THE EFFECTS OF BITCOIN AND ETHEREUM ON THE RETURNS AND VOLATILITY OF A STOCK PORTFOLIO IN 2016-2021

Lappeenranta-Lahti University of Technology LUT

Bachelor's Thesis (Strategic Finance)

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Examiner: Associate Professor Anni Tuppura

ABSTRACT

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Bachelor's thesis
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36 pages, 3 figures, 5 graphs, 6 tables, and 1 appendix
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Keywords: cryptocurrency, Bitcoin, Ethereum, portfolio analysis, stock index, returns, volatility

The purpose of this bachelor's thesis is to study the effects of Bitcoin and Ethereum on the returns and volatility of a stock investment portfolio compiled of three diverse indices during 2016-2021. The portfolios are compiled with three different levels of allocation of the cryptocurrencies, with an additional benchmark portfolio containing solely the stock indices. The effects of Bitcoin and Ether on the benchmark portfolio are studied with a portfolio analysis approach using absolute returns, volatility, the Sharpe ratio, the Treynor measure, and Jensen's Alpha as tools of measurement. Previous studies have had varying results due to the short history of the cryptocurrencies and the scarcity of academic research, but they agree that cryptocurrencies increase portfolio volatility.

The results of the study indicate that Bitcoin and Ethereum have been exceptionally profitable investments during the period of the study. The currencies increased absolute portfolio returns and volatility by a great margin, and the risk-adjusted performance measures produced similar conclusions. The results reflect the exceptional market price development of the currencies and conclude that Bitcoin and Ether achieve formidable excess returns during 2016-2021.

TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto LUT
LUT-kauppakorkeakoulu
Kauppatieteet, strateginen rahoitus

Joel Keltto

Bitcoinin ja Ethereumin vaikutukset osakeportfolion tuottoon ja volatiliteettiin vuosina 2016–2021

Kauppatieteiden kandidaatintutkielma
2022
36 sivua, 3 kuviota, 5 kuvaajaa, 6 taulukkoa, ja 1 liite
Tarkastaja: Tutkijaopettaja Anni Tuppura

Avainsanat: kryptovaluutta, Bitcoin, Ethereum, portfolioanalyysi, osakeindeksi, tuotto, volatiliteetti

Kandidaatintutkielman tarkoituksena on tutkia Bitcoinin ja Ethereumin vaikutuksia kolmen eri indeksin osakesijoitusportfolion tuottoihin ja volatiliteettiin vuosina 2016–2021. Portfoliot kootaan kolmella eri kryptovaluuttojen painotuksella sekä viiteportfoliona käytetyn osakeindeksikokonaisuuden kanssa. Bitcoinin ja Etherin vaikutuksia vertailuportfolioon tutkitaan portfolioanalyysimenetelmällä, jossa käytetään absoluuttista tuottoa, volatiliteettia, Sharpen lukua, Treynorin lukua, ja Jensenin Alphaa mittausvälineinä. Aiempien tutkimusten tulokset ovat vaihdelleet kryptovaluuttojen lyhyen historian ja akateemisen tutkimuksen niukkuuden vuoksi, mutta konsensus on, että kryptovaluutat nostavat portfolion volatiliteettia.

Tutkimuksen tulokset osoittavat, että Bitcoin ja Ethereum ovat olleet poikkeuksellisen kannattavia investointeja tutkimuskauden aikana. Valuutat kasvattivat salkun absoluuttista tuottoa ja volatiliteettia suurella marginaalilla, ja riskikorjatut tulosmittarit tuottivat samankaltaiset johtopäätökset. Tulokset kuvastavat valuuttojen poikkeuksellista markkinahintakehitystä ja ajavat johtopäätökseen, että Bitcoinilla ja Etherillä saavutetaan merkittävät ylituotot vuosien 2016–2021 aikana.

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1. Introduction

This bachelor's thesis is focused on the potential investment opportunities that cryptocurrencies produced on a stock portfolio during 2016-2021. The thesis aims to provide investment insight on two of the major cryptocurrencies, Bitcoin and Ether, and their effects on the returns and volatility in an investment portfolio compiled of three stock indices. The currencies' effects on the stock portfolio will be determined by creating three copies of the portfolio – each with different weights on the cryptocurrencies. The study attempts to determine which of these portfolios achieves the highest returns for the investments with minimal risk of losing capital as Platanakis & Urquhart (2020) state that relatively little is known about the investment possibilities and benefits of cryptocurrencies. The timespan of interest for the study includes some abnormal circumstances in the markets, such as the start of the Covid-19 pandemic at the very end of the period.

Since their inception to the realm of investing and day-trading, cryptocurrencies have attracted countless people looking to get rich quick. Bitcoin entered the world as the first digital currency to combat a lack trust towards financial institutions during the recession in 2008. The creator of the cryptocurrency intended it to be used as cash for all transactions, but the investing community had other plans. However, only a handful of investors saw the potential of blockchain technology in the early 2010's. The price of Bitcoin remained at moderate levels for a couple of years after its launch and surpassed $100 per unit for the first time in early 2013. The interest towards the currencies and the technology underneath skyrocketed in 2017 and the lucky few who invested early enough made millions with petty cash. The first cryptocurrency, Bitcoin inspired countless coders to create alternative currencies known as altcoins from the basis of the blockchain behind Bitcoin, with varying algorithmic designs (Chuen, Guo & Wang 2018, 16). Several of these altcoins ended up gaining traction either due to their unique design or qualities. One of these successful altcoins is Ether, in which this study focuses alongside Bitcoin.

1.1. Research objective, questions, and limitations

The subject of "cryptocurrencies' effects on a stock portfolio in 2016-2021" is an interesting one to study because crypto currencies are an invention of this century (Böhme et al. 2015, 213) and possess traits that are new to a stock investor. Although digital assets have gained a lot of attention and interest in the investing community, Sifat, Mohamad & Shariff (2019, 306) argue that their return and co-movement structures remain largely unexplored. The aim is to study the effects of the two instruments on the portfolio's volatility and profit by deriving several portfolios, weighed at three different levels by the cryptocurrencies. The focus in the literature of the study in relation to the two cryptocurrencies is on Bitcoin, as it is the first cryptocurrency to launch, and the Ethereum blockchain was developed on its basis. However, the effects of the two currencies on the stock portfolio are evaluated with equal importance. The subject is highly relevant as Symitsi & Chalvatzis (2019, 97) point out that "the literature on cryptocurrencies' properties and potential benefits for investors is still in its infancy". The goals of the thesis are to identify the effects of the cryptocurrencies, and to define the optimal weight from the assigned options for both currencies in a stock portfolio that maximizes returns in different timespans. The main research question is posed as:

Do cryptocurrencies improve the risk-adjusted performance of the stock portfolio?

In addition to the main research question, other aspects of the subject should be considered. For instance, cryptocurrencies' marketplace is not limited by trading hours (Jain, McInish & Miller 2019, 1031) as the stock market. This is to be considered when assessing the increase or decrease on the profit of the portfolio. To form a justified conclusion of the currencies' effects, several portfolios with different compositions of the instruments should be derived from the initial state. These variables are considered by forming and answering additional sub-questions to procure a wider scope around the main research question. The sub-questions are posed as:

1. *What are the effects of the cryptocurrencies on the volatility of the stock portfolio?*

2. *How does the stock portfolio react to different weights of cryptocurrencies in terms of profit?*

The main limiting factor to the study is that cryptocurrencies are a relatively new investment vehicle. Therefore, the data are limited to only about a decade of price changes, which cannot be generalized into the future. The popularity of these currencies has caused unprecedented surges of thousands of percentage points in their prices and as Platanakis & Urquhart (2020, 2) point out, this has nothing to do with the currency's ability to act as a medium of exchange but that it is viewed as an investment. The currencies are considered to be highly volatile securities but that might not be the case in ten years' time.

1.2. Research methodology

The study is conducted by quantitative methods and is narrowed by geographical parameters to improve the detection of common factors on the returns. In addition, the selected indices, S&P 500, OMXH 25 and the MSCI Emerging Markets Index differ profoundly from one another in terms of their composure, market cap, and geographical interest. It is notable that the timespan of interest is affected by some exceptional events, which are the sudden rise of cryptocurrencies, and the start of the Covid-19 pandemic in late 2019. These events have had a major impact on the financial system at large and are expected to have an effect on the study. The methodology of the research is a quantitative analysis from the data acquired from the trading platform Tradingview and Yahoo Finance.

Unlike the traditional securities market, cryptocurrencies markets are active around the clock. In order to be able to use traditional means of return and volatility measurement, the cryptocurrencies' data is to be consolidated with that of the stock indices. Due to the use of daily price points and the consolidation of the price data, the logarithmic return model offers a slight advantage over the arithmetic return model, in which multiplying numbers close to zero can cause arithmetic overflow (Mickolczi 2017, 129).

1.3. Structure of the study

This study examines the effects of two of the major cryptocurrencies', Bitcoin's and Ether's effects on a stock portfolio's volatility and returns. The structure of the theory section is composed of two main chapters. The following literature review covers foundations on which the study is built on by summarizing the founding of blockchain, the essential aspects of both cryptocurrencies, as well as their utility as vehicles on investment, and as a medium of exchange. Chapter 3 will focus on the research methods used in this thesis and provides an overview of the approaches and means used in determining the effects of the two cryptocurrencies on the stock index portfolio compiled for the study. The results from the completed analyses will be disclosed in Chapter 4 with separate sub-chapters focusing on the absolute return measures and volatilities, and risk-adjusted performance. Chapter 5 then presents the results in a summary, reviews them in the light of previous studies, and addresses the limitations of the study in light of the results. The conclusions are formed in the final chapter, along with critical analysis of the study, and suggestions for further research.

2. Literature review

The literature around Bitcoin and Ethereum in this thesis focuses on delivering a novel understanding of the two cryptocurrencies and examines their roles as instruments of investment and as mediums of exchange. The following chapters approach the main focus of the thesis, cryptocurrencies, by first exploring blockchain technology, and subsequently delving into the two main currencies Bitcoin and Ether. The following sub-sections will provide an overview of all the concepts and identify key characteristics for each cryptocurrency, as well as briefly narrate the state of world economy that led to the creation of Bitcoin and its underlying technology by Satoshi Nakamoto.

2.1. What are cryptocurrencies and the technology underneath?

Blockchain technology has existed since the launch of Bitcoin, in 2009. In their first few years of existence, Bitcoin drew most of the oncoming attention and the technology underneath was overshadowed by the currency. (Ali, Ally, Clutterbuck, Dwivedi 2020) However, in recent years blockchain technology, also referred to as the distributed ledger technology, has been realized to have possibilities far beyond the virtual currency by experts and academic researchers (Ølnes, Ubacht & Janssen 2017, 355). Still, according to Ali et al. (2020), while being the main driving force in financial technology, the predominant usage of distributed ledger technology has thus far been in the narrow field of payments. Cryptocurrencies like Bitcoin and Ether operate in P2P (peer-to-peer) networks, and they utilize cryptography as well as a public key infrastructure as a form of safe data transferring (Böhme, Christin, Edelman & Moore 2015, 215). To be exact, there is no requirement of a trusted third party in the system to secure users' assets and transactions, for the network is protected by the proof-of-work protocol, derived from Adam Back's *Hashcash* (Nakamoto 2008; Böhme et al. 2015) Moreover, the entire code behind blockchain is open sourced, which assures its users of total transparency, and excludes the possibility of any backdoors being in the system (Ali et al. 2020). The unique characteristics of blockchain technology, decentralization, and trust (Ali et al. 2020) laid the foundation of the acceptance of the technology in the wake of the financial crisis when both these traits were sought after (De Filippi, Mannan & Reijers 2020, 2).

As many scientific researchers have noticed the potential of blockchain technology in the 2010's, the concept of decentralized currencies as a subject of academic research has been gaining traction for the better part of a decade, although rigorous research attempts to blockchain itself have been scarce (Hoffman, Ibáñez & Simperl 2020, 2). Within the scope of interest in academic study of both Bitcoin, and the underlying technology, has increasingly been the relevant security concerns, such as Denial-of-Service (DoS) attacks against users, and on the technology itself (Andrychowicz, Dziembowski, Malinowski & Mazurek 2015; Vasek, Thornton & Moore 2014). Furthermore, blockchain technology has been found to face certain challenges that influence the possible applications of the technology. These are namely in the areas of adaption, regulation, scalability and flexibility, and transaction costs in addition of those of security. (Ali et al. 2020; Ølnes et al. 2017)

2.1.1. Blockchain technology

According to Iansiti and Lakhani (2017), blockchain is "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way". Blockchains collect informational transactions in a distributed network, which means that no controlling central authority is required. (Imteaj, Amini & Pardalos 2021, 3) A single block stores some or all of the transactions in a time period. The block not only stores the transactions, but also a timestamp, the hash value of the block before, and a random number to verify the hash, known as a nonce (Nofer, Gomber, Hinz & Schiereck 2017, 184). Once the information related to the transaction is complete, the data moves to the blockchain as a part of the permanent database. Blocks are linked to one another in chronological order with each individual block containing a hash function of the previous block, referred to as a *parent* block by Zheng, Xie, Dai & Wang (2018), connecting the two (Shen, Xu & Zhu 2020, 15). In the context of Ethereum blockchain, the *uncle blocks* (children of the block's ancestors) hashes are stored as well (Zheng et al. 2018, 355). Newly created blocks can be validated by the network with cryptographic means (Nofer et al. 2017, 184) involving a distinct method of public and private keys (Zheng et al. 2018, 356).

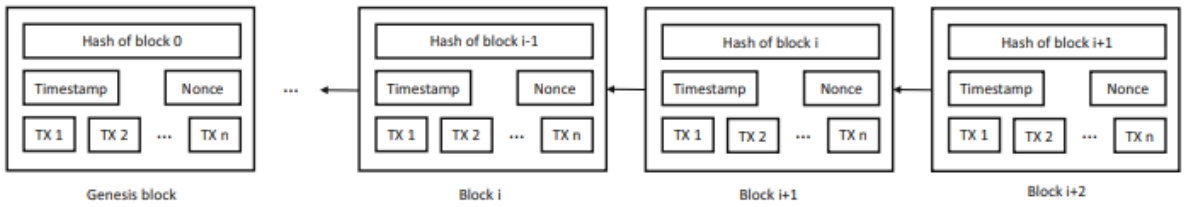


Figure 1. Example of a blockchain (Zheng et al. 2018, 355).

Each user has a private key, that is unlike any other, and is used to sign (encrypt) the transactions. In addition, every user also has a public key to verify (decrypt) transactions. The signed transactions are spread throughout the collective network and accessed with public keys that are visible to everyone in the network. (Zheng et al. 2018, 356)

Blockchains can be distinguished from one another by their qualities regarding ledger maintenance. A blockchain can be public, in which anyone who follows the rules of the blockchain can view transactions, make changes, and create additional blocks. Alternatively, the creator can restrict access to the blockchain or some of its properties in the permissioned model of the technology. (Kher & Terjesen 2021, 1701) A blockchain system can also be private, in which case only nodes from a single organization can maintain the ledger.

2.1.2. Bitcoin

"Bitcoin is an online communication protocol that facilitates the use of a virtual currency, including electronic payments." (Böhme, Christin, Edelman & Moore 2015, 213). Bitcoin was introduced in 2009 by an anonymous group of developers appearing by the name of Satoshi Nakamoto (Böhme et al. 2015, 213). Nakamoto (2008) describes the technology as a peer-to-peer version of electronic cash that would allow secure private online transactions between two parties without the need of financial institutions.

Bitcoin implements money by using hash-functions and digital signatures without relying on central trusted authorities, like banks. A Bitcoin block consists of two main parts, which are an ordered set of transactions (typically 1000-2500) and a block header. The basic idea of Bitcoin is rather simple; a coin is represented by a series of signatures over data strings, the owner of which is determined by these signatures, and public keys. The owner of an amount of virtual

currency is recognized in the data string. The owner can transfer the currency to a new owner by using their private key, digitally signing a transaction statement, which is verified with the new owner's signature public key and includes the unique hash value of the previous statement to imply the amount of money to be transferred. (van Oorschot 2021, 376)

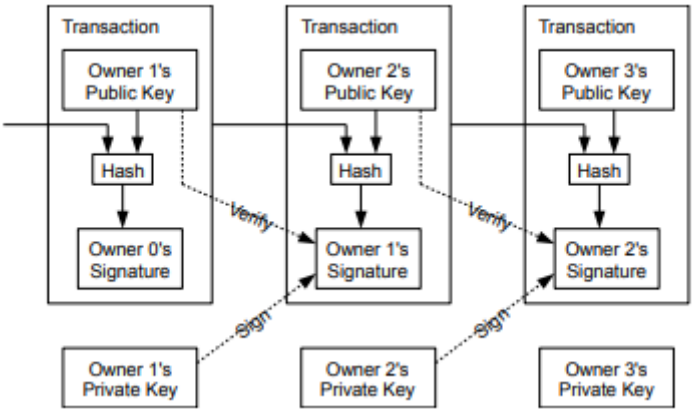


Figure 2. Example of the mechanics of a Bitcoin transaction (Nakamoto 2008, 2)

All transactions that are made within approximately ten minutes are compiled in a block to be verified (van Oorschot 2021, 385). The verifying is done by competing Bitcoin miners, who use their computing power to solve mathematical equations, called Proof-of-Work. Once a miner solves an equation, thus providing proof-of-work, they publish the block containing the solution, and the list of transactions in the block to be appended as the latest component of the blockchain. (Nakamoto 2008) To understand which individual miner is the first to solve the proof-of-work and to compile the block, one needs to understand the mechanics of *Merkle hash trees*. A Merkle hash tree is a data structure used in each block to provide a unique fingerprint for determining its position in the chain. In order to construct a Merkle hash tree of transactions, the block miner sorts the transactions in a fixed order. The transaction IDs (txID) of the ordered transactions are then paired with each concatenation being given a hash value. The newly created hashes form level two entries, which are again paired, concatenated, and assigned a hash value, and so on. The hash value combining all of the branches together is called the merkle-root, which is in the header of the block. The idea is that the merkle-root incorporates the ordered transactions to the header, which also contains the hashlink to identify the previous block. The merkle-root thus provides the block with a statistically unique 256-bit header hash.

The probability of two blocks having the same hash in its header is $\frac{1}{2}^{256}$, which in practice is zero. (van Oorschot 2021, 384-385)

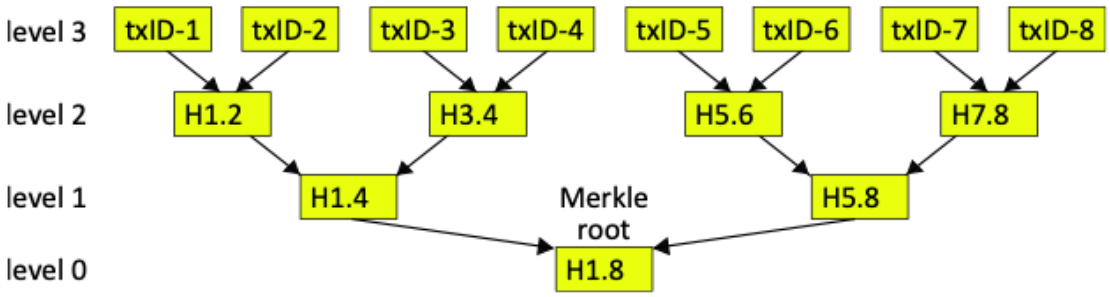


Figure 3. Merkle hash tree (van Oorschot 2021, 385)

The incentive in the verifying process is that the miner who manages to be the first to provide proof-of-work to a new block gets a reward in new Bitcoins. The amount of Bitcoin received was initially 50 BTC, in 2008. The system is designed as such that the reward is halved every 210 000 created blocks. (Nakamoto 2008) According to Bitcoinwiki (2022), the first split in the reward for mining occurred in 28.11.2012. This system of declining reward eventually leads to a situation, where miners are no longer incentivized to verify new blocks. The final amount of circulating Bitcoin is fixed at 21 million units, which is approximated to arrive in the year 2140. Once the predetermined number of Bitcoins have entered circulation, the incentive system can be transitioned to rewarding transaction fees to the miners. (Nakamoto 2008)

2.1.3. Ethereum

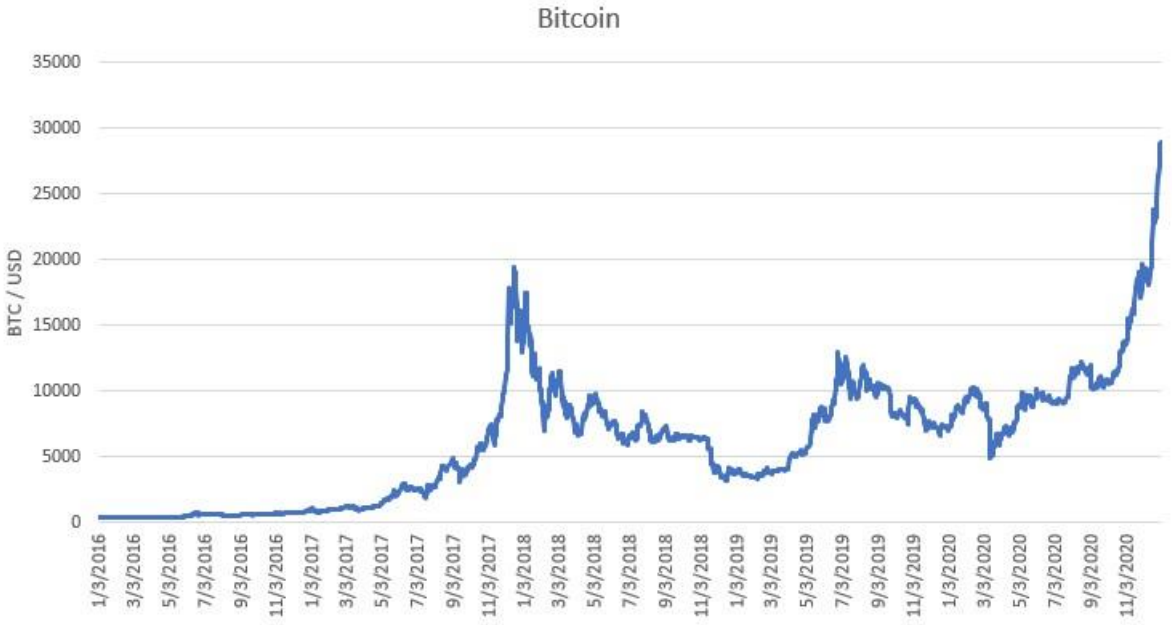
The Ethereum blockchain was founded and developed by Vitalik Butkerin in 2013 from the idea of Bitcoin. Ethereum was funded with an online public crowd sale of Ether, in which approximately $18 million worth of Bitcoins was raised in 2014. Unlike Bitcoin, Ethereum was coded with JAVA programming, and it provides users with a decentralized virtual machine. (Chuen et al. 2018, 20) The groundbreaking detail about Ethereum is that the open-sourced virtual machine in the blockchain allowed for the deployment of smart contracts in transactions. A smart contract is a general-purpose computer program that is hosted and executed by Ethereum (Zarir, Oliva, Jiang & Hassan 2021, 28). The cryptocurrency used in the

Ethereum blockchain is Ether (the two terms are often interchangeable), which has risen to be the second most used cryptocurrency after Bitcoin since its launch, in 2015. The blockchain being programmable doesn't just allow flexibility in the context of its currency but enables all computer programs to be built in to utilize the blockchain. (Ethereum, 2021) This has led to coders to raise funds through ICOs and develop their own cryptocurrencies to address issues experienced in existing algorithms or for other purposes. ICO stands for Initial Coin Offering, which will be further discussed in the next section. In late 2017 just before the price hike of Ether, 869 cryptocurrencies and 269 crypto tokens had been launched, with a total market capitalization of nearly $150 billion. Today, the total market capitalization of digital assets stands at slightly under $800 billion, after the recent collapse of FTX exchange. The market's high point thus far has been the November of 2021, when the entire crypto market capitalization exceeded $3 trillion, with Bitcoin alone at over $1 trillion. (CoinDesk 2022) As of November 2022 there are 9310 cryptocurrencies worldwide (Statista 2022).

2.2. Cryptocurrencies as vehicles of investment

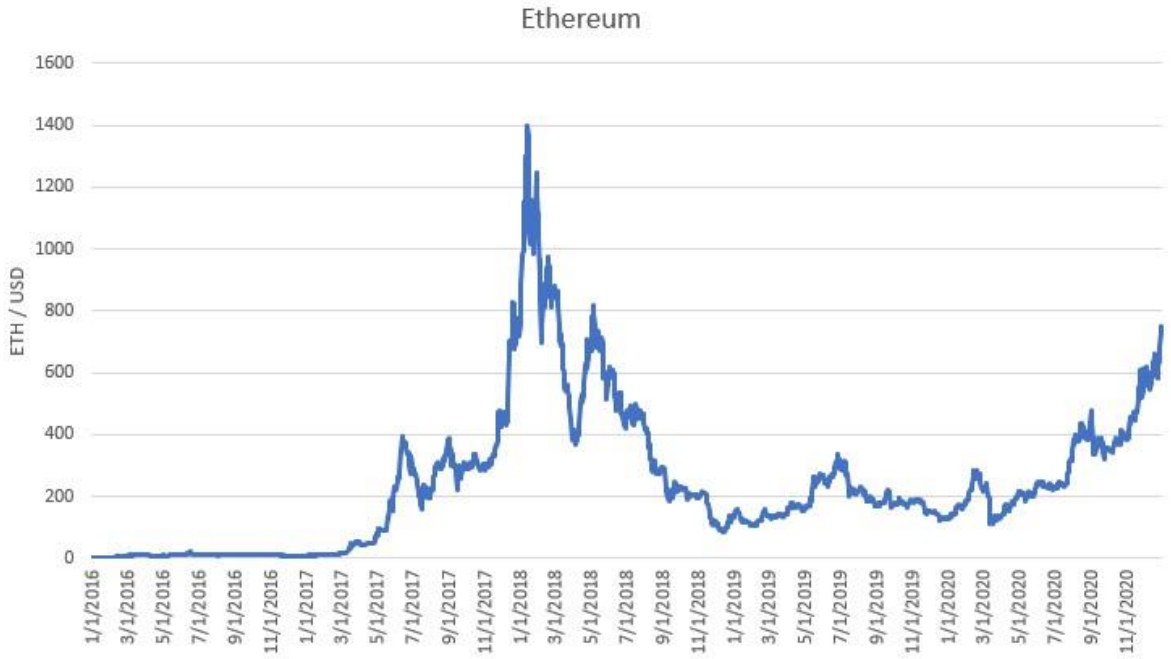
The interest towards blockchain and cryptocurrencies as instruments of investing has skyrocketed and the cryptocurrency market has been drenched in capital as FinTech has gradually accepted blockchain technology to be the next big thing (Sifat et al. 2019, 307). The rapidly growing hype around cryptocurrencies also has its negatives, as pointed out by Chuen et al. (2018, 17), who maintain that investors should be sure to understand the return-risk structure of these assets before making commitments. Graph 1 shows the price development of Bitcoin during the scope of the study. They argue that the highly volatile market of cryptocurrencies is mainly driven by investor sentiment, rather than changes in fundamentals. This is especially important as Zhao and Zhang (2021, 1209) note that not much emphasis has been given in the scientific community to finding empirical evidence of the impact of financial literacy and investing experience on cryptocurrency investors. The findings of Chuen et al. (2018) are supported by Glas (2019, 97) who found no dependency between cryptocurrencies on the macroeconomic environment and concluded that traditional capital market mechanics could not yet be applied to cryptocurrency markets. Therefore, Auer and Tercero-Lucas (2022) suggest that the cryptocurrency markets could benefit from a clarifying and supervisory framework, as they find that the goals of cryptocurrency investors are similar to those of an investor of any other asset class. That being said, cryptocurrencies may offer diversification

advantages to investors because their returns seem not to correlate with other asset classes (Shahzad, Bouri, Rehman & Roubaud 2022).



Graph 1. Bitcoin price development in U.S. dollars

The introduction of smart contracts in the Ethereum blockchain allowed users to create their own cryptocurrencies and distribute them using Ethereum's platform. An instance, such as this, is called an ICO or Initial Coin Offering, where distributed ledger technology-based ventures raise capital by selling tokens to investors. The tokens can be considered to be a substitute for shares of a stock in the realm of cryptocurrency. There are three widely acknowledged types of tokens, which are (1) currency-, (2) utility-, and (3) equity tokens. Currency tokens are what is generally known as "cryptocurrency" - in effect, Bitcoin, Ether, Litecoin, et cetera. Utility tokens grant users access to a product or a service within the blockchain. Lastly, equity tokens represent ownership rights to assets like a company's stock or its debts. (Masiak, Block, Masiak, Neuenkirch & Pielen 2019, 1113-1115) The diversity of possibilities in the Ethereum blockchain lured users and investors alike to the platform and caused the surge of the currency's price relative to the U.S. dollar, as depicted in graph 2.



Graph 2. Ether price development in U.S. dollars

2.2.1. Cryptocurrencies as a medium of exchange

The role of digital currency has grown steadily during the past decade, namely driven by the increasing popularity of Bitcoin. Cryptocurrency is being used regularly in real-world transactions, as well as in the dark web because of the absence of a controlling central authority as intermediary. The strong security affiliated with the peer-to-peer network has made the currencies appealing to all who value anonymity. (Uddin 2022, 2) Auer and Tercero-Lucas (2022) emphasize that one cannot overlook the possibility that one of the motivations behind the creation of cryptocurrencies is the goal of having a new form of exchange that is out of reach for governments and financial institutions to debase or censor.

The recognizable catalyst that created the need for an alternative to the current monetary system was the financial crisis of 2008, otherwise known as the sub-prime crisis. The United States' housing market crashed in 2008 with drastic consequences due to heavily misaligned incentives that lead to double spending in the financial sector. The aftermath of the catastrophic events of 2008 left the world economy without trust in the financial system at large, and simultaneously created space for the takeoff of Bitcoin. (Dhillon, Metcalf & Hooper 2021, 2) In the whitepaper, published by an anonymous individual or a group of developers by the pseudonym Satoshi

Nakamoto, they introduce an alternate payment system that would not require trust between parties due to its basis in cryptographic proof instead of trust (Nakamoto 2008). However, in their survey study Auer and Tercero-Lucas (2022, 2-3) found no evidence that cryptocurrencies are sought after due to trust issues with commercial banking services, although they did find that those who are concerned about the security of traditional institutions in finance tend to be keen on at least acquiring information about cryptocurrencies.

3. Research methods and used metrics

The study is conducted with quantitative research methods and means of portfolio analysis. The data is acquired from the trading platform Tradingview, and Yahoo Finance and processed with Microsoft Excel. As mentioned in the introductory section, in order to be able to use traditional tools of performance measurement, the price data of Bitcoin and Ether have been consolidated with that of the stock indices. The statistical measuring tools used to determine the effects of Bitcoin and Ether on the portfolios are the Sharpe ratio, Treynor's index (otherwise known as the Treynor measure) and Jensen's Alpha. The relevant equivalent to the risk-free rate of return used in this study is the mean interest rate on the 10-year United States Treasury bond (Macrotrends 2022) during the scope of the study.

The data used in the study consisted of daily closing prices of the S&P 500-, the OMXH 25-, and the MSCI Emerging Markets index, as well as Bitcoin and Ether. The data was consolidated by the removal of stock market holidays of each index's country of origin and by removing the corresponding dates from both cryptocurrencies' price data. The scope of the study was from January 4th, 2016, to December 30th, 2020.

3.1. Volatility

Volatility is a commonly used indicator for risk management in the financial markets (Mittnik, Robinzonov & Spindler 2015, 1). However, as clarified by Poon & Granger (2003, 478), it is not the same as risk. In the context of finance, the volatility of an asset describes the standard deviation of an asset's returns to the expected value (Poon & Granger 2003, 480), in effect the average returns. However, in terms of statistics volatility can be expressed as simply the standard deviation of a sample. In simpler terms, according to Knüpfer & Puttonen (2018, 136), volatility increases as the number of observations that differ substantially from their mean rise. This thesis will focus on the financial definition of volatility, as explained above, by calculating volatility from the variance of an asset's returns.

$$\sigma_i = \frac{s}{\sqrt{n}} \quad (1)$$

σ_i = portfolio volatility

s = standard deviation of returns

n = time period involved

3.2. Returns

The profits of an investment can be calculated with simple calculus. Assuming the actual share price index is known, the traditional *simple net return* approach of calculating profit margins of stocks where the price range of stock is divided by its original price, presents some issues where the returns are negative. The returns of an investment can also be calculated with the Compound Annual Growth Rate (CAGR) model - a measure of the investment's annual growth rate, which takes the effect of compounding returns into account. (Corporate Finance Institute 2022) The *continuously compounding return* model, or the logarithmic return model involves the compounding effect like the CAGR model and solves the issue of determining negative returns by allowing observations to surpass -100 percent. In addition, logarithmic returns are more normally distributed due to the natural symmetry of the yields the model predicts. (Vaihekoski 2022, 204-205)

$$R_p = ln(P_t + D_t) - ln(P_{t-1}) = ln(\frac{Pt+Dt}{Pt-1}) \quad (2)$$

R_p = asset return

ln = natural logarithm

P_t = asset price at time t

D_t = asset dividend at time t

P_{t-1} = asset price at time $t-1$

3.3. The Sharpe Ratio

Originally devised from the Sharpe-Litner Capital Asset Pricing Model and mean-variance analysis, the Sharpe ratio is one of the most commonly used indicators of performance in financial analytics. The ratio is of the excess expected return of an investment to the standard deviation of the return. Due to the fact that volatilities and expected returns are generally not observable to a degree, they have to be estimated with an intrinsic margin of error. (Lo 2002, 36) As observed by Basile and Ferrari (2016, 246-247), one of the advantages of the Sharpe ratio is its ability to be compared over multiple investments or portfolios. The highest ratio is of the portfolio that yields the highest excess returns per unit of total risk (Basile & Ferrari 2016, 246).

$$Sharpe\ ratio\ = \frac{R_i - R_f}{\sigma_i} \tag{3}$$

R_i = mean portfolio returns over the interval considered
R_f = risk-free rate over the interval considered
σ_i = standard deviation of the portfolio returns

The ratio is formed by deducting the risk-free rate of return from the return of the investment and dividing the resulting excess return with the standard deviation of returns (Lo 2002, 37; Basile & Ferrari 2016, 246). However, the Sharpe ratio does have its flaws. As pointed out by Hodoshima and Otsuki (2019, 4284), the Sharpe ratio fails to capture high moments of the underlying distribution of probabilities resulting from non-frequent but catastrophic events. The ratio can therefore be misleading in some instances and must be accompanied by other measures of performance to achieve an accurate assessment of the full scope of risks and return potential involved.

3.4. The Treynor Measure

The Treynor ratio, or the Treynor measure, was conceptualized by Jack Treynor in 1965 to measure excess returns of an investment over the risk-free rate by dividing the calculated alpha with the portfolio beta (Bodie, Kane & Marcus 2005, 868; Hübner 2005, 415). The Treynor measure is very similar to the Sharpe ratio. Their difference on the level of their equations is merely the denominator, which in the equation of the Treynor measure is the systematic risk, β_i, as opposed to standard deviation or volatility used in the Sharpe ratio (Knight & Satchell 2002, 4). In effect, the Sharpe ratio takes a higher standpoint on risk by deriving its measure from the total risk than the Treynor measure, which looks at the portfolio's systematic risk, the capital asset pricing model's (CAPM) beta (Knight & Satchell 2002, 5).

$$Treynor\ measure\ = \frac{R_i - R_f}{\beta_i} \tag{4}$$

R_i = mean portfolio returns over the interval considered
R_f = risk-free rate over the interval considered
β_i = systematic risk of the portfolio

As explained by Ang (2021), the higher the Treynor measure, the better the risk-adjusted performance of the portfolio. However, there are notions to consider with the Treynor measure and the beta. According to Hodges, Taylor, and Yoder (2003, 503), the systematic risk of a portfolio is typically estimated using short-term return intervals, which creates a problem when the investment horizon is of longer term. Compounding returns being non-linear presents a risk for miscalculation of the beta if not properly taken into account. The beta can either be calculated as a 12-period (multiperiod) beta, or by using annual return data to derive an annual (single-period) beta.

$$\beta_i\ = \frac{Cov(R_i, R_m)}{\sigma_m^2} \tag{5}$$

β_i = systematic risk of the portfolio

R_i = return on asset *i* (portfolio)

R_m = return on the market portfolio

$Cov(R_i , R_m)$ = covariance of returns for asset *i* and the market portfolio

σ^2_m = variance of market returns

3.5. Jensen's Alpha

Jensen's alpha is defined as the portfolio's excess return over the required average return (Hübner 2005, 415). Jensen's alpha and its multifactor variants are among the most used methods of determining the economic excess value that portfolio managers add for their clientele (Bunnenberg, Rohleder, Scholz & Wilkens 2018, 234). However, Bunnenberg et al. (2018) point out that the measure shows downward bias towards portfolios that are successful in timing the markets and are trading accordingly. The alphas of these portfolios that succeed in timing the market perfectly may even be negative with statistical significance (Bunnenberg et al. 2018, 234).

$$\alpha_i = R_i - [R_f + \beta_i(R_m - R_f)] \quad (6)$$

α_i = portfolio Alpha

R_i = return on asset *i* (portfolio)

R_f = risk-free rate

β_i = systematic risk of the portfolio

R_m = return on the market portfolio

4. Results

The purpose of this section is to lay out the findings of the analyses conducted on the data around the cryptocurrencies Bitcoin and Ether, and the indices S&P500, MSCI EM and OMXH25. The data consists of the daily closing price-points of the indices and currencies. The results of the performed analyses are divided into the following two sections, first of which focuses on the absolute returns and volatilities of the securities. The latter section focuses on reviewing the results from the risk-adjusted performance measuring tools. In both these sections, the observed securities are divided into four portfolios, first of which being the stock portfolio that is compiled solely of the indices and that is used as a benchmark for the cryptocurrencies' performance. The three other portfolios contain all of the securities with differing weights on the cryptocurrencies.

The expected results are that both crypto currencies have a significant effect on the stock portfolio's risk-adjusted, and absolute returns, as well as an increasing effect on the volatility of the portfolio due to the unique conditions that prevailed in the markets. These conditions being the low level of trust in traditional capital markets in the aftermath of both the financial crisis, and the eurozone crisis, as well as the unprecedented surge of the cryptocurrencies' price as investors rallied to buy them in 2017. These results could nonetheless have a positive impact on the investment strategies of conventional stock investors.

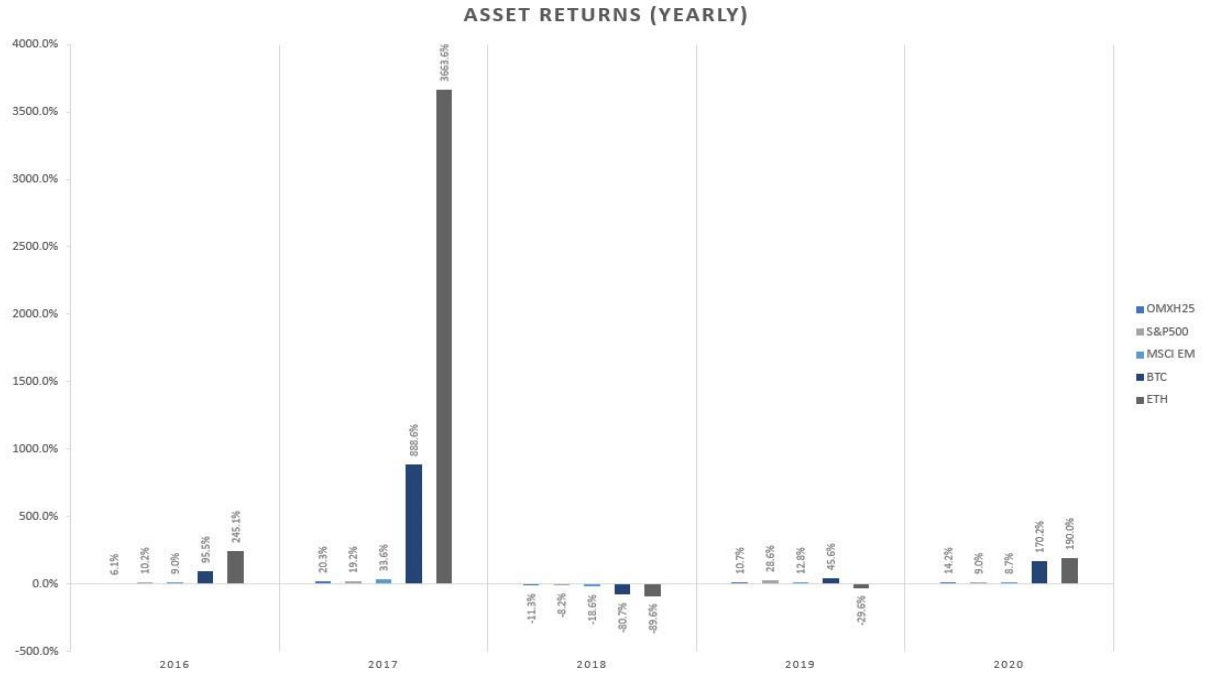
	Stock portfolio	Portfolio 10%	Portfolio 20%	Portfolio 40%
S&P 500	33.33%	30.00%	26.67%	20%
OMXH 25	33.33%	30.00%	26.66%	20%
MSCI Emerging Markets	33.34%	30.00%	26.67%	20%
Bitcoin	-	5%	10%	20%
Ethereum	-	5%	10%	20%

Table 1. Asset weights

4.1. Portfolio returns and volatility

The continually compounding returns of each security as seen in graph 3 are overshadowed by Ether's price surge in 2017, during which its price rose from just over $9 to more than $700 –

a whopping 7390% increase. The sudden price hike can partly be explained by the market waking up to the properties of smart contracts in the Ethereum blockchain. Countless start-ups used Ethereum's platform to create derivative tokens with relative values to Ether. The year is now often referred to as "Year of the ICO" (Forbes 2017). The year 2017 was not only exceptional for Ether, but to nearly all cryptocurrencies including Bitcoin, which rose by 1285%, from $959 to $14340. Through 2018, all assets experienced a downturn and all of them performed with negative returns, most significant of which were the returns of the portfolio most heavily loaded with the cryptocurrencies, which declined by -52,44%. The returns of the stock indices by each year can be better seen in graph 4. The most significant year for the benchmark portfolio was 2019, when it achieved nearly as good returns as any of the cryptocurrency portfolios. The returns for the stock portfolio in 2019 were 17,4%, which was only 1,33 percentage points lower than the 10% crypto portfolio, and 1,75 percentage points below the returns of the 40% crypto portfolio. The best performer that year was the 20% portfolio with 19,53 per cent returns.



Graph 3. Asset returns, all (yearly)

The performance of the stock indices during the scope of interest is close to the long-term average of the stock market. The year 2018 was sub-optimal in the stock market due to a

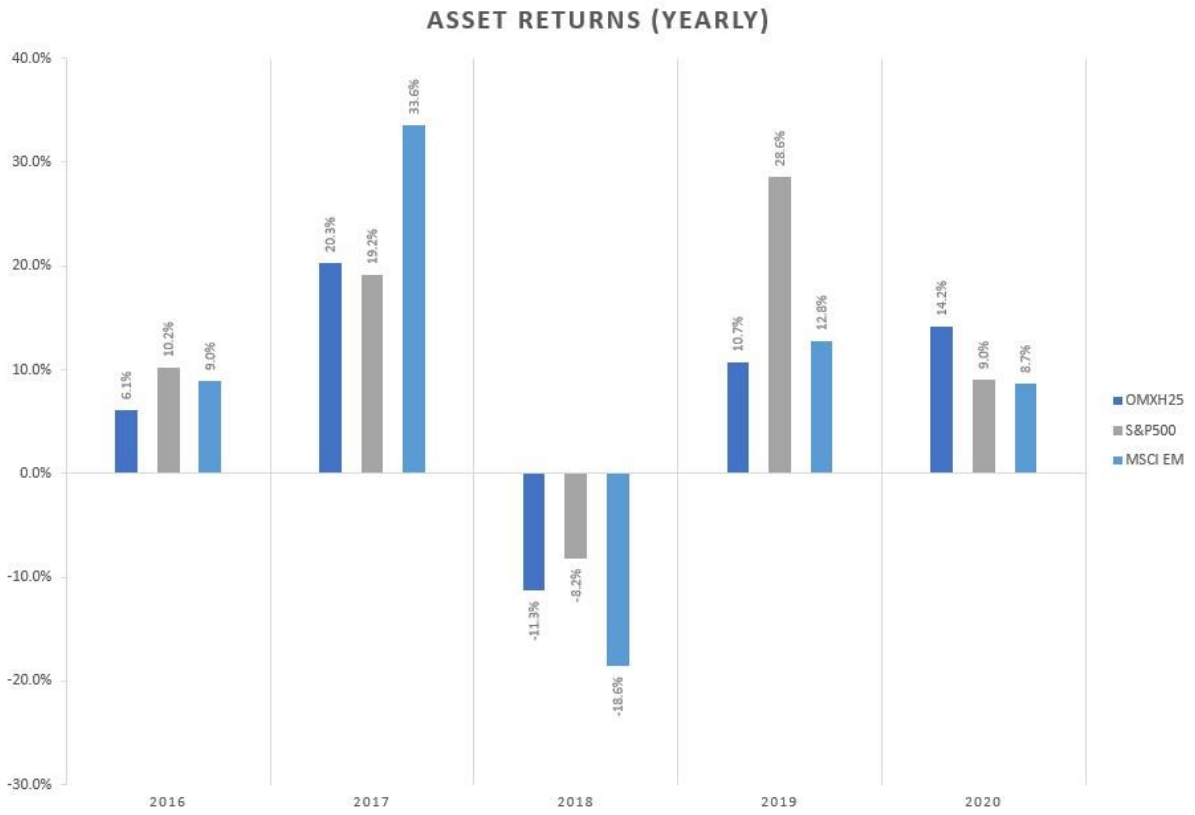
number of factors, some political and some financial. One can speculate that President Trump's tariff policy, the Federal Reserve's four separate interest rate hikes during the year, and the scrutiny that Big Tech faced concerning their policies on user privacy had a significant impact on the financial markets.

The return calculations compiled in table 2 show the returns of each portfolio by year, as well as the continuously compounded returns throughout the 5-year period. The final column represents the average returns of each portfolio calculated from the yearly data. From this table, the differences caused by Bitcoin and Ether can be seen more clearly and they seem to conform to a pattern of roughly duplicating the absolute values of returns between the portfolios each year. The only year where this pattern is not apparent is 2019, in which the returns are quite close to one another.

returns	2016	2017	2018	2019	2020	compounding	p.a.
Stock Portfolio	8.95%	24.46%	-12.33%	17.40%	11.62%	**55.8%**	**10.0%**
Portfolio 10%	25.08%	73.67%	-23.90%	18.77%	27.48%	**150.3%**	**24.2%**
Portfolio 20%	42.67%	140.26%	-34.44%	19.53%	44.53%	**288.2%**	**42.5%**
Portfolio 40%	82.10%	348.22%	-52.44%	19.15%	81.55%	**739.8%**	**95.7%**

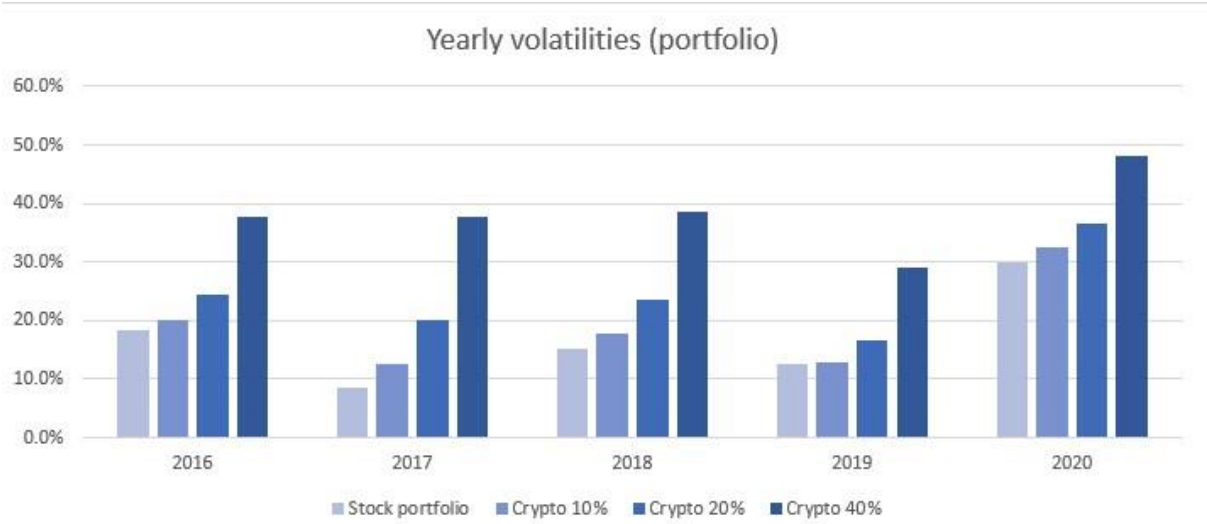
Table 2. Portfolio returns by year

The best performer in the stock portfolio was the S&P 500 -index, which achieved an average annual return rate of slightly under 14% and outperformed its counterparts, the OMXH 25- and the MSCI EM -indices with their respective mean annual return rates of 8,6% and 9,1% through the entire series.



Graph 4. Asset returns, stocks (yearly)

The volatilities of the portfolios composed for the purposes of this study can be seen in graph 5. Adding cryptocurrencies to the portfolio increases its year-by-year volatility. The difference in portfolio volatilities between the stock portfolio and the 40% crypto portfolio in 2017 is the largest in the scope of the study, at approximately 29 percentage points. The smallest difference between the volatilities of the two portfolios was achieved in 2019 with a difference of 16 percentage points. As volatility is often used as a synonym for riskiness, these results indicate a very clear message that incorporating Bitcoin and Ether in one's investment portfolio increases its risk by a significant factor. However, volatility alone cannot be considered as a sufficient measure of total investment risk as it takes both directions of price and return changes into account. Therefore, by accounting nothing but volatility, an investment in Ether in the end of 2016 would have been considered as risky as investing in the same currency at the end of the following year even though one would make returns of thousands of per cents, and the other would experience a steep decrease in capital.



Graph 5. Volatilities of all portfolios (yearly)

Nonetheless, high volatility securities are riskier than their counterparts and should be approached with caution. In the next chapter, the focus of the analysis shifts to risk-adjusted measuring tools, which provide a more in-depth-perspective to the returns of the portfolios.

4.2. Portfolio risk-adjusted performance

The decision to apply the logarithmic return model in the calculations of returns was made because it is less influenced by the cryptocurrency price surge of 2017 than the compound annual growth rate model and therefore produces more valid results in the risk-adjusted performance measurements. The betas used in both Treynor's Measure, and Jensen's Alpha have been calculated as per the single-period method from the annualized logarithmic returns. The risk-adjusted performance measurements below are calculated for the portfolios in relation to one another and do not claim that any of the securities are good investments beyond any doubt. The benchmark for these measurements is the three-index portfolio, compiled of the S&P 500, the OMXH 25, and the MSCI Emerging Markets and all indicators are calculated against those of the stock index portfolio. The figures therefore merely place the portfolios in ranking order.

	Stock Portfolio	Portfolio 10%	Portfolio 20%	Portfolio 40%
Annualized Returns	11.12%	30.55%	49.98%	88.84%
Risk Free Rate	2.02%	2.02%	2.02%	2.02%
Annualized Volatility	18.35%	19.98%	24.55%	37.83%
Sharpe Ratio	**0.50**	**1.43**	**1.95**	**2.29**

Table 3. Sharpe Ratio

The Sharpe Ratios shown in table 3 of the portfolios rise as expected when moving towards a higher weight on the cryptocurrencies since their compounding returns were significantly high compared to the indices. The higher Sharpe Ratio of the portfolio containing Bitcoin and Ether can be seen to be explained by the portfolio's high returns as they increase at a higher relative rate than the volatilities when moving towards higher weights on the cryptocurrencies. The volatilities were calculated taking correlation between the assets into account by building variance-covariance matrices. This being said, the volatility of the benchmark portfolio of stocks was surprisingly high at 18,35%, which could partly be explained by the last year of the series, 2020, in which all of the securities plunged significantly due to the beginning of the pandemic. However, from table 3 one can draw the conclusion that by incorporating the two cryptocurrencies into the portfolio, the risk-adjusted performance of the investment increases when measured with the Sharpe Ratio.

	Stock Portfolio	Portfolio 10%	Portfolio 20%	Portfolio 40%
Annualized Returns	11.12%	30.55%	49.98%	88.84%
Risk Free Rate	2.02%	2.02%	2.02%	2.02%
Beta	1	0.76	0.46	0.36
Treynor Ratio	**0.091**	**0.373**	**1.046**	**2.391**

Table 4. Treynor Measure

Differing from the Sharpe Ratio, the Treynor Measure utilizes the beta factor, which is an indicator of systematic risk instead of annualized volatility. As can be seen from table 4, the portfolio beta decreases as Bitcoin and Ether are included in the mix. A decreasing beta factor indicates of decreasing systematic risk compared to the stock portfolio. This may seem counter-intuitive since the volatility of the portfolio increased as the cryptocurrencies' percentage of allocation was increased in table 3. The elevating Treynor measure and the decreasing volatility

of the portfolios show that the risk-adjusted performance of the portfolio rises as more Bitcoin and Ether are included, from which can be deducted that the superb performance of the cryptocurrencies overcompensates for their added risk.

Both performance measures support the conclusion that Bitcoin and Ether have been good investments in the context of this study and increase the risk-adjusted returns of the portfolio. The third and final performance measure Jensen's Alpha approximates the percentage of excess returns against the market average - in this case, the stock portfolio compiled of the S&P 500, the OMXH 25, and the MSCI Emerging Markets. Therefore, the alpha for the stock portfolio is 0%, and its beta factor is 1.

	Stock Portfolio	Portfolio 10%	Portfolio 20%	Portfolio 40%
Annualized Returns	11.12%	30.55%	49.98%	88.84%
Risk Free Rate	2.02%	2.02%	2.02%	2.02%
Beta	1	0.76	0.46	0.36
Return on Market	0.1112	0.1112	0.1112	0.1112
Jensen's Alpha	**0.00%**	**21.57%**	**43.79%**	**83.52%**

Table 5. Jensen's Alpha

Each portfolio containing cryptocurrency has achieved excess returns during the scope of the study, measured by Jensen's Alpha. The values of the calculated alphas rise regularly as more Bitcoin and Ether is allocated to the portfolio. As mentioned in chapter 3.5, the performance measure has an intrinsic downward bias of statistical significance towards portfolios that succeed in timing the markets. However, the bias seems not to be present in this study because the scope of the study extends to the beginning of 2016, and not to the early months of 2017 just before the spike in the price of Ether and Bitcoin. Had there been a bias present in the larger set of data, the two sets of calculated alphas would have been closer to one another. The results from table 5 indicate that the portfolio with even weights on all securities (portfolio 40%) would have made 84% excess returns against the indices alone. A part of the risk-adjusted performance measures' results could be explained by the phenomenal returns of Bitcoin, and especially Ether in 2017 but as both of the currencies fell considerably during the following year, the high peak cannot be credited for the performance.

5. Discussion

In this chapter, the results from the sections above are viewed, compiled, and reviewed in the light of previous studies. The results from key calculations and measurements have been summarized in table 6 to allow easy re-inspection. In addition to the results presented in earlier chapters, the table also contains year-by-year measurements that were used to calculate arithmetic means and averages, some of which were not displayed in the previous chapters. However, these numbers help to evaluate the full scope of the findings. This chapter will also answer the research questions stated in the introduction, as well as attempt to evaluate the contribution that the thesis offers to the field. The limitations of the study are addressed in a separate sub-section, where its reliability is also reviewed.

The results of this study indicate that the incorporation of Bitcoin and Ether into the diverse portfolio of three stock indices does in fact increase the absolute, and risk-adjusted performance of the portfolio. This finding has also been made by Platanakis & Urquhart (2020) concerning Bitcoin, who state that their risk-adjusted measures increased each time Bitcoin was being added to the portfolio. Although the inclusion of the two cryptocurrencies into the portfolio elevated its year-by-year volatility, the higher risk was compensated with proportionally higher returns. The cryptocurrencies caused a significant elevation in each of the risk-adjusted return measures, which was surprising due to the added volatility. Matching results were found by Symitsi & Chalvatzis (2019) in their study, according to whom the extreme performance of the cryptocurrency market in the years 2012-2018 drove the risk-adjusted portfolio returns of the study despite high volatility.

		2016	2017	2018	2019	2020	compounding	p.a.
Stock Portfolio	Returns	8.95%	24.46%	-12.33%	17.40%	11.62%	55.8%	10.0%
	Volatility	17.8%	8.4%	15.2%	12.6%	30.0%		18.3%
	Beta	1.00	1.00	1.00	1.00	1.00		1.00
	Sharpe Ratio	0.39	2.66	-0.95	1.22	0.32		0.50
	Treynor Measure	0.069	0.224	-0.144	0.154	0.096		0.091
	Jensen's Alpha	0%	0%	0%	0%	0%		0%
Portfolio 10%	Returns	25.08%	73.67%	-23.90%	18.77%	27.48%	150.3%	24.2%
	Volatility	16.9%	12.5%	17.8%	12.9%	32.4%		20.0%
	Beta	0.94	0.46	0.74	0.82	0.9		0.77
	Sharpe Ratio	1.36	5.75	-1.45	1.3	0.79		1.43
	Treynor Measure	0.246	1.57	-0.349	0.205	0.284		0.371
	Jensen's Alpha	16.57%	61.41%	-15.25%	4.21%	16.86%		21.5%
Portfolio 20%	Returns	42.67%	140.26%	-34.44%	19.53%	44.53%	288.2%	42.5%
	Volatility	19.7%	20.2%	23.6%	16.8%	36.5%		24.5%
	Beta	0.57	0.17	0.44	0.4	0.74		0.46
	Sharpe Ratio	2.06	6.83	-1.54	1.04	1.16		1.95
	Treynor Measure	0.716	7.977	-0.837	0.441	0.577		1.038
	Jensen's Alpha	36.72%	134.35%	-30.21%	11.40%	35.43%		43.8%
Portfolio 40%	Returns	82.10%	348.22%	-52.44%	19.15%	81.55%	739.8%	95.7%
	Volatility	31.4%	37.7%	38.6%	28.9%	48.0%		37.8%
	Beta	0.13	0.05	1.1	0.08	0.46		0.36
	Sharpe Ratio	2.55	9.17	-1.41	0.59	1.66		2.29
	Treynor Measure	6.229	69.584	-0.493	2.224	1.716		2.382
	Jensen's Alpha	80.05%	345.09%	-38.60%	15.95%	75.08%		83.5%

Table 6. Summary

The findings do not suggest contradiction to the results of Shahzad et al. (2020), who found little to no correlation between the returns of cryptocurrencies and other asset classes. Based on the return data, the cryptocurrencies seem independent from the indices. However, some major economic downturns have affected all securities during the scope of the study but asset reactions during stressed market conditions cannot be generalized to apply at other times. The correlations have been calculated in appendix 1, from which can be seen that the two cryptocurrencies correlate 0,54 and the highest correlation between either crypto and any index is between the S&P 500 and Ether with a value of 0,186. All correlations calculated in appendix 1 are statistically significant.

The results of this study indicate that the two cryptocurrencies do in fact improve the risk-adjusted performance of the stock portfolio. All of the used measures of risk-adjusted returns obtained heightened values in an increasing trend when applied to each of the crypto portfolios. The cryptocurrencies increased the portfolio's volatility as their weights were elevated, which indicates an undeniable effect of increasing variation caused by Bitcoin and Ethereum. Judging by all measures, the portfolio reacted significantly to the increase of the weight on the cryptocurrencies. The absolute returns of the portfolio roughly doubled each time as the sum

weight of Bitcoin and Ethereum was increased equally from 10% to 20% to 40%. The currencies' added returns to the stock portfolio conformed to a linear increase, which was not anticipated before the analyses.

5.1. Limitations and reliability of the study

This study had some limitations that weaken the validity and reliability of the results. A five-year period is not sufficient enough for the generalization of findings. In addition, the period was also partly affected by stressed market conditions due to the starting of the Corona virus pandemic in late 2019, which was seen as a decrease in the returns and elevated volatility of the securities for the year 2020. The impact of the pandemic in these securities was fueled by the media, which spread panic among investors in the United States. The pandemic was widely covered in the news media during 2020, which affected retail investors' market behavior in that time. The validity suffers from the consolidation of the securities, as a considerable amount of data was discarded from the series of Bitcoin's and Ether's daily prices. Nevertheless, the removal of the data was necessary to be able to produce compatible results with the stock indices. The indices were selected to be fairly diverse from one another to account for a possible bias towards a single industry or geographic. Their size was also a factor in the selection process to ensure a diverse data set. However, a sample of merely three stock indices might not enough to determine absolute effects nor is it enough to be able to generalize the results to a broader scale. Another limitation, and a decreasing factor on the reliability of the study is also the choice to ignore transaction costs of the securities, which affects both of the used methodologies of return determination. Some aspects of the study that increased its reliability were: (1) the use of the logarithmic return model to counter the highly volatile cryptocurrencies and the sudden spike of price in 2017, (2) the availability of previous studies close to the subject, and (3) the diversity of the selected indices.

6. Conclusions and future research

As the popularity of digital currencies and the attention they draw grows, their importance in the investing community becomes ever more pressing. This thesis contributed to the spectrum of research around the applicable return models for cryptocurrencies and to the variety of available data about the investment opportunities that cryptocurrencies produce to traditional investors. The research was conducted by means of quantitative analysis and using selected methods of portfolio analysis. The objective of the study was to identify the effects of the cryptocurrencies, and to define the optimal weight from the assigned options for both currencies in a stock portfolio that maximizes returns in different timespans.

The study identified the two cryptocurrencies under examination – Bitcoin and Ether, to be the driving components of the portfolio that was assembled for the purposes of the research. Consequently, the returns of the portfolio were highest in the copy with the largest percentage of allocation to the cryptocurrencies. This portfolio, with equal weights to all securities achieved the best performance out of all the candidates, with an estimated excess return percentage of 83,5 and the lowest estimated relative systematic risk of 0,36. The portfolio outperformed all other portfolios each year except for 2018, in which it produced worst results out of all subjects. The year 2018 was challenging in the stock market as well as in the crypto markets, which explains the poor performance of each portfolio that year. However, in the following year 2019 the evenly weighted portfolio achieved the highest measured relative excess returns once again. Therefore, in light of the results of the study, the allocation of capital to Bitcoin and Ether during the investigated time period offers greater absolute and risk-adjusted returns even with the relatively high volatility they produce on the portfolio. In addition to the improved return potential they display, Chu, Chan, and Zhang (2021, 20) agree that Bitcoin provides investors some hedging and diversification advantages. These findings are in part contradicted by Long, Pei, Tian, and Lang (2021), who found no hedging ability in Bitcoin. They also concluded that Bitcoin has had less merit than gold as a safe haven against the turbulence of the stock market. This is a similar discovery than those of this study as Bitcoin and Ether were deemed highly volatile and despite the low correlation with stocks, the volatility mitigated their potential to protect the stock portfolio against losses of capital. This finding is again supported by Koutmos (2020, 474), according to whom Bitcoin's price evolvement was found to be disconnected from economic fundamentals. The results of this study conform

largely to those of previous studies along with the notion that further, more extensive research should be done to properly assess the many properties of cryptocurrencies in the context of investing. Due to the relatively recent appearance of cryptocurrencies in the capital markets it is likely that their high volatility and detachment of economic fundamentals is not their long-term state. It is possible that as regulation is applied to the crypto markets and institutional investors grow accustomed to their unique nature, they become less volatile, and will offer more stable and reliable advantages in hedging and diversifying portfolios.

The limitations of the study encourage further examination and research of the subject with a broader selection of indices to which the cryptocurrencies could be measured against. In addition, a more far-reaching sample of data would ensure that the series is not skewed as much by an anomaly in the markets. This study however, provided some insight into the performance of cryptocurrencies during an uncertainty shock in a bull market, as suggested for further research by Long et al. (2021, 10). Research towards a broad variety of performance measuring tools and the development of methods to be specifically applied for the analysis of cryptocurrencies should be given more attention in the future. Furthermore, the changing field calls for the development of specialized portfolio analysis tools for digital assets, as much of the available spectrum of methods cannot be applied to the complex environment of cryptocurrency research.

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Appendices

Appendix 1. Asset Correlation Matrix

Correlation Matrix					
	ETH	*BTC*	*EEM*	*SPY*	*OMXH*
ETH	1				
BTC	0.541672094	1			
EEM	0.158781694	0.14876545	1		
SPY	0.186765052	0.183546542	0.81250986	1	
OMXH	0.100274398	0.109183075	0.585909137	0.573974317	1