVaR allows this study to account for the expected amount of loss that exceeds the VaR loss (Lee et al., 2017; Tutuncu, 2012). CVaR was computed using Matlab.

Measures of risk are helpful in optimising portfolios where there is uncertainty and potential losses. The CVaR and VaR are measures of risk. However, the VaR is not stable and it is not easy to utilise when there is extreme risk and when losses are non-normal. Another weakness of VaR is that it does not provide for losses than can be made beyond the amount specified by VaR. VaR is more geared towards the optimisation of portfolios than allowing for conservative risk management of a portfolio. The CVaR overcomes the weaknesses of the VaR (Rockafellar & Uryasev, 2002). The CVaR's advantages are that it can be utilised to measure large amounts of risk, estimate the chances of the target return being fulfilled and the CVaR, which is also known as the Expected Shortfall (ES) and Expected Tail Loss (ETL), shows the expected extreme loss of an investment (Cowell, 2013). In portfolio optimisation, the CVaR allows for the minimisation of the risk, while targeting a specific return. It also allows for the minimisation of the return based on a constraint of the CVaR and it permits the maximisation of CVaR in relation to return (Rockafellar & Uryasev, 2002). Its disadvantage is that it does not naturally account for the higher moments, being skewness and kurtosis (Amédée-manesme, Barthélémy, & Maillard, 2018; Lee et al., 2017). If a specific return is targeted for both the MV and CVaR analyses, the composition of the portfolio will be the same using both research designs. However, the weights within the portfolios will differ between the MV and CVaR analyses (Miskolczi, 2016).

3.5.2.3. Spanning test

To assess the performance of cryptocurrencies in relation to alternative and traditional assets within a portfolio of investments, the regression test below was used.

$$R_{2t} = \alpha + \beta R_{1t} + \varepsilon_t \qquad t = 1,2, \ldots T \tag{11}$$

where R_{2t} is the N-vector returns on N test assets (being the respective cryptocurrencies), R_{1t} is the K-vector returns on the K benchmark assets (being the alternative and traditional assets), ε_t is the error term, α is a coefficient and t represents time which is in days (Brière et al., 2015; Kan & Zhou, 2012).

The expected returns of N test + K benchmark assets are:

$$\mu = E[R_t] = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \tag{12}$$

and the covariance matrix of N test + K benchmark assets is:

$$V = Var[R_t] = \begin{bmatrix} V_{11} & V_{12} \\ V_{21} & V_{22} \end{bmatrix} \tag{13}$$

and

$$\Sigma = V_{22} - V_{21} V_{11}^{-1} V_{12} \tag{14}$$

In obtaining the "exact distributions of the test statistics" that are assumed "conditional on R_{1t}, the disturbances ε_t are independent and identically distributed as multivariate normal with mean zero and variance Σ" (Kan & Zhou, 2012, p. 144). The regression model is based on the CAPM and MPT (Cowell, 2013). The cryptocurrencies, alternative assets and traditional assets that form part of the test and benchmark assets.

The spanning test that was used is the Huberman and Kandel (1987) multivariate OLS regression Wald test, which was computed using SAS. The strength of Huberman and Kandel's (1987) multivariate OLS regression Wald test is that it is easier to perform than its counterparts, the Lagrange Multiplier test and the Likelihood Ratio test. Alternatively, the Lagrange Multiplier (LM) or the Likelihood Ratio (LR) test could have been used, although these tests are not completely equivalent in rejecting or accepting the null hypothesis. The Lagrange Multiplier (LM) test performs better under asymptotic spanning tests but only when T is not tiny and the Wald test performs better for finite samples in testing. However, its disadvantage is that it sometimes results in a Type I error. T is the amount of time in a time series (Kan & Zhou, 2012). Therefore, the Wald test was chosen due to the statistical software capabilities of this test.

"The necessary and sufficient conditions for spanning in terms of restrictions" (Brière et al., 2015, p. 368; Kan & Zhou, 2012, p. 142) are:

$$H_0\colon \alpha = 0 \text{ and } \beta 1_k = 1_N \qquad (15)$$

where (15) suggests the mean-variance spanning and implies that, for each N test asset, there is a portfolio of the K benchmark assets that has the same mean but smaller variance than the test assets (Brière et al., 2015; Kan & Zhou, 2012). The Wald statistic test has the asymptotic distribution:

$$W = T(\lambda_1 + \lambda_2) \sim \chi^2_{2N} \qquad (16)$$

where:

$$\lambda_1 = max_r \frac{1+\theta_2^2(r)}{1+\theta_1^2(r)} - 1 \qquad (17)$$

$$\lambda_2 = max_r \frac{1+\theta_2^2(r)}{1+\theta_1^2(r)} - 1 \qquad (18)$$

and $\theta_2^2(r)$ and $\theta_1^2(r)$ are the Sharpe ratios for the risk-free rate, while the portfolio consists of K benchmark assets and N test assets (Brière et al., 2015; Kan & Zhou, 2012).

N = 1 and thus the F-test is:

$$\left(\frac{1}{U}-1\right)\left(\frac{T-K-1}{2}\right) \sim F_{2,T-K-1} \quad (19)$$

The regression test is run multiple times with N = 1. This is done by running the regression multiple times with different cryptocurrencies and CRIX, to assess whether each cryptocurrency has diversification advantages. This was done as CRIX is overwhelmed by Bitcoin, with Bitcoin making up 64.51% of CRIX (refer to Appendix 1 for further details). Now that the analytical framework has been discussed, the following section will focus on research reliability and validity.

3.6. Research reliability and validity

A quantitative research method was used to analyse the data. Secondary data analysis was used and selected because of time and funding, and because, according to the researcher's knowledge to date, there is a need to assess the performance of cryptocurrencies relative to South African traditional and alternative assets quantitatively. Brière et al. (2015) performed a study on Bitcoin's performance and characteristics as an investment and diversification asset for the US investor. Furthermore, Lee et al. (2017) performed a study on cryptocurrencies as a diversification asset in relation to traditional and alternative assets, but not from a South African investor's perspective. Data existed that were useful to testing the constructs of this study, and this data were used. With secondary data, the reliability and vitality of data were more difficult to ascertain.

As this study used secondary data, it was unable to control the mistakes made in the collection of the original data. In addition, this study was limited to the data collected by the original data collectors' aims therefore there might be mistakes that relate to the analysis of the background of the data in comparison to the original data collectors' intentions. However, secondary data can still be deemed reliable and valid by verifying the author's reputation; the time period over which the data was collected; and the location from which the data originates (Leacock et al., 2015; Mouton, 2015). Therefore, the data sourced were verified using the author's reputation, the reputation of the source, the period over which the data related, the plausibility of this time collection period and the location from which it was sourced. More limitations will be discussed in relation to the study.

3.7. Research limitations

There were limitations and challenges in obtaining data and using the statistical design. The first limitation was the limited access to data because cryptocurrencies and the internet are recent. No data were collected on a country wide and regional level for cryptocurrencies, as global data have been collected for Bitcoins and other cryptocurrencies. Therefore, the study was limited, as it could not filter the data for Bitcoins and cryptocurrencies to a country wide or regional level. Due to these issues, the cryptocurrencies and CRIX data within the study are based on a global context. Cryptocurrencies are mainly used in developed countries and thus may not yet be a widely-used investment tool in South Africa. The second limitation was the lack of availability of the weighting of the top 10 cryptocurrencies that made up CRIX throughout the period of testing, as recommended by Lee et al. (2017). However, the composition of the top 25 cryptocurrencies was available on set dates. The composition of CRIX during the period of testing consisted of cryptocurrencies that were not fully available during the entire testing period as many cryptocurrencies were only formed during the period of testing. This necessitated excluding some of these cryptocurrencies from the regression testing, as they did not exist for the entire period of testing from 11 August 2015 to 31 October 2018. Moreover, the 10 cryptocurrencies within the top 20 cryptocurrencies were used for testing in this study based on the market capitalisation on 1 October 2018. For further details on the 10 individual cryptocurrencies included in the study, refer to Appendix 1 (CoinMarketCap, 2018). These cryptocurrencies formed part of the top 25 cryptocurrencies that made up CRIX on 1 October 2018 (Chen, Chen, Härdle, Lee, & Ong, 2016; Härdle, Trimborn, et al., 2018). The third limitation was the lack of the inclusion of the third and fourth moments, being skewness and kurtosis, respectively, which could not be incorporated within the CVaR efficient frontier construction, as per the Cornish-Fisher expansion and Lee et al. (2017). This limited the study as it could not fully assess the CVaR efficient frontier that accounted for high-moments risk and therefore the study could not fully account for the complete risk within the CVaR efficient frontier. However, the CVaR was constructed at the targeted risk (Lee et al., 2017), as per the resources available to the researcher.

The fourth limitation was the lack of testing of data relating to a drastic 35% decline in cryptocurrency prices during November 2018. This was due to time constraints and also because November 2018 was beyond this study's period of testing (Ouimet, 2018). The fifth limitation was that the regression testing for this study did not include the spanning step-down testing that deals with the problem of the Huberman and Kandel (1987) multivariate OLS regression Wald test sometimes resulting in a Type I error. This was not performed due to limitations in the researcher's knowledge of the implementation of the step-down test using SAS. Moreover, the general method of moments (GMM) Wald spanning test, which accounts for excess kurtosis, and the fat tail risk of stock returns were not performed, also due to a limited knowledge of performing the GMM Wald test for time series data (Kan & Zhou, 2012). Nevertheless, the researcher performed testing using the Huberman and Kandel (1987) multivariate OLS regression Wald test, the mean-variance analysis and the CVaR efficient frontier, which assisted in meeting the objectives of the study (Brière et al., 2015; Kan & Zhou, 2012; Lee et al., 2017). The sixth limitation was the time period of the study, which could be deemed short, in order to explore the investment performance of cryptocurrencies fully in light of traditional and alternative assets (Brière et al., 2015; Lee et al., 2017). The seventh limitation relates to the possible duplication of the JSE South African listed companies across the various indices utilised in the study, which could not be accounted for due to time constraints. Therefore, there could be a higher concentration of some companies in the study than others. The next section discusses ethical considerations.

3.8. Ethical considerations

The ethical considerations within this study were not significant however an ethical consideration was still present. The ethical consideration that was noted within this study related to the utilisation of secondary data. The data were obtained from the internet and online through publically available databases and websites. Therefore, no permission from the supplier of the data was required nor was it sought.

3.9. Conclusion

This chapter highlighted the importance of the research methodology in meeting the objectives of the study. Statistical modelling and secondary data analysis was carried out by utilising the MV analysis, CVaR analysis and OLS regression Wald test. These were performed by Matlab, SAS, Microsoft Excel and SPSS Statistics statistical software. Time-series data that spanned from 11 August 2015 to 31 October 2018 were utilised. This data were selected using purposive sampling. Moreover, there were a combination of 21 independent and dependent variables that were utilised. Due to various reasons, there were numerous research limitations that were experienced. The following chapter seeks to discuss the findings of this investigation.

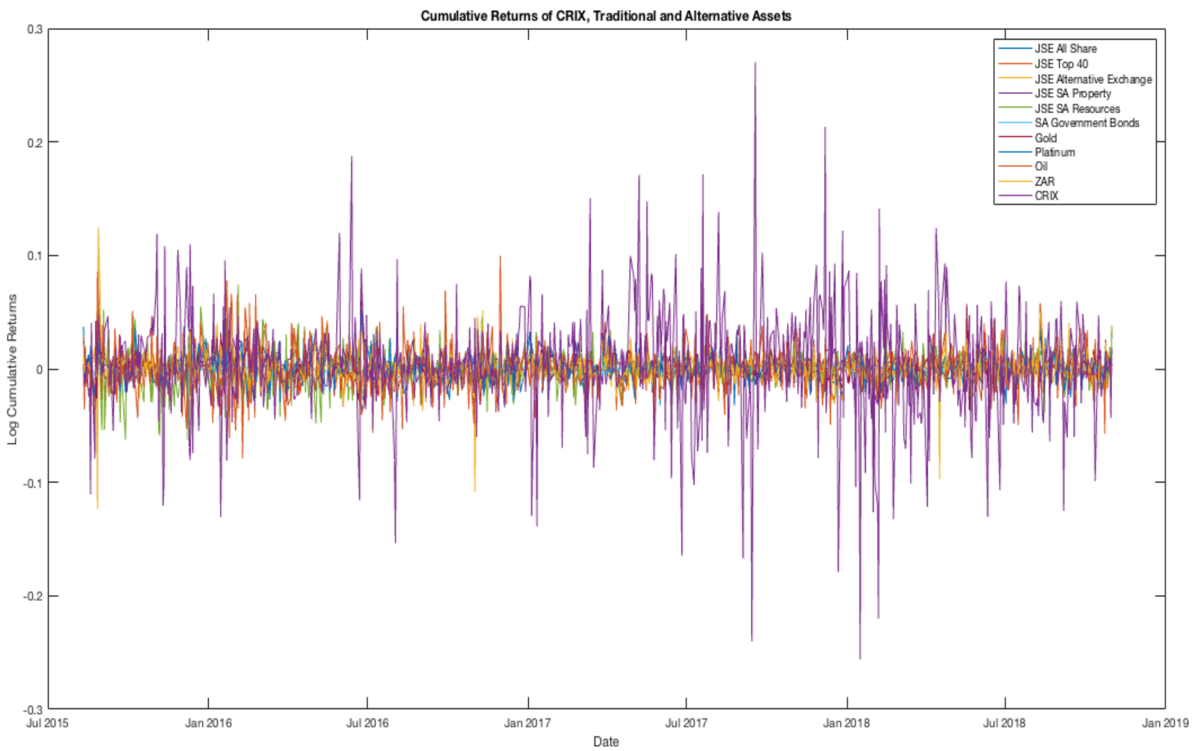
CHAPTER 4: DISCUSSION OF FINDINGS

4.1. Introduction

This chapter presents the findings and analysis, which are based on the empirical investigations that were performed. The discussion of findings consists of seven sections. The first section is the trend analysis of the log cumulative returns, this is followed by the descriptive statistics which assessed the characteristics of the variables and thereafter the relationships between the variables are assessed. The fourth section is the MV analysis, which is followed by the CVaR analysis, and a discussion and analysis of the spanning test. The last section, concludes the findings and the analysis.

4.2. Trend analysis

Figure 5: Cumulative returns of CRIX, traditional and alternative assets



Source: Data from author's computations and Matlab output.

In Figure 5, log cumulative returns are used for the trend analysis, similar to studies by Brière et al. (2015) and Lee et al. (2017). However, this study used an arithmetic rate of return based on the daily historical closing prices for all the testing performed other than for the trend analysis. The studies performed by Brière et al. (2015) and Lee et al. (2017) used weekly returns and average daily returns for all the testing performed other than for the trend analysis. This directed the use of log cumulative returns in the trend analysis and arithmetic rate of return being used for all the other tests performed in this study. The log cumulative returns are used within the study by Brière et al. (2015). Cumulative returns refer to the returns over a period of time determined as between the initial period and the end of the period under study. Cumulative returns are the overall effect of change in price on investment based on the fluctuations of an investment (Damon, 2019; Dumotier, 2019). Cumulative returns have been defined as the overall value of an investment that has increased or decreased by over time. This increase or decrease is dependent on the period of time over which the change occurs (Chen, 2019). Therefore, cumulative returns can be calculated over days, weeks, months or years. Brière et al. (2015) used weekly cumulative returns, although the labelling of the x-axis in the trend analysis graph used months. Lee et al. (2017) labelled the x-axis of the trend analysis graph in years but did not give the cumulative return period used. Therefore, similar to the study carried out by Brière et al. (2015) that used the same period for the trend analysis and the testing performed for all the other tests carried out in the study, this study used same period for the trend analysis and the testing performed for all the other tests carried out in the study.

In Figure 5, daily log cumulative return graphs of CRIX and the traditional and alternative assets from 11 August 2015 to 31 October 2018 were created to analyse the trend of the various financial assets over time. Refer to Appendix 3 for a breakdown of each asset's daily log cumulative returns graph. As per Figure 5 and Figures 10 to 20 in Appendix 3, the returns of the assets oscillate and are symmetric around zero. The returns of bonds, property and JSE Alternative Exchange index (AtlX) move mainly between 0.05 and -0.05, very close to zero, below 0.05 and -0.05 and 0.02 and -0.02 respectively. These also show that the returns of bonds, property and AtlX are less volatile and lower on average than those of the other assets. The returns of JSE All Share index (ALSI), gold, platinum, oil, resources, Top 40 and ZAR move between 0.08 and -0.06 and they were more volatile and higher on average than bonds, property and AltX. The CRIX returns moved between 0.2 and -0.2 for most of the period and 0.3 and -0.3 between late 2017 and early 2018 and then moved back to between 0.2 and -0.2 after early 2018 after significant price adjustments in cryptocurrencies. Thus, CRIX has the highest volatility and returns in comparison to the other assets. As found by Kim et al. (2018), there was an upswing in the BTC and ETH price that was caused by BTC and ETH being used to buy other cryptocurrencies in 2017. As per a study by Lee et al. (2017), cryptocurrencies average daily returns exceeded those of traditional assets while a study by Brière et al. (2015) found that BTC cumulative weekly returns exceed those of other assets on average. Therefore, based on current and prior studies, the cumulative log returns and volatility of CRIX and cryptocurrencies, on average, exceed those of traditional and alternative assets. Descriptive statistics will now be discussed below.

4.3. Descriptive statistics

Table 2: Descriptive statistics for daily returns of traditional and alternative assets

	All [a]	Top40 [a]	AltX [a]	Property [a]	Resources [a]	Bonds [a]	Gold	Platinum	Oil [a]	ZAR [a]
Mean	0.01%	0.01%	-0.04%	-0.03%	0.04%	0.03%	0.04%	0.01%	0.10%	0.03%
Annual mean	1.41%	1.27%	-9.82%	-7.68%	9.26%	8.13%	10.23%	2.77%	24.09%	6.55%
Median	0.04%	0.03%	-0.02%	0.01%	0.08%	0.04%	0.04%	0.02%	0.05%	-0.04%
Standard deviation	0.99%	1.07%	1.14%	1.07%	1.72%	0.21%	1.25%	1.29%	2.11%	1.15%
Variance	0.01%	0.01%	0.01%	0.01%	0.03%	0.00%	0.02%	0.02%	0.04%	0.01%
Minimum	-3.56%	-3.97%	-11.60%	-7.72%	-6.27%	-2.46%	-6.20%	-4.25%	-7.59%	-5.09%
Maximum	3.72%	3.97%	13.27%	7.61%	7.71%	1.44%	7.31%	5.30%	10.45%	5.09%
Skewness	-0.0809	-0.0550	-0.5111	-0.1653	0.0041	-2.2300	0.3946	0.2301	0.3559	0.2864
Kurtosis	1.0478	1.0898	50.1184	11.4181	1.4832	31.2595	2.8043	0.3803	1.7130	1.2491
One-lag autocorrelation	-0.0220	-0.0393	-0.2601	0.0459	0.0553	0.1140	-0.0188	-0.0549	0.0291	0.0369
Observations	800	800	800	800	800	800	800	800	800	800

Source: Data from author's computation and SPSS Statistics output.

[a] Note: All = JSE All Share index, Top40 = JSE Top 40 index, AltX = JSE Alternative index, Property = JSE SA Property index, Resources = JSE SA Resources index, Bonds = SA Government Bonds, Oil = Brent Crude oil and ZAR = South African Rand.

Table 3: Descriptive statistics for daily returns of CRIX and cryptocurrencies

	CRIX	BTC [b]	ETH [b]	XRP	Dash	NEM	XLM [b]	LTC [b]	Doge [b]	Usdt [b]	XMR [b]
Mean	0.57%	0.53%	0.96%	0.93%	0.74%	1.57%	1.25%	0.60%	0.81%	0.03%	1.05%
Annual mean	142.82%	132.34%	242.70%	233.47%	186.51%	396.24%	315.49%	150.55%	203.99%	6.84%	263.65%
Median	0.52%	0.45%	0.12%	-0.28%	0.13%	-0.14%	-0.68%	-0.14%	-0.10%	-0.05%	0.00%
Standard deviation	4.81%	4.83%	9.14%	9.92%	7.10%	14.20%	14.34%	7.84%	9.82%	1.35%	9.65%
Variance	0.23%	0.23%	0.84%	0.98%	0.50%	2.02%	2.06%	0.61%	0.97%	0.02%	0.93%
Minimum	-22.60%	-20.98%	-60.90%	-29.96%	-22.83%	-29.88%	-30.62%	-32.77%	-39.02%	-7.36%	-25.55%
Maximum	31.01%	30.49%	67.50%	114.97%	47.51%	169.63%	272.00%	71.57%	124.43%	6.60%	104.18%
Skewness	0.1642	0.5174	1.0421	4.1632	1.2775	5.2624	9.6281	3.3969	4.4427	(0.0437)	3.0169
Kurtosis	5.3541	5.7265	9.4996	33.6579	6.2524	49.1036	164.4675	26.4026	44.0225	2.7714	24.3495
One-lag autocorrelation	(0.0005)	0.0015	0.0766	0.1708	(0.0110)	(0.0755)	0.0961	0.0755	0.0379	(0.0309)	0.0085
Observations	800	800	800	800	800	800	800	800	800	800	800

Source: Data from author's computation and SPSS Statistics output.

[b] Note: BTC = Bitcoin, ETH = Ethereum, XLM = Steller, LTC = Litecoin, Doge = Dogecoin, Usdt = Tether and XMR = Monero.

Refer to Table 2 and Table 3 for the discussion of the descriptive statistics. The annual mean of traditional and alternative assets is low, with most of the annual means being positive or negative single digit returns on assets whereas the annual mean of CRIX and cryptocurrencies are all positive triple digits. Therefore, the annual means of CRIX and cryptocurrencies are high and far exceed those of the relatively low returns of alternative and traditional assets. This suggests that the annual returns of cryptocurrencies are very high in relation to traditional and alternative assets. These results are supported by the studies carried out by Brière et al. (2015) and Lee et al. (2017). The standard deviations and variances of the alternative and traditional assets are low in comparison to those of CRIX and cryptocurrencies, which are high. Therefore, the risk of cryptocurrencies largely exceeds that of alternative and traditional assets. Most traditional and alternative assets have a skewness of between 0.5 and -0.5, with the exception being bonds with skewness of -2.23. This means that most of these assets are relatively symmetric. Most cryptocurrencies have skewnesses of above 0.5, which means that the data is heavily skewed (McNeese, 2016). This positive skewness also illustrates that returns increase rapidly and drop at a slow pace. Similar results were found in the studies performed by Brière et al. (2015) and Lee et al. (2017). Kurtosis of most traditional and alternative assets is lower than three, with AltX, Prop and bonds being exceptions, with kurtosis exceeding 11.42. The lower than three kurtosis suggests that most of these assets' returns are platykurtic. Moreover, the kurtosis of CRIX and all the cryptocurrencies also exceeds three. This means that returns of these assets are leptokurtic and subject to fat-tailed or extreme cases of risk (Forsberg, 2019) while the low one-lag autocorrelation for all the assets reflects a lack of predictability of the returns. This finding is similar to that of Lee et al. (2017).

4.4. Correlation analysis

Table 4: Pearson correlation matrix

	All	Top40	AltX	Prop	Res	Bonds	Gold	Plat	Oil	ZAR	CRIX	BTC	ETH	XRP	Dash	NEM	XLM	LTC	Doge	Usdt	XMR
All	1																				
Top40	.994**	1																			
AltX	0.044	0.037	1																		
Prop	.488**	.441**	-0.002	1																	
Res	.660**	.651**	-0.013	.110**	1																
Bonds	.198**	.156**	0.004	.462**	-0.021	1															
Gold	-.147**	-.133**	-0.006	-.296**	.078*	-.407**	1														
Plat	0.031	0.031	-0.010	-.154**	.253**	-.227**	.730**	1													
Oil	.238**	.248**	0.017	-0.038	.342**	-.128**	.185**	.239**	1												
ZAR	-.109**	-.078*	0.018	-.296**	0.015	-.524**	.774**	.508**	.284**	1											
CRIX	0.010	0.013	-0.012	-0.062	0.016	-.137**	.153**	.098**	.089*	.197**	1										
BTC	-0.014	-0.008	-0.015	-.077*	0.003	-.158**	.164**	.100**	.082*	.225**	.711**	1									
ETH	-0.067	-0.068	0.018	-0.040	-0.042	-.070*	.086*	0.053	-0.022	.097**	.397**	.370**	1								
XRP	0.020	0.023	-0.004	-0.028	-0.005	-0.068	.101**	.078*	0.045	.117**	.317**	.309**	.196**	1							
Dash	0.039	0.041	0.053	-0.035	0.030	-0.063	.071*	0.034	.100**	.126**	.401**	.464**	.423**	.242**	1						
NEM	0.007	0.010	-0.036	-0.017	0.002	-0.033	.083*	0.031	.075*	.091**	.253**	.278**	.161**	.295**	.262**	1					
XLM	-0.027	-0.028	0.033	-0.017	-0.037	-0.034	.083*	0.067	0.051	.095**	.311**	.301**	.169**	.596**	.218**	.360**	1				
LTC	0.000	0.009	0.008	-0.041	0.016	-0.068	.114**	.072*	.072*	.166**	.418**	.521**	.312**	.330**	.411**	.271**	.274**	1			
Doge	-0.018	-0.025	0.047	-0.021	-0.003	-0.046	.095**	.093**	0.050	.093**	.424**	.443**	.339**	.401**	.386**	.317**	.460**	.372**	1		
Usdt	-.112**	-.087*	0.006	-.253**	0.002	-.450**	.666**	.437**	.247**	.865**	.144**	.173**	.084*	.094**	.093**	0.053	.094**	.093**	0.063	1	
XMR	0.054	0.053	0.003	0.019	0.047	-0.023	0.055	0.037	0.045	.079*	.348**	.413**	.340**	.234**	.435**	.196**	.238**	.315**	.304**	0.041	1

Source: Data from author’s computations and SPSS Statistics output.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

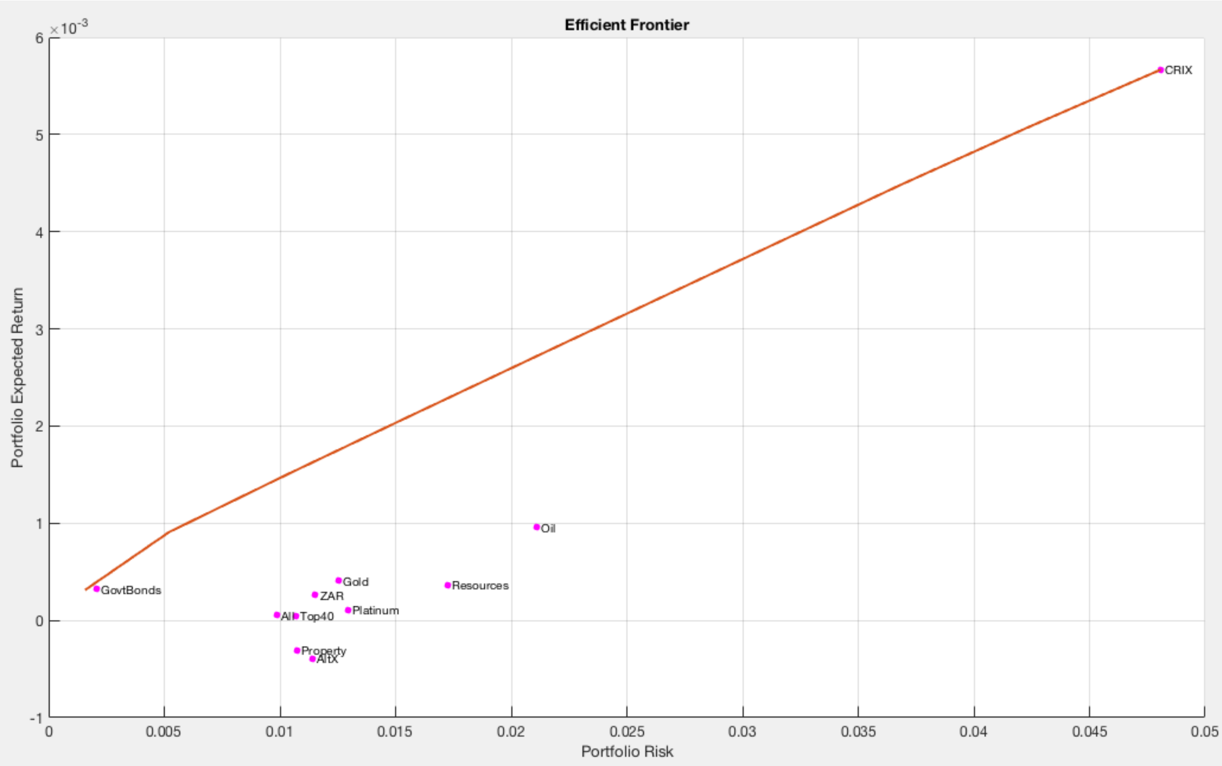
Note: All = JSE All Share index, Top40 = JSE Top 40 index, AltX = JSE Alternative index, Prop = JSE SA Property index, Res = JSE SA Resources index, Bonds = SA Government Bonds, Plat = Platinum, Oil = Brent Crude oil and ZAR = South African Rand, BTC = Bitcoin, ETH = Ethereum, XLM = Steller, LTC = Litecoin, Doge = Dogecoin, Usdt = Tether and XMR = Monero.

Table 4 that illustrates the Pearson correlation matrix will now be discussed. Most correlations between the cryptocurrencies and the alternative and traditional investments are below 0.1 and -0.1. However, the correlations between Usdt and All, Usdt and Prop, CRIX and bonds, BTC and bonds, CRIX and gold, BTC and gold, XRP and gold, LTC and gold, BTC and plat, Dash and oil were above 0.1 and -0.1 at -0.112, -0.253, -0.137, -0.158, 0.153, 0.164, 0.101, 0.114, 0.1 and 0.1 respectively. The correlations between Usdt and bonds, Usdt and gold, Usdt and plat, and Usdt and oil are -0.450, 0.666, 0.437 and 0.247 respectively while those between ZAR and most cryptocurrencies were below 0.5 and -0.5, with the exception of the correlation between Usdt and ZAR at 0.865. This suggests that there are several weak positive and negative relationships and correlations of below 0.1, -0.1, 0.5 and -0.5 between cryptocurrencies and alternative and traditional assets. There is a moderate to strong positive relationship and correlation between Usdt and gold at 0.666 and Usdt and ZAR at 0.865. All the correlations between the cryptocurrencies are below 0.5 except for CRIX and BTC which are 0.711. This affirms that the relationship between cryptocurrencies is a weak positive relationship and correlation. However, there is a strong positive relationship between CRIX and BTC, which is expected, due to the dominant nature of BTC in CRIX at 65.41%, as displayed in Appendix 1. Most correlations between the alternative and traditional investments are below 0.5 and -0.5. This suggests that the relationship between cryptocurrencies is a weak positive and negative relationship and correlation. The correlations between All and Top 40, All and Prop and All Res, Top 40 and Res, gold and plat, gold and ZAR and plat and ZAR were significant to moderate. However, this is for very few of the traditional and alternative assets.

Similar results of low correlations between BTC and traditional and alternative assets, as well as CRIX and traditional and alternative assets, respectively were found in studies by Brière et al. (2015) and Lee et al. (2017). From 2011 to 2016, low correlations between BTC and traditional and alternative assets were also found in a study by Burniske and White (2017). This study found that BTC has, on average, a low correlation of -0.05 correlated to emerging market currencies. This study also revealed that gold had a low to moderate correlation to BTC. Burniske and White (2017) stated that assets, such as BTC, with near zero correlations to other assets should form part of their own asset class. This suggests that, due to the low correlations of cryptocurrencies to traditional and alternative assets, cryptocurrencies should be considered to be in their own asset class. Most of the weak correlations and relationships within these studies show that there is no risk of multicollinearity and thus there is no risk between the variables. This poses little to no challenge to a multivariate OLS regression test. It also shows that cryptocurrencies are potentially good diversifiers of traditional and alternative assets. However, correlations are known to change over time and these results should be assessed with caution (Brière et al., 2015). Moving forward below, the MV analysis findings are discussed.

4.5. Mean-variance analysis results

Figure 6: Efficient frontier



Source: From author's computations and Matlab output.

Note: All = ALSI = JSE All Share index, Top40 = JSE Top 40 index, AltX = JSE Alternative index, Property = JSE SA Property index, Resources = JSE SA Resources index, GovtBonds = SA Government Bonds, Oil = Brent Crude oil and ZAR = South African Rand.

The results of the mean-variance analysis efficient frontier are presented in Figure 6. The figure indicates that cryptocurrencies generate higher returns in relation to risk than South African traditional and alternative assets. The only asset that lies on the efficient frontier is

CRIX, while the bonds lie very close to the lower end of the efficient frontier. All the remaining assets, being: gold, oil, ALSI, Top 40, platinum, property, AltX, resources and ZAR, do not lie individually as assets on the efficient frontier. The assets that lie on the lowest point are property, which is followed by AltX. That means that AltX is the asset with the lowest return and with a respectively high level of risk. The efficient frontier is a line that consists of numerous optimised investment portfolios, which are a combination of the assets at different weights, risks and returns (Malkiel, 2015). Therefore, the efficient frontier is the point at which the investment portfolio return is maximised per unit of risk (Mangram, 2013; Pfiffelmann et al., 2016; Watsham & Parramore, 1997).

In Figure 6, at the furthest point of the efficient frontier, CRIX is set to a portfolio investment of 100%. CRIX is the asset in the portfolio, that is, if the respective investor was willing to take the very high risk, for the high return at the top of the efficient frontier. If an investor were to hold the best investment to derive the highest return, it would have to be 100% CRIX, despite the high risk involved. It shows that CRIX results in a higher return per unit of risk than gold, oil, ALSI, Top 40, platinum, property, AltX, resources and ZAR. Similar results were derived by Lee et al. (2017) in their investigation, which also found that CRIX is on the top of the efficient frontier. However, their study was not from a South African investor's perspective, but from a British investor's perspective. Their study found that the S&P 500, the Real Estate Investment Trusts (REITs), gold, oil, private equity and Goldman Sachs Commodity Index (GSCI) all lay below the efficient frontier, with oil being the asset with the smallest return for its respectively high level of risk.

The reason for CRIX resulting in better returns at a specified risk is due to it being an amalgamation of numerous cryptocurrencies which have high risks but also high returns. Cryptocurrencies are known to be volatile as their prices are susceptible to implosions or bubbles (Brière et al., 2015; Hickey, 2017; Taylor, 2015).

JSE listed indices consist of various top performing listed entities on the JSE which is the 19th largest stock market globally that caters to various types of investors. The JSE has to ensure that the investments are regulated, efficient and that they are kept safe (JSE, 2019a). Brière et al. (2015) found that gold, oil and hedge funds have different characteristics to Bitcoin.

Therefore, it would be expected that the risk and return of traditional and alternative assets would be lower than those of CRIX and cryptocurrencies.

Table 5: CRIX, traditional and alternative assets' Sharpe ratios

Names	Sharpe Ratio
JSE All Share index (ALSI)	0.0901
JSE Top 40 index (Top 40)	0.0747
JSE Alternative index (AltX)	-0.5423
JSE SA Property index (Prop)	-0.4507
JSE SA Resources index (Res)	0.3381
SA Government Bonds (bonds)	2.4648
Gold	0.5148
Platinum	0.1346
Brent Crude oil (oil)	0.7196
South Africa Rand (ZAR)	0.3578
CRIX	1.8712

Source: Data from author's computations and Microsoft Excel output.

The Sharpe ratios for ALSI, Top 40, AltX, Prop, Res, bonds, gold, platinum, oil, ZAR and CRIX were 0.09, 0.07, -0.54, -0.45, 0.34, 2.46, 0.51, 0.13, 0.72, 0.36, 1.87 respectively. The Sharpe ratio measures the risk-adjusted return of an asset. The CRIX Sharpe ratio exceeds the Sharpe ratio of ALSI, Top 40, AltX, Prop, Res, gold, platinum, oil and ZAR. The CRIX Sharpe ratio is more than double the Sharpe ratio of ALSI, Top 40, AltX, Prop, Res, gold, platinum, oil and ZAR. However, the Sharpe ratio of the bonds exceeds that of CRIX. The risk-adjusted return of CRIX better than that of ALSI, Top 40, AltX, Prop, Res, gold, platinum, oil and ZAR. While the risk-adjusted return of the bonds better than that of the CRIX. The Sharpe ratio analysis shows that overall CRIX is a better investment than South African traditional and alternative assets.

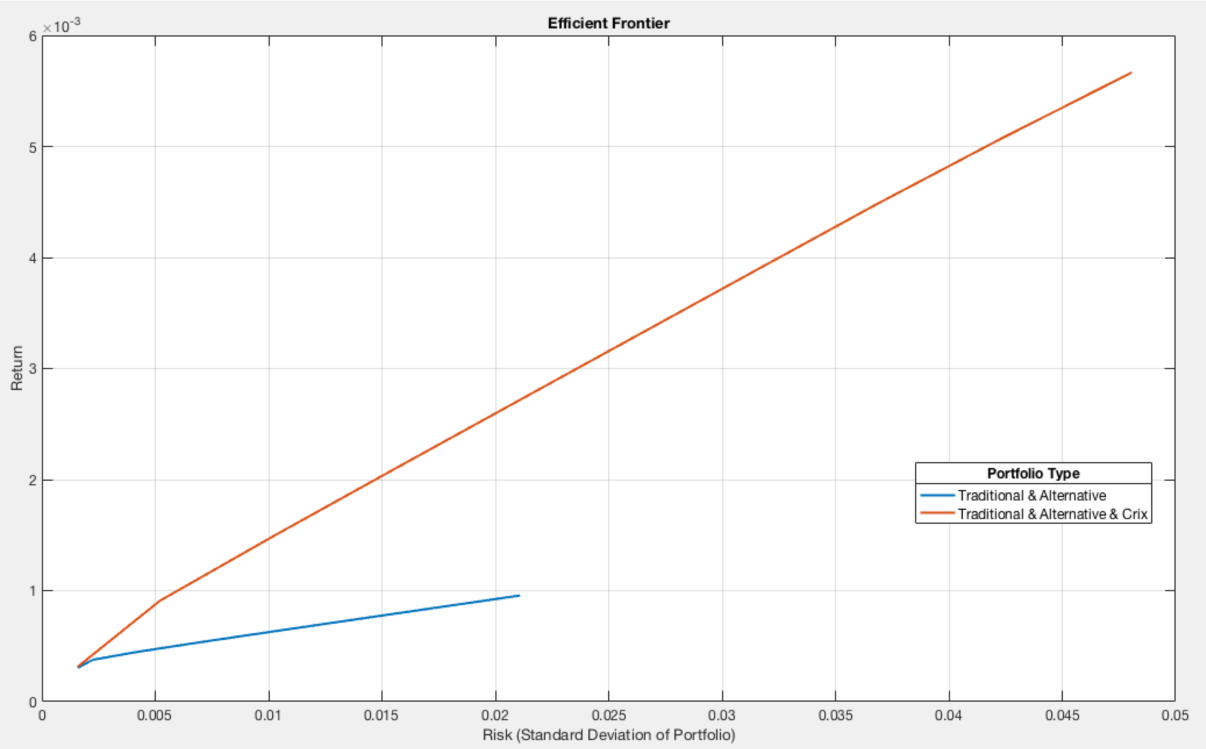
Table 6: Optimal portfolio asset weights

Names	Weights
JSE All Share index (ALSI)	0.0000
JSE Top 40 index (Top 40)	0.0000
JSE Alternative index (AltX)	0.0000
JSE SA Property index (Prop)	0.0000
JSE SA Resources index (Res)	0.4231
SA Government Bonds (bonds)	88.4173
Gold	2.4589
Platinum	0.0000
Brent Crude oil (oil)	1.1346
South Africa Rand (ZAR)	5.5372
CRIX	2.0290

Source: Data from author's computations and Matlab output.

This study finds that, although CRIX lies on the highest point of the efficient frontier, the optimal point on the efficient frontier for an investor is known as the tangency portfolio, where the Sharpe ratio is maximised or where the investor gets the best return-risk ratio (Jorion, 1992; Kan & Zhou, 2012). This study also finds that overall CRIX has a better risk-adjusted return than traditional and alternative assets. As seen in Table 6, tangency portfolio weights are as follows: 88.42% for bonds, 2.46% for gold, 1.13% for oil, 5.54% for ZAR and 2.03% for CRIX. Therefore, due to the high-risk nature of cryptocurrencies, investors cannot invest 100% of their funds in cryptocurrencies but rather a lower portion, as per the tangency portfolio, in a portfolio that consists of cryptocurrencies, traditional and alternative assets. Due to CRIX being a cryptocurrency index, the testing of CRIX in a portfolio inadvertently tests a combination of cryptocurrencies in a portfolio. In line with the research performed by Brière et al. (2015), the findings reflect that cryptocurrencies perform better than both South African traditional and alternative investments in terms of risks-returns analysis. Therefore, cryptocurrencies are a better investment than South African traditional and alternative assets. The study will now discuss the findings of the second hypothesis.

Figure 7: Efficient frontier with and without CRIX



Source: From author's computations and Matlab output.

Table 7: Efficient portfolio performance with and without CRIX

	Optimised		6% volatility		12% volatility	
	Without CRIX	With CRIX	Without CRIX	With CRIX	Without CRIX	With CRIX
Annual mean	8.641%	11.636%	11.561%	20.272%	14.934%	34.807%
Annual standard deviation	2.579%	2.931%	6.000%	6.000%	12.000%	12.000%
Sharpe ratio	3.2147	3.7563	1.8238	3.0775	1.1602	2.4904
Sortino ratio	5.3741	6.4663	2.8320	5.1069	1.7406	4.0053
CRIX (%)	0.000%	2.029%	0.000%	7.154%	0.000%	15.283%

Source: Data from author's computations and Matlab output.

Utilising the mean-variance analysis, the study tests the second hypothesis that cryptocurrencies have diversification advantages in South African investment portfolios. As per Figure 7, the efficient frontier of the optimised portfolio, consisting of traditional assets, alternative assets and CRIX is higher and larger than that consisting only of traditional and alternative assets.

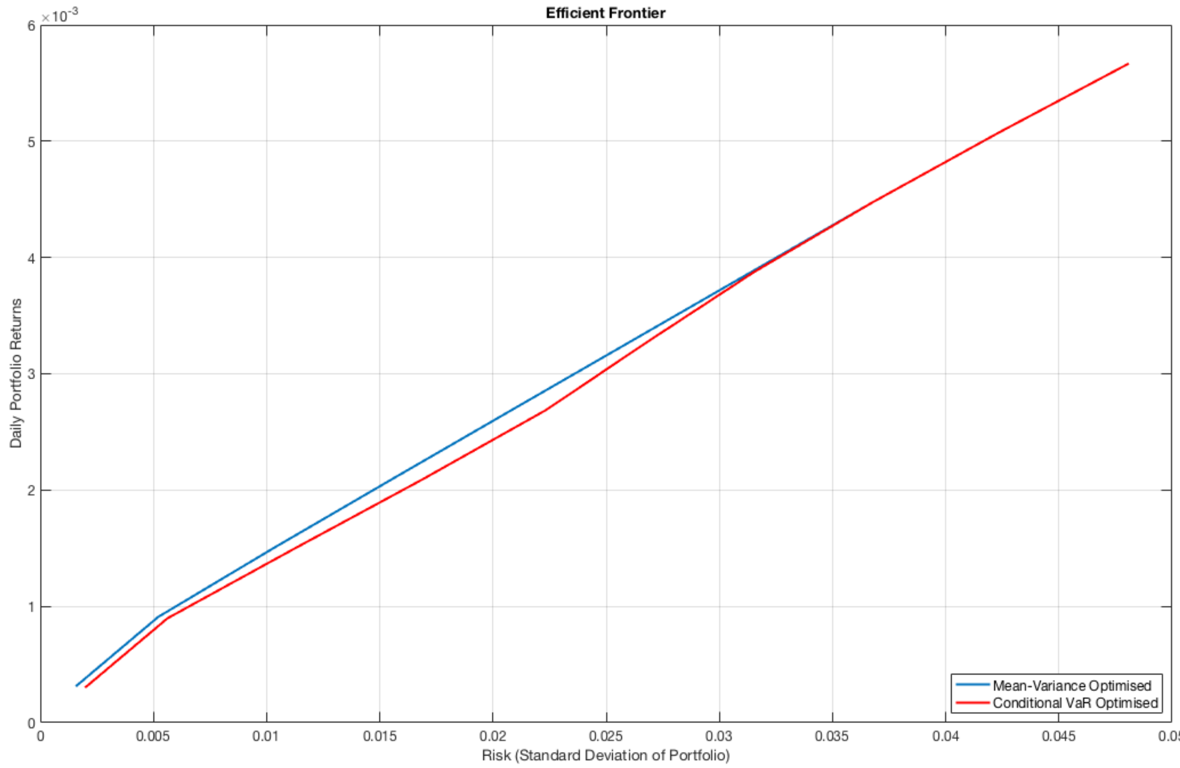
The portfolio optimised using the Sharpe ratio within Figure 7 and Table 7 will now be discussed. Under the optimised portfolio, the annual mean of the portfolio without CRIX is 8.64% and with CRIX, it is 11.64%, while the standard deviation is 2.58% for the portfolio without CRIX and with CRIX, it is 2.93%. This means that the returns improved for a portfolio with CRIX rather than without, while the risk increased slightly. The Sharpe and Sortino ratios both increased from 3.21 to 3.76 and 5.37 to 6.47 respectively, for portfolios without CRIX to those with CRIX. The Sortino ratio that exceeds the Sharpe ratio shows that there are greater excess returns per unit of downside volatility in comparison to excess returns per unit of total volatility. Moreover, the results show that, by including CRIX within an optimised portfolio, utility can be slightly improved, although at a slightly increased risk level. A previous study performed by Lee et al. (2017) illustrated that a portfolio under the same risk level had higher returns with CRIX than without CRIX.

Referring to Table 7, volatility levels of 6% and 12% were used within the study. This is similar to a study carried out by Brière et al. (2015). At a volatility of 6%, the annual mean of the portfolio without CRIX of 11.561% leaps to 20.727% for portfolios with CRIX. This means that the returns improved drastically for a portfolio with CRIX over one without CRIX. The Sharpe and Sortino ratios both increased from 1.82 to 3.08 and 2.83 to 5.11 respectively, for portfolios without CRIX to those with CRIX. This shows that, by including CRIX within a portfolio that targets a 6% volatility, utility is almost doubled. At double the volatility of 12%, the annual mean of the portfolio without CRIX of 14.93% jumps to 34.81% for portfolios with CRIX. This means that the returns improve drastically for a portfolio with CRIX over those without. The Sharpe and Sortino ratios both increased from 1.16 to 2.49 and 1.74 to 4.01 respectively, for portfolios without CRIX to those with CRIX. The Sortino ratio that exceeds the Sharpe ratio shows that there are greater excess returns per unit of downside volatility in comparison to excess returns per unit of total volatility. Moreover, this shows that, by including CRIX within a portfolio that targets 12% volatility, utility is more than doubled. A previous study by Brière et al. (2015) that compared portfolios with and without Bitcoin overall also found that, for moderately risk-averse investors, including Bitcoin in their portfolios would drastically increase their portfolios’ performance but at a greatly increased risk level. Therefore, the current study establishes that including CRIX and cryptocurrencies within a portfolio of investments results in a moderate to significant improvement in the South African investment portfolio, although at moderate to significantly increased risk levels. It also suggests that CRIX and cryptocurrencies have moderate to significant diversification advantages in South African investment portfolios. The third hypothesis will now be assessed using the CVaR analysis.

4.6. Conditional Value-at-risk analyis results

The results of the CVaR analysis efficient frontier are presented in Figure 8. The figure indicates that cryptocurrencies have diversification advantages in South African portfolios. At a given return, the mean-variance efficient frontier has lesser risk than the CVaR efficient frontier at a significance level of 0.01.

Figure 8: Efficient frontier under CVaR and MV



Source: From author’s computations and Matlab output.

This is mainly due to more risk being accounted for by the CVaR than the mean-variance analysis. This shows that, under the CVaR analysis, cryptocurrencies have diversification benefits. During their study, Lee et al. (2017) found that the CVaR efficient frontier at a significance level of 0.01, which included higher risk and moments of skewness and kurtosis, performs slightly worse than the mean-variance frontier. Additionally, the asset allocation was similar under the CVaR analysis. This study did not account for higher moments, as per the Cornish-Fisher expansion, due to certain research limitations but results were similar to those of a previous study. This investigation found that, under the CVaR analysis, the utilities under the CVaR and MV analyses are similar. Therefore, cryptocurrencies have diversification advantages under the CVaR analysis. The CVaR accounts expected an extreme loss of an investment (Cowell, 2013). The similarity between the CVaR and MV analyses results reveals that there is a similar expected extreme loss of an investment when the South African investors include and exclude cryptocurrencies in their investment portfolios. The results of the spanning test will now be discussed.

4.7. Spanning test results

Table 8: Spanning test for cryptocurrencies' effect on portfolio constructed of alternative and traditional assets

Asset	Alpha	F-Test	p-Value
CRIX	0.0058	6.0200	0.0025
Bitcoin	0.0054	5.4500	0.0045
XRP	0.0093	3.3600	0.0352
Ethereum	0.0102	4.7500	0.0089
Dash	0.0071	4.0500	0.0178
NEM	0.0142	4.2700	0.0143
Stellar	0.0121	3.0900	0.0461
Litecoin	0.0052	2.5000	0.0826
Dogecoin	0.0082	2.7000	0.0678
Tether	0.0000	-	0.9997
Monero	0.0101	4.5700	0.0106

Source: Data from author's computations and SAS output.

Although the MV and CVaR analysis studies performed above illustrate that cryptocurrencies have diversification gains, the studies were performed using CRIX. As per Appendix 1, it is shown that, at 64.51%, Bitcoin forms an overwhelming part of CRIX. As a result, at this stage, it is uncertain whether only CRIX, Bitcoin or the individual cryptocurrencies result in diversification benefits. This prompted the testing of the last hypothesis that states that individual cryptocurrencies have diversification advantages in South African investment portfolios. Using the Huberman and Kandel (1987) multivariate OLS regression Wald test at a level of significance or alpha of 0.05, the results of the spanning test were derived. As per Table 8, the research shows that the p-values of CRIX, Bitcoin, XRP, Ethereum, Dash, NEM, Stellar and Monero were all below 0.05, as 0.0025, 0.0045, 0.0352, 0.0089, 0.0178, 0.0143, 0.0461 and 0.0106 respectively while, the p-values of Litecoin, Dogecoin and Tether were greater than 0.05 at 0.0826, 0.0678 and 0.9997 respectively. This means that, since the p-value of CRIX, Bitcoin, XRP, Ethereum, Dash, NEM, Stellar and Monero is less than an alpha of 0.05, we reject the H_0 or null hypothesis. Therefore, there is significant evidence to support the fact that CRIX, Bitcoin, XRP, Ethereum, Dash, NEM, Stellar and Monero have diversification advantages. However, since the p-value of Litecoin, Dogecoin and Tether is greater than an alpha of 0.05, we do not reject the H_0 or null hypothesis. There is significant evidence showing that Litecoin, Dogecoin and Tether do not have diversification advantages. Therefore, seven out of ten cryptocurrencies and CRIX have diversification benefits.

An investigation of a similar nature was performed by Brière et al. (2015) and Lee et al. (2017). Brière et al. (2015) discovered that Bitcoin spans traditional and alternative assets. Therefore, Bitcoin was found to have diversification benefits in a portfolio. While, Lee et al. (2017) found that most cryptocurrencies and CRIX improve the performance of a portfolio, with six out of ten cryptocurrencies and CRIX that span and diversify portfolios constructed of traditional and alternative assets but not tangency portfolios. Although it utilised the MV analysis on each cryptocurrency and portfolio, another study carried out by Ketelaars (2018) illustrated that the inclusion of Bitcoin, Steller, XRP, Litecoin and Monero in a portfolio increased the efficient frontier and the Sharpe ratio. As a result, they each have diversification benefits. From the current and previous studies, we can conclude that CRIX and most cryptocurrencies span the traditional and alternative investment portfolios. We can also conclude that CRIX and most cryptocurrencies have diversification advantages in these portfolios, excluding tangency portfolios. For further details on the spanning test and OLS regression Wald test performed, refer to Appendix 4.

4.8. Conclusion

Cryptocurrencies have far larger returns and risks than South African traditional and alternative assets. The findings illustrate that cryptocurrencies are a superior investment in comparison with traditional and alternative assets in South Africa. Additionally, cryptocurrencies have shown to have diversification benefits in South African portfolio investments.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

Hofstee (2013) states that the conclusion chapter is one that wraps up the entire dissertation. This chapter articulates the summary of findings and contributions of the assessment of the attractiveness of cryptocurrencies in relation to traditional and alternative investments in South Africa. Furthermore, this chapter encapsulates the avenues for future research as well as the overall conclusions reached from the investigation.

5.2. Summary of findings

There were various findings that were made during the study performed from 11 August 2015 to 31 October 2018. The first finding is that the cumulative log returns and volatility of cryptocurrencies exceeded those of South African traditional and alternative assets. The cryptocurrency return variables observed are CRIX, Bitcoin, Ethereum, Monero, Stellar, XRP, Litecoin, Tether, Dash, NEM and Dogecoin. The traditional asset returns variables observed were the JSE All Share index, JSE Top 40 index, JSE Alternative Exchange index and South African government bonds while the alternative asset return variables consisted of JSE SA Listed Property, JSE SA Resources, gold, platinum, Brent Crude oil and South African Rand. The second finding is that the mean and risk of cryptocurrency returns is far greater than that of traditional asset returns. The risk related to cryptocurrencies was not only high but is considered extreme. Moreover, cryptocurrencies are heavily skewed, meaning that their risks increase quickly and decrease gradually. The returns of all the assets were found to be unpredictable. It was also found that most of the relationships were weak negative and positive relationships between cryptocurrencies, South African traditional and alternative assets. These findings are similar to studies carried out by Brière et al. (2015) and Lee et al. (2017), that were done from a US and British investor’s perspective respectively.

There were more findings in addition to those already mentioned. CRIX, which was the representative asset of cryptocurrencies, was the only asset on the efficient frontier constructed of traditional and alternative assets that lay on the furthest top point of the efficient frontier. No alternative or traditional assets lay on the efficient frontier. This study was in line with that performed by Lee et al. (2017). The Sharpe ratio of CRIX was greater than all traditional and alternative investments, except for bonds. This revealed that overall CRIX has a better risk-adjusted return than traditional and alternative assets. The efficient frontier of South African investment portfolios including CRIX performed better than those that did not include CRIX. The Sharpe and Sortino ratios illustrated that investment portfolios with CRIX had greater utility, though at greater risk, than those without CRIX. It also showed that investment portfolios with risk targets of both 6% and 12% had better utility than that of an optimised portfolio, although at far greater risk. These findings depict those of Brière et al. (2015) in their investigation. The mean-variance efficient frontier has less risk than the CVaR efficient frontier at a given return. This is mainly due to more risk being accounted for by the CVaR than the mean-variance analysis. Lee et al. (2017) had similar results although they included the third and fourth moment in their study, unlike this study, which only has two moments while the last finding was supported by the discoveries of Lee et al. (2017) in their spanning test. This study's spanning test illustrated that CRIX, Bitcoin, XRP, Ethereum, Dash, NEM, Stellar and Monero all individually improved the South African traditional and alternative investment portfolios whereas Litecoin, Dogecoin and Tether did not. Therefore, seven out of the ten and CRIX improved the South African traditional and alternative portfolios.

5.3. Conclusions

Traditional and alternative South African investments have been struggling and returning less than satisfactory returns to their investors. This study sought to assist these investors by investigating alternative assets into which they can invest. In doing so, this investigation sought to meet four research objectives. The first objective was to compare the return relative to risk derived from cryptocurrencies and South African traditional and alternative assets. This was achieved using the mean-variance analysis and the Sharpe ratio that found that CRIX has a higher return per unit of risk than traditional and alternative assets. This demonstrated that cryptocurrencies are a better investment than South African traditional and alternative assets. The second objective was to compare the performance of South African investment portfolios with cryptocurrencies to portfolios without cryptocurrencies. This objective was achieved by comparing mean-variance with and without CRIX. It was found that including cryptocurrencies within the portfolio increases the financial gains of the portfolio. This also means that including cryptocurrencies in a portfolio leads to diversification benefits. The third objective was achieved using the CVaR analysis that illustrated that risk-return under CVaR and MV analyses are similar and that diversification advantages are still derived under the CVaR efficient frontier. Lastly, the fourth objective was realised using the spanning test which used the multivariate OLS regression Wald test. This showed that, individually, not only CRIX but most cryptocurrencies tested spanned traditional and alternative assets. Therefore, the CRIX and individual cryptocurrencies resulted in diversification advantages in investment portfolios, other than in tangency portfolios. Investigations performed by Brière et al. (2015) and Lee et al. (2017) supported the above findings and conclusions but not from a South African investor’s perspective. In the following section a summary of the contributions of the study will be made.

5.4. Summary of contributions

This study has contributed to knowledge about investment portfolios in South Africa. It has illustrated that cryptocurrencies should be included in South African investment portfolios to derive better risk-adjusted returns and reap the diversification benefits that cryptocurrencies offer. This contribution adds to the already existing pool of knowledge of cryptocurrencies.

Previous empirical studies and their findings will now be discussed. A previous study by Brière et al. (2015) found that Bitcoin has very low correlation to both traditional and alternative assets. This study also found Bitocin to be a good diversification asset. Another study by Osterrieder and Lorenz (2017) found that Bitcoin has greater volatility and risk than G10 currencies. Rohrbach et al. (2017) found that cryptocurrencies and emerging market currencies fared better than G10 currencies. The investigation by Lee et al. (2017) found that cryptocurrencies outperformed traditional investments on an average daily return. Another outcome was that there is a low correlation between cryptocurrencies and traditional investments and that cryptocurrencies are a reasonable investment. Kim et al. (2018) established that BTC, ETH and LTC’s purchasing power is less certain than those of Japan, US, Britain, South Africa and Mexico fiat currencies and thus cryptocurrencies are too volatile to be considered as currencies. Moreover, they also established that there was an upswing in the BTC and ETH price that was caused by BTC and ETH being used to buy other cryptocurrencies in 2017.

None of the previously mentioned empirical studies covered South African traditional investments which implies that this study has practical implications for South Africa. The practical implications of this investigation are that, within the South African investors' universe of investments, cryptocurrencies should be considered not only by individual investors but also by institutional investors. Lastly, the suggestions for further research will be discussed below.

5.5. Suggestions for further research

Subsequent to the period of assessment of 31 October 2018, there was a 35% decline in the cryptocurrency prices on average in November 2018 (Ouimet, 2018). This large decrease in the price of cryptocurrencies could ha3ve altered the results of the investigation performed within this dissertation. As this period was beyond that of this study, only the possible implications and not the actual implications of the price decrease are discussed. The large price decline could have resulted in cryptocurrencies not being a better investment than South African traditional and alternative assets and may have resulted in the inclusion of cryptocurrencies within an investment portfolio causing financial loss rather than financial gain. Another possible result of the large price decline could have been that the CRIX and individual cryptocurrencies do not result in diversification benefits within the South African investment portfolios. These are a few of the many possibilities that could have arisen from the 35% decline in the cryptocurrency prices in November 2018. Only future research can reveal the outcome of cryptocurrency price decreases on traditional and alternative assets within South African portfolios.

This study was based on the influence of cryptocurrencies on the portfolio investments of the South African investor. It was limited to a comparison of cryptocurrencies in relation to traditional and alternative assets in South Africa therefore, resulting in the following suggestions for future research:

- The diversification benefits of cryptocurrencies should be investigated in South Africa3 and other countries beyond November 2018, due to the 35% drop in cryptocurrency prices on average in November 2018 (Ouimet, 2018).
- The GMM Wald test should be performed to assess the effects of cryptocurrencies on

traditional and alternative asset portfolios in South Africa.

- The step-down spanning test should be carried out to assess the effects of cryptocurrencies on traditional and alternative asset portfolios in South Africa.
- The CVaR analysis that includes skewness and kurtosis should be performed to assess whether cryptocurrencies have diversification advantages under higher moments.
- There are far more cryptocurrencies globally than those investigated in this study. Therefore, the diversification benefits of these cryptocurrencies should be investigated.
- The diversification advantages of cryptocurrencies within other African countries should be carried out.

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Appendix 1: 10 Cryptocurrencies that are included in CRIX

Table 9: 10 Cryptocurrencies included in CRIX on 1 October 2018

Number	**Cryptocurrency Name**	**Symbol**	**Market Capitalisation**	**Percentage of Market Capitalisation**[a]
1	Bitcoin	BTC	R 1,619,344,831,706	64.51%
2	Ethereum	ETH	R 333,297,114,307	13.28%
3	XRP	XRP	R 327,427,298,382	13.04%
4	Stellar	XLM	R 68,876,842,252	2.74%
5	Litecoin	LTC	R 50,263,838,354	2.00%
6	Tether	USDT	R 39,705,678,904	1.58%
7	Monero	XMR	R 26,962,499,811	1.07%
8	Dash	DASH	R 22,064,326,921	0.88%
9	NEM	XEM	R 12,349,926,054	0.49%
10	Dogecoin	DOGE	R 9,879,132,427	0.39%

Source: Data from CoinMarketCap market capitalizations (2018).

[a] Source: Author’s own calculation, percentage of market capitalisation = (market capitalisation of the cryptocurrency divided by the sum of the total market capitalisation of the 10 cryptocurrencies included in CRIX) x 100.

Appendix 2: Asset definitions and descriptions

Bitcoin is one of the more widely used forms of cryptocurrencies (Dandapani, 2017). It was created in 2009 by Satoshi Nakamoto and only a limit of 21 million Bitcoins can be issued (Lee et al., 2017).

Brent crude oil is a well-known oil benchmark against which oil prices are determined. It is a combination of Shell, British Petroleum and the United Kingdom's (UK) North Sea oil ("Brent crude," 2019).

CRIX is a cryptocurrency index that consists of cryptocurrencies based on their market capitalisation (Härdle, Trimborn, et al., 2018).

Dash is a cryptocurrency that is used to send anonymous instant transactions (Lee et al., 2017).

Dogecoin is a cryptocurrency that was created to appease people. It has no tangible purpose and an unlimited number of Dogecoins can be created (Lee et al., 2017).

Ethereum is a commonly used cryptocurrency that is used for smart contracts (S. Kim et al., 2018; Lee et al., 2017) that allow for the automation of the implementation of the contract terms and conditions.

Gold is a commodity that consists of a yellow metallic element ("Gold," 2019).

JSE All Share index is the most significant index on the JSE and consists of approximately 150 of South African JSE listed companies (JSE, 2019e).

JSE Alternative Exchange index is an index that is made up of all the companies with ordinary shares that are listed on the JSE Alternative Exchange (JSE, 2019d).

JSE SA Listed Property index is an index that is listed on the JSE that consists of 20 of the highest liquid companies that are included in the JSE Real Estate Investment Trusts Sector and Real Estate Investment & Services Sector (JSE, 2019b).

JSE SA Resources index is an index that is listed on the JSE and it comprises of the companies that are on the Industry Classification Benchmark (ICB) Basic Materials and Industries Oil & Gas (JSE, 2019c).

Litecoin is a peer-to-peer digital currency that allows global and prompt near zero cost payment, that can process settlements four times faster than Bitcoin (Dandapani, 2017; S. Kim et al., 2018).

Monero is a cryptocurrency that is used to send encrypted transactions (Lee et al., 2017).

NEM is a cryptocurrency that is a peer-to-peer platform that used to transmit payments and messages (Lee et al., 2017).

Platinum is a grey non-corrosive heavy metal commodity ("Platinum," 2018).

South African Rand which is also known as the ZAR, is the fiat currency that is backed by the South African government (OANDA, 2019).

Stellar is a cryptocurrency that operates as a platform that allows for the movement of money between people and financial service providers (Stellar, 2019).

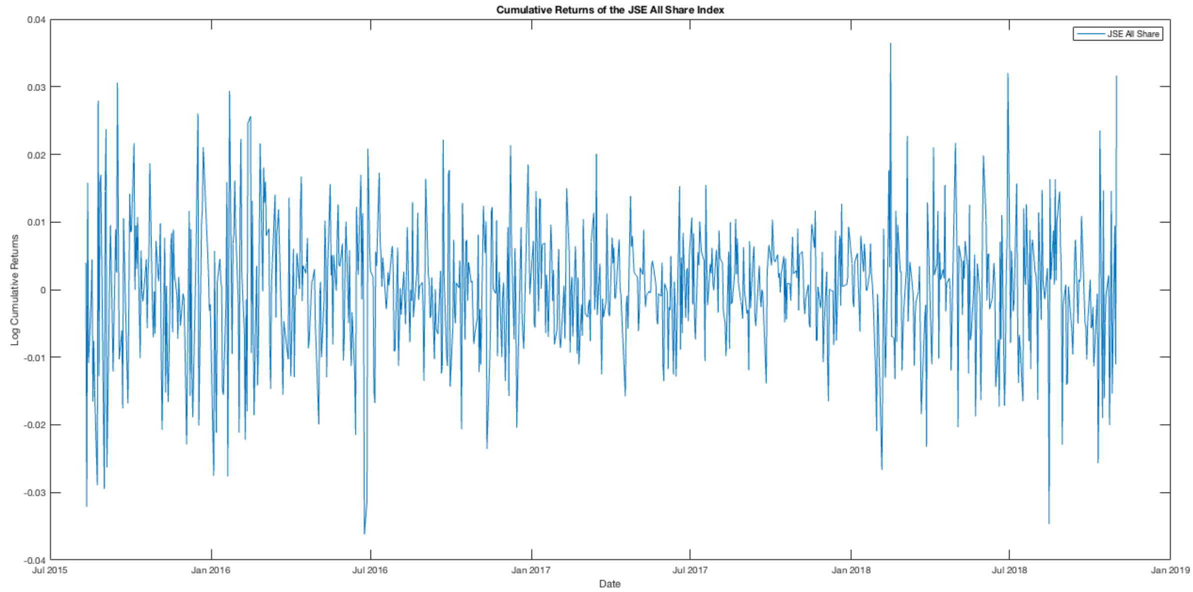
Tether is a cryptocurrency that is pegged to the US dollar and its intention was to be a stable cryptocurrency that would be like digital US dollars ("What is Tether?," 2019).

South African government bond is the bond issued by the South African government through National Treasury, in order to raise funding for the South African fiscal year ("What are RSA bonds," 2019).

XRP is a cryptocurrency that transfers digital currencies over the Ripple blockchain ("What Is Ripple. Everything you need to know," 2019).

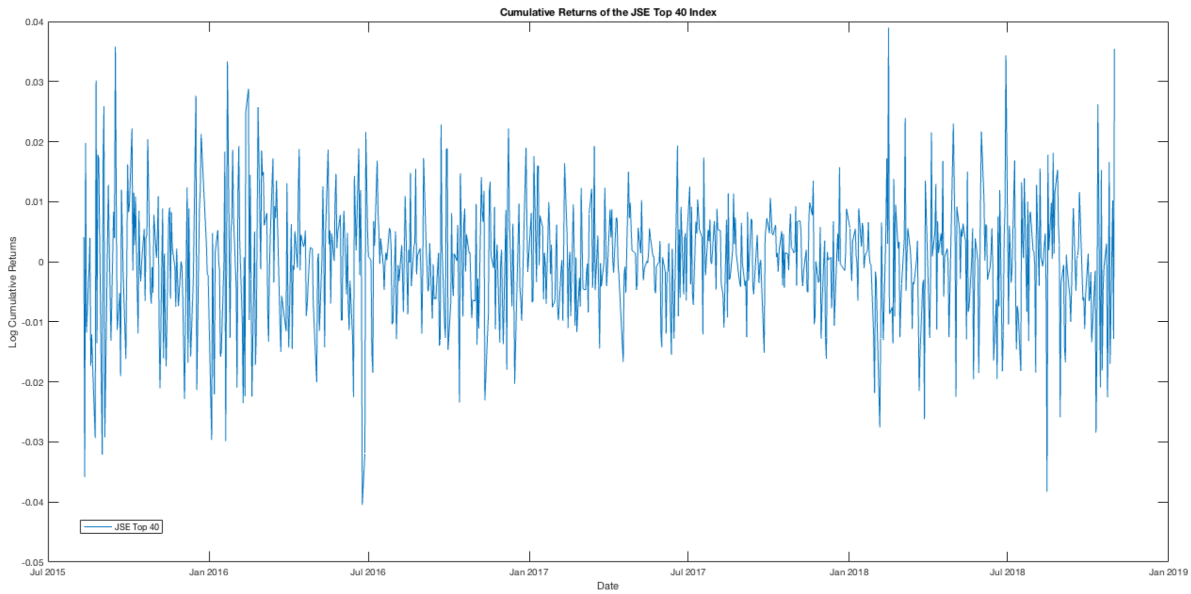
Appendix 3: Daily log cumulative returns graphs for each variable

Figure 9: Cumulative returns of the JSE All Share index



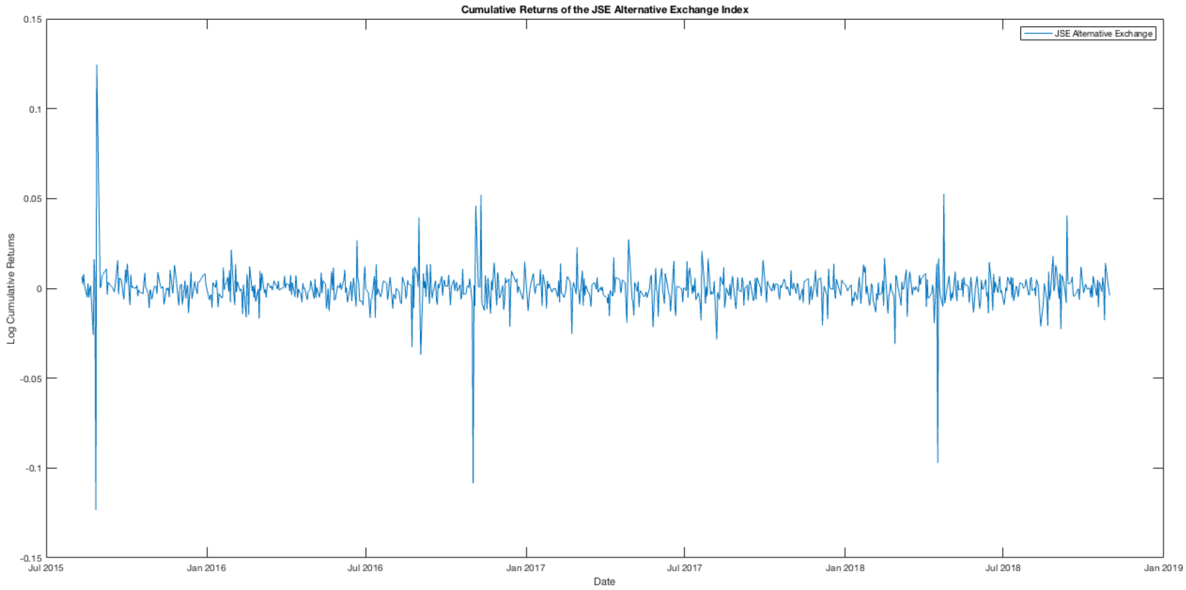
Source: Data from author's computations and Matlab output.

Figure 10: Cumulative returns of the JSE Top 40 index



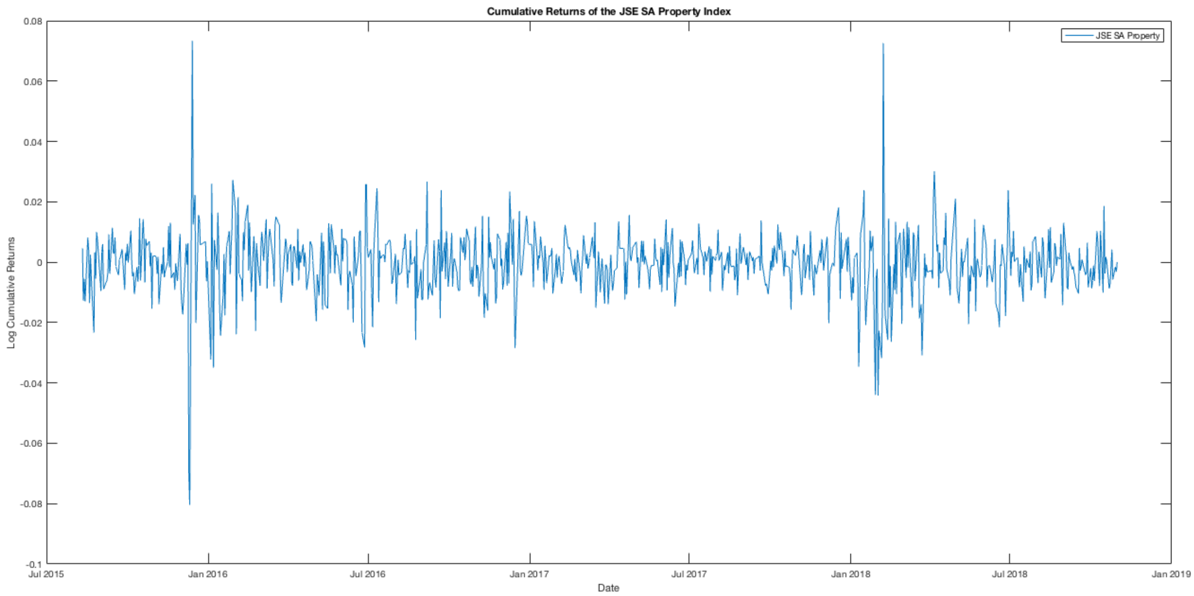
Source: Data from author's computations and Matlab output.

Figure 11: Cumulative returns of the JSE Alternative Exchange index



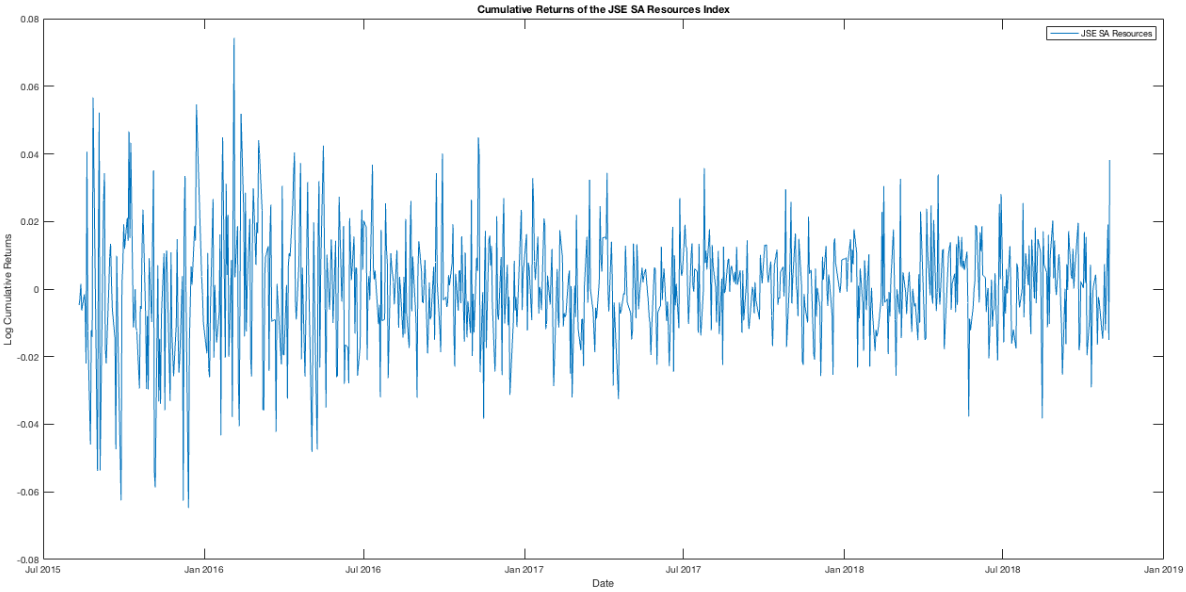
Source: Data from author's computations and Matlab output.

Figure 12: Cumulative returns of the JSE SA Property index



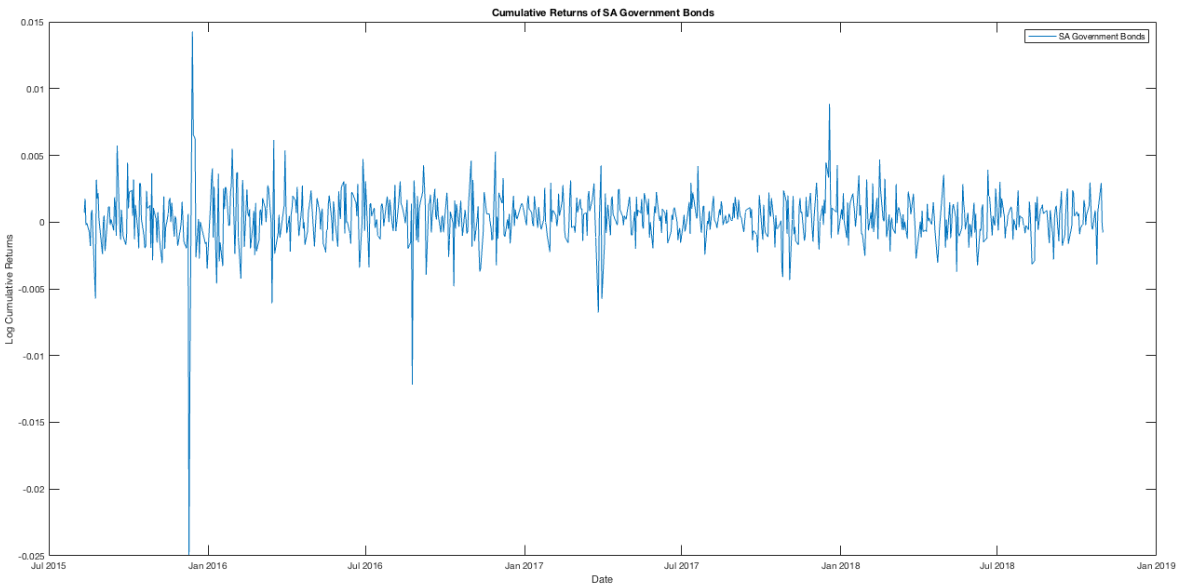
Source: Data from author's computations and Matlab output.

Figure 13: Cumulative returns of the JSE SA Resources index



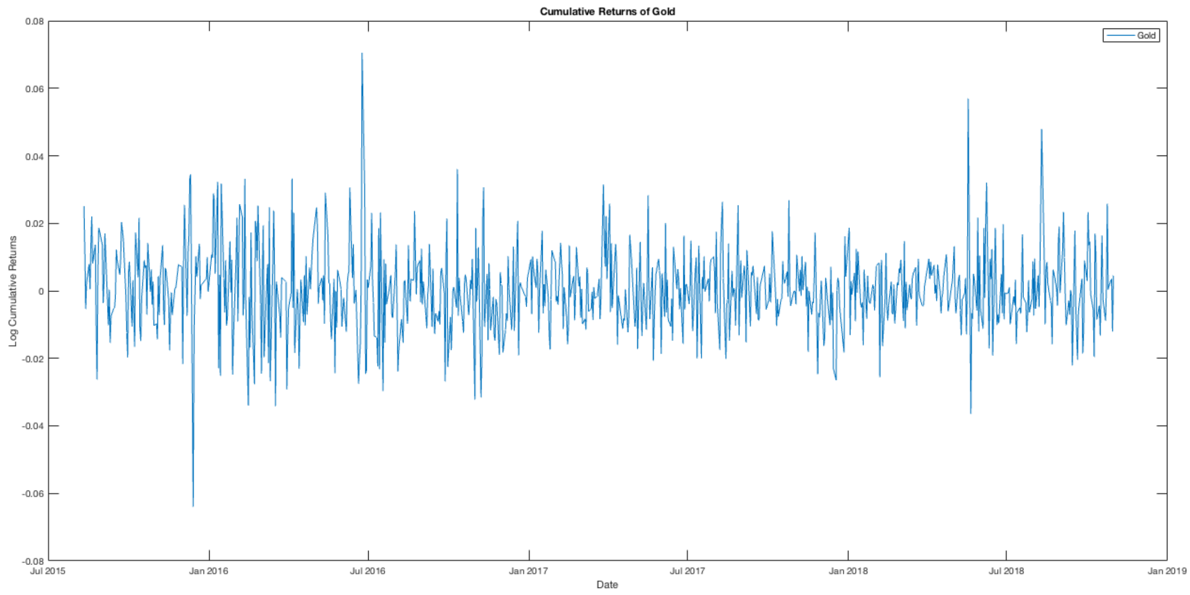
Source: Data from author's computations and Matlab output.

Figure 14: Cumulative returns of the SA government bonds



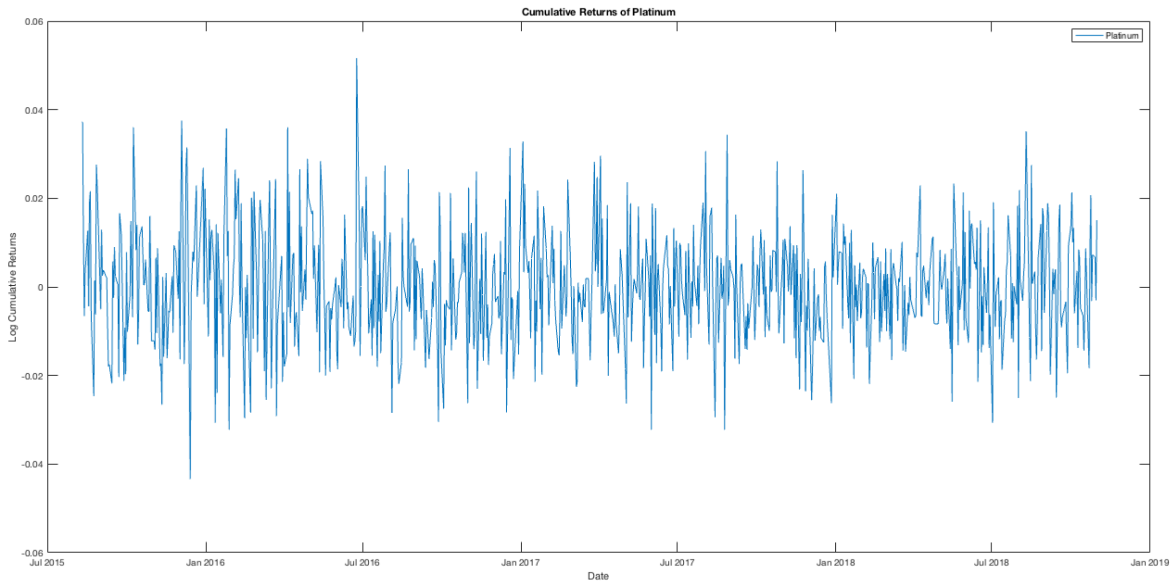
Source: Data from author's computations and Matlab output.

Figure 15: Cumulative returns of gold



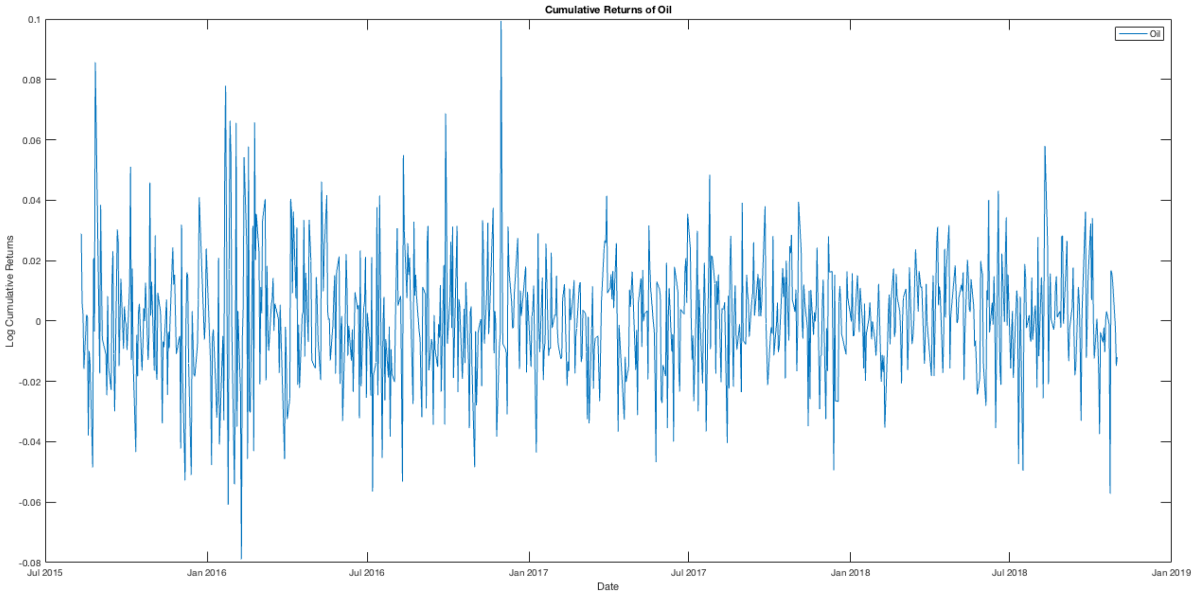
Source: Data from author's computations and Matlab output.

Figure 16: Cumulative returns of platinum



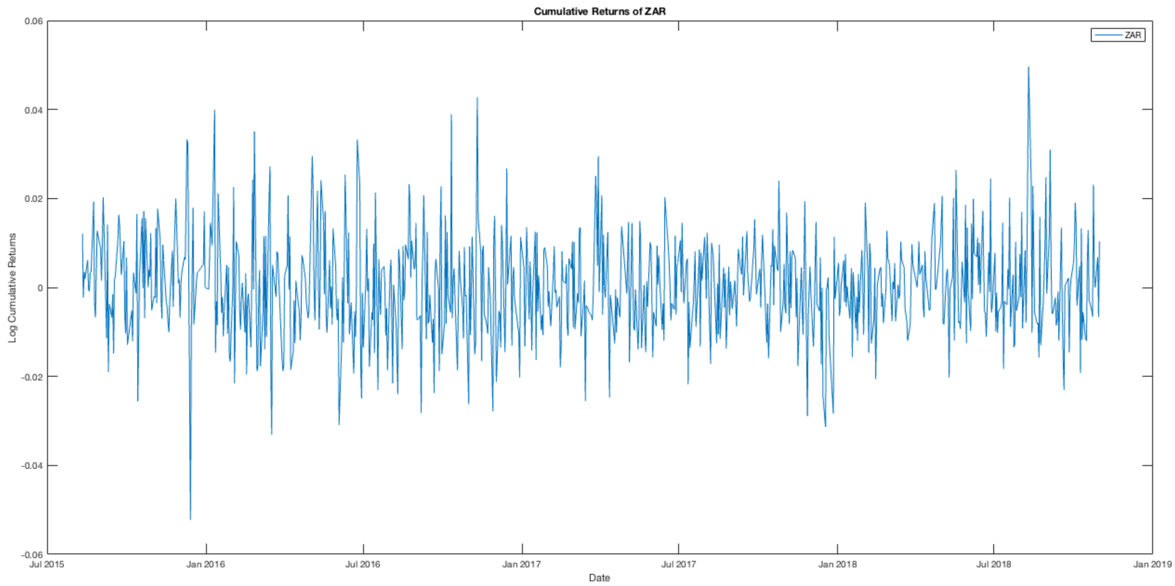
Source: Data from author's computations and Matlab output.

Figure 17: Cumulative returns of Brent Crude oil



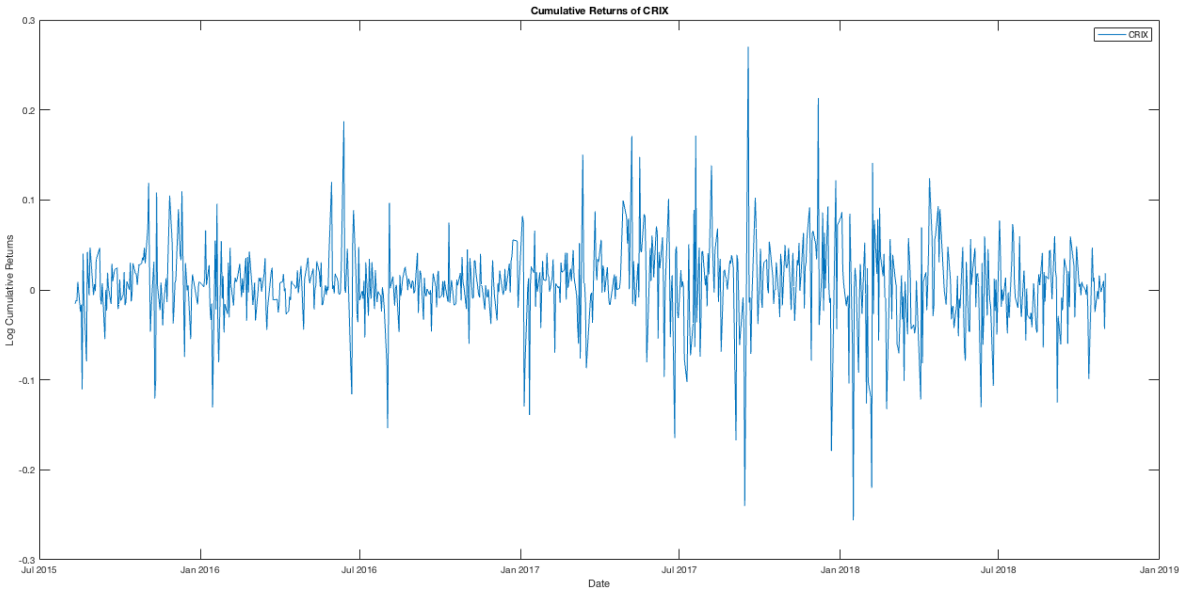
Source: Data from author’s computations and Matlab output.

Figure 18: Cumulative returns of the South African Rands/ZAR



Source: Data from author’s computations and Matlab output.

Figure 19: Cumulative returns of CRIX



Source: Data from author's computations and Matlab output.

Appendix 4: Spanning test

Table 10: Spanning test for CRIX effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	CRIX				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.088258	0.008826	3.96	<.0001
Error	789	1.75881	0.002229		
Corrected Total	799	1.847067			
Root MSE	0.04721	R-Square	0.04778		
Dependent Mean	0.00567	Adj R-Sq	0.03571		
Coeff Var	833.08829				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.005791	0.001715	3.38	0.0008
AllShare	1	4.104976	2.066158	1.99	0.0473
Top	1	-3.32694	1.809925	-1.84	0.0664
AltX	1	-0.10966	0.147957	-0.74	0.4588
Property	1	-0.24862	0.227604	-1.09	0.275
Resources	1	-0.18663	0.150546	-1.24	0.2155
GovtBonds	1	-1.61089	1.044387	-1.54	0.1234
Gold	1	0.077625	0.277483	0.28	0.7797
Platinum	1	-0.07364	0.20078	-0.37	0.7139
Oil	1	0.087098	0.089401	0.97	0.3302
ZAR	1	0.680138	0.262343	2.59	0.0097
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	6.02	0.0025	WALD_TEST	

Source: SAS output.

Table 11: Spanning test for Bitcoin effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Bitcoin				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.103774	0.010377	4.65	<.0001
Error	789	1.761464	0.002233		
Corrected Total	799	1.865238			
Root MSE	0.04725	R-Square	0.05564		
Dependent Mean	0.00525	Adj R-Sq	0.04367		
Coeff Var	899.74872				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.005436	0.001717	3.17	0.0016
AllShare	1	2.303267	2.067716	1.11	0.2657
Top	1	-1.86349	1.81129	-1.03	0.3039
AltX	1	-0.10545	0.148069	-0.71	0.4766
Property	1	-0.14162	0.227776	-0.62	0.5343
Resources	1	-0.12458	0.15066	-0.83	0.4085
GovtBonds	1	-1.59492	1.045175	-1.53	0.1274
Gold	1	-0.04002	0.277693	-0.14	0.8855
Platinum	1	-0.05616	0.200931	-0.28	0.7799
Oil	1	0.054047	0.089469	0.6	0.546
ZAR	1	0.87462	0.262541	3.33	0.0009
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	5.45	0.0045	WALD_TEST	

Source: SAS output.

Table 12: Spanning test for XRP effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	XRP				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.146405	0.014641	1.5	0.1357
Error	789	7.717441	0.009781		
Corrected Total	799	7.863846			
Root MSE	0.0989	R-Square	0.01862		
Dependent Mean	0.00926	Adj R-Sq	0.00618		
Coeff Var	1067.51012				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.009292	0.003593	2.59	0.0099
AllShare	1	2.763298	4.328035	0.64	0.5234
Top	1	-1.5762	3.791297	-0.42	0.6777
AltX	1	-0.10263	0.309929	-0.33	0.7406
Property	1	-0.28935	0.476768	-0.61	0.5441
Resources	1	-0.50594	0.315353	-1.6	0.109
GovtBonds	1	-1.20403	2.187705	-0.55	0.5822
Gold	1	0.218554	0.581252	0.38	0.707
Platinum	1	0.188446	0.420579	0.45	0.6542
Oil	1	0.069521	0.187271	0.37	0.7106
ZAR	1	0.641994	0.549536	1.17	0.2431
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	3.36	0.0352	WALD_TEST	

Source: SAS output.

Table 13: Spanning test for Ethereum effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Ethereum				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.116205	0.011621	1.4	0.1768
Error	789	6.563263	0.008318		
Corrected Total	799	6.679468			
Root MSE	0.09121	R-Square	0.0174		
Dependent Mean	0.00963	Adj R-Sq	0.00494		
Coeff Var	946.98639				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.010165	0.003314	3.07	0.0022
AllShare	1	4.759297	3.991297	1.19	0.2335
Top	1	-4.67185	3.496319	-1.34	0.1819
AltX	1	0.113291	0.285816	0.4	0.6919
Property	1	-0.01862	0.439674	-0.04	0.9662
Resources	1	-0.08817	0.290818	-0.3	0.7618
GovtBonds	1	-1.68079	2.017493	-0.83	0.405
Gold	1	0.000892	0.536028	0	0.9987
Platinum	1	0.066014	0.387856	0.17	0.8649
Oil	1	-0.16464	0.1727	-0.95	0.3407
ZAR	1	0.759988	0.50678	1.5	0.1341
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	4.75	0.0089	WALD_TEST	

Source: SAS output.

Table 14: Spanning test for Dash effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Dash				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.113664	0.011366	2.29	0.0118
Error	789	3.911298	0.004957		
Corrected Total	799	4.024962			
Root MSE	0.07041	R-Square	0.02824		
Dependent Mean	0.0074	Adj R-Sq	0.01592		
Coeff Var	951.30943				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.007055	0.002558	2.76	0.006
AllShare	1	3.822442	3.081162	1.24	0.2151
Top	1	-2.972	2.699055	-1.1	0.2712
AltX	1	0.256912	0.220641	1.16	0.2446
Property	1	-0.37526	0.339415	-1.11	0.2692
Resources	1	-0.1376	0.224503	-0.61	0.5401
GovtBonds	1	-0.16686	1.557445	-0.11	0.9147
Gold	1	-0.11927	0.413798	-0.29	0.7732
Platinum	1	-0.26073	0.299414	-0.87	0.3841
Oil	1	0.215066	0.13332	1.61	0.1071
ZAR	1	0.937157	0.391219	2.4	0.0168
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	4.05	0.0178	WALD_TEST	

Source: SAS output.

Table 15: Spanning test for NEM effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	NEM				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.266638	0.026664	1.33	0.2109
Error	789	15.84368	0.020081		
Corrected Total	799	16.11032			
Root MSE	0.14171	R-Square	0.01655		
Dependent Mean	0.01572	Adj R-Sq	0.00409		
Coeff Var	901.22008				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.014247	0.005148	2.77	0.0058
AllShare	1	2.128107	6.201292	0.34	0.7316
Top	1	-1.38363	5.432244	-0.25	0.799
AltX	1	-0.51254	0.444073	-1.15	0.2488
Property	1	-0.15304	0.683123	-0.22	0.8228
Resources	1	-0.33503	0.451844	-0.74	0.4586
GovtBonds	1	1.043797	3.134587	0.33	0.7392
Gold	1	1.190802	0.832828	1.43	0.1532
Platinum	1	-0.79981	0.602614	-1.33	0.1848
Oil	1	0.458224	0.268325	1.71	0.0881
ZAR	1	0.51353	0.787386	0.65	0.5145
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	4.27	0.0143	WALD_TEST	

Source: SAS output.

Table 16: Spanning test for Stellar effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Stellar				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.258892	0.025889	1.26	0.2468
Error	789	16.16186	0.020484		
Corrected Total	799	16.42075			
Root MSE	0.14312	R-Square	0.01577		
Dependent Mean	0.01252	Adj R-Sq	0.00329		
Coeff Var	1143.21397				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.012119	0.0052	2.33	0.02
AllShare	1	5.628391	6.26325	0.9	0.3691
Top	1	-4.9199	5.486519	-0.9	0.3701
AltX	1	0.339994	0.44851	0.76	0.4486
Property	1	-0.07988	0.689948	-0.12	0.9079
Resources	1	-0.6505	0.456359	-1.43	0.1544
GovtBonds	1	0.204223	3.165905	0.06	0.9486
Gold	1	0.091443	0.841149	0.11	0.9135
Platinum	1	0.352162	0.608635	0.58	0.563
Oil	1	0.311122	0.271006	1.15	0.2513
ZAR	1	0.924112	0.795253	1.16	0.2456
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	3.09	0.0461	WALD_TEST	

Source: SAS output.

Table 17: Spanning test for Litecoin effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Litecoin				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.152933	0.015293	2.54	0.0051
Error	789	4.752502	0.006023		
Corrected Total	799	4.905435			
Root MSE	0.07761	R-Square	0.03118		
Dependent Mean	0.00597	Adj R-Sq	0.0189		
Coeff Var	1299.10665				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.005231	0.00282	1.86	0.0639
AllShare	1	-4.2921	3.396372	-1.26	0.2067
Top	1	3.829501	2.975174	1.29	0.1984
AltX	1	0.058498	0.243213	0.24	0.81
Property	1	0.158258	0.374138	0.42	0.6724
Resources	1	0.113554	0.24747	0.46	0.6465
GovtBonds	1	1.452657	1.716775	0.85	0.3977
Gold	1	-0.10322	0.45613	-0.23	0.821
Platinum	1	-0.0467	0.330044	-0.14	0.8875
Oil	1	0.076932	0.146958	0.52	0.6008
ZAR	1	1.252111	0.431242	2.9	0.0038
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	2.5	0.0826	WALD_TEST	

Source: SAS output.

Table 18: Spanning test for Dogecoin effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Dogecoin				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.170796	0.01708	1.79	0.0591
Error	789	7.539933	0.009556		
Corrected Total	799	7.71073			
Root MSE	0.09776	R-Square	0.02215		
Dependent Mean	0.00809	Adj R-Sq	0.00976		
Coeff Var	1207.63444				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.008193	0.003552	2.31	0.0213
AllShare	1	9.992194	4.277971	2.34	0.0198
Top	1	-8.99245	3.747442	-2.4	0.0166
AltX	1	0.317784	0.306344	1.04	0.2999
Property	1	-0.29642	0.471254	-0.63	0.5295
Resources	1	-0.29136	0.311706	-0.93	0.3502
GovtBonds	1	-1.29135	2.1624	-0.6	0.5506
Gold	1	0.035538	0.574528	0.06	0.9507
Platinum	1	0.377284	0.415714	0.91	0.3644
Oil	1	0.16161	0.185105	0.87	0.3829
ZAR	1	0.541802	0.543179	1	0.3188
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	2.7	0.0678	WALD_TEST	

Source: SAS output.

Table 19: Spanning test for Tether effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Tether				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.109625	0.010963	236.55	<.0001
Error	789	0.036565	0.000046		
Corrected Total	799	0.14619			
Root MSE	0.00681	R-Square	0.74988		
Dependent Mean	0.00027	Adj R-Sq	0.74671		
Coeff Var	2507.04125				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	5.40E-06	0.000247	0.02	0.9826
AllShare	1	0.165328	0.297912	0.55	0.5791
Top	1	-0.18712	0.260967	-0.72	0.4736
AltX	1	-0.01233	0.021333	-0.58	0.5633
Property	1	0.0118	0.032817	0.36	0.7193
Resources	1	0.001585	0.021707	0.07	0.9418
GovtBonds	1	-0.00272	0.150587	-0.02	0.9856
Gold	1	-0.01908	0.040009	-0.48	0.6337
Platinum	1	0.003166	0.02895	0.11	0.9129
Oil	1	0.004766	0.01289	0.37	0.7117
ZAR	1	1.032583	0.037826	27.3	<.0001
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	0	0.9997	WALD_TEST	

Source: SAS output.

Table 20: Spanning test for Monero effect on portfolio of alternative and traditional assets

Model	LINEAR_REGRESSION_MODEL				
Dependent Variable	Monero				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.08997	0.008997	0.96	0.4728
Error	789	7.357362	0.009325		
Corrected Total	799	7.447332			
Root MSE	0.09657	R-Square	0.01208		
Dependent Mean	0.01046	Adj R-Sq	-0.00044		
Coeff Var	922.99622				
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.010064	0.003508	2.87	0.0042
AllShare	1	4.280043	4.225861	1.01	0.3115
Top	1	-3.43937	3.701794	-0.93	0.3531
AltX	1	-0.03352	0.302613	-0.11	0.9118
Property	1	0.000984	0.465513	0	0.9983
Resources	1	0.046597	0.307909	0.15	0.8798
GovtBonds	1	0.146735	2.136059	0.07	0.9453
Gold	1	0.022644	0.56753	0.04	0.9682
Platinum	1	-0.19006	0.41065	-0.46	0.6436
Oil	1	0.032628	0.18285	0.18	0.8584
ZAR	1	0.90273	0.536563	1.68	0.0929
Test Results					
Num DF	Den DF	F Value	Pr > F	Label	
2	789	4.57	0.0106	WALD_TEST	

Source: SAS output.