LUND UNIVERSITY | SCHOOL OF ECONOMICS AND MANAGEMENT

Can Portfolio Performance Be Improved with Bitcoin during a Global Crisis?

A Study of Portfolio Performance with Diverse Assets during the COVID-19 Outbreak

Kristian Stemme & Otto Lyth Berg

Undergraduate Thesis in Economics

School of Economics and Management, Lund University

Supervisor: Nagihan Simeth

May 2022

Abstract

As a relatively new form of financial asset with unique properties, Bitcoin is increasingly included in portfolios to improve performance. However, research remains limited on how Bitcoin actually affects portfolio performance. This study aimed to broaden the field of research by exploring whether Bitcoin can improve portfolio performance during a global crisis. It sought to answer the question by analyzing how the inclusion of Bitcoin affects a diversified portfolio of Swedish assets during the COVID-19 crisis. The study measured how Bitcoin compares to more traditional assets, such as gold, in a portfolio constructed of the Swedish market index OMXS 30 and a Swedish real estate fund. In line with previous research, the results showed that Bitcoin had a low correlation to the portfolio assets selected for the study between 2019 and 2022. More importantly, the thesis concluded that Bitcoin had the relatively highest Sharpe-ratio and thereby confirmed the study hypothesis that Bitcoin would have improved the risk-adjusted returns of all the selected portfolios had it been included. The study therefore suggests that Bitcoin should be viewed as a serious diversification option in times of global crisis.

Table of contents

Abstract 2
List of Figures 4
List of Tables 4
1. Introduction 5
2 Literature Review 7
3 Theoretical Framework and Hypothesis 10
3.1 Modern Portfolio Theory 10
3.2 Assumptions 11
3.3 Sharpe-ratio 12
3.4 Hypothesis 13
4 Data and Variables 14
4.1 Description of Assets 14
4.1.1 Bitcoin 14
4.1.2 Gold 15
4.1.3 OMXS 30 16
4.1.4 Länsförsäkringar Fastighetsfond A 16
4.1.5 Fixed Income Securities 17
4.2 Sample 18
4.3 Variables 19
4.4 Descriptive statistics 20
5 Methodology 23
5.1 Selection of assets 23
5.2 Portfolio constructions 24
6 Results 25
6.1 Minimum Variance Portfolio: 0 26
6.2 Portfolio: 1 26
6.3 Portfolio: 2 28
6.4 Portfolio: 3 29
6.5 Portfolio: 4 31
6.6 Portfolio: 5 32
7 Discussion 34
8 Conclusion 37
References 39

List of Figures

Figure 1 : The price development of all the assets during a five-year period from 2017-2022. (Avanza.se, 2022) 17

Figure 2 : Efficient frontier curve, with individual assets and portfolio: 1..... 27

Figure 3 : Efficient frontier curve, with individual assets and portfolio: 2..... 29

Figure 4 : Efficient frontier curve, with individual assets and portfolio: 3..... 30

Figure 5 : Efficient frontier curve, with individual assets and portfolio: 4..... 32

Figure 6 : Efficient frontier curve, with individual assets and portfolio: 5..... 33

List of Tables

Table 1 : Summary of function and observations for all assets 18

Table 2 : Descriptive statistics for selected assets (investing, 2022)..... 20

Table 3 : Correlation matrix of all assets, Blue – high correlation, White – low correlation, Red– negative correlation..... 21

Table 4 : Presentation of the five portfolio constructions..... 24

Table 5 : Presentation of all optimized portfolios, composition, and performance statistics 25

Table 6 : Minimum variance portfolio..... 26

Table 7 : Optimized portfolio: 1 with weights and performance results 26

Table 8 : Optimized portfolio: 2 with weights and performance results 28

Table 9 : Optimized portfolio: 3 with weights and performance results 29

Table 10 : Optimized portfolio: 4 with weights and performance results 31

Table 11 : Optimized portfolio: 5 with weights and performance results 32

1 Introduction

Bitcoin has long been the center of discussion in news outlets and economic circles on the viability of cryptocurrencies. Public opinion on Bitcoin is divided and equally so among the experts. Recently, however, Bitcoin has received a more established status within the finance world and increasingly serious investors are entertaining the idea of diversifying their portfolios using this relatively novel phenomenon. In contrast to traditional assets, Bitcoin's underlying premise is structured differently. By understanding how Bitcoin functions independently as well as in relation to other assets, its unique potential can be utilized in managing portfolio performance.

This study aims to examine the question of whether portfolio performance can be improved through investing in Bitcoin during a global crisis. It will seek to answer this question by analyzing the performance of Bitcoin in portfolios with diverse Swedish assets during the COVID-19 outbreak. This will provide insights into how Bitcoin performs in relation to other assets, such as the Swedish market index OMXS 30, Swedish real estate, and gold, during a global crisis and more broadly enrich the recent body of research seeking to uncover the role of Bitcoin in investment portfolios.

The study will analyze the performance of Bitcoin through a theoretical framework grounded in modern portfolio theory combined with the Sharpe-ratio, which will highlight the performance of Bitcoin in relation to other assets within a portfolio. The results will provide evidence to support the hypothesis that Bitcoin does improve the Sharpe-ratio in all portfolios in which it is included in. The findings are complementary to previous research on correlation between Bitcoin and traditional assets as well as confirming its high-risk high-reward characteristics.

The thesis begins with Chapter 2 providing an overview of relevant academic research on Bitcoin and portfolio performance in the literature review. Chapter 3 outlines the theoretical framework used for analyzing portfolio performance, which is grounded in modern portfolio theory, along with presenting the research hypothesis. Once the theoretical background is established, Chapter

4 describes the data and variables in their respective sections with a summary of each asset and their descriptive statistics. Chapter 5 provides an explanation of the methodology shaping the portfolio constructions. The eventuated portfolio compositions with their corresponding performance statistics are demonstrated and evaluated in Chapter 6. Chapter 7 subsequently situates the findings in a broader context and discusses the insights along with the limitations of the study. Chapter 8 concludes the thesis with a summary of the study along with recommending directions for further research.

2 Literature Review

The literature review will provide an outline of research on the relatively recent phenomenon of Bitcoin. It will review studies on Bitcoin's performance and its role in portfolio constructions. Since Bitcoin and the blockchain technology behind Bitcoin are relatively new in finance, there is only a limited amount of research that has been conducted to explore if and how Bitcoin should be used in an investment portfolio in order to enhance its performance. Given the increasing popularity of Bitcoin amongst investors, Bitcoin and other cryptocurrencies have gained a lot of traction and media attention in recent years, which has made new research into Bitcoin's place in investment portfolios soar (Corbet et al. 2018).

Brière et al. (2015) found that Bitcoin had weak correlations to other assets during the time frame of their study and thus, the inclusion of Bitcoin in a well-diversified portfolio may greatly enhance risk-return characteristics of the portfolio. However, they stress that the results should be interpreted cautiously given that historic data does not have to be a representative forecast of future data; Bitcoin's weak correlation with other assets does not necessarily have to mean that Bitcoin will always perform well in times of financial crisis. Notwithstanding, a study by Baur et al. (2018) shows that the return properties of Bitcoin are not only very different from traditional assets, such as stocks and bonds, but also currencies due to it being uncorrelated to these asset classes. This suggests that Bitcoin is great for diversification both in normal times and times of crisis.

Bauer et al. (2018) further examined whether Bitcoin is used as a speculative investment or a medium of exchange and an alternative currency. They drew the conclusion that it was used more as a speculative investment since very few users of Bitcoin appeared to use it as a medium of exchange, thus making it more suitable for an investment portfolio. This corresponds to the findings of Wu and Pandey (2014), who investigated the role of Bitcoin as a currency and an investment option. Rather than Bitcoin functioning as a currency because of its very limited

acceptability as a method of payment at the time, they found that Bitcoin is more suitable as an investment opportunity and can improve the performance of an investment portfolio.

Kajtazi and Moro (2019) examined 21 portfolios divided into three categories, one with European, one with U.S and one with Chinese assets and found that in most cases, Bitcoin can improve the performance of the portfolios measured using risk-return. They concluded that the higher performance is due to the increase in returns rather than a lower volatility, which was the case in 18 out of the 21 different portfolio cases. Even though Bitcoin has high volatility, its returns are also high, which can be useful for diversification in an investment portfolio.

By using eight different portfolio optimization techniques and three different risk aversion levels, a study by Platanakis and Urquhart (2020) similarly demonstrated that including Bitcoin to a portfolio of stocks and bonds is beneficial as it develops greater risk-adjusted returns. The results suggested that even though Bitcoin has a high risk, it can still be favorable to investors with high risk aversion to include Bitcoin in their portfolio.

Uddin, Ali and Mashi (2020) researched whether Bitcoin can be considered an asset class comparable to stocks and bonds and whether it has potential hedging and diversification capabilities. They concluded that the return of Bitcoin is mean reverting. This means that Bitcoin's price volatility will revert to a mean value in the long run and therefore can be considered a sustainable asset class even though it is highly volatile. They further confirmed that Bitcoin can be used as a positive diversification asset in a portfolio both in the short and long-run.

Cheah and Fry (2015) proposed a more critical view and analysis of Bitcoin. They investigated whether Bitcoin has any fundamental value and if the price has characteristics of a speculative bubble. They concluded that Bitcoin's valuation is inclined to speculative bubbles and that the fundamental value of Bitcoin is zero. They also raised the social and economic concerns generated by Bitcoin, one of which Foley, Karlsen and Putniņš (2018) examined, which was the amount of illegal activity that Bitcoin is used for. They claimed that one quarter of all users and nearly half

of all transactions at the time were related to criminal activity. This raises the question of the ethics and sustainability underlying the use of Bitcoin in investment portfolios. Although outside the scope of this thesis, this direction of research deserves further attention.

Overall, despite limited studies on Bitcoin having been conducted due to its relatively short existence, it demonstrates a growing and promising field of research within investment portfolio management. The studies discussed above have shown that despite Bitcoin being a relatively new phenomenon in finance, it can prove highly beneficial to a diversified portfolio. The evidence suggests that Bitcoin weakly correlates to other assets and maintains relatively independent return properties, which indicates that Bitcoin can be important to investment portfolios in normal times and during times of financial crisis. Bitcoin further appears to work poorly as a currency and better as an asset class for investment opportunities. It remains important to stress that the social and economic concerns of Bitcoin should not be overlooked. Nonetheless, given the promising potential of Bitcoin to strengthen investment portfolios, this thesis will particularly explore its performance together with a diverse set of assets during a time of global crisis.

3 Theoretical Framework and Hypothesis

3.1 Modern Portfolio Theory

The theoretical framework of this thesis will be grounded in modern portfolio theory, which was established by Harry Markowitz (1952). Markowitz (1952) introduced a mathematical approach for security selection, which gave the highest expected return for a certain level of risk. As a measurement of expected return, Markowitz (1952) utilized the geometric mean of returns and the variance of returns when it came to risk. In this way, the investor can construct a portfolio with minimized variance given a pre-set expected return and vice versa maximize expected returns given a pre-set level of risk. These portfolios make up the efficient frontier, plotted with the variance on the x-axis and expected return on the y-axis. This illustrates that a diversified portfolio consisting of diverse assets is more efficient in terms of maximizing returns while minimizing risk, than a non-diversified portfolio. This is due to the covariance between assets neutralizing some of the variance for individual assets. By combining uncorrelated or negatively correlated assets in a portfolio the overall variance diminishes. The expected return and variance of a portfolio may therefore be calculated by the following general equations:

Expected return:

$$E(r_p) = \sum_{i=1}^{n} w_i \, E(r_i) \qquad \text{Equation 1}$$

Variance:

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

w_i represents the weight of the individual asset *i* and summing all the individual weights equals to one, $\sum_{i=1}^{n} w_i = 1$. The covariance between the assets *i* and *j* is denoted by σ_{ij}.

Covariance:

$$\sigma_{ij} = Cov(r_i, r_j) = \frac{1}{N}\sum_{t=0}^{n}\left(r_{i,t} - E(r_i)\right)\left(r_{j,t} - E\left(r_{j,t}\right)\right) \qquad \text{Equation 3}$$

3.2 Assumptions

It is important to acknowledge that modern portfolio theory includes various assumptions that may not always reflect the reality of a financial market. Markowitz (1952) built his portfolio selection theory on a couple of key assumptions that are highlighted by Myles E. Mangram:

> 1.) Investors are rational (they seek to maximize returns while minimizing risk), 2.) Investors are only willing to accept higher amounts of risk if they are compensated by

higher expected returns, 3.) Investors timely receive all pertinent information related to their investment decision, 4.) Investors can borrow or lend an unlimited amount of capital at a risk free rate of interest, 5.) Markets are perfectly efficient, 6.) Markets do not include transaction costs or taxes, 7.) It is possible to select securities whose individual performance is independent of other portfolio investments (Myles E. Mangram, 2013, p.61).

3.3 Sharpe-ratio

Sharpe (1963) extended and streamlined Markowitz's portfolio theory in relation to portfolio analysis. He further developed the portfolio theory framework by creating an equation for measuring the risk-reward ratio of a portfolio, which is known as the Sharpe-ratio. It can be used when comparing different assets in a portfolio and is computed as follows (Sharpe, 1966):

Sharpe-ratio:

$$Sharpe - Ratio = \frac{(r_p - r_f)}{\sigma_p}$$ Equation 4

r_p - r_f is the excess return of the portfolio when subtracting the risk-free rate. σ_p is the standard deviation of the portfolio.

In combining Markowitz (1952) portfolio theory and the Sharpe-ratio, one can create the optimal portfolio by choosing weights of assets in a manner that will maximize the Sharpe ratio, which aligns with the efficient frontier. Nonetheless, the Sharpe-ratio also has its limitations. Smetters and Zhang (2013) examined and concluded that the Sharpe-ratio accurately measures and ranks

risky investments when they are normally distributed but has difficulties in accurately giving the right rankings when returns of the portfolio are not normally distributed. This is why an Anderson-Darling test has been included in the data processing to examine the distribution of each asset.

3.4 Hypothesis

Since there are still concerns and uncertainties regarding the role of cryptocurrencies, such as Bitcoin, as financial instruments, this thesis intends to complement the current body of literature with the following hypothesis:

Portfolio performance during the COVID-19 pandemic (2019-2022) improves if Bitcoin is included.

The hypothesis assumes certain limitations, such as confining the portfolio assets to Sweden and the time frame from April 2019 to April 2022. The performance of the portfolios will be determined by their respective returns, volatility, and Sharpe-ratio. The Sharpe-ratio is the main measure of performance since it is derived from the relative return to risk ratio. In the next section, the data and variables used to test this hypothesis will be described.

4 Data and Variables

4.1 Description of Assets

The following section will serve to describe the essence of the assets used as data variables in this thesis. These assets have been chosen based on their trading volume and representative qualities. Bitcoin is the most traded cryptocurrency with the highest market capitalization and therefore serves as an optimal representative for cryptocurrencies (CoinMarketCap, n.d.a). Gold holds major historical importance as a financial instrument and as a highly desired commodity (Nationalencyklopedin, n.d.). Combined with its popularity as a historical hedge against financial turmoil, it provides a good comparison to the performance of Bitcoin. OMXS 30 is the Swedish stock index for the 30 most traded companies in terms of volume and is used as the general market benchmark for Sweden. It is therefore a suitable representative of the Swedish stock market and conventional stocks (Nasdaq, 2022). Lastly, a real estate fund is included – Länsförsäkringar Fastighetsfond A – since it broadens the range of assets into real estate. This specific fund was selected due to its size and concentration in Swedish real estate investments (Avanza, 2022). Given the central focus on the role of Bitcoin in portfolio performance, the first section will describe the functioning of Bitcoin. The following section will focus on gold, continued by OMXS 30 and finally Länsförsäkringar Fastighetsfond A.

4.1.1 Bitcoin

The idea of Bitcoin (BTC) was first formalized in a white paper published in the name of Satoshi Nakamoto in 2008, which provided solutions to security issues regarding a peer-to-peer online electronic payment system. This system was designed to circumvent the necessity of a third party, such as a bank or financial institution, in virtual cash transfers between two parties (Nakamoto, 2008). As per Nakamoto's (2008) paper, the issue with online transactions having to pass through financial institutions was the inefficiency of the process and the large necessity of trust it required from all parties involved. It is worth noting that the timing of Nakamoto's (2008) solution came at

the end of 2008 when the world was experiencing a financial crisis, which undermined the general trust in financial institutions. Instead, Nakamoto (2008) proposed a decentralized virtual system, where transactions could be made without institutional oversight. This system would secure the transactions between parties by utilizing cryptography and having separate nodes on the virtual network cooperating to generate and verify the encryption of transactions. Alongside an incentive structure was built into the system, which rewarded the nodes contributing to the process with new currency. This is what is referred to as “mining”; when one sacrifices electricity and computational resources for the functionality of the encryption system, they are rewarded with newly generated currency on that system. This incentive structure is a cornerstone of the security of the whole payment system since any potential attacker will gain more from contributing to the system than from subverting it. However, the number of Bitcoins in circulation is designed to be finite, summing up to a final cap of 21,000,000 BTC, with the current circulation in May of 2022 being approximately 19,000,000 BTC (CoinMarketCap, n.d.a). Nakamoto (2008) suggests that this incentive structure can be transitioned into consisting of transaction fees once the predetermined amount of Bitcoins have entered circulation, making the currency inflation free.

Since then, Bitcoin has become the world's predominant cryptocurrency with a market cap of about 751,450,386,523 USD and with a circulation of approximately 19,024,462 BTC (CoinMarketCap, n.d.a). This results in a price of 39,426 USD per BTC, which reached its highest valuation at 66,972 USD per BTC on 11 September 2021. The current cryptocurrency market share of Bitcoin was about 40% on the 24 April 2022, which is below its most recent five-year peak of 70% on 3 January 2021.

4.1.2 Gold

Gold has for a long time been used for jewelry and a symbol for status and power. Gold was first used as a financial asset around 600 B.C when the first gold coins were made Nationalencyklopedin (n.d.). As trade began to increase in the world, precious metals, such as gold, were used in many countries as the basis for the monetary system (a gold standard). Gold

has many different characteristics as a financial asset, and it is an important source for countries' financial reserves. It carries no counterparty risk or credit risk which makes it a trustworthy asset for nations. A fifth of all gold that has ever been mined is held by central banks across the world (Reuters, 2022). Gold is priced in U.S. dollars across the world which makes for an inverse relationship between the two. If there is high inflation and or the dollar depreciates then gold typically appreciates. It can therefore be used as a hedge against these two scenarios, but it can also be used as a safe haven for investors in uncertain times. Historically when there has been economic and political uncertainty in the world investors have tended to buy gold, which increases its price due to higher demand, "[i]n general, the stronger the pullback in the stock market, the more negatively correlated gold becomes with the market…" (World Gold Council, 2020, p.3). All these aspects and characteristics of gold as a financial asset have made it a popular tool for diversification in an investment portfolio.

4.1.3 OMXS 30

OMXS 30 is a market index of the 30 largest companies on the Nasdaq Stockholm stock exchange in terms of market value. It contains companies in many different sectors such as banking, manufacturing, finance, construction, telecom among others, making it a diversified index. OMXS 30 is a reliable indicator for showing how the Swedish financial market is performing (Nasdaq, 2022).

4.1.4 Länsförsäkringar Fastighetsfond A

Länsförsäkringar fastighetsfond A is a real estate fund that is actively managed and mainly has Swedish real estate and construction companies in it. It is the highest ranked real estate fund in Sweden in terms of number of investors on Avanza. It also had the highest return out of all real estate funds on Avanza during the last five years (Avanza, 2022).

4.1.5 Fixed Income Securities

A fixed income security is an investment that will give the holder a fixed periodic return from interest payments when the security reaches its maturity. The holder of a fixed income security knows in advance how much interest he will receive from the security. This type of financial asset is issued by governments, corporations, and other financial institutions. One type of fixed income security is bonds, where an investor loans money to the issuer with a promise of repayment at the maturity date plus a coupon payment which corresponds to the interest rate (Corporate finance institute, n.d.). The risk of a fixed income security is low, which translates to its low returns. In many cases, a fixed income security is used as a proxy for the risk-free rate. This makes it a popular asset to have in a portfolio to diversify and lower the volatility of the portfolio.

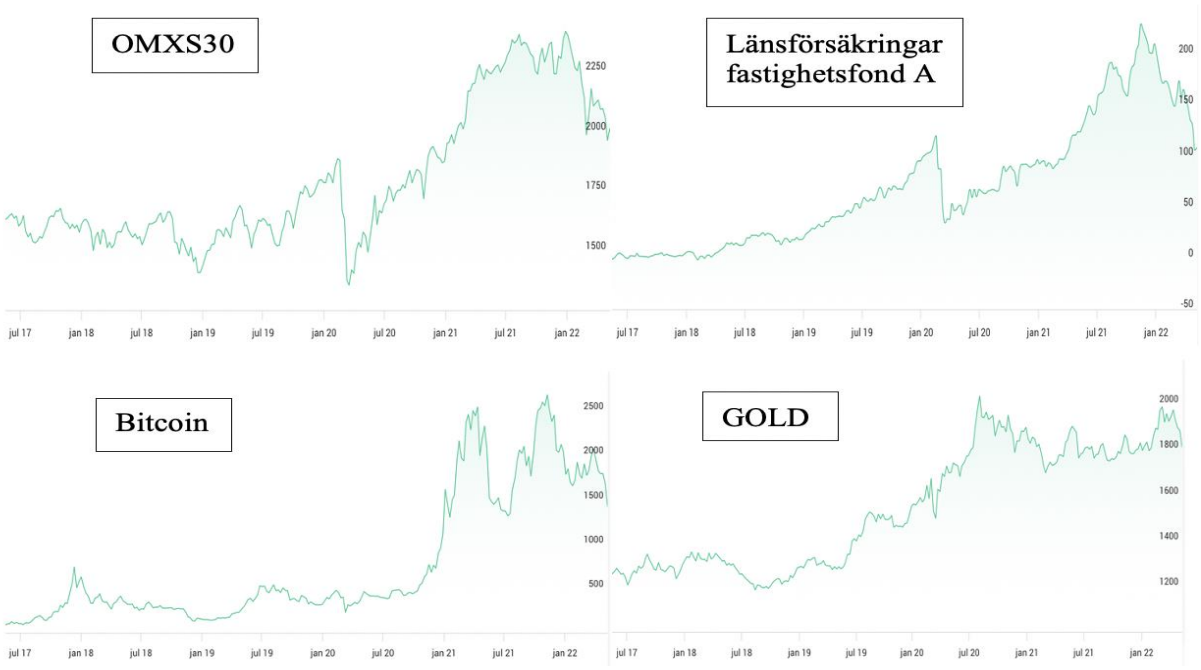

Figure 1: The price development of all the assets during a five-year period from 2017-2022. (Avanza.se, 2022)

4.2 Sample

Table 1: Summary of function and observations for all assets

Asset	Function	Number of observations	First Observation	Last Observation
OMXS 30	**Market Index**	**819**	**2019-04-02**	**2022-04-01**
F. fond	**Real Estate Fund**	**745**	**2019-04-02**	**2022-04-01**
BTC	**Cryptocurrency**	**1186**	**2019-04-02**	**2022-04-01**
Gold	**Commodity**	**848**	**2019-04-02**	**2022-04-01**

The data was collected from two sources. All the assets were collected from the website investing (investing.com) on the ninth of May 2022. The data was set to the time frame starting on the second of April 2019 and finishing on the first of April 2022. This is the time frame for the analysis. As the data for the assets was collected, it was also verified with two other sources to ensure that the price observations were correct. The two other sources were: Avanza (avanza.se) and Yahoo finance (finance.yahoo.com). To ensure comparability between the assets, their datasets were all valued in Swedish krona (SEK).

The data for the risk-free rate was extracted from statistikmyndigheten (scb.se) on 12th of May 2022. The time frame was set from 2016 to 2022.

4.3 Variables

For simplicity, the datasets were converted into log-returns based on the instructions of Benninga (2014). Providing the following equation for returns:

Log-returns:

$$r_{i,t} = ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \quad \text{Equation 5}$$

The average daily returns as well as the standard deviation was calculated. For the descriptive statistics, the daily data was annualized based on the number of days the specific asset had been traded during one year. This conversion was done in accordance with the following two equations, using the previously calculated log-returns.

Annualized returns:

$$r_{ann.} = r_{daily} \times (days\ traded) \quad \text{Equation 6}$$

Annualized standard deviation:

Equation 7

$$std.Dev_{ann.} = std.Dev_{daily} \times \sqrt{(days\ traded)}$$

Further descriptive statistics were derived for each respective statistic; number of observations, mean, standard deviation, skewness, and kurtosis. An Anderson-Darling test was executed on each dataset to measure the probability of the observed log-returns following a normal distribution. The Anderson-Darling test was done in accordance with the instructions of Shanaev (2020).

Mean excess return on an annual basis was also calculated by subtracting the proxy for risk free rate from the mean return for each asset. The Sharpe-ratio was derived from the mean excess return and standard deviation as described in Equation 4, however, substituting the portfolio notation *p* to *i* to measure the individual Sharpe-ratio of each asset.

4.4 Descriptive Statistics

Table 2: Descriptive statistics for selected assets (investing, 2022)

Assets	Number of observations	Mean return	Standard deviation	Skewness	Kurtosis	Anderson-Darling test	Mean excess return	Sharpe-ratio
OMXS 30	**819**	**15.95%**	**0.21**	**-0.80**	**7.85**	**3.65**	**14.39%**	**0.67**
F. fond	**745**	**24.35%**	**0.25**	**-1.16**	**8.26**	**4.12**	**22.79%**	**0.91**
BTC	**1186**	**114.18%**	**0.77**	**-0.40**	**10.47**	**4.95**	**112.62%**	**1.46**
Gold	**848**	**16.73%**	**0.16**	**-0.76**	**4.47**	**2.42**	**15.17%**	**0.93**

The descriptive statistics for all assets have been summarized in table 2 above. Following equations 5 and 6 the mean returns and standard deviations have been annualized. All datasets for respective assets reached an Anderson-Darling value which rejects the assumption of them following a normal distribution with a significance level at 1%. This means there is no reasonable chance that the deviation from the normal distribution at the tail-ends can be explained by pure chance. This rejection is further supported by the high level of excess kurtosis measured as it indicates high tail volatility. As expected, these values are the highest for Bitcoin and lowest for gold, demonstrating the risk profile of each asset.

In terms of returns and volatility the more traditional assets of OMXS 30, the real estate fund and gold all lie within a relatively close interval range compared to Bitcoin which has an annual return far exceeding the others. However, this is somewhat offset by the high volatility of Bitcoin which is multiple magnitudes higher than that of the traditional assets. Bitcoin still comes out on top with the highest Sharpe-ratio out of all the individual assets.

Table 3: Correlation matrix of all assets, Blue – high correlation, White – low correlation, Red– negative correlation

OMXS 30	1	0,58824988	0,212050488	-0,220413535
F. fond	0,58824988	1	0,128868478	-0,073112127
BTC	0,212050488	0,128868478	1	0,080418747
Gold	-0,220413535	-0,07311	0,080419	1
	OMXS 30	F. fond	BTC	Gold

Table 3 highlights the correlations between the assets on a color scale ranging from red for -1 to white for 0 to blue for 1. Accordingly, the cells with higher color intensity are further from 0, meaning that the correlation is either significantly more negative or positive. Therefore, the lateral section of 1s is the deepest blue, since it represents the correlation of each asset with itself. Notably, Bitcoin is weakly correlated with most other assets, including the market index, and gold is the only asset to achieve negative correlations with any other assets. This is relevant since diversification theory draws on combining assets with low or negative correlation.

5 Methodology

5.1 Selection of assets

A base portfolio was constructed as a reference to compare Bitcoin and gold as potential additions to a portfolio in times of economic crisis. The assets of the base of the portfolio were purposely selected for a private investor that wants to diversify his portfolio with Swedish assets.

Firstly, the OMXS 30 index was chosen, as previously stated it is an index of the 30 companies with the highest trade volume on the Nasdaq Stockholm stock exchange market. It has a broad selection of stocks in different sectors which is good for portfolio diversification. Secondly, a real estate fund was chosen, "Länsförsäkringar Fastighetsfond A," for the purpose of further diversifying the portfolio and adding assets from the real estate market.

Bitcoin and gold are the assets that are being tested and compared to the base portfolio. Bitcoin was chosen due to it being the largest and most dominant cryptocurrency in terms of market capitalization during the observed time frame (CoinMarketCap, n.d.b). Gold was chosen due to the diversification properties of the asset and the arguable similarities with Bitcoin where both assets have safe haven and hedging characteristics (Bauer et al. 2018).

The Swedish three-month treasury bill was supposed to be used as the represented risk-free rate, but it was negative during the time frame (Riksbanken, 2022). Instead, a theoretical risk-free rate was used. By taking the average inflation for the past five years as a proxy for the risk-free rate because government bonds usually only pay interest that keeps up with inflation (Fisher, 2013). The risk-free rate was calculated to 1,56%.

5.2 Portfolio constructions

Five different portfolios were constructed. Four out of the five portfolios had, as mentioned earlier, a base of two different assets, OMXS 30 and the Swedish real estate fund Länsförsäkringar Fastighetsfond A. Bitcoin and gold was then added in different variations to make up the four portfolios. A fifth portfolio was constructed by removing the real estate fund and keeping all other assets. All portfolios were constructed with short-sale constraints, meaning that no short selling was allowed. This was done in order to mimic more realistic market conditions for the average retail investor. Below in table 4 is a presentation of the five portfolios and the respective assets included in each portfolio. A more detailed description of each portfolio's performance will be provided in the following result section.

Table 4: Presentation of the five portfolio constructions

Portfolio 1:	**Portfolio 2:**	**Portfolio 3:**	**Portfolio 4:**	**Portfolio 5:**
OMX 30	**OMX 30**	**OMX 30**	**OMX 30**	**OMX 30**
F. fond	**F. fond**	**-**	**F. fond**	**F. fond**
-	**-**	**BTC**	**BTC**	**BTC**
-	**Gold**	**Gold**	**-**	**Gold**

6 Results

The results for the five portfolios optimal construction, the weights and the combination of assets that maximizes the Sharpe-ratio for each portfolio and the expected return and standard deviation for each portfolio are given in the table below. A separate table for the minimum variance portfolio and an individual evaluation of each portfolio will be given further down in this section.

Table 5: Presentation of all optimized portfolios, composition, and performance statistics

Asset:	Portfolio: 1	Portfolio: 2	Portfolio: 3	Portfolio: 4	Portfolio: 5
OMXS 30	**23.2%**	**19.8%**	**27.7%**	**0.0%**	**8.3%**
F. fond	**76.8%**	**23.7%**	**-**	**62.5%**	**25.6%**
BTC	**-**	**-**	**15.6%**	**37.5%**	**14.8%**
Gold	**-**	**56.5%**	**56.7%**	**-**	**51.3%**
Return	**22.4%**	**18.4%**	**31.7%**	**58.0%**	**33.0%**
Std. Deviation	**0.22**	**0.12**	**0.17**	**0.35**	**0.17**
Excess Return	**20.8%**	**16.8%**	**30.1%**	**56.5%**	**31.5%**
Sharpe-ratio	**0.93**	**1.41**	**1.77**	**1.63**	**1.86**

6.1 Minimum Variance Portfolio: 0

Table 6: Minimum variance portfolio

Portfolio: 0 (Min. Variance)							
Asset weights:				Performance:			
OMXS 30	F. fond	BTC	Gold	Return	Std. Deviation	Excess Return	Sharpe-ratio
33.82%	6.72%	0.00%	59.46%	17.0%	0.11	15.4%	1.35

The minimum variance portfolio serves as a reference point to the other portfolios, as well as the starting point of the efficient frontier line. It is the portfolio with the lowest possible standard deviation given the selected assets and short-sale constraints. As showcased in table 6 the minimum variance portfolio has a 0.00% allocation in Bitcoin, with a high preference for gold and a relatively high allocation in OMXS 30. Of special notice is the low volatility which is lower than all following portfolios with maximized Sharpe-ratios.

6.2 Portfolio: 1

Table 7: Optimized portfolio: 1 with weights and performance results

Portfolio: 1							
Asset weights:				Performance:			
OMXS 30	F. fond	BTC	Gold	Return	Std. Deviation	Excess Return	Sharpe-ratio
23.2%	76.8%	-	-	22.4%	0.22	20.8%	0.93

The performance of portfolio: 1 is showcased above, this is the optimized portfolio with constraints in both Bitcoin and gold. Portfolio: 1 heavily favors the real estate fund to the market index OMXS 30, with an approximate ratio of three to one distribution in the real estate fund above OMXS 30. As figure 2 illustrates the excess returns from portfolio: 1 are short of those from the single real

estate fund asset, yet this is compensated by the portfolio's lower standard deviation. Portfolio: 1 serves as a baseline portfolio for comparison when assets are included and excluded.

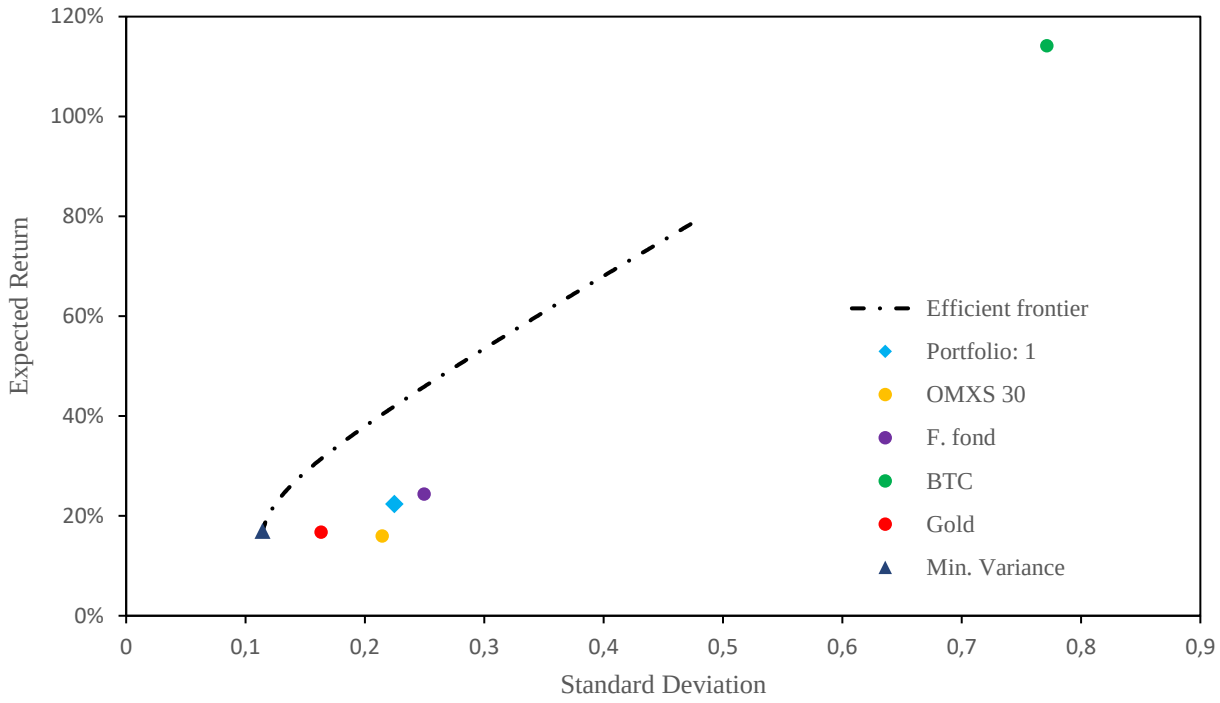

Figure 2: Efficient frontier curve, with individual assets and portfolio: 1.

6.3 Portfolio: 2

Table 8: Optimized portfolio: 2 with weights and performance results

Portfolio: 2							
Asset weights:				Performance:			
OMXS 30	F. fond	BTC	Gold	Return	Std. Deviation	Excess Return	Sharpe-ratio
19.8%	23.7%	-	56.5%	18.4%	0.12	16.8%	1.41

Portfolio: 2 has constraints in Bitcoin and results in the most evenly balanced portfolio out of the ones with constraints, still heavily favoring gold above OMXS 30 and the real estate fund. Portfolio: 2 manages the lowest risk performance out of all five portfolios and places quite close to the minimum variance portfolio at the beginning of the efficient frontier line, plotted in figure 3 below. This results in a relatively low excess return, but still slightly above that of the market index and gold. When adding gold to the baseline portfolio the excess return decreases by 4%, however, the standard deviation used to measure risk decreased even more significantly from 0.22 to 0.12. This relative change gave portfolio: 2 a distinctively higher Sharpe-ratio compared to portfolio: 1.

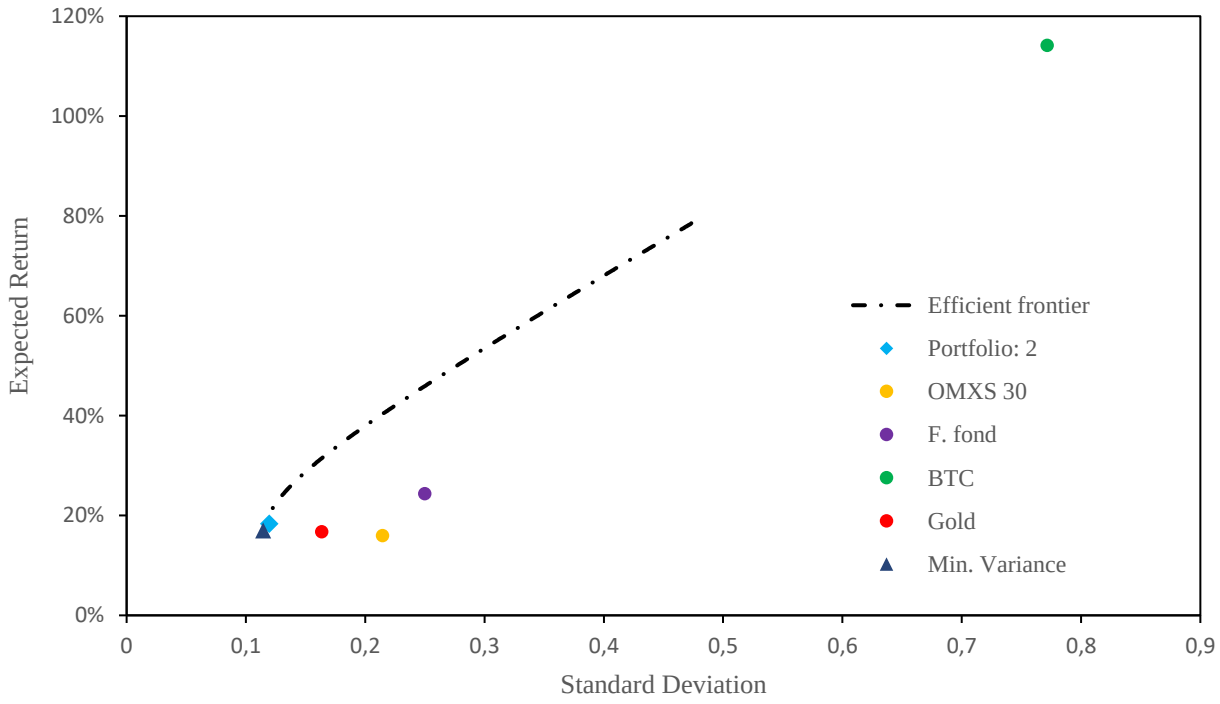

Figure 3: Efficient frontier curve, with individual assets and portfolio: 2.

6.4 Portfolio: 3

Table 9: Optimized portfolio: 3 with weights and performance results

Portfolio: 3							
Asset weights:				**Performance:**			
OMXS 30	**F. fond**	**BTC**	**Gold**	**Return**	**Std. Deviation**	**Excess Return**	**Sharpe-ratio**
27.7%	**-**	**15.6%**	**56.7%**	**31.7%**	**0.17**	**30.1%**	**1.77**

Portfolio: 3 includes all assets except the real estate fund and is the best performing portfolio out of the constrained portfolios. Again, a considerable proportion of the weight allocation is found in gold (56.7%), well above the distributions into OMXS 30 (27.7%) and Bitcoin (15.6%). It keeps a volatility level close to that of gold and has an excess return above all the traditional assets, as seen in figure 4. This portfolio has both higher returns and lower volatility than the baseline portfolio (portfolio: 1). It also has a higher return than portfolio: 2 but also higher volatility. The Sharpe-ratio exceeds that of both previous portfolios with a value of 1.77.

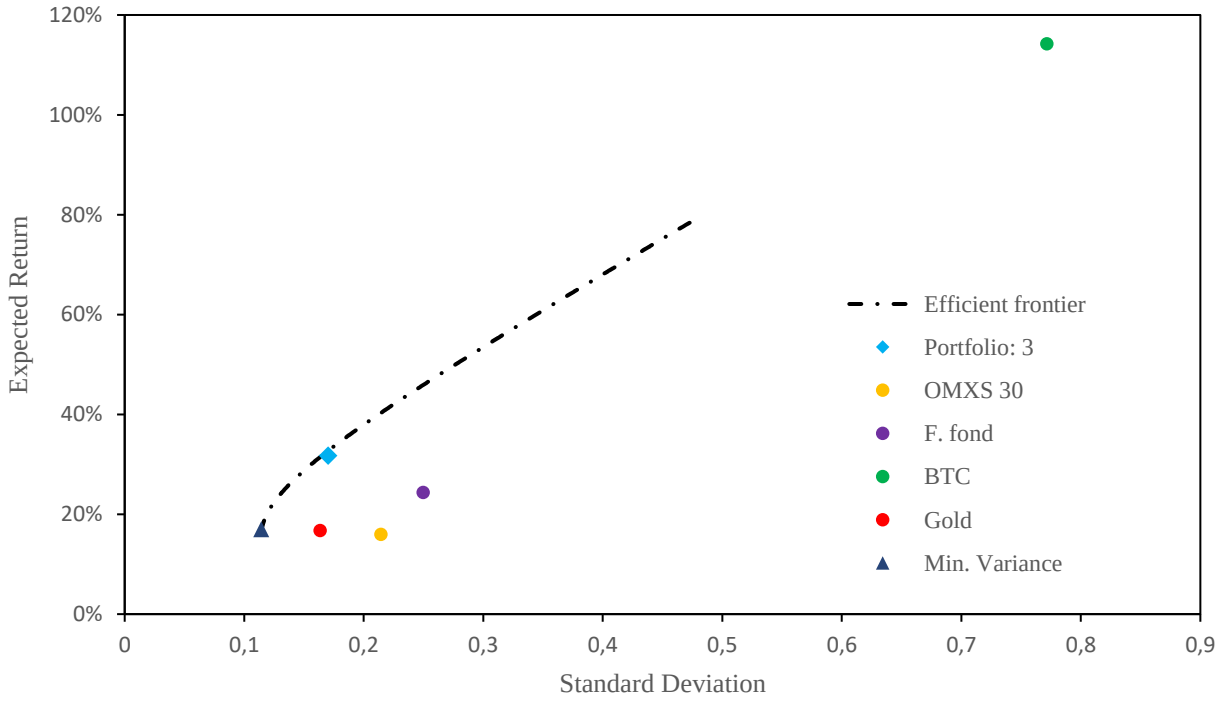

Figure 4: Efficient frontier curve, with individual assets and portfolio: 3.

6.5 Portfolio: 4

Table 10: Optimized portfolio: 4 with weights and performance results

Portfolio: 4							
Asset weights:				Performance:			
OMXS 30	F. fond	BTC	Gold	Return	Std. Deviation	Excess Return	Sharpe-ratio
0.0%	62.5%	37.5%	-	58.0%	0.35	56.5%	1.63

Portfolio: 4 is only constrained in allocations to gold, still the optimized portfolio has allocated 0.0% into OMXS 30. The largest allocation is found in the real estate fund with some extra weight in Bitcoin. Portfolio: 4 has the highest excess return, as well as standard deviation from all portfolios constructed. This is seen in figure 5 with an excess return far above the traditional assets and standard deviation significantly lower than that of just Bitcoin. Comparing this portfolio to the portfolio with gold (portfolio: 2) the standard deviation increased with a factor of three, whilst the excess return rose a remarkable 39.7% from 16.8% to 56.5%. This made the comparable Sharpe-ratios between portfolio: 2 and 4 to increase from 1.41 to 1.63, when including Bitcoin instead of gold.

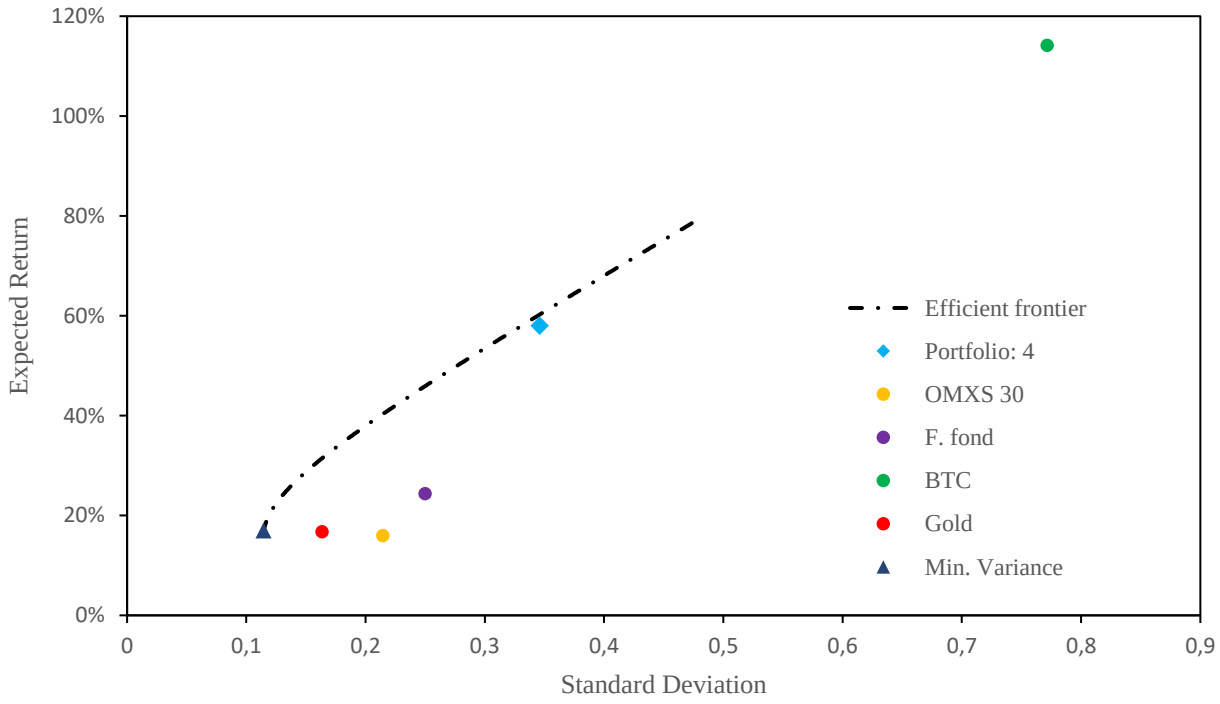

Figure 5: Efficient frontier curve, with individual assets and portfolio: 4.

6.6 Portfolio: 5

Table 11: Optimized portfolio: 5 with weights and performance results

Portfolio: 5							
Asset weights:				**Performance:**			
OMXS 30	**F. fond**	**BTC**	**Gold**	**Return**	**Std. Deviation**	**Excess Return**	**Sharpe-ratio**
8.3%	**25.6%**	**14.8%**	**51.3%**	**33.0%**	**0.17**	**31.5%**	**1.86**

Table 11 above was the result from the portfolio including all assets, which was also the best performing portfolio out of the five in terms of maximizing Sharpe-ratio. Portfolio: 5 has a large allocation in gold, making up more than 50%. Followed by a 25% placement in the real estate fund. The lowest allocations are found in OMXS 30 (8.3%) and Bitcoin (14.8%). Portfolio: 5 maintains a low standard deviation of 0.17, close to that of gold's 0.16. However, manages to outperform the individual asset with an excess return approximately twice as high. This can be seen in figure 6 below, where gold reaches an excess return of 15.17%, while the portfolio performs at 31.5%.

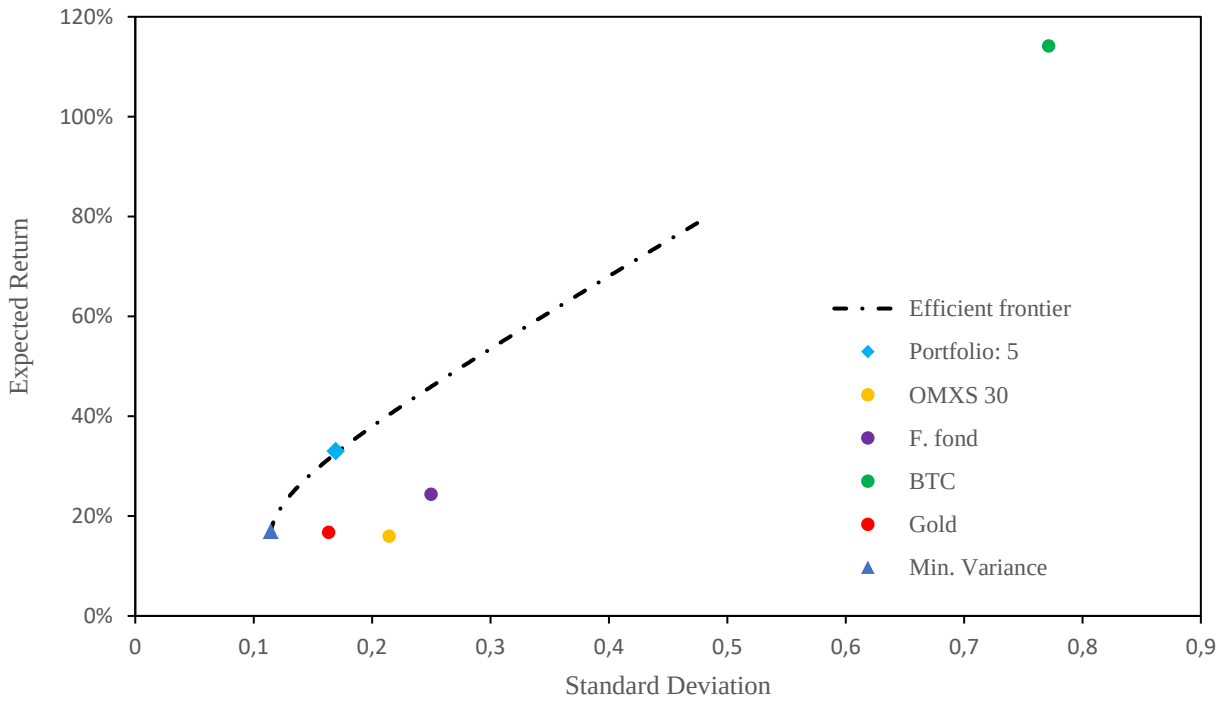

Figure 6: Efficient frontier curve, with individual assets and portfolio: 5.

7 Discussion

Upon analyzing the results of the optimized portfolios, the hypothesis that Bitcoin would improve portfolio performance by increasing the Sharpe-ratio was confirmed. Several interesting findings were discovered through the portfolio simulations. In accordance with Markowitz's (1952) arguments for diversification, the study found clear results that indicate the superiority of a well-diversified portfolio with portfolio 5 achieving the best Sharpe-ratio out of all portfolios. This is because portfolio 5 did not have any asset constraints and was therefore able to achieve a higher degree of optimization when allocating its asset weights.

It should be noted that in portfolio 4, almost nothing has been allocated into the market index even though there were no constraints for it. This is likely due to the high correlation between OMXS 30 and the real estate fund, with the latter having a similar standard deviation but significantly higher excess return. It is therefore not strange for the optimized portfolio to choose the fund above the market index, as it is regarded as a substitute with higher return. This explanation is further supported by the results of portfolio 1, which only included OMXS 30 and F. fond. Through observing figure 2, the placement of portfolio 1 can clearly be seen between the two assets. Had the real estate fund not been placed to the right of OMXS 30, all of the portfolio allocation would have gone into F. fond in order to maximize the Sharpe-ratio.

By examining portfolio 2, it can be observed that a portfolio of traditional assets aligns more with the excess returns of conventional investments. It is also an indicative illustration of the hedging potential of gold, which constitutes more than half of the portfolio. Portfolio 2 manages to limit the risk significantly while still maintaining a stable return. This is reinforced again in portfolio 3 and 5, where the portfolios are using gold to hedge their risk against both the market index as well as the real estate fund and Bitcoin. It can thereby be concluded in the limited scope of this study that Bitcoin does not serve as good of a hedge against volatility as gold.

More importantly, the results support previous research that diversification with Bitcoin can improve portfolio performance. Although Brière et al. (2015) suggested that bitcoin does not need to remain low in times of crisis merely because of its weak correlation with other assets, this study found that during the COVID-19 crisis, Bitcoin performed well as an asset for diversification. The study thereby confirms the results from Bauer et al. (2018) that Bitcoin can diversify a portfolio in times of crisis.

Portfolio 4 with traditional assets and Bitcoin had the highest excess return out of all portfolios. When comparing portfolio 2, which contains all assets except Bitcoin, with portfolio 5, including all assets, a considerable difference in excess return can be observed. Despite the standard deviation in portfolio 5 being higher, it still managed to outperform portfolio 2. This supports the reasoning of Kajtazi and Moro (2019), who assert that the higher performance of a portfolio including Bitcoin is due to higher returns rather than lower volatility.

There is always a risk when investing in assets, which holds especially true for Bitcoin. In addition to Bitcoin's high standard deviation, it also faces other risks and concerns as stressed by Cheah and Fry (2015); Bitcoin has no fundamental value comparable to other traditional assets and instead only has value because people believe in it. There is nothing physical to back it up, which warrants caution by investors. Even though the results of the study make Bitcoin appear to be a profitable and sound investment, Bitcoin's unique properties also mean that novel risks are involved in investments.

Although the results show that Bitcoin could have been used as a portfolio enhancer during the COVID-19 crisis, there are certain further limitations worth stressing. First, as with any analysis of the price of assets, historical values do not need to reflect future values. The intention of the study was to examine how Bitcoin performed in a portfolio during the COVID-19 crisis in order to strengthen the overall understanding of Bitcoin's viability to improve portfolio performance in global crises; nonetheless, future values may behave differently, and further research is needed to test the proposition.

Secondly, the data collected was from a three-year time period and a very characterizing historical time. The Bitcoin price during this period fluctuated substantially and was very volatile compared to earlier years when many of the previous studies on Bitcoin were made. The COVID-19 crisis reflected a tumultuous time in the sphere of economics, which is important to acknowledge. Since it was a unique event in terms of financial circumstances, it is possible that the results would have been different, and Bitcoin would not have enhanced portfolio performance if the COVID-19 crisis had never happened.

Thirdly, as stressed earlier, the methods used in this analysis have limitations. Given that the modern portfolio theory is based on a set of assumptions that do not perfectly reflect the nature of economic activity, such as all actors acting rationally, and the Sharpe-ratio being of limited value when returns of the portfolio are not normally distributed, the outcome of the analysis will invariably be affected (see Mangram, 2013; Smetters and Zhang, 2013). There are many other methods that can be used when testing portfolio optimizations. For example, Platanakis and Urquhart (2020) employed eight different methods that could be used to construct asset allocation in a portfolio; interestingly, however, they still obtained similar results suggesting that Bitcoin is beneficial to include in a portfolio with traditional assets.

8 Conclusion

The study has sought to test the hypothesis of whether Bitcoin would improve portfolio performance together with diverse assets during the COVID-19 crisis. The intention behind the hypothesis was to draw inferences into a larger debate whether portfolio performance can be improved with Bitcoin during a global crisis.

Overall, the study concludes that including and diversifying a portfolio with Bitcoin would have enhanced its performance during the COVID-19 crisis. This conclusion was reached through simulating and comparing different portfolios' performances during the time frame with a focus on asset allocation and the Sharpe-ratio.

However, the study further found that Bitcoin does not provide as good of a hedge against volatility as gold would have done during the crisis. Inadvertently, a portfolio including Bitcoin would likely have seen only minor risk benefits if combined with traditional market assets as reflected by OMXS 30, a real estate fund and gold. The advantage of including Bitcoin in a portfolio would have been in the significant return that was achieved by Bitcoin during this time period. The study has confirmed that this effect applied to a portfolio with only Swedish assets during the COVID-19 crisis. By expanding the data pool through focusing on the Swedish market instead of major international ones, along with complementing previous research on the portfolio theory and the role of Bitcoin, the study has expanded the academic research on this subject.

The study further emphasized that Bitcoin is highly volatile, and the historical price of Bitcoin and other assets does not guarantee the same development in the future. Further research is highly recommended given that cryptocurrencies are relatively new financial assets. More general research and analysis on the future price and volatility development of these assets will be beneficial in order to strengthen overall understanding and make wiser investment decisions in the future. Further research on the portfolio performance of a combination of cryptocurrencies together

with or without traditional assets could equally offer valuable insights into how portfolios can be constructed for optimal performance.

Ultimately, how a portfolio is constructed tends to strongly depend on one's level of risk aversion. For investors with a higher risk tolerance, investing more in Bitcoin appears to be a better option than gold because of its high-risk, high-reward characteristics. It is however important to be aware of the different types of risk that Bitcoin gives rise to as per Cheah and Fry (2015). On the other hand, for more risk-averse investors it is better to invest in gold because of its lower risk, lower return properties. Notwithstanding, the best risk-adjusted performance, i.e. the highest Sharpe-ratio, is achieved when including both Bitcoin and gold in a diversified portfolio. This is because they both increase the level of diversification when combined with traditional market assets and provide certain hedging properties.

In conclusion, the study has both discussed and shown the potential of Bitcoin to diversify a portfolio and improve its performance. The results of the study demonstrate that including Bitcoin in a diversified portfolio of Swedish assets during the COVID-19 crisis is beneficial and improves performance based on the high returns of Bitcoin during the time frame. It thereby suggests that Bitcoin can improve portfolio performance during a global crisis.

References

Avanza. (2022). Fond inspiration, Available online: https://www.avanza.se/fonder/fondinspiration.html [Accessed 10 May 2022]

Bauer, D. G., Hong, K., & Lee, A. D. (2018). Bitcoin: Medium of exchange or speculative assets?, *Journal of International Financial Markets, Institutions and Money*, vol. 54, pp. 177-189

Benninga, S. (2014). Financial Modeling fourth edn, London: The MIT Press Cambridge, p. 99

Briere, M., Oosterlinck, K., & Szafarz, A. (2015). Virtual currency, tangible return: Portfolio diversification with Bitcoin, *Journal of Asset Management,* vol. 16, no. 6**,** pp. 365-373

Cheah, J & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin, *Economics Letters*, Vol. 130, pp. 32-36

CoinMarketCap. (n.d.a). Historical Snapshot - April 24 2022 [Online]. Available online: https://coinmarketcap.com/historical/20220424/ [Accessed: 1 May 2022]

CoinMarketCap. (n.d.b). Bitcoin. Available online: https://coinmarketcap.com/currencies/Bitcoin/ [Accessed 10 May 2022]

Corbet, S., Lucey, B., Urquhart, A., & Yarovaya, L. (2018). Cryptocurrencies as a Financial Asset: A systematic analysis [pdf], Available online: https://deliverypdf.ssrn.com/delivery.php [Accessed 13 May 2022]

Corporate finance institute. (n.d.), fixed income securities, available online: **https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/fixed-income-securities/** [Accessed 22 April 2022]

Fisher, P. R. (2013). Sovereign Risk: A World Without Risk-Free Assets? *Bank For International Settlement*, no, 72, Available online: https://ssrn.com/abstract=2420000 [Accessed 13 May 2022]

Foley, S., Karlsen, J. R., & Putniņš T.J. (2018). Sex, Drugs, and Bitcoin: How Much Illegal Activity Is Financed Through Cryptocurrencies?, *Review of Financial Studies, Forthcoming*,]https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3102645 [Accessed 20 May 2022]

Investing. (2022). Investing.com – Stock Market Quotes & Financial News, Available online: https://www.investing.com[Accessed 9 May 2022]

Kajtazi, A. & Moro, A. (2019). The role of Bitcoin in well diversified portfolios: A comparative global study, *International Review of Financial Analysis*, vol. 61, pp. 143-157

Markowitz, H. (1952), Portfolio selection, *The Journal of Finance*, vol 7, no. 1, pp. 77-91

Myles E. Mangram. (2013). A simplified perspective of the Markowitz portfolio theory, *Global Journal of Business Research*, vol. 7, no. 1, p. 61

Nakamoto, S. (2008), Bitcoin: A Peer-to-Peer Electronic Cash System, Available online: https://Bitcoin.org/Bitcoin.pdf [Accessed 28 April 2022]

Nasdaq. (2022). OMXS30, OMX STOCKHOLM 30 INDEX, (SE0000337842), Available online: **http://www.nasdaqomxnordic.com/indexes/index_activity?Instrument=SE0000337842** [Accessed May 16 2022]

Nationalencyklopedin. (n.d.). Guld, Available online: https://www.ne.se/uppslagsverk/encyklopedi/lång/guld [Accessed 21 April 2022]

Platanakis, E. & Urquhart, A. (2020). Should investors include Bitcoin in their portfolios? A portfolio theory approach, *The British Accounting Review*, vol 52, no. 4

Reuters. (2022), Why central banks buy gold, Available online: **https://www.reuters.com/article/sponsored/why-central-banks-buy-gold** [Accessed 21 April 2022]

Shanaev, S. (2020). NEDL. [video online], Available at: https://www.youtube.com/watch?v=2DhFR6JDO-k [Accessed 15 May 2022]

Sharpe, W. F. (1963). A simplified model for portfolio analysis, *Management science*, vol. 9, no. 2**,** pp. 277-293

Sharpe, W. F. (1966). Mutual fund performance, *The Journal of business*, vol. 39, no. 1**,** pp. 119-138

Smetters, K & Zhang, X. (2013). A sharper ratio: A general measure for correctly ranking non-normal investment risk, working paper, *National Bureau of economic research*, Available online: https://www.nber.org/system/files/working_papers/w19500/w19500.pdf [accessed 5 May 2022]

Statistikmyndigheten SCB. (2022). Konsumentprisindex, 12-månadersförändring, procent (inflationstakten), Available online: https://www.scb.se/hitta-statistik/statistik-efter-amne/priser-och-konsumtion/konsumentprisindex/konsumentprisindex-kpi/pong/tabell-och-diagram/konsumentprisindex-kpi/kpi-12-manadersforandring-inflationstakten/ [Accessed 12 May 2022]

Sveriges Riksbank. (2022) Sök räntor & valutakurser, Available online. https://www.riksbank.se/sv/statistik/sok-rantor--valutakurser/?g6-SETB1MBENCHC=on&g6-SETB3MBENCH=on&g6-SETB6MBENCH=on&g7-SEGVB2YC=on&g7-SEGVB5YC=on&g7-SEGVB7YC=on&g7-SEGVB10YC=on&from=2019-01-02&to=2021-12-30&f=Day&c=cAverage&s=Comma [Accessed 10 May 2022]

Uddin, A., Ali, H., & Mashi, M. (2020). Bitcoin – a hype or digital gold? Global evidence, *Australian economic paper*s, vol. 59, no. 3, pp. 215-231

World Gold Council. (2020), Investment Update: Gold, an efficient hedge, available online: **https://www.gold.org/goldhub/research/investment-update-gold-efficient-hedge** [Accessed 21 April 2022]

Wu, C. Y. & Pandey, V. K. (2014). The value of Bitcoin in enhancing the efficiency of an investor's portfolio, *Journal of Financial Planning,* vol. 27, no. 9, pp. 44-52