ERASMUS UNIVERSITY ROTTERDAM
ERASMUS SCHOOL OF ECONOMICS
Bachelor Thesis Economics & Business

The Effect of Cryptocurrency on Investment Portfolio Effectiveness Revisited… Do NFTs matter?

Author: Daan Goedhuys
Student number: 564633
Thesis supervisor: dr. Ruben de Bliek
Second reader: Sipke Dom
Finish date: 27-08-2023

The views stated in this thesis are those of the author and not necessarily those of the supervisor, second reader, Erasmus School of Economics or Erasmus University Rotterdam.

ABSTRACT

This study examines the effect of cryptocurrencies, in particular Non-Fungible Tokens, on the effectiveness of an investment portfolio. Using a quantitative study on assets from FOREX and commodities, stocks, Exchange-Traded Funds (ETFs) and cryptocurrency, the effectiveness of portfolios with and without cryptocurrencies is calculated. I find a positive effect on portfolio effectiveness, expressed as an increase in Sharpe ratio, mostly when adding Ripple and to a lesser extent NFTs. Even though cryptocurrencies are often seen as highly volatile, they should not be overlooked when creating an effective investment portfolio.

Keywords: Cryptocurrency, Non-Fungible Tokens, Portfolio optimisation, investing.

JEL codes: G0, G1

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1 Introduction

The last few years, cryptocurrencies have been covered in the news many times. Cryptocurrencies are very risky digital currencies into which people can invest, often leading to very volatile positive or negative returns. Andrianto and Diputra (2017) have shown that adding the cryptocurrency Bitcoin to an investment portfolio significantly increases the effectiveness of the portfolio. One of the most covered cryptocurrencies today are non-fungible tokens (NFTs), which are explained as digital art pieces. Prices for these digital art pieces vary enormously, ranging from 10 million to 50 million dollars. Similarly to Bitcoin, NFTs are also highly volatile. NFTs could also potentially increase the effectiveness of an investment portfolio, maybe even more than for example Bitcoin. This paper studies the effect of cryptocurrencies on an investment portfolio, and the differences in effect of cryptocurrencies, such as NFTs and Bitcoin.

There has been a fair share of research regarding the place of cryptocurrencies in investment portfolios. Andrianto and Diputra (2017) researched the cryptocurrencies Bitcoin, Ripple and in combination with the assets Foreign Currencies, Commodities, Stocks and ETFs. First, they looked at the return, risk (measured in standard deviation) and Sharpe ratio of multiple portfolios: A portfolio of eleven asset types of foreign exchange (FOREX) and commodities, a portfolio of six stocks, and a portfolio of five Exchange-Traded Funds (ETFs). Within these portfolios they had multiple sub-portfolios, where the allocation percentage of these assets differ. After this they added the cryptocurrencies Bitcoin, Ripple and Litecoin to all the three portfolios, and looked at the change in return, risk, and Sharpe ratio. They often found a statistically significant increase in return and Sharpe ratio in combination with a statistically significant decrease in risk, which was mostly because of the effect of Bitcoin. After this, they used some assets from the previous portfolios with the best performance to form an optimal portfolio consisting of mixed assets. Here they also looked at the return, risk, and Sharpe ratio, before and after adding cryptocurrencies. The same result was found, with Bitcoin significantly increasing the return and Sharpe ratio while simultaneously decreasing the risk. They found that the optimal allocation percentage of cryptocurrency ranges from 5% to 20%, depending on the investor's risk tolerance.

Mazur (2021) analysed the risks and returns of NFTs and obtained some interesting results. NFTs earn first-day returns of 130% on average, which is higher than first day returns of Initial Public Offerings (IPOs). IPOs also have superior long-term returns, even adjusted for risks. As expected, the volatility of NFTs is still very high. NFTs are also found to be potential portfolio diversifiers, as they can reduce the variance of a portfolio without changing the expected return. This last point was also discovered by Ko et al. (2022). They added NFTs to a traditional assets' portfolio, and their findings suggested that NFTs are different from traditional assets and potentially diversify a portfolio. They also found significant

evidence that NFTs improve performances of equally weighted and tangency portfolios, measured in terms of Sharpe ratio. This confirms the diversification potential of NFTs.

It seems like NFTs might be able to increase the return and Sharpe ratio and decrease the risk of a portfolio as well, perhaps even better than Bitcoin. However, this is still unclear. In this study I will replicate the experiment by Andrianto and Diputra and adding NFTs into the portfolio when adding the cryptocurrencies. This way the difference in effect between Bitcoin and NFTs can be discovered and potentially give investors more options in creating a solid portfolio. This potential difference between Bitcoin and NFTs is very interesting to discover, as it can create another option for portfolio investing. This creates the following research question: How do non-fungible tokens (NFTs) affect the performance of investment portfolios and how does this compare to other cryptocurrencies?

To study this research question primary data is collected on all assets used in the study of Andrianto and Diputra. The data is taken from www.investing.com, https://finance.yahoo.com and www.cryptocompare.com. As NFTs are relatively new, the period of data will be from March 2021 until March 2023. This data is processed with the Microsoft Excel software, in the same way Andrianto and Diputra (2017) did. For the FOREX and commodities, the assets used are USD/RUB - US Dollar Russian Ruble, USD/DKK – US Dollar Danish Krone, USD/CNY - US Dollar Chinese Yuan, USD/HKD - US Dollar Hong Kong Dollar, USD/CAD – US Dollar Canadian Dollar, USD/SGD - US Dollar Singapore Dollar, USD/CHF - US Dollar Swiss France EUR/GBP – Euro British Pound, Gold, and Silver. For the stocks, I use the assets The Kraft Heinz Company (KHC), Wells Fargo & Company (WFC), The Coca-Cola Company (KO), International Business Machines Corporation (IBM), American Express Company (AXP), and Phillips 66 (PSX). Similar to the research of Andrianto and Diputra, this research assumes that these stocks represent stock assets in stock portfolios. For the ETFs, the assets used are Vanguard Total Stock Market ETF (VTI), Vanguard Total Bond Market ETF (BND), Vanguard FTSE All-World ex-US ETF (VEU), PowerShares DB US Dollar Bullish ETF (UUP), and SPDR S&P Metals and Mining ETF (XME). For the cryptocurrencies, the assets used are Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), and for the NFTs I will use the CryptoCompare Index NFTX (NFTX). I removed Litecoin from the assets and added Ethereum to have the three biggest cryptocurrencies.

Next, I want to find the annual return and standard deviation. I calculate, among other things, the standard deviation, correlation, covariance, and the mean. The main function that I will use is a solver, which can provide the asset allocations for the different portfolios. Four portfolios are created: FOREX and commodity portfolio (1), Stocks (2), ETFs (3) and a combined portfolio of the best performing assets of the first three portfolios (4).

I expect to find a stark difference in the way that NFTs affect the investment portfolio, compared to the other cryptocurrencies that are researched. I also expect to find different results on the effect of Bitcoin, Ripple and Ethereum compared to previous research, as these cryptocurrencies have become more popular in the last years. I hypothesize that cryptocurrencies do still affect portfolio effectiveness in a positive way. However, NFTs might not have a significant effect, as NFTs are mostly limited by the movements of the cryptocurrencies that are used to buy NFTs (Ante, 2022). This might minimize the effect of NFTs on portfolio effectiveness, potentially creating a significant difference in effect between NFTs and other cryptocurrencies. This study aims to provide an accurate and up-to-date representation of the effect of some of the biggest cryptocurrencies and NFTs on investment portfolios.

The remainder of this paper is structured as follows. Section 2 discusses the relevant literature and previous research. Section 3 and 4 describe the data and methodology used for this paper. Section 5 presents the results of the research followed by a discussion of these results. Section 6 will conclude this research.

CHAPTER 2 Theoretical Framework

2.1 Portfolio Optimisation

To study the effectiveness of adding NFTs into a portfolio, we must first look at the relevant literature regarding portfolio optimisation. Portfolio optimisation is a widely known concept in the financial world. It is introduced in the Modern Portfolio Theory (MPT) (Markowitz, 1952), and it is known as maximizing the return of a portfolio based on existing market risks. Markowitz (1952) introduced an Efficient Frontier, a set of optimal portfolios that have the highest expected return for a predefined level of risk, or the lowest risk for a predefined level of expected return. The Modern Portfolio theory differs a lot from the theory of the firm and consumer, which is made up of multiple economic theories and predicts the way firms behave and exist in the market. First, it is meant for investors, instead of firms and consumers. Second, it is concerned with decision making under uncertainty. Uncertainty plays a big role in investing according to Markowitz. If there was no uncertainty and investors knew the future returns of securities, they would only invest in the security with the highest return. However, diversification is discussed and applied commonly when investing. This is done to reduce the uncertainty of investing. Third, the Modern Portfolio Theory is not only a theory, but can also be used in practice if investors have enough resources and tools (Markowitz, 1991).

However, even though the Modern Portfolio Theory was made popular with Markowitz' publication in 1952, this was not the first time the same ideas were presented. Roy (1952) measured the cost of risk for certain intervals or levels of payoffs. This composition of risks for every interval effectively creates the same Efficient Frontier, as discussed in the Modern Portfolio Theory. The biggest difference between these two papers was that Roy's analysis allowed for going short on a stock whereas Markowitz' required non-negative investments (Markowitz, 1999). With the help of this Modern Portfolio Theory, we can identify potential assets and portfolios which optimize returns.

In the Modern Portfolio Theory process several factors are measured, such as the return, correlation, covariance, and standard deviation, often done using historical statistical methods. There are often several optimal portfolios, with different returns and risk levels. This makes choosing a portfolio a trade-off between risks and returns. This relationship was first introduced in Sharpe's (1964) Capital Asset Pricing Model (CAPM), which provides a relationship between the expected returns and systematic risk, also known as beta. CAPM is often used for the pricing of assets and construction portfolios. To measure the effectiveness of the assets and portfolios, the Sharpe ratio is used. The Sharpe ratio essentially measures the excess return of an investment or portfolio when adjusting for market returns. A higher Sharpe ratio equals a better return. The relationship between the return and risks of different portfolios is graphically represented by the efficient frontier.

2.2 Cryptocurrency in Portfolio Optimisation

Cryptocurrencies are virtual currencies which have become popular in the last 10 years, with Bitcoin being the cryptocurrency with the largest market capitalization of all cryptocurrencies (Yermack, 2013). According to Ciaian, Rajcaniova and Kancs (2014), there are three factors determining the price of Bitcoin: Demand and supply, attractiveness, and market developments. These factors make price changes very unpredictable, which in turn leads to cryptocurrencies being very volatile.

The most popular cryptocurrency is Bitcoin, developed by Satoshi Nakamoto in 2009. Other popular cryptocurrencies are Ethereum, Ripple, Litecoin and more recently Non-Fungible Tokens (NFTs). The unique thing about cryptocurrencies is the fact that they are decentralized. Instead, cryptocurrencies use a peer-to-peer network. All transactions and information are saved on all computers of users of the cryptocurrency network, known as a public ledger. This means that the government or other financial institutions cannot control or monitor these transactions, which makes the use of cryptocurrency as a form of payment favorable for criminal activity. For example, trading Bitcoin on the site 'Silk Road', in exchange for criminal activity such as acquiring drugs (Trautman, 2014).

The peer-to-peer network works due to blockchain. This is a block with transactions, with unique codes, dates of transactions and amount of the transactions. These are created by miners, people using their computer's power to verify blocks on the blockchain by putting every block through an algorithm. The verification process ensures that the blockchain cannot be attacked by small criminals trying to add fake transactions (Nakamoto, 2008). All-in-all, cryptocurrencies look like trustworthy currencies that can be used as a payment method, but are they also worth investing in?

There has been a lot of research into the effectiveness of cryptocurrencies on investment portfolios. Using the Modern Portfolio Theory approach, Andrianto and Diputra (2017) studied the effect of cryptocurrency on investment portfolio effectiveness. Cryptocurrencies increased their effectiveness by minimizing the standard deviation and creating more allocation options for investors. They concluded that portfolios should consist of 5% to 20% cryptocurrencies. Saksonova and Kuzmina-Merlino (2019) also found that cryptocurrencies should have a part in an investment portfolio, but added that the portfolio should be diversified and regularly rebalanced. The cryptocurrency should also be easily exchangeable to a fiat currency to reduce risks.

Letho et al. (2022) tested the effect of cryptocurrencies on a portfolio's risk-adjusted returns. Using daily returns from 2015 to 2018, they found that cryptocurrencies improve the efficient frontier and risk-adjusted returns. The diversification benefits of cryptocurrencies helped broaden the Modern Portfolio Theory. Brauneis and Mestel (2019) also found that cryptocurrencies improve portfolio performance, but added that it is better to diversify the cryptocurrencies and not invest in a single cryptocurrency.

Almeida and Gonçalves (2022) studied the already existing literature and found that cryptocurrencies offer a safe haven for investors, which means that cryptocurrencies could hedge against multiple assets such as stocks, fiat currencies and geopolitical- and Economic Policy Uncertainty (EPU) risk. All in all, a lot of evidence has been found in literature and practical studies that supports the idea of adding cryptocurrencies into investment portfolios to increase overall portfolio performance.

2.3 NFTs in Portfolio Optimisation

Expanding on the general cryptocurrency principles, a question that arises from the previous literature is how do Non-Fungible Tokens (NFTs) affect portfolio performance? Valeonti et al. (2021) define an NFT as *a cryptographically unique, indivisible, irreplaceable and verifiable token that represents a given asset, be it digital, or physical, on a blockchain.* NFTs are a form of cryptocurrency which, when owned, give the owner the unique ownership of a digital or real-world item, such as art or real estate. They are unique, so no NFT can be replicated, and they can be sold for money or other cryptocurrencies. They have been around since 2014, but recently gained popularity for being a way to buy and sell digital artwork (Conti & Schmidt, 2021). NFTs are different form the earlier cryptocurrencies such as Bitcoin, particularly in their intrinsic features (Wang et al., 2021). Whereas Bitcoin is a digital coin with every Bitcoin having the same value, NFTs are unique and do not have same value as other NFTs. In other words, Bitcoins are interchangeable (or fungible), while NFTs are not interchangeable.

NFTs are often associated with high risks and high returns. A study on NFT-based startups showed that NFTs can have great returns of up to 4000% over the long-term, but also have an above-average beta (Mazur, 2021). Ante (2022) looked at the relationship between NFTs and Bitcoin and Ethereum. A bitcoin price shock increased the NFT sales, whereas an Ethereum price shock reduced the number of active NFT wallets. The research suggests that large cryptocurrency markets influence the NFT market and that there is no reverse effect.

As NFTs are often compared to artwork, it might be useful to first look at the way art influences investment portfolios. Worthington and Higgs (2004) studied the risk return and prospects for portfolio diversification among major painting and financial markets over a 25-year period. They concluded that paintings had a lower return and higher risk compared to conventional investment markets. Artwork was not able to provide a diversification option for financial asset portfolios, but in portfolios only consisting of artwork, diversification did have a benefit.

It is possible that the risks and returns of art are dependent on the beauty of the art itself. This is probably the case with NFTs. Kong and Lin (2021) studied the collection 'Cryptopunks', which is one of the earliest NFT collections. It was developed by two Canadians in 2017 and built on the Ethereum blockchain. Cryptopunks are pixel art characters, each having different attributes such as the

background, hairstyle, and clothes. Kong and Lin studied the transactions between June 2017 and June 2022, and found that scarcity and the aesthetic preference of the NFT largely influences the price of the corresponding NFT. Schaar and Kampakis (2022) studied the Cryptopunks collection as well and found that the rarity of the attributes massively influences the pricing of the NFT. The results also indicated that the Cryptopunks collection was the best investment over the time frame from 1 June 2018 until 31 May 2021. The average monthly return was 34,19% and the standard deviation 61,76%. On top of this, the NFTs had a Sharpe ratio which indicated a healthy risk-return trade-off. Lastly, they found that Cryptopunks had diversification potential for portfolios due to the low correlation with other assets. Ko et al. (2022) tried to show the portfolio diversification potential of NFTs. They added NFTs to traditional asset portfolios and examined certain statistics. Their findings suggested that NFT are different than traditional assets and therefore have portfolio diversification potential. There was statistically significant evidence of NFTs improving the Sharpe ratio of portfolios, and therefore having a diversification effect on traditional asset-based portfolios. This study will try to combine the findings of cryptocurrency in general and the insights on Non-Fungible Tokens to expand on the findings of portfolio optimization.

CHAPTER 3 Data

For this quantitative study, historical data is collected of multiple assets. This data is taken from the website investing.com. As this study aims to replicate the study of Andrianto and Diputra, I tried to use the same assets that were used in their study. The data is split up in four different asset classes. The first class is FOREX and commodities and consists of the following assets: USD/RUB - US Dollar Russian Ruble, USD/DKK – US Dollar Danish Krone, USD/CNY - US Dollar Chinese Yuan, USD/HKD - US Dollar Hong Kong Dollar, USD/CAD – US Dollar Canadian Dollar, USD/SGD - US Dollar Singapore Dollar, USD/CHF - US Dollar Swiss France EUR/GBP – Euro British Pound, Gold, and Silver. FOREX is similar to the traditional cryptocurrencies, as they are all forms of payment. Gold, and silver to an extent, are useful to include because they are considered safe assets and compared to Bitcoin as both are resistant to economic shocks (Baur et al., 2016). The second class is stocks and consists of The Kraft Heinz Company (KHC), Wells Fargo & Company (WFC), The Coca-Cola Company (KO), International Business Machines Corporation (IBM), American Express Company (AXP), and Phillips 66 (PSX). These stocks are assumed to be representable stocks that are used in stock portfolio formation. The third class are Exchange-Traded Funds (ETFs) and consists of the ETFs Vanguard Total Stock Market ETF (VTI), Vanguard Total Bond Market ETF (BND), Vanguard FTSE All-World ex-US ETF (VEU), PowerShares DB US Dollar Bullish ETF (UUP), and SPDR S&P Metals and Mining ETF (XME). These ETFs are popular among investors. The fourth class is cryptocurrencies, and here the assets used are Bitcoin (BTC), Ethereum (ETH), Ripple (XRP). Unlike the research of Andrianto and Diputra, Litecoin is replaced by Ethereum, to have data on the three largest cryptocurrencies. For the NFTs the CryptoCompare Index NFTX (NFTX) is used. NFTX is an online platform which creates tokens backed by NFT collectibles that can be traded. It is aiming to be the main distributor of NFT tokens. It can be seen as tokenized index fund for NFTs (Barbereau et al., 2022).

The data of these assets are monthly prices from the period of March 2021 until the end February 2023. In total there are 24 observations for each asset. This timeframe ensures that the information of this research is representable of the most recent times. This will give a clear image of the effects of all assets on the portfolio optimisation process. Another reason for choosing this period is the fact that NFTs have not been a mainstream topic in the years before the chosen timeframe. In the first four months of 2021, NFT trading volume was more than ten times the trading volume of the whole of 2020 (Nadini et al., 2021). Therefore, I believe it is better to not use the years before this surge of trading volume, as it would not be representable enough for the current investing climate.

Table 1

Descriptive statistics of monthly returns of the FOREX and Commodity assets

Asset	USD/RUB	USD/DKK	USD/CNY	USD/HKD	USD/CAD	USD/SGD	USD/CHF	EUR/GBP	GOLD	SILVER
Mean return	0.39%	0.48%	0.26%	0.04%	0.38%	0.02%	0.02%	0.15%	0.41%	-0.41%
Standard error	2.01%	0.48%	0.39%	0.04%	0.44%	0.33%	0.50%	0.30%	0.86%	1.56%
Minimum return	-16.34%	-5.14%	-2.93%	-0.50%	-2.30%	-3.85%	-5.53%	-2.44%	-7.00%	-11.89%
Maximum return	22.26%	4.97%	4.24%	0.39%	5.32%	2.71%	5.51%	3.02%	7.75%	13.92%

Tables 1 until 4 provide the descriptive statistics of the four asset classes defined above. Most of the FOREX and Commodity assets have a mean under one percent and a low standard error. The USD/RUB asset has the highest standard error, lowest minimum, and highest maximum of monthly returns, which could be an effect of the ongoing tensions between the U.S.A. and Russia. Silver is the only asset with a negative return.

Table 2

Descriptive statistics of monthly returns of the Stock assets

Asset	KHC	WFC	KO	IBM	AXP	PSX
Mean return	0.09%	1.16%	0.66%	0.28%	1.26%	1.48%
Standard error	1.36%	1.86%	1.09%	1.41%	1.79%	2.13%
Minimum return	-11.26%	-14.42%	-9.22%	-9.95%	-17.89%	-18.67%
Maximum return	15.35%	15.31%	12.89%	16.40%	18.40%	29.20%

As can be seen in table 2 and 3, the stock and ETF assets have on average a higher mean and standard error than the FOREX and commodity assets. Philips is the best stock, with an average return of 1,48% per month, whereas Kraft Heinz Company only has a return of 0,09% per month. The ETF assets are on average the worst performing class, with BND and VEU having a negative monthly return and VTI a 0% monthly return, leaving only UUP and XME with a positive return. XME however, has the highest return of all assets without cryptocurrency.

Table 3

Descriptive statistics of monthly returns of the ETF assets

Asset	VTI	BND	VEU	UUP	XME
Mean return	0.00%	-0.68%	-0.53%	0.56%	2.08%
Standard error	1.19%	0.44%	1.11%	0.47%	2.32%
Minimum return	-9.61%	-4.38%	-10.17%	-4.73%	-19.08%
Maximum return	9.35%	3.43%	13.15%	4.83%	26.13%

The cryptocurrencies have on average a higher return and a substantially higher standard error. Cryptocurrencies are often known to be very volatile while also having much higher returns than other asset classes. This is confirmed in Table 4. This asset class also contains the two assets with the highest mean return of all assets covered (ETH and XRP). This also goes hand in hand with the fact the high beta assets are often associated with a higher potential return (Pettengill et al., 1995).

Table 4

Descriptive statistics of monthly returns of the Cryptocurrency assets

Asset	BTC	ETH	XRP	NFTX
Mean return	-2.10%	2.45%	4.49%	1.00%
Standard error	4.11%	5.51%	9.51%	12.29%
Minimum	-37.32%	-44.95%	-34.70%	-55.39%
Maximum	39.90%	57.15%	180.40%	216.68%

CHAPTER 4 Method

To analyse and visualise the collected data of all assets, I will mainly use the solver function of Microsoft Excel. This function is an add-in program which makes it possible to find an optimal value for certain formulas, by using certain constraints on values or formulas in the worksheet. But to be able to use the solver, first other values need to be calculated.

First, the monthly return is calculated by using the formula:

$$return = \frac{new\ price - old\ price}{old\ price} \tag{1}$$

After this I find the average monthly return and the standard deviation of each asset. This makes it possible to identify well-performing assets to be used in creating an optimal portfolio of assets later. The next step is to calculate the correlation and covariance of the assets. This is done with the *correlation* and *covariance* function of Excel.

Following these calculations, it is possible to set up the formulas and portfolio for the solver to use. For example, for the FOREX and commodities asset class, the assets are positioned under each other, with their annual return next to the corresponding asset. The next row contains the weights of the assets in the portfolio, starting with an equal percentage on assets.

$$weight = \frac{100\%}{number\ of\ assets}. \tag{2}$$

Next, I calculate the returns and volatility of the portfolio, taking into account the weight and monthly return of each asset, as well as the covariance of each asset. After this I formula the Sharpe ratio of the portfolio, which measures the return of an investment compared to the risk:

$$Sharpe\ ratio = \frac{Portfolio\ return}{Portfolio\ volatility}. \tag{3}$$

This is the start for each step in the solver. With these formulas, I give the solver certain commands, such as calculating the maximum return (allocation 2), minimum volatility (allocation 3), maximum volatility (allocation 4) and maximum Sharpe ratio (allocation 5). These commands are performed with the constraints that the total asset weight is 100% and that there are no negative weights possible, so going short on an asset is not possible. Allocation 1 consists of all assets having the same weight.

These calculations are done for all asset classes, except for the cryptocurrency class. After this, the solver is used again in these asset classes, with the same constraints. Except, this time I add cryptocurrencies to all asset classes. This will make it possible to identify the benefits or limitations of adding cryptocurrency to an investment portfolio.

The final step of this research is to combine the best-performing assets of each asset class to form an optimal investment portfolio with the best returns and check what kind of effect cryptocurrencies can have on this portfolio. This is done by looking at the assets with the highest annual return across all asset classes. These assets are then combined and used in the same calculations as before. After this, cryptocurrencies are added again to check for an effect of cryptocurrencies on the portfolio. The results of these calculations are discussed in Chapter 5.

CHAPTER 5 Results & Discussion

The models in the following sections were estimated with the solver, giving it certain restrictions as explained in the methodology section. The returns and volatility are annual returns and volatility. The Sharpe ratio is formulated using formula 3. Returns is the percentage of the initial investment that is obtained, on top of the initial investment. For example, a return of 5%, means that, when investing 100 euro´s, after a year this will have grown to 105 euro´s. Volatility is how much the return can differ from the indicated return percentage.

Allocation 1 – All assets have the same weight (formula 2 of methodology)
Allocation 2 – Maximum return of portfolio
Allocation 3 – Minimum volatility of portfolio
Allocation 4 – Maximum volatility of portfolio
Allocation 5 – Maximum Sharpe ratio of portfolio

5.1 FOREX and Commodity assets

Table 5

Asset Allocation Portfolio of FOREX and Commodities, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	2,11%	5,77%	0,81%	4,73%	3,97%
Volatility	4,27%	7,86%	0,76%	32,66%	2,15%
Sharpe Ratio	49,45%	73,40%	106,97%	14,47%	185,11%
USD/RUB	10,00%	0,00%	0,01%	100,00%	1,95%
USD/DKK	10,00%	100,00%	0,00%	0,00%	27,56%
USD/CNY	10,00%	0,00%	0,39%	0,00%	23,85%
USD/HKD	10,00%	0,00%	84,96%	0,00%	0,00%
USD/CAD	10,00%	0,00%	3,03%	0,00%	0,00%
USD/SGD	10,00%	0,00%	6,37%	0,00%	0,00%
USD/CHF	10,00%	0,00%	0,69%	0,00%	0,00%
EUR/GBP	10,00%	0,00%	0,00%	0,00%	24,75%
GOLD	10,00%	0,00%	4,41%	0,00%	21,89%
SILVER	10,00%	0,00%	0,13%	0,00%	0,00%

This portfolio consists of ten Foreign Exchange and Commodity assets. Table 5 shows the returns, volatilities, and Sharpe ratios of the above-mentioned allocations. The allocation of assets proportionally gives a return of 2,11% and a risk of 4,27%. The highest Sharpe ratio of 185,11% is achieved when investing in only five of the ten assets.

Table 6 includes the four cryptocurrency assets Bitcoin, Ethereum, Ripple and NFTX and checks whether this inclusion affects the portfolio results. Allocation 1 shows an increase in return, but an even bigger increase in volatility. This was expected, as cryptocurrencies often have high returns together with high risks. This is also confirmed with allocation 2 and 4, as investing in XRP and NFTX gives the highest return and volatility, respectively. Based on allocation 5, there is a slight increase in portfolio performance when adding cryptocurrencies to the portfolio of FOREX and Commodity assets. An investment of 0,32% into Ethereum results in a higher return and only a small increase in volatility, leading to a higher Sharpe ratio, 186,33% compared to 185,11%

Table 6

Asset Allocation of Cryptocurrency in Portfolio of FOREX and Commodities, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	6,52%	53,86%	0,50%	12,02%	4,02%
Volatility	27,05%	154,55%	0,49%	199,69%	2,16%
Sharpe Ratio	24,08%	34,85%	102,38%	6,02%	186,33%
USD/RUB	7,14%	0,00%	0,00%	0,00%	1,63%
USD/DKK	7,14%	0,00%	0,00%	0,00%	27,37%
USD/CNY	7,14%	0,00%	1,58%	0,00%	23,55%
USD/HKD	7,14%	0,00%	95,22%	0,00%	0,00%
USD/CAD	7,14%	0,00%	0,00%	0,00%	0,00%
USD/SGD	7,14%	0,00%	0,00%	0,00%	0,00%
USD/CHF	7,14%	0,00%	0,00%	0,00%	0,00%
EUR/GBP	7,14%	0,00%	1,96%	0,00%	25,79%
GOLD	7,14%	0,00%	0,00%	0,00%	21,34%
SILVER	7,14%	0,00%	1,25%	0,00%	0,00%
BTC	7,14%	0,00%	0,00%	0,00%	0,00%
ETH	7,14%	0,00%	0,00%	0,00%	0,32%
XRP	7,14%	100,00%	0,00%	0,00%	0,00%
NFTX	7,14%	0,00%	0,00%	100,00%	0,00%

5.2 Stock assets

Table 7

Asset allocation Portfolio of Stocks, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	9,87%	17,79%	6,56%	13,97%	12,99%
Volatility	18,82%	34,61%	15,72%	30,22%	20,89%
Sharpe Ratio	52,43%	51,40%	41,71%	46,24%	62,20%
KHC	16,67%	0,00%	18,64%	0,00%	0,00%
WFC	16,67%	0,00%	14,17%	100,00%	0,00%
KO	16,67%	0,00%	46,77%	0,00%	40,01%
IBM	16,67%	0,00%	20,41%	0,00%	0,00%
AXP	16,67%	0,00%	0,00%	0,00%	31,81%
PSX	16,67%	100,00%	0,00%	0,00%	28,18%

This portfolio looks at six different stocks. Allocation 1 gives the portfolio a return of 9,87% and risk of 18,82%. An all-in position in PSX gives the highest return of 17,79%. The highest Sharpe ratio is achieved when investing in KO, AXP and PSX. An allocation between allocation 3 and 5 would be the best for risk-averse investors, whereas an allocation between 2 and 5 would be better for risk-seeking investors looking for a possible higher return.

Table 8 shows the effect of adding cryptocurrencies. As seen in the FOREX and Commodity portfolio, the inclusion of cryptocurrencies increases both the return and risk of the portfolio. Allocation 3, surprisingly, shows that investing partly in NFTX gives the lowest possible volatility. The highest Sharpe ratio is achieved by investing in Ripple and NFTX. It increases the Sharpe ratio with an absolute percentage of 11,02%. The return increases a lot, while the volatility only increases slightly. This result clearly shows that, in a portfolio of stocks, including cryptocurrencies increases portfolio performance.

Table 8

Asset allocation of Cryptocurrency in Portfolio of Stocks, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	12,93%	53,86%	2,65%	12,02%	15,77%
Volatility	38,55%	154,55%	14,49%	199,69%	21,54%
Sharpe Ratio	33,54%	34,85%	18,27%	6,02%	73,22%
KHC	10,00%	0,00%	16,46%	0,00%	0,00%
WFC	10,00%	0,00%	3,92%	0,00%	0,00%
KO	10,00%	0,00%	37,07%	0,00%	42,29%
IBM	10,00%	0,00%	32,28%	0,00%	0,00%
AXP	10,00%	0,00%	0,00%	0,00%	12,62%
PSX	10,00%	0,00%	0,00%	0,00%	36,40%
BTC	10,00%	0,00%	8,93%	0,00%	0,00%
ETH	10,00%	0,00%	0,00%	0,00%	0,00%
XRP	10,00%	100,00%	0,00%	0,00%	7,17%
NFTX	10,00%	0,00%	1,34%	100,00%	1,52%

5.3 ETF assets

Table 9

Asset allocation Portfolio of ETFs, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	3,45%	24,93%	-0,19%	24,93%	9,56%
Volatility	13,44%	37,73%	2,83%	37,73%	6,51%
Sharpe Ratio	25,67%	66,07%	-6,76%	66,07%	146,80%
VTI	20,00%	0,00%	0,00%	0,00%	0,00%
BND	20,00%	0,00%	44,64%	0,00%	0,00%
VEU	20,00%	0,00%	3,58%	0,00%	0,00%
UUP	20,00%	0,00%	50,79%	0,00%	84,53%
XME	20,00%	100,00%	0,98%	100,00%	15,47%

The third group I looked at was the portfolio of Exchange-Traded Funds, consisting of 5 ETFs. Table 9 illustrates the results of the five allocations applied to the ETFs. A proportionally divided weight across the ETFs gave a return of 3,45% and a volatility of 25,67%, resulting in a Sharpe ratio smaller than 100%. The ETF with the highest return was XME, which simultaneously was the ETF with the highest volatility as well. The lowest risk of the portfolio is achieved with allocation 3. However, this would come with a negative return and Sharpe ratio, making it a rather unattractive strategy. Allocation 5 represents the portfolio with the highest Sharpe ratio of 146,80%, which is achieved by investing in a mixture of UUP and XME.

When adding cryptocurrencies to the ETFs and giving every asset the same weight, the return and volatility increase drastically, lowering the Sharpe ratio slightly. When looking at allocation 3, by investing a bit into XRP, the volatility remains almost the same, while increasing the return, yet this allocation remains with a negative Sharpe ratio. In allocation 5, the inclusion of cryptocurrency increases the return while decreasing the risk of the portfolio. This once again shows the positive factors of cryptocurrency when investing. However, NFTX is not included in this portfolio, creating doubts about the efficiency of NFTs when investing.

Table 10

Asset allocation of Cryptocurrency in Portfolio of ETFs, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	9,70%	53,86%	-0,01%	12,02%	10,01%
Volatility	43,43%	154,55%	2,81%	199,69%	6,43%
Sharpe Ratio	22,35%	34,85%	-0,29%	6,02%	155,58%
VTI	11,11%	0,00%	0,00%	0,00%	0,00%
BND	11,11%	0,00%	43,81%	0,00%	0,00%
VEU	11,11%	0,00%	3,82%	0,00%	0,00%
UUP	11,11%	0,00%	51,25%	0,00%	84,31%
XME	11,11%	0,00%	0,90%	0,00%	14,28%
BTC	11,11%	0,00%	0,00%	0,00%	0,00%
ETH	11,11%	0,00%	0,00%	0,00%	0,00%
XRP	11,11%	100,00%	0,22%	0,00%	1,41%
NFTX	11,11%	0,00%	0,00%	100,00%	0,00%

5.4 Optimal portfolio

Table 11

Asset allocation Portfolio of best performing assets, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	11,43%	24,93%	6,75%	24,93%	6,98%
Volatility	14,32%	37,73%	3,08%	37,73%	3,14%
Sharpe Ratio	79,85%	66,07%	219,01%	66,07%	222,28%
USD/RUB	14,29%	0,00%	1,34%	0,00%	0,61%
USD/DKK	14,29%	0,00%	0,00%	0,00%	0,00%
Gold	14,29%	0,00%	30,79%	0,00%	29,26%
AXP	14,29%	0,00%	0,00%	0,00%	1,12%
PSX	14,29%	0,00%	5,26%	0,00%	6,12%
UUP	14,29%	0,00%	62,61%	0,00%	62,89%
XME	14,29%	100,00%	0,00%	100,00%	0,00%

The final step before this research can be concluded, is to analyse the returns and volatility of a portfolio consisting of the best performing assets of each previous portfolio. The assets are chosen by their annual return. The assets that are used in the portfolio are USD/RUB, USD/DKK, Gold, AXP, PSX, UUP and XME. This last step is important to discuss, as it can illustrate whether cryptocurrencies are able to improve an optimal portfolio with greatly performing assets, or if cryptocurrencies only affect portfolios that are suboptimal.

Table 11 shows the results for the five different allocation goals. The proportionally divided portfolio, with each asset having a weight of 14,29%, has a suboptimal Sharpe ratio of 79,85%. The portfolio with the highest return only invests in XME, which simultaneously also makes up the portfolio with the highest risk. Allocation 3 and 5 look similar to each other, with almost identical weights on all the assets. Both allocations achieve a very high Sharpe ratio in excess of 200%.

Adding the four cryptocurrencies to the first allocation improves the return, but increases the risk as well, making the Sharpe ratio fall. As can be seen in table 12 the highest return and volatility of the portfolio is achieved with a weight of 100% in Ripple and NFTX, respectively. Allocation 3 has the lowest volatility. However, this volatility is slightly higher than allocation 3 of the portfolio without cryptocurrency. On top of this the Sharpe ratio is lower, which might indicate that cryptocurrencies increase the risk of a portfolio more than the return. However, allocation 5 disproves this possibility, as the Sharpe ratio is higher than the fifth allocation of table 11, which is achieved by investing 0,65% in Ripple.

Table 12

Asset allocation of Cryptocurrency in Portfolio of best performing assets, return, volatility, and Sharpe ratio of the portfolio in percentages, and the corresponding weights of the assets included.

Allocation	1	2	3	4	5
Return	13,65%	53,86%	6,54%	12,02%	7,29%
Volatility	36,43%	154,55%	3,13%	199,69%	3,13%
Sharpe Ratio	37,47%	34,85%	209,12%	6,02%	232,57%
USD/RUB	9,09%	0,00%	0,24%	0,00%	0,53%
USD/DKK	9,09%	0,00%	38,63%	0,00%	0,00%
Gold	9,09%	0,00%	31,33%	0,00%	28,80%
AXP	9,09%	0,00%	0,00%	0,00%	0,00%
PSX	9,09%	0,00%	5,33%	0,00%	6,97%
UUP	9,09%	0,00%	24,15%	0,00%	63,06%
XME	9,09%	0,00%	0,00%	0,00%	0,00%
BTC	9,09%	0,00%	0,00%	0,00%	0,00%
ETH	9,09%	0,00%	0,00%	0,00%	0,00%
XRP	9,09%	100,00%	0,32%	0,00%	0,65%
NFTX	9,09%	0,00%	0,00%	100,00%	0,00%

5.5 Discussion

In all the portfolios in this research, the inclusion of cryptocurrencies did increase the maximum Sharpe ratio. This was mostly due to a significant increase in returns of the portfolio, while the volatility or risk remained around the same level. Table 13 shows the change in Sharpe ratio between the portfolios with the highest Sharpe ratios with and without cryptocurrency. The stocks portfolio increases the most when adding cryptocurrencies.

Table 13

Difference in Sharpe ratio between portfolios with and without cryptocurrencies.

Portfolio	With Cryptocurrencies	Without Cryptocurrencies	Percentage Change
FOREX and Commodities	186,33%	185,11%	0,65%
Stocks	73,22%	62,20%	17,72%
ETFs	155,58%	146,80%	5,98%
Optimal Portfolio	232,57%	222,28%	4,63%

My results show that adding cryptocurrencies do increase the Sharpe ratio and therefore the effectiveness of a portfolio. This finding is similar to the previous studies of Andrianto and Diputra (2017), Saksonova and Kuzmina-Merlino (2019) and Letho et al. (2022). However, Andrianto and Diputra suggested a weight of 5% to 20% for cryptocurrencies, whereas my research had weights between 0,32% and 8,69%. This could be partly explained by the returns of cryptocurrencies, as Bitcoin for example had a very high return during the period studied by Andrianto and Diputra, but a negative return during the period of my research.

Another difference between previous research and this study is that in most portfolios, investing in one cryptocurrency is seen as the best option. Only in the portfolio of Stocks it was best to invest in Ripple and NFTX. This is not in line with the studies of Saksonova and Kuzmina-Merlino (2019) and Theory. Brauneis and Mestel (2019), who recommended investing in multiple cryptocurrencies to decrease the risk of a portfolio.

Comparing my study to the study of Andrianto and Diputra (2017), cryptocurrencies do seem the affect portfolio performance in a similar way. However, in my study, Ripple was the best cryptocurrency instead of Bitcoin. This should be because of the negative return of Bitcoin compared to a high monthly return of Ripple during my test period. In the study of Andrianto and Diputra, the opposite was true.

Whereas cryptocurrencies in general do improve the effectiveness of a portfolio, it is not clear if NFTs have the same effect on their own. Only in the portfolio of Stocks it was the best to invest partly in NFTX. In all the other portfolios NFTX had a weight of 0,00% when achieving the highest Sharpe ratio. Schaar and Kampakis (2022) argued that NFTs have a diversification potential because of a low correlation with other assets. This is mostly not true. However, NFTX did have a low correlation with

four of the six stock assets, which could explain the fact the weight of NFTX was higher than 0,00% in only the stock portfolio.

A concern for this study is the fact that portfolio performance is judged on the past returns of assets. This might not produce similar results when performing the same tests 5 years into the future, as the returns of the assets would have changed. However, these results are useful in identifying a successful investment strategy by identifying well performing assets to create an optimal portfolio, which should be able to increase the effectiveness of an investment.

CHAPTER 6 Conclusion

In this thesis I have looked at the effect of cryptocurrencies, in particular the effect of Non-Fungible Tokens (NFTs), on the effectiveness of an investment portfolio. Previous literature has shown that adding Bitcoin to an investment portfolio significantly increases its effectiveness. As NFTs are similar to Bitcoin in returns and volatility, it was apparent that NFTs could potentially be used in the same way. This led to the following question to study in this research: How do non-fungible tokens (NFTs) affect the performance of investment portfolios and how does this compare to other cryptocurrencies?

To answer this question, historical data is collected of the asset classes FOREX and commodities, stocks, Exchange-Traded Funds (ETFs). With these assets, four portfolios were formed: FOREX and commodities, stocks, Exchange-Traded Funds (ETFs) and an optimal portfolio of the best performing assets of the other three portfolios. This data was then used to calculate, among other things, monthly returns, and volatility, and find the best distribution of the assets to achieve the most effective portfolio. This process was repeated and this time cryptocurrencies were added to the data. In all four portfolios an increase in portfolio effectiveness was found when adding cryptocurrencies, with Ripple having the biggest effect and NFTs having a small effect. Bitcoin and Ethereum had no positive effect.

This study therefore concludes that, similar to the previous studies on this topic, the adding of cryptocurrencies to investment portfolios has a positive effect to the effectiveness of these portfolios. This is highly likely because of the high returns and low correlation to non-cryptocurrency assets. These results suggest that having a small investment in cryptocurrencies should improve the results of someone's investments.

REFERENCES

Almeida, J., & Gonçalves, T. C. (2022). Portfolio diversification, hedge and safe-haven properties in cryptocurrency investments and financial economics: A systematic literature review. *Journal of Risk and Financial Management*, *16*(1), 3.

Andrianto, Y., & Diputra, Y. (2017). The effect of cryptocurrency on investment portfolio effectiveness. *Journal of finance and accounting, 5*(6), 229-238. 10.11648/j.jfa.20170506.14

Ante, L. (2022). The non-fungible token (NFT) market and its relationship with Bitcoin and Ethereum. *FinTech, 1*(3), 216-224.

Barbereau, T., Sedlmeir, J., Smethurst, R., Fridgen, G., & Rieger, A. (2022). Tokenization and regulatory compliance for art and collectibles markets: from regulators' demands for transparency to investors' demands for privacy. In *Blockchains and the Token Economy: Theory and Practice* (pp. 213-236). Cham: Springer International Publishing.

Baur, D. G., Hong, K., & Lee, A. D. (2016). Virtual currencies: media of exchange or speculative asset?.

Brauneis, A., & Mestel, R. (2019). Cryptocurrency-portfolios in a mean-variance framework. *Finance Research Letters*, *28*, 259-264.

Constantinides, G. M., & Malliaris, A. G. (1995). Portfolio theory. *Handbooks in operations research and management science*, *9*, 1-30.

Conti, R., & Schmidt, J. (2021). What you need to know about non-fungible tokens (NFTs). *Forbes advisor*.

Ko, H., Son, B., Lee, Y., Jang, H., & Lee, J. (2022). The economic value of NFT: Evidence from a portfolio analysis using mean–variance framework. *Finance Research Letters,* 47, 102784.

Kong, D. R., & Lin, T. C. (2021). Alternative investments in the Fintech era: The risk and return of Non-Fungible Token (NFT). *Available at SSRN 3914085*.

Letho, L., Chelwa, G., & Alhassan, A. L. (2022). Cryptocurrencies and portfolio diversification in an emerging market. *China Finance Review International*.

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/10.2307/2975974

Markowitz, H. M. (1991). Foundations of portfolio theory. *The journal of finance*, *46*(2), 469-477.

Markowitz, H. M. (1999). The early history of portfolio theory: 1600–1960. *Financial analysts journal*, *55*(4), 5-16.

Mazur, M. (2021). Non-fungible tokens (NFT). The analysis of risk and return. Available at SSRN 3953535.

Nadini, M., Alessandretti, L., Di Giacinto, F., Martino, M., Aiello, L. M., & Baronchelli, A. (2021). Mapping the NFT revolution: market trends, trade networks, and visual features. *Scientific reports*, *11*(1), 20902.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. *Decentralized business review*, 21260.

Pettengill, G. N., Sundaram, S., & Mathur, I. (1995). The conditional relation between beta and returns. *Journal of Financial and quantitative Analysis*, *30*(1), 101-116.

Roy, A. D. (1952). Safety first and the holding of assets. *Econometrica: Journal of the econometric society*, 431-449.

Saksonova, S., & Kuzmina-Merlino, I. (2019). Cryptocurrency as an investment instrument in a modern financial market. *Вестник Санкт-Петербургского университета. Экономика*, *35*(2), 269-282.

Schaar, L., & Kampakis, S. (2022). Non-fungible tokens as an alternative investment: Evidence from cryptopunks. *The Journal of The British Blockchain Association*.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The journal of finance*, *19*(3), 425-442.

Trautman, L. J. (2014). Virtual currencies; bitcoin & what now after liberty reserve, silk road, and Mt. Gox?. *Richmond Journal of Law and Technology*, *20*(4).

Valeonti, F., Bikakis, A., Terras, M., Speed, C., Hudson-Smith, A., & Chalkias, K. (2021). Crypto collectibles, museum funding and OpenGLAM: challenges, opportunities and the potential of Non-Fungible Tokens (NFTs). *Applied Sciences*, *11*(21), 9931.

Wang, Q., Li, R., Wang, Q., & Chen, S. (2021). Non-fungible token (NFT): Overview, evaluation, opportunities and challenges. *arXiv preprint arXiv:2105.07447*.

Worthington, A. C., & Higgs, H. (2004). Art as an investment: Risk, return and portfolio diversification. in major painting markets. *Accounting & Finance*, *44*(2), 257-271.

Yermack, D. (2015). Is Bitcoin a real currency? An economic appraisal. In *Handbook of digital currency* (pp. 31-43). Academic Press.