THE EFFECT OF CRYPTOCURRENCIES ON DIVERSE PORTFOLIOS

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PLAGIARISM

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ÖZET

Bu çalışmanın amacı kripto para birimlerinin iyi çeşitlendirilmiş portföylere dahil edilmesi durumunda herhangi bir fayda sağlayıp sağlamadığını incelemektir. Kripto para birimlerinin çeşitlendirilmiş bir portföydeki performansları, standart para birimi ve emtiaların performansıyla karşılaştırılmaktadır. Optimal portföyler, iki varlık, üç varlık ve dört varlık portföyleri için maksimum Sharpe Ratio'nun yanı sıra Global Minimum varyansa göre oluşturulur ve her durumda elde edilen çeşitlendirme etkileri diğer varlıklarla, yani standart para birimi olarak USD/TRY ve emtia olarak altın ile karşılaştırılır. Bizim çalışmamızda altın ve örneklemimizdeki tüm para birimlerinin piyasa portföyüne eklendiği en kapsamlı durum olan dört varlık durumu için analizlerimizi hem ana örneklem periyodunda (05/04/21 – 28/04/23), hem de 29/04/22 - 28/04/23 tarihlerini kapsayan "Covid-19 sonrası dönem" ve 29/04/22 – 02/03/23 tarihlerini kapsayan Covid-19 sonrası – 6 Şubat 2023 depremi öncesi alt dönemleri için tekrarladık. Her optimal portföy için çeşitli risk ve getiri ölçütleri hesaplandı. Sonuçlarımız, kripto para birimlerinin genel olarak portföy çeşitlendirmesi için iyi bir araç olabileceğini gösteriyor. Örnek dönemimiz için Etherium'un, çeşitlendirilmiş portföylerde Bitcoin'e kıyasla daha iyi performans gösterdiği gözüküyor.

Anahtar Kelimeler: Portföy Optimizasyonu, maksimum Sharpe Oranı, Global Minimum Varyans Portföyü, Çeşitlendirme Faydaları, Kripto para birimleri, Standart Para Birimi, Altın

ABSTRACT

We examine whether cryptocurrencies provide any benefits if they are included in the well diversified portfolios. Their performance in a diversified portfolio is compared to those of standard currency and commodities. Optimal portfolios are created based on maximum Sharpe Ratio as well as on Global Minimum variance for two-asset, for three-asset and for four-asset portfolios, and the diversification effects obtained in each case are compared with the other assets, namely USD/TRY as standard currency and gold as commodity. For the four asset case, which is the most comprehensive case, where all types of currencies along with gold are added to the market portfolio, we repeat our analyses for the period of 04/05/21 - 04/28/23, which is the "main sample" period, for he "post-Covid-19 era," which includes the sub-sample period of 04/29/22 - 04/28/23, and for the "post-Covid-19 pre-Feb 6" period, which covers 04/29/22 – 02/03/23 excluding the period of the Feb. 6, 2023 great earthquake disaster in Turkey from the post-Covid-19 period. For each optimal portfolio, various risk and return metrics are estimated and compared. Our results show that cryptocurrencies can be good instruments for portfolio diversification in general. For our sample period, Etherium seems to perform better in diversified portfolios compared to Bitcoin.

Keywords: Portfolio Optimization, maximum Sharpe Ratio, Global Minimum Variance Portfolio, Diversification Benefits, Cryptocurrencies, Standard Currency, Gold

To my family

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LIST OF ABBREVIATIONS

BTC : Bitcoin

CVAR: Conditional Variance

ETH : Ethereum

EVAR: Entropic Value at Risk

GMV : Global Minimum Variance

MPT : Modern Portfolio Theory

MSR: Maximum Sharpe Ratio

VAR: Value at Risk

XAUUSD : GOLD

XU030 : BIST30

CHAPTER 1

1. INTRODUCTION

With the development of the capital markets, the management of the investments has started to gain importance and different methods have been put forward to create the most efficient portfolios. Until the 1950s, investors were trying to build their portfolios with traditional methods on the basis of lean diversification (Lee et al., 2016). Although portfolios with lower risk compared to a single security could be created with this type of diversification, it was not widely accepted in the field of finance because it had no quantitative basis. In the 1950s, Harry Markowitz brought a new dimension to the field of portfolio management with an approach where risk was defined mathematically (Markowitz, 1952). This method put forward by Markowitz has been an infrastructure for subsequent portfolio management approaches (Markowitz, 1959).

The distribution of assets in the portfolio is the most important decision affecting the return and risk of the portfolio. We need to use optimal weights for the distribution of each asset in the portfolio to achieve the desirable risk-return combination. So, at this point the portfolio optimization comes into play. The distribution of assets in the portfolio may vary depending on the risk threshold of the investor.

With the recent growth of crypto money markets, some have claimed that cryptocurrencies can be seen as a new type of investment tool (Corbet et al., 2018). When it comes to seeing cryptocurrencies as a new investment tool or an alternative asset, there are two issues that investors should consider. The first of these is the risks specific to investments, the second is the relationships of cryptocurrencies with other assets, and more importantly, the diversification benefits and hedging capabilities of cryptocurrencies (Feng et al., 2018).

The purpose of this study is to test whether cryptocurrencies can contribute to portfolio diversification and management and how they affect portfolio performance.

The high volatility in cryptocurrencies makes it difficult for investors to take the right position and develop investment strategies (Lee et al., 2018). Investments in crypto money markets involve high risks. Chief among these risks are operational risks and security risks (cyber risk). On the other hand, today, it is seen that investors still seriously believe in the rumors and speculations about cryptocurrencies. There are studies in the literature that say that Bitcoin and other cryptocurrencies should be seen as "speculative" assets. Early research on Bitcoin's price dynamics states that Bitcoin has an extraordinarily speculative nature (Brauneis & Mestel, 2019).

As of 2022, Bitcoin has been pulled to the $ 20,800 band and has seen the bottom of exactly last 1.5 years After seeing the peak level of $ 69,000 in 2021, those who entered the crypto money market suffered a great loss with the rhetoric that 'it will be $100,000, $200,000 is coming' during 2021. Ethereum, which ranks second in terms of trading volume, fell below $100,000 during the same period. Due to the increasing inflation pressure, especially in the USA and EU countries, with the signals and steps of the central banks to return from the expansionary monetary policies implemented in the Covid-19 period, Bitcoin and cryptocurrencies, which are the leaders of risky assets, entered into selling pressure in 2022.

The expectation that central banks will strengthen the ongoing tight monetary policy steps in the form of ending asset purchases, increasing interest rates and shrinking the balance sheet due to the increasing inflation pressure at the global level shows its effect in the crypto money market. Terra USD (UST) was called one of the most reliable stablecoins indexed to the dollar in the cryptocurrency market. This coin was a crypto stable at 1 dollar 1 UST. This has worked for many stablecoins so far. However, the USD unexpectedly turned upside down. The fact that the stable coin, which should be $ 1 and even more valuable when Bitcoin fell, fell below $ 0.2, shaken investor confidence in May 2022.

Terra Coin (LUNA), the crypto money of the same group and shown among the most powerful and reliable cryptocurrencies in the top 10, lost more than 99 percent in value and fell below 1 cent. LUNA was trading at $85 just in May 2022. Its value in the previous month was $119.

Investing is risky business, you pay off over time. The cryptocurrency markets provides huge volatility in both directions, presenting both incredible gains and crushing losses as possible outcomes.

Compared to traditional assets, cryptocurrency is extremely volatile and requires investors to prepare themselves for any scenario. Cryptocurrencies offer an impressive value proposition where you can invest small amounts and make big profits, but this does not mean that there is no risk. Most cryptocurrency investors minimize risk by spreading their portfolios across multiple assets.

It is necessary to consider whether cryptocurrency investment is the right investment alternative for you. All cryptocurrencies are highly speculative investments subject to extreme volatility. Since the long-term success of cryptocurrencies cannot be guaranteed, you should make sure that you have a very high tolerance for risk before deciding to invest in this markets.

Cryptocurrencies have grown significantly in number and frequency of transactions since 2008, despite their advantages and disadvantages. In inefficient financial markets, it is possible for investors to obtain profits by investing based extensive analyses and forecasting. For these reasons, the volatility in the prices of cryptocurrencies is of interest to especially to investors who invest large portions of their portfolio in stock market. Therefore, it is important for investors to reveal the behavior of cryptocurrencies in the market for portfolio risk management.

1.1. Definition of Background Concepts

In this study we aim to determine how inclusion of cryptocurrencies effects the diversification benefits in optimal portolios. The remaınder of this section presents the relevant background concepts for this study.

1.1.1 Portfolio Optimization

There are two main studies on portfolio management applications. The first is traditional portfolio management, and the second is modern portfolio management. Historically, traditional portfolio management started in the early 1900s and lasted until 1952, when the American scientist Harry Markowitz introduced modern portfolio management. Due to some shortcomings of the traditional portfolio approach, the modern portfolio theory has been developed. In order to understand the processes of modern portfolio management and the development of some related theories, it is necessary to know the content and characteristics of traditional portfolio management.

In traditional portfolio management, it has been determined that the allocation of the total investment budget over different stocks and assets, that is, diversification, will reduce the risk factor, and it is thought that the investor can design a financially optimal portfolio by choosing the assets with low risk and high expected return potential. The traditional approach accepts that investing in different assets from different sectors will create a good diversity phenomenon, but the phrase "not putting eggs in the same basket", which we often hear in the economic sciences, expresses the real world risks of the traditional portfolio approach. While the hypothesis that the thought of investing in different assets will reduce risk is relatively correct, the "diversity" factor in traditional portfolio management has some disadvantages. For example, investing in 20 assets instead of 10 can protect the risk factor only to a limited level, because investments always carry systematic risk factors and systematic risks are not risks that can be eliminated by increasing asset types. It may not be logically correct to say that the increase in the number of invested asset types will create an optimal portfolio, because increasing the asset types alone is not enough to minimize the risk and the increase in the number of stocks in the

portfolio are factors that increase the cost of process management in terms of monitoring and management processes.

The collection of investor information, which is the first stage of portfolio planning, makes it possible to achieve the goal of creating the most appropriate portfolio. In the traditional portfolio approach, the analysis of investor information is the basis for determining investment criteria and ultimately establishing a comprehensive portfolio objective. Therefore, the selection of securities should be made after the investor's situation has been thoroughly studied. However, after this stage, securities suitable for the investor's situation can be recommended. At this stage, investment advisors can help the investor to make a decision in accordance with his financial goals. Because the different needs of the investor at different times and the uncertainty of future events are among the factors that make it difficult to make a decision. Whether the investment is made for a person or an organization, the most important and first issue to be determined is the potential investment amount. The total amount of assets that can be invested constitutes the essence of the investment and affects the decisions to be made at every stage of the investment. In addition, it should be considered that the funds that investors will set aside to create a portfolio will be entirely their own savings, as well as that they will remain attached to the portfolio for a certain period of time. Otherwise, the portfolio created may be converted into cash at inopportune time periods according to the investor's fund needs. That is, it becomes difficult to obtain the desired return from the portfolio.

1.1.2 Risks

Portfolio risk refers to the likelihood that the actual returns on a portfolio will be different from the expected returns. Tamplin (2023) explained that are several types of portfolio risks that investors should be aware of :

Market Risk: This type of risk is the most common form of risk, and it refers to the risk that the entire market or a specific asset class will experience a decline in value. Market risk cannot be diversified away, but it can be reduced by diversifying investments across multiple asset classes.

Credit Risk: This type of risk refers to the risk that a borrower will default on their debt obligations, such as interest or principal payments. Credit risk can be mitigated by investing in high-quality, investment-grade bonds or by diversifying across multiple issuers.

Liquidity Risk: This type of risk refers to the risk that an investor will not be able to buy or sell an asset quickly enough or at a fair price. This can occur when there is a lack of buyers or sellers in the market or when there is a sudden increase in market volatility. Liquidity risk can be reduced by investing in liquid assets, such as stocks and bonds that trade frequently on public exchanges.

Inflation Risk: This type of risk refers to the risk that the purchasing power of a portfolio will be eroded over time due to inflation. Inflation risk can be reduced by investing in assets that have the potential to keep pace with inflation, such as commodities or real estate.

Currency Risk: This type of risk refers to the risk that changes in foreign currency exchange rates will impact the returns on investments denominated in foreign currencies. Currency risk can be reduced by hedging foreign currency exposures or by investing in assets that are denominated in the investor's home currency.

Understanding the various types of portfolio risks is important for investors to make informed investment decisions and to manage their risk exposure effectively.

Portfolio risk, unlike the expected return of the portfolio, is not the simple weighted average of the securities in the portfolio, but a lower value than the weighted average of the risks of these securities. This is due to the relationship between the securities in the portfolio. The statistical measure of this relationship is covariance. Covariance is a measure of the relationship of the mobility of two random variables over a given time.

The total risk of the portfolio depends on the value of the covariance between the securities in the portfolio. For example, a positive covariance between the returns of two securities indicates

that the movement direction of these securities is the same, while a negative value indicates an inverse relationship.

If the returns of investments are not interdependent, that is, the increase or decrease in the return of one security does not provide information about the direction of the return of the other security, the covariance value is zero.

Financial Risks: It is the factor or all of the factors that affect the positive or negative realization probabilities of the expected returns after the investment decisions. Tamplin (2023) listed and explained financial risks classification for portfolio management in the below.

Systematic Risk: It is the type of risk that occurs when changes arising from economic, policy and sociological factors affect financial markets. It is seen that all commercial institutions in the market are affected by these risks at the same time and in the same direction, fluctuations are observed in the expected investment returns from assets (securities). The diversity factor in portfolio management is ineffective in situations where systematic risk is encountered, because since there is a situation where the markets are affected holistically, all assets are affected by such risks. Risks on factors such as interest, inflation, market, market policy and purchasing power are examples of systematic risk.

Unsystematic Risk: It is the type of risk that the risk does not spread to the markets and the market as a whole, but has its effect on a specific sector, commercial institution or all commercial institutions in the sector. The diversity factor in portfolio management appears as a security criterion for taking precautions against unsystematic risks. Sharing the weights of the assets in the portfolio over the assets in different sectors is important for the portfolio to maintain its existence with minimum damage in case of sector-based crises.

1.1.3 Modern Portfolio Theory

Modern Portfolio Theory (MPT) is a framework for building investment portfolios that aim to maximize expected returns for a given level of risk, or to minimize risk for a given level of expected returns. It was introduced by Harry Markowitz in 1952 and has since become one of the most widely used investment theories.

According to MPT, the risk and return of a portfolio are not determined solely by the individual assets held in the portfolio but also by how those assets are combined. The theory suggests that investors should diversify their portfolios across a range of asset classes and individual securities to minimize risk and maximize returns.

MPT assumes that investors are rational and risk-averse and seek to maximize the expected return for a given level of risk. The theory uses statistical techniques to measure the expected risk and return of different assets and to calculate the efficient frontier, which is the optimal set of portfolios that offer the highest expected return for a given level of risk.

MPT also introduced the concept of the Capital Asset Pricing Model (CAPM), which is a model that calculates the expected return of an asset based on its level of risk and the risk-free rate of return. CAPM is used to determine the optimal portfolio allocation by calculating the expected returns and risks of individual assets and then selecting a combination of assets that will maximize the expected return for a given level of risk.

MPT has had a significant impact on the field of finance and has helped to shape the way investors and fund managers construct and manage portfolios. However, it is important to note that MPT has been subject to criticism, and some argue that it makes unrealistic assumptions about investor behavior and does not account for certain types of risks, such as systemic or tail risks.

In investment processes, generally higher risk is associated with higher probability of return, while lower risk is associated with lower return on investment. Modern portfolio theory assumes that investors can be as risk-averse as possible using risk analysis, that is, given two portfolios offering the same expected return, investors may choose the less risky one. Therefore, an investor can only invest in assets where he sees the potential for expected returns large enough to offset the risk when he expects high returns.

In addition to the risk factor in relation to the expected return, another phenomenon that appears in modern portfolio theory is the "diversity" factor. Modern Portfolio Theory says it's not enough to just look at the expected risk and return of a particular stock. An investor who invests in more than one stock can enjoy the benefits of diversity, one of which is to reduce the risk of the portfolio. Risk is about how volatile the asset is, if you have more than one stock in your portfolio we also need to consider how these stock movements relate to each other. One of the benefits of diversification is to further reduce the risks of the riskiest assets in your portfolio by optimizing the weight of the stocks in the portfolio.

There are two main factors (return and risk) in the optimization model. The following formula is used to find the expected return and risk values of portfolios consisting of more than one asset.

$$E(r_p) = \sum_{i=1}^{n} \mathrm{E}(r_i)x_i$$

$$\sigma_p^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} cov(r_{i,} r_j)x_i x_i$$

1 Portfolio Return and Variance

While creating the optimal portfolio in portfolio optimization performed with modern portfolio theory, Markowitz wants to keep the expected return at the highest level and aims to create a portfolio with minimum risk (minimum variance) while achieving this return.

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_i \sigma_{ij}$$

2 Minimum Variance

According to Markowitz, assuming that capital markets are efficient and investors are rational, investors should only make investment decisions based on expected return and risk, and the standard deviation of past returns is the only mathematical indicator of risk. The Markowitz model tries to find the portfolio with the minimum variance (minimum risk) that will meet the expected expected return level.

Returns on investments can be expressed as outputs of investments. The investor's risk estimate is proportional to the variance of the returns on the assets or portfolio. Investors are willing to use only expected return and variance of return as model parameters when making their decisions. Investors tend to avoid risk. It will choose the minimum risk it can achieve at any expected level of return and the maximum return it can achieve at any risk level.

Markowitz argued that securities should be preferred according to their correlation coefficients. A portfolio can be created in hundreds of different combinations from dozens of securities that can be invested.

Starting the portfolio selection problem with the choice of securities and ending the portfolio as a whole, Markowitz thought that among the alternative portfolios, the combination of the lowest risk and the highest return would be the preference of a rational investor.

Modern portfolio theory and investment analysis can be summed up in a simple philosophy. Every single investment has an element of risk and an element of reward. The investments you will make by finding the optimum balance between these two opposite elements will give the best performance. When you combine each of your other investments that you have optimally thought about, you get the portfolio with the least risk and the highest return.

Modern portfolio theory is based on the fundamental principle that investing in more than one type of asset protects your investment against industry or industry-based shocks. Indeed, the risk level of the entire portfolio determines the difference between the risk levels of the stocks. Individual investments may be largely unrelated and react differently to certain market conditions.

A stock portfolio that holds together only positively correlated investments ignores the fundamentals of diversification and is unlikely to survive a crisis. So if all investments are correlated, they all fall at the same time in worse times. Therefore, the loss of a particular group of shares is not compensated by an increased value group of shares.

Investors usually try to balance the portfolio as much as possible. According to the creator of the Modern Portfolio Theory (MPT), an efficient portfolio is a set of investments that investors want and can take, that can generate maximum returns with the lowest possible risk.

In the past 30 years, a newer trend, known as post-modern portfolio theory, has emerged. This theory, which uses advanced concepts such as downward bias to calculate risk-adjusted returns, differs from the traditional modern portfolio theory by focusing on negative returns to measure risk. This theory is one of many other approaches to investing in stocks that offer sound alternatives to modern portfolio theory.

Modern Portfolio Theory (MPT) was introduced by Harry Markowitz and serves as a framework for investors to build an optimal investment portfolio. The theory suggests that risk and reward are inextricably linked and are about a combination of stocks with a higher risk/return ratio and stocks with a lower risk and return. Investors recommend including multiple investments in a given portfolio that vary in return and risk. This risk spreading process is called diversification and is the guiding principle behind Modern Portfolio Theory (MPT).

1.1.4 Cryptocurrencies

Cryptocurrency is a digital or virtual currency that uses cryptography for security and operates independently of a central bank or government. Cryptocurrencies use decentralized technology known as blockchain to manage transactions and verify the transfer of funds. The most well-known cryptocurrency is Bitcoin, which was created in 2009 by an unknown person or group using the pseudonym Satoshi Nakamoto ((2009).

Unlike traditional currencies, cryptocurrencies are not backed by a physical commodity or centralized authority. Instead, the value of a cryptocurrency is determined by supply and demand in the market. Cryptocurrencies can be used to buy goods and services, and they can also be traded on various online exchanges.

One of the key features of cryptocurrencies is their decentralized nature. Transactions are verified by a network of computers rather than a central authority, which makes them less susceptible to fraud or manipulation. However, this also means that there is no recourse if funds are lost or stolen.

Another feature of cryptocurrencies is their anonymity. While transactions are recorded on the blockchain, the identities of the buyers and sellers are not disclosed. This has led to concerns about the use of cryptocurrencies for illegal activities such as money laundering and drug trafficking.

Cryptocurrencies have seen significant growth and volatility in recent years, with some investors seeing them as a potential hedge against inflation or a store of value. However, cryptocurrencies remain a highly speculative investment, and their value can be affected by a range of factors, including market sentiment, regulatory changes, and technological developments.

The cryptocurrency market, which has grown considerably in recent years, is also frequently

addressed by financial and government institutions globally. Among the thousands of cryptocurrencies, Bitcoin is the most well-known due to the size of its capitalization. As of 2020, the crypto money with the highest market value Bitcoin is followed by Ether and Ripple, respectively.

Measuring market risk for those who use cryptocurrencies, which are known to be highly volatile, for investment purposes in stock markets, has gained more importance, especially with the news of the Covid-19 pandemic in the markets. Cryptocurrency; They are digital currencies that allow safe transactions in encrypted form and create an additional electronic money supply. Cryptocurrencies have existed as a phenomenon with an alternative currency structure. Cryptocurrencies are decentralized. The control of this structure is carried out by the database to the related transactions ledgers (Blockchain etc.).

The amount and supply of money in circulation, in what form and when it will be put into circulation are determined during the establishment of the crypto money system. This also means that the money supply cannot be increased. In the crypto money system, there is no control mechanism such as the Central Bank or an institution or person that carries out basic banking transactions. The high volatility in cryptocurrencies makes it difficult for investors to take the right position and develop investment strategies. Investments in crypto money markets involve high risks. Chief among these risks are operational risks and security (cyber risk) risks. There are studies in the literature that say that Bitcoin and other cryptocurrencies should be seen as "speculative" assets. Early research on Bitcoin's price dynamics states that Bitcoin has an extraordinarily speculative nature.

Turkish investors also play an important role in this market. On a country-by-country basis, Turkey ranks in the top five in registered crypto currency transactions. Cryptocurrencies that attract the most attention of Turkish investors; Ethereum, Ripple and Bitcoin are the ones with the largest transaction volume.

Bitcoin is the original cryptocurrency and has the most recognition and reputation of all cryptocurrencies. Breaking its old peak as of December 2020, Bitcoin caught a very strong trend

and exceeded the level of 64,000 USD by 2021. With this rise, the crypto money ecosystem has also grown and the total market value has exceeded 2 Trillion USD. The share of Bitcoin in the entire crypto money ecosystem is close to 40%.

For example, institutions or merchants that accept cryptocurrencies as a form of payment are more likely to accept Bitcoin than other digital currencies. Widespread adoption appears to be key to the long-term success of this digital currency.

Therefore, it can be said that Bitcoin is one step ahead of its competitors. In addition, Bitcoin is often referred to as "digital gold" because it can be produced in limited numbers. This scarcity in production is a feature that increases the value of Bitcoin and indicates that this increase may continue in the future.

Ethereum is the most popular cryptocurrency after Bitcoin. Technically, Ethereum is a type of blockchain technology and Ether is a “coin” hosted on the Ethereum blockchain. The biggest advantage of Ethereum is that it has different applications beyond being a cryptocurrency. For example, Ethereum; A Non-Fungible Token (NFT), in its shortest definition, is the blockchain behind one-of-a-kind digital assets and is the foundation of decentralized finance.

NFTs represent one-of-a-kind digital assets, from collector's items to virtual gaming content and digital properties. Blockchain technology has the potential to revolutionize many businesses, and Ethereum is one of the biggest players in the blockchain space.

Although Ether is not as popular as Bitcoin, it has great potential in the eyes of its supporters. Since it does not have the same history, it should be considered more risky than Bitcoin, but it should be kept in mind that it has a higher return potential due to this risk.

Cryptocurrencies Market Dominance (Source: Coin Market Cap., 2023)

Crypto	Symbol	Market Value ($)	Circulating Supply	Market Dominance
Bitcoin	BTC	511,295,616,356	19,384,000 BTC	2,48%
Ethereum	ETH	216,885,499,206	120,258,106 ETH	2,5%
Tether	USDT	83,073,203,007	83,063,097,247 USDT	22,94%
BNB	BNB	47,082,211,244	155,857,544 BNB	0,82%
USD Coin	USDC	29,045,055,117	29,048,178,413 USDC	8,75%
XRP	XRP	24,009,243,960	51,873,152,538 XRP	3,45%
Cardano	ADA	12,414,854,920	34,873,335,522 ADA	1,27%
Dogecoin	DOGE	9,839,138,160	139,500,186,384 DOGE	1,63%
Polygon	MATIC	8,265,772,094	9,279,469,069 MATIC	3,78%
Solana	SOL	7,588,766,040	396,203,611 SOL	2,08%

Investors have preferred the dollar and gold as a safe haven since the first days of the pandemic. In addition, cryptocurrencies have also been among the investment tools preferred by investors in this process. It is seen that confidence in cryptocurrencies has increased during the pandemic process.

When we look at the period before the pandemic, it is seen that the value of 1 Bitcoin on January 2, 2020 is 6 thousand 946 dollars. In March, when the pandemic increased its effect, it fell to the level of 5 thousand 24 dollars.

On the other hand, as of December 22, 2020, this value has radically increased to the level of 23 thousand 826 dollars. When we look at the data, there has been a very serious increase in transactions in cryptocurrencies, especially during the pandemic period. This situation has led to an increase in the value of cryptocurrencies.

The highly growing cryptocurrency market is also frequently addressed by financial and government institutions globally. Cryptocurrencies have grown significantly in number and frequency of transactions since 2008, despite their advantages and disadvantages.

In inefficient financial markets, it is possible for investors to take positions by making analysis and forecasts on returns. For these reasons, the volatility in the prices of cryptocurrencies is of interest to users in the stock market.

1.1.5 Cryptocurrency Risk

There are several risks associated with cryptocurrencies that investors should be aware of:

Volatility Risk: Cryptocurrencies are highly volatile and subject to large price fluctuations in short periods of time. This means that their value can change rapidly, which can result in significant gains or losses for investors.

Market Risk: Cryptocurrencies are not backed by a government or a physical commodity, and their value is determined solely by supply and demand in the market. This means that they are subject to market forces and can be influenced by factors such as investor sentiment, regulatory changes, and technological advancements.

Security Risk: Cryptocurrencies are stored in digital wallets, and if a wallet is hacked or compromised, the investor can lose their entire investment. This risk can be mitigated by using reputable wallet providers and taking steps to secure one's digital assets.

Regulatory Risk: Cryptocurrencies are largely unregulated, and regulatory changes could affect their value and the ability of investors to buy and sell them. Governments around the world are currently debating how to regulate cryptocurrencies, and new laws and regulations could have a significant impact on the industry.

Liquidity Risk: Cryptocurrencies are still relatively new, and the market for them is not as liquid as traditional investments such as stocks and bonds. This means that it may be difficult to buy or sell cryptocurrencies quickly or at a fair price, particularly during times of market volatility.

Investors should carefully consider these risks and conduct thorough research before investing in cryptocurrencies. It is important to have a well-diversified portfolio and to only invest funds that one can afford to lose.

1.1.6 Cryptocurrency Agenda

The agenda of cryptocurrencies is to create a decentralized and digital alternative to traditional currencies that is not subject to the control of governments or central banks. Cryptocurrencies aim to enable secure and anonymous transactions, eliminate the need for intermediaries such as banks or payment processors, and provide a way for individuals to have more control over their own finances.

Some proponents of cryptocurrencies also believe that they have the potential to provide greater financial inclusion for individuals who are unbanked or underbanked, particularly in developing countries. Cryptocurrencies can be accessed by anyone with an internet connection, and they can be used to send and receive payments anywhere in the world without the need for a traditional bank account.

Cryptocurrencies also offer the potential for new business models and applications that were not possible before. For example, cryptocurrencies can be used to create new decentralized applications (dApps) that enable peer-to-peer transactions, smart contracts, and other innovative features.

Overall, the agenda of cryptocurrencies is to create a new financial system that is more democratic, transparent, and decentralized than the traditional system. However, the adoption of cryptocurrencies is still in its early stages, and it remains to be seen how they will develop and whether they will become a mainstream form of payment and investment.

CHAPTER 2

2. LITERATURE REVIEW

Chekhlov et al. (2004) stated that this approach predicts portfolio risk more successfully than alternative approaches and creates more stable portfolios in their study based on the conditional drawndown at-risk risk function.

Reveiz and Leon (2008) examined the performance of the Maximum Drawdown portfolio optimization method, they stated that this method can overcome some of the disadvantages of the Markowitz (1952) mean variance method, and therefore it is a useful method for portfolio optimization.

Kabundi and Mwamba (2012) experimented with different strategies and investigated how the return of a portfolio of various assets was affected. Starting with Markowitz, investors' primary goal has been maximizing the risk adjusted returns for their portfolio. The most common solution for risk minimization is portfolio diversification.

Over the years, financial contractions and crises have shown that an investor should evaluate his investments not only in his own country or in a certain sector, but also in more than one country or sector.

The idea of investing in well-diversified portfolios instead of the "putting eggs in the same basket" approach, which is common in traditional portfolio management, will reduce risk and increase earnings in the same way.

Kabundi and Mwamba (2012) worked on the mean variance model for potfolio. Portfolio optimization was made by using Genetic Algorithm to create a portfolio in international markets in order to maximize the returns of investors in South Africa. The performance of the genetic algorithm was compared with the mean-square-variance model from other nonlinear models. It is concluded that the square mean-variance model does not consider the risk propensity of the

investor when investing in foreign stocks and does not reflect the benefits of international diversification.

Holton (2014) explained that in portfolio, a given time horizon, and a given probability p, p-VaR can be defined as the maximum possible loss during that period after excluding all worse outcomes whose combined probability is at most p.

Carpenter (2016) studied that how the cryptocurrencies affect the portfolio during the uncertain market conditions. As a result of his research using the data for the period of January 2012-May 2016, stated that despite the high volatility of Bitcoin, it can be a valid and important portfolio diversification tool due to its high return and low correlation with other assets.

Gangwal (2016) focused on the effect of adding Bitcoin to a portfolio of assets such as stocks, bonds, and gold. He carried out his study using the data for the period July 2010-August 2016 and stated that Bitcoin allows to create more effective portfolios, therefore it can be used in portfolio diversification.

Bessler et al. (2017) using Markowitz's mean variance approach, asset weights in the protfolio are optimized using variance-covariance estimators for the assets in the portfolio. However, we see in practice that this method may still need to low-performance portfolios due to estimation errors, extreme solutions, and missing data.

Klein et al. (2018) compared Bitcoin and gold and various other assets with econometric techniques in terms of their volatility, correlations, and performance within the portfolio. As a result, They argued that it could not they found that Bitcoin and gold have essentially different characteristics, that gold plays an important role in financial markets, that they could not find any evidence that Bitcoin could be part of the portfolio as a hedging instrument, and therefore Bitcoin is a safe haven as gold is.

Lee et al. (2018) focused on the role of cryptocurrencies in portfolio diversification. As a result of the analyzes they carried out with the data for the period of August 2014-March 2017, they found a low correlation between CRIX (cryptocurrency index) and traditional assets (such as gold, oil), at the same time, they can provide additional benefits to investors by increasing portfolio performance, and therefore cryptocurrencies can be used in portfolio diversification they argued.

Wong et al. (2018) examined whether cryptocurrencies could contribute to portfolio diversification and hedging skills in particular Bitcoin, Litecoin and Ripple. Based on the data for the period of May 2013-August 2018, they declared that Bitcoin and Litecoin can be used as a hedging tool and Ripple can be used for portfolio diversification.

Gkillas and Katsiampa (2018) stated that cryptocurrencies are more volatile and therefore more risky than traditional currencies due to the volatility in price movements. Cryptocurrency returns violating the assumption of normality have led investors to see it as an alternative financial asset.

Ankenbrand and Bieri (2018) pointed out the importance of diversification as an investment tool if cryptocurrencies are accepted as assets. In the study, first of all, the characteristics of cryptocurrencies were examined, then the analysis of crypto money and other asset portfolios created by numerical methods was made. Cryptocurrencies have been found to contain high volatility and are seen as a good option for investment diversification due to their low correlation with traditional assets, while they have stated that low trading volumes are a disadvantage.

Amaury and Ward anker (2018) analyzed that the benefits of combining a portfolio of well-diversified European stocks with Bitcoin's data covering three years from 2014 to 2017. In this research, which used Markowitz's Modern Portfolio Theory to examine the risk change in diversification, Bitcoin; are grouped by adding them to an equally weighted portfolio, a long-term-only portfolio, and a short-selling portfolio. Research results show that adding Bitcoin to

about 2% of a well-diversified European portfolio significantly increases the Sharpe ratio in both the short sell and long sell portfolio.

Padmantyo and Prasojo (2019) examined the performance of diverse portfolios. America, Germany and internationally diversified and locally diversified portfolios are compared in Indonesian stock indices. The relationship between portfolio size and portfolio risk has been examined. As a result of the analysis, it has been observed that the risk level of portfolios created with international diversification is lower than that of nationally diversified portfolios. It is concluded that the more stocks in the portfolio, the lower the level of risk. As a result of the analysis, it is emphasized that the effect of diversification on stock investment is positive and that the portfolio size should be increased in order to obtain portfolios with low risk.

Ftiti et al. (2019) analyzed the dynamics of the relationship between Bitcoin and other financial assets they determined with the data for the period of January 2012-January 2018, and tried to determine whether Bitcoin provides benefits to investors in terms of portfolio diversification and risk management. As a result, they found that Bitcoin could provide benefits for investors in terms of hedging and portfolio diversification.

Kajtazi et al. (2019) examined whether Bitcoin provides benefits in terms of portfolio diversification. As a result, they said that the portfolio performance increased with the addition of Bitcoin, but it should not be overlooked that this situation is mostly due to the increase in returns, not the decrease in volatility, and that this performance increase is related to the performance of Bitcoin especially in 2013. In general, they stated that although Bitcoin is speculative, it can play an important role in portfolio diversification.

Liu et al. (2019) examined the investability of cryptocurrencies and their role in diversification. The researcher, who carried out his study based on the data of 10 cryptocurrencies for the period of August 2015-April 2018, declared that investing in a portfolio of cryptocurrencies, instead of investing in a single crypto currency, provides better results.

Castro et al. (2019) On the other hand, in their study where they applied the portfolio optimization method based on the Omega ratio to the asset set consisting of stock indices and cryptocurrencies, they stated that the optimal portfolio consisted of traditional financial assets such as stock indices rather than cryptocurrencies.

İnci and Lagasse (2019) examined the role of cryptocurrencies in improving the performance of portfolios constructed from traditional asset classes. Using a long sample period covering not only the large increases in value but also the dramatic declines at the beginning of 2018, this paper aims to provide a more comprehensive analysis of the dynamic nature of cryptocurrencies as individual investment opportunities and as components of optimal portfolios. prove that the best cryptocurrency as a single investment is Ripple, followed by Bitcoin and Litecoin.

Moreover, cryptocurrencies have a useful role in optimal portfolio construction and investments, in addition to their original purposes for which they were created. Bitcoin is the best cryptocurrency that improves the characteristics of the optimal portfolio. Ripple and Litecoin follow in terms of their usefulness in an optimal portfolio as individual cryptocurrencies. Including all these cryptocurrencies in a portfolio leads to the best (most optimal) results.

Alfieri et al. (2019) find that bitcoin’s correlation is low with the market index and with factor-like portfolios, indicating opportunities for risk diversification. Bitcoin's performance (α) is positive and significant; this result is robust across period and world region specifications.

Lucey et al. (2020) They stated that, like Bitcoin, Ether and LiteCoin can be added to a portfolio containing stocks to take advantage of diversification. Using sliding window analysis to examine the change in Bitcoin's diversification capabilities with time variability, they establish hedging ratios for a period ahead.

Platanakis and Urquhart (2020) According to the results of their portfolio analysis, they emphasized that investors should include Bitcoin in their portfolios, as it provides significantly higher risk-adjusted returns.

Schellinger (2020) stated that the coin portfolio with maximum utility at a risk aversion of $\lambda = 10$ outweighs the alternative frames. The portfolios optimized by maximizing the Sharpe ratio for coins and tokens tend to perform poorly. Testing the maximized utility for different levels of risk aversion confirms the results of this empirical study and adds robustness to them.

Aliu et al. (2020) tested that Crypto Index 20 was on average 76 times riskier than FTSE 100, 55 times riskier than FTSE MIB, 44 times riskier than IBEX 35, 10 times riskier than CAC 40 and 9 times riskier than DAX and MDAX. The Crypto Index 20 has a stronger positive correlation and is exposed to higher volatility than six selected European stock indices.

Gonzales et al. (2020) examined the performance of three optimised investment portfolios consisting of stocks, bonds, and a cryptocurrency or gold for the period immediately before and during the financial crisis COVID -19.

They compared the performance of these portfolios to a cash portfolio consisting of two assets, stocks and bonds. Cryptocurrencies have the potential to control risk, as most portfolios containing cryptocurrencies consistently have risk no more than 50 basis points higher than cash portfolios.

Trimborn et al. (2021) based on the data of 39 cryptocurrencies for the period of April 2014-March 2017, examined whether additional gains can be achieved with the inclusion of cryptocurrencies in portfolios. In this context, they developed a method called LIBRO (Liquidity Bounded Risk-Return Optimization). They argued that cryptocurrencies increase the performance of portfolios.

Nugroho (2021) examined that present dynamic optimization on minimum variance (MVP), equal risk contribution (ERC), and most diversified portfolio (MDP). Dynamic optimization

improved the risk-adjusted return. Moreover, dynamic MDP and ERC were able to win the naive strategy (1/N) under different estimation windows and forecast lengths when transaction costs ranged from 10 bps to 50 bps.

Dube and Şahin (2021) studied that bitcoin markets exhibit a month-of-the-year effect and whether such anomalies exist between markets that differ in fees, trading requirements, size, and the extent of legal support in their host countries.support the findings of studies claiming that bitcoin markets are inefficient due to various anomalies, suggesting a reverse January effect based on cryptocurrency market characteristics, such as uncertainty in market fundamentals and information inefficiencies, and contradict previous findings of weak efficiency.

Padmavarthini (2021) anlayzed, which uses SOLVER, modern portfolio theory and the system of comparing portfolios with FOREX & commodity, portfolios with equity securities, portfolios with ETFs and finally combining all asset classes in one portfolio with cryptocurrencies. The portfolios that were optimized by maximizing the portfolio return have comparatively low performance, as with other assets. Testing the maximized utility for different levels of risk aversion confirms the results of this empirical study and adds robustness to them. Given the persistently high volatility in cryptocurrency markets, the empirical results confirm that portfolio managers are advised to construct a global portfolio with minimal variance. In the absence of sophisticated optimization models, retail investors can invest according to the market values of cryptocurrencies.

Thaker and Mand (2021) investigated that BTC and Asian stock indices from July 20, 2010 to April 26, 2019 in terms of long- and short-term relationships, correlations, volatilities, and time frames, as well as lead-lag analysis. In the long term, BTC and JPN showed strong common movement, while lead-lag analysis predicted a phase category. BTC, KOR, and STI showed a similar result where the co-movement between the markets was very small and the lead-lag analysis showed a counter-phase relationship.

Aggarwal (2022) showed that Litecoin is the most influential volatility sender in the basket of these three cryptocurrencies. Portfolio weighting shows that investors can use Litecoin and

Ripple to create an optimized two-asset portfolio with the least exposure to Stellar. Market participants with a long position in Ripple can hedge most favorably by shorting Stellar.

Özdurak et al. (2022) Comparing with traditional financial assets, they showed that major cryptos have high volatility but potential. Investors emphasized that they can use traditional portfolio allocation approaches to adjust asset allocations by weighting volatility inversely. Clearly, with this approach, assets with higher volatility will have a lower share of the portfolio.

Letho et al. (2022) examined the impact of cryptocurrencies on the risk-adjusted portfolio returns of traditional and alternative investments in an emerging market. They showed that diversification benefits of cryptocurrencies through the use of mean-variance tests, improving the efficient frontier, and the risk-adjusted returns of the emerging market portfolio of investments.

Aliu et al. (2022) researched that diversification benefits of crypto portfolios in combination with commodities, equities and foreign exchange instruments.Their results with 270 trails showed that approximately equities reduce the portfolio risk of crypto portfolios by 36%, followed by fiat currency with 30.9% and commodities with 20.8%. The average daily returns are consistent with standard portfolio theories that riskier portfolios offer higher returns and vice versa.

Culjak et al. (2022) İdentified that the benefits of sectoral cryptocurrency classification portfolio optimization and its performance. Six optimization targets are tested: MinVar, MinCVaR, MaxSR, MaxSTARR, MaxUT, and MaxMean. We compare the obtained portfolios with the performance of the CRIX index (representing the crypto market) over the same period. Our results show that five of the six portfolio strategies performed better when they contained sectoral cryptocurrencies, namely from the financial, stock market, and business services sectors.

Kim (2022) analyzed the benefits of putting cryptocurrencies in a diversified portfolio by running a simulation with backfilled cryptocurrency returns. Specifically, they performed factor analysis to identify significant factors based on lasso regression to explain cryptocurrency returns in the post-ICO bubble period.

Kaya and Mostowfi (2022) reported that investing in highly concentrated cryptocurrency portfolios with low volatility and a six- to twelve-month look-back and holding period generates statistically significant excess returns. Incorporating a simple stop-loss rule significantly reduces the downside risk of cryptocurrency portfolios and significantly improves Sharpe ratios.

Moreno et al. (2022) evaluated that the cost of liquidity preferences for portfolios combining traditional assets and cryptocurrencies. We find that taking liquidity into account, the portfolios with the highest expected returns are no longer available and the rest suffer performance losses of 10-25% at the efficient frontier. If we focus on a traditional investor who limits exposure to cryptocurrencies, the benefits of adding cryptocurrencies to the investor's portfolio decrease by around 15%, depending on the liquidity metric analysed.

Dhillon and Nikbakth (2023) reported that the risk-return ratio of a new portfolio using the Sharpe ratio improves when crypto assets are added to simulated stock, bond, and real estate portfolios. One caveat is that the contribution of a cryptoasset to a well-diversified traditional portfolio is different from the performance of an investment in a single and isolated cryptoasset.

Trichilli and Abbes (2023) focused on pandemic period and find a strong lead-lag relationship between all financial market returns. Using the Bayesian approach, the results show that the Bayesian efficient frontier shifts to the left when Bitcoin is included in portfolio optimization before or during the period COVID -19, which provides investors with a better risk-return ratio. Consequently, Bitcoin serves as a safe haven for the two sub-periods: before COVID -19 and COVID -19.

Osman et al. (2023) examined the conditional value at risk (CVaR) of two portfolio optimization approaches that include assets from the financial and crypto markets. They first capture the conditional interdependence structure between each variable through the Vine-Copula GARCH model before merging it with the Mean CVaR model. They optimized each portfolio and found out the optimal allocation while evaluating the exact risk. The results suggest that the D-Vine copula is more appropriate for both portfolios and that the crypto market components can act as a weak hedge/safe haven against financial market indices when various conditional stock index information is considered. Since CVaR performs better than Markowitz mean-variance in both portfolios, both risk measures also indicate that when including cryptocurrencies in a portfolio, the S&P 500 should not be included.

Menvouta et al. (2023) stated that non-fungible tokens (NFTs) represent a novel asset class with the potential to diversify portfolios. Little research supports this hypothesis at the collection level, but the question remains as to how this potential can be realized in practice. Because they are not fungible, the liquidity of the asset that leads to a mathematically optimal portfolio is not always present. In this letter, we present a viable portfolio optimization strategy for NFTs based on machine learning, more specifically robust hierarchical risk parity. When applied to portfolios containing highly rated NFT collections, they find that the inclusion of these collections in the portfolio improves the overall portfolio return.

Auh and Cho (2023) investigated that the parsimonious factor model mitigates idiosyncratic noise in historical data for portfolio optimization. They used market predictors and machine learning to incorporate forward-looking information into expected returns. Combining the factor model with forward-looking returns improves out-of-sample performance and is consistent with the theoretical assumption that mean and variance correspond to future returns.

They showed that a simple factor model can reduce the impact of estimation noise on allocation results. Moreover, machine learning results suggest that forward-looking information can improve portfolio performance in all respects, underscoring the importance of having the right inputs to the model.

Sosa et al. (2023) suggested that ARFIMA-HYGARCH is the best model to analyze BTC volatility and ARFIMA-FIGARCH is the best approach to model ETH volatility. Empirical evidence also confirmed the existence of long memory for the returns and BTC volatility parameters. Their results showed that the proposed models do not perform as well for modeling ETH volatility as they do for BTC.

Zhou et al. (2023) stated that predicting cryptocurrency price movements and constructing a portfolio is about finding valuable data related to price changes of a particular cryptocurrency. By combining portfolio theory, text sentiment analysis and machine learning, this paper proposes a novel cryptocurrency portfolio optimization model that can improve the out-of-sample performance of cryptocurrency portfolio strategies.

Edmonton (2023) stated that diversification is a critical strategy for investors looking to invest in cryptocurrencies in 2023. He explained volatility of the cryptocurrency market can make it a risky investment, but by diversifying your portfolio across different cryptocurrencies, asset classes, and regions, you can reduce your overall risk and potentially improve your investment returns.

Nikolova (2023) argued that scryptoassets, while more volatile and risky than fiat currencies, do indeed provide additional returns to an investor's portfolio and should be used cautiously depending on individual risk and return preferences.

Elu and Williams (2023) find that policy should be designed to adequately address wealth inequalities in the cryptocurrency market. They argued that all investors need to consider that if the market is overly bullish with high returns, it will be difficult for some, if not most, demographic groups to participate in this space or market. This is because equity prices will be excessively high, crowding out those with existing wealth and income disparities, especially minorities.

Han et al. (2023) examined the diversification benefits of out-of-sample cryptocurrencies from a generalised perspective, i.e., at the cryptocurrency factor level, with traditional and machine

learning-assisted asset allocation strategies. They find that the inclusion of transaction costs, an alternative benchmark portfolio, and a rolling-window estimation scheme are robust.

Rashid et al. (2023) find that Bitcoin has a positive relationship with equity markets in both bull and bear markets, a positive relationship with foreign exchange markets and gold in bull markets, and a negative relationship with energy in both regimes. In addition, the study found that Bitcoin differs significantly from USD/EUR and gold in terms of its relationship with the studied variables in both regimes. The results also showed that Bitcoin is related to all variables except BDI in the bullish regime while it is not related to any of the variables in the bearish phase, unlike the characteristics of gold.

Ko et al. (2023) studied performance evaluation with respect to various downside risks under different economic conditions and explored the impact of investor benefits based on expected utility and prospect theory. They confirmed apparent economic gains from using portfolio insurance in the cryptocurrency market and demonstrated reduced downside risks with a higher omega ratio, implying a reasonable risk-managed gain compared to buy-and-hold. Most importantly, portfolio insurance provided opportunities for higher returns in cryptocurrencies than in the traditional equity market, indicating a greater economic value of portfolio insurance.

CHAPTER 3

3. SAMPLE AND METHODOLOGY

As an attempt to determine the diversification benefits of cryptocurrencies we collected daily data for BIST30 index, which is used as a proxy for diversified portfolio, for BTC and ETH as cryptocurrencies, for GOLD (XAU/USD) as a commodity proxy and for USDTRY as a comparative standard currency for the period of April 5, 2021 to April 28, 2023 using adjusted closing prices. The primary data source is investing.com. We created maximum Sharpe Ratio and minimum global variance optimal portfolios and compare the diversification benefits of cryptocurrencies. Optimization were made using Microsoft Excel program with the help of certain formulas, Data Analysis and Solver add-ons. Among our assumptions in optimized portfolios were that the probabilities of the returns are normally distributed; that investors act rationally and can access information quickly and freely; that no short selling is possible and that stock trading commission, tax and transfer costs are accepted as zero.

Through optimization we created maximum Sharpe Ratio portfolios as well as Global Minimum variance portfolios for two-asset, for three-asset and for four-asset portoflios, and compare the diversificiation effects obtained in each case with the others. For the four asset case, which is the most comprehensive case where all currencies along with gold are added to the diverfied market portfolio, we repeat our analyses for the period of 04/05/21 - 04/28/23, which is the "main sample" period, for he "post-Covid-19 era," which includes the sub-sample period of 04/29/22 - 04/28/23, and for the "post-Covid-19 pre-Feb 6" period, which covers 04/29/22 – 02/03/23 excluding the period of the Feb. 6, 2023 great earthquake disaster in Turkey from the post-Covid-19 period. For each optimal portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values are reported.

Table 1 About Here

Table 1 shows mean, median, standard deviation, minimum, maximum values are reported. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). GOLD (XAU/USD), USDTRY, BTC_USD and ETH_USD are Gold-Dollar, U.S. Dollars-Turkish Lira, Bitcoin Dollar and Etherium Dollar, respectively. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023.

Table 2 About Here

Pairwise correlations are reported in Table 2. BIST30 represents the diversified porfolio, in other words, the market portfolio based on Borsa Istanbul 30 Index (BIST30). GOLD (XAU/USD), USDTRY, BTC_USD (BTC) and ETH_USD (ETH) are Gold-Dollar, U.S. Dollars-Turkish Lira, Bitcoin Dollar and Etherium Dollar, respectively. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023.

In this study, in which the effects of cryptocurrencies on portfolio risk and return are measured and interpreted; The usability of cryptocurrencies as a useful portfolio tool for investors was researched, their use as an active currency was examined, and performance measurements were made with various portfolio contents. Since cryptos are very risky investment and payment instruments, their relationship with other assets can be considered as high risk in portfolio distribution.

Portfolios were created using Markowitz's Mean Variance model. With the Sharpe performance criterion where portfolios will offer the maximum return per unit of risk were selected among these portfolios. In this study, the usability of cryptocurrencies in portfolio diversification and their effects on portfolio performance were investigated. In this context, the two cryptocurrencies (Bitcoin, BTC; Ethereum, ETH) with the highest market value as of the date of the study, as well as BIST 30 shares, exchange rate (USDTRY) and commodities (GOLD) were included in the study.

The arithmetic return of the data Rt, the value of the data Pt on day t, the value of the previous day of the data Pt-1. By applying the continuous compound return formula to the original data containing the trend, it was stabilized and recovered from the trend.

$$\mathrm{Rt} = \ln \frac{\mathrm{Pt}}{\mathrm{Pt}-1}$$

Eq. 3 *Compound Return*

Portfolio returns were compared by changing the weight distributions in the created portfolios. By performing variance maximization and variance minimization, it was examined how the distributions were affected. When the Sharpe ratio is fixed at an optimal level, what happens to the portfolio return is examined.

Since the existence of the relationship between the assets in the portfolio is not taken into account in the traditional portfolio approach, it is assumed that the portfolio risk may decrease depending on the increase in the number of securities in the portfolio. Since the covariance values between the securities are assumed to be equal to zero, the portfolio risk will be expressed as follows:

$$\sigma_p^2 = \sum_{i=1}^{n} w_i^2 \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,} w_j cov\left(R_{i,} R_j\right) \quad i \neq j$$

Eq.4 Portfolio Risk with no correlation

$$\sigma_p^2 = \sum_{i=1}^{n} w_i^2 \sigma_i^2$$

Eq.5 Portfolio Variance

The risk for a portfolio to be composed of n securities (wi=1/n) of equal weight:

$$\sigma_p^2 = \sum_{i=1}^{n} \frac{1}{n^2}\sigma_i^2 = \frac{1}{n}\sum_{i=1}^{n} \frac{1}{n^2}\sigma_i^2 = \frac{1}{n}\overline{\sigma_1^2}$$

Eq.6 Portfolio Risk Formula

It is necessary to calculate the expected return and risk of each of the securities to be included in the portfolio. Markowitz diversification is done by adding securities with negative correlations to the portfolio in order to reduce the portfolio risk without sacrificing the return of the portfolio. With this diversification method, the total risk can be reduced to the systematic risk level.

The mean-variance model aims to minimize portfolio risk. The model tries to find the minimum risk portfolio at the expected expected return level. Therefore, the portfolio variance that needs to be minimized is the objective function, represented as follows:

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,} w_j \, \sigma_{ij} = Var(R_p)$$

Eq.7 Minimization of Portfolio Variance

Where,

n is the number of assets in the portfolio, i = 1, 2, … , n

σij: covariance between entities i and j,

wi, wj : decision variables

There are two main constraints of the model. The first one is to provide the expected return level to be achieved:

$$E(R_p) = \sum_{i=1}^{n} w_i E(R_i)$$

Eq.8 Expected Return

Another basic constraint in the model is the condition that the sum of the weights of the assets in the portfolio is equal to 1:

$$\sum_{i=1}^{n} w_i = 1$$

Eq.9 Total Weight

3.1. Sharpe Ratio

The Sharpe ratio is the most preferred criterion among the performance criteria, and it shows the additional return that the investor will demand for one unit of risk, above the risk-free interest rate. Increasing the yield and decreasing the standard deviation increase the Sharpe ratio. We can show this ratio on the graph as in Figure 1.

$$S_p = \frac{R_p - R_f}{\sigma_p}$$

Eq. 10 Sharpe Ratio

Sp : Sharpe Ratio

Rp : Return on the Portfolio

Rf : Risk Free Rate

σp : Standard Deviation of the Portfolio

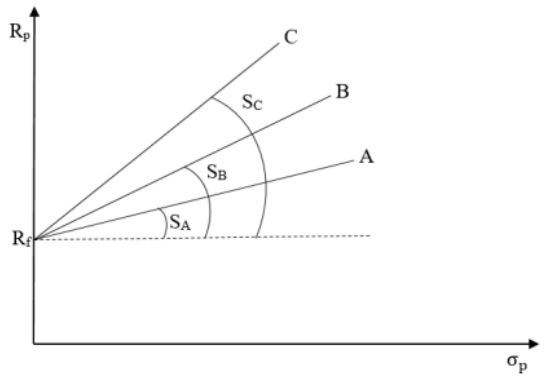


Figure 1 Sharpe Ratio Comparisons

The figure 1 shows the Sharpe ratios of portfolios A, B and C. For example, the Sharpe ratio of portfolio A is the slope of the RfA line. A portfolio with a higher slope is more successful than its alternative. Accordingly, portfolio C is the portfolio option with the best performance among these 3 portfolios. The Sharpe ratio measures the excess return over the risk-free rate per unit of volatility. This ratio allows investors to determine whether higher returns are due to wise investment decisions or taking too much risk.

Sharpe (1994) stated that any measure that attempts to summarize even an unbiased prediction of performance into a single number requires a set of assumptions to justify it. In practice, such assumptions are at best only approximate. The use of unadjusted historical (ex post) Sharpe ratios as a proxy for unbiased predictions of ex ante ratios is certainly open to serious question. Despite these reservations, there is a strong case for preferring a ratio that at least takes into account both risk and expected return to an alternative that focuses only on the latter. He also explained that the ratio of expected incremental return per unit of incremental risk is a practical summary of two important aspects of any strategy, which includes the difference between the return of a fund and that of a relevant benchmark. The Sharpe ratio is intended to provide such a measure. Properly applied, it can improve investment management. Below is the so called Sharpe ratio Statement:

- Sharpe Ratio < 0 : Strategy unprofitable (Bad)
- $0 <$ Sharpe Raito < 1.0 : Risk does not pay off. Such strategies can be considered when there is no alternative (Uncertain)
- Sharpe Ratio ≥ 1.0 : It pays for risk and portfolio/strategy can show positive results (Good)
- Sharpe Ratio ≥ 3.0 : A high value indicates very low probability of loss on each trade (Very Good)

3.2 Sortino Ratio

The Sortino ratio is a variation of the Sharpe ratio, which separates harmful volatility from total volatility by using the standard deviation of negative portfolio returns (downward deviation) of the asset instead of the total standard deviation of portfolio returns.

The Sortino rate takes the return on an asset or portfolio and subtracts the risk-free rate and then divides that amount by the negative bias of the asset. Ratio is named after Frank A. Sortino.

Sortino & Price (1994) explained that the Sortino ratio differs from the Sharpe ratio in that it only considers the standard deviation of the downside risk rather than the overall (up + down) risk.

Since the Sortino ratio focuses on the negative deviation of a portfolio's returns from the mean, it is considered to provide better insight into the portfolio's risk-adjusted performance, as positive volatility is a benefit.

The Sortino ratio is a useful way for investors, analysts, and portfolio managers to evaluate the return on an investment for a given level of bad risk.

The Sortino ratio is a useful way for investors, analysts, and portfolio managers to evaluate the return on an investment for a given level of bad risk. This ratio addresses the problem of using total risk or standard deviation, as it only uses downward deviation as a measure of risk; This is important because upside volatility is beneficial for investors and is not a factor that most investors worry about.

Rollinger and Hoffman (2013) stated that Sortino ratio improves the Sharpe ratio by isolating negative or negative volatility from total volatility by dividing the excess return by the downside deviation instead of the total standard deviation of a portfolio or asset. The Sharpe ratio penalizes the investment for good risk, resulting in positive returns for investors. However,

determining which ratio to use depends on whether the investor wants to focus on the total or standard deviation, or just the negative deviation.

Srivastava and Mazhar (2018) researced that the Sortino ratio variant of the Sharpe ratio takes into account only the negative volatility and not the total volatility used to calculate the Sharpe ratio. The theory behind the Sortino Variant is that upside volatility is a plus for the investment and therefore should not be included in the risk calculation.

Therefore, the Sortino Ratio takes the upside volatility out of the equation and only includes the downside standard deviation in the calculation, rather than the total standard deviation used in the Sharpe Ratio calculation. The Sharpe Ratio is also an effective measure for long-term and short-term analysis of portfolio performance.

Like the Sharpe ratio, a higher Sortino ratio result is better. When looking at two similar investments, a rational investor would prefer the one with the higher Sortino ratio because it means that he gets more returns per unit from the bad risk the investment is taking.

$$Sortino\ Ratio = \frac{Rp - Rf}{\sigma d}$$

Eq.11 Sortino Ratio Formula

Rp: the portfolio's expected rate of return

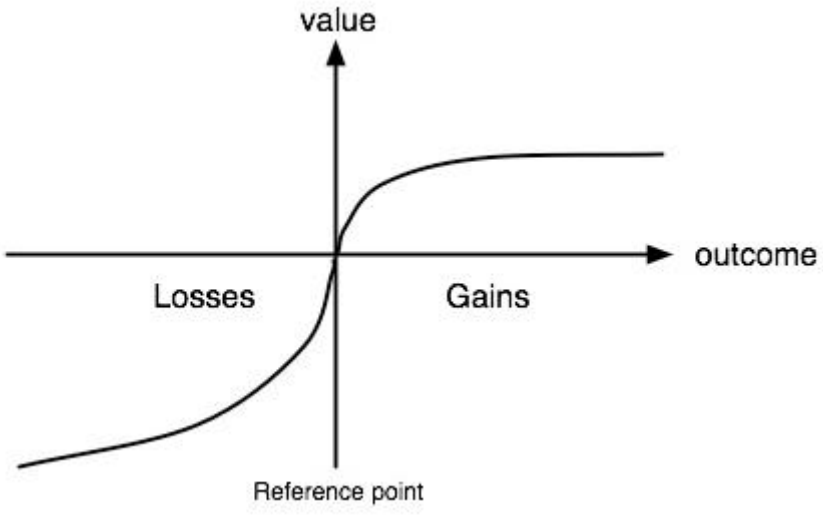
Rf: the risk-free or minimum acceptable rate of return

σd: the standard deviation of negative asset return (downside risk)

3.3 Value at Risk (VaR) and CVaR

It is a statistical method used to measure the risk of financial assets in the company or an investment portfolio. The method indicates the highest level of loss that can occur in the value of a portfolio during a predetermined period of time within a certain confidence interval. Risk managers aim to measure and control the risk undertaken with the VaR method. More specifically, VaR is a statistical technique used to quantify the amount of potential loss that could occur on an investment portfolio over a given period of time. Value at Risk gives the probability of losing more than a certain amount in a given portfolio.

Although risk calculation is a reliable method, it has two important shortcomings due to its structure: The first is that the results can be partially open to manipulation with the method changes used in the calculation, and the second is that the models are developed by selecting a set suitable for regression from the historical data of statistical models, especially 'unprecedented periods'. This is the case where the outputs of the model may lack foresight. VaR is very useful as it shows the risk of the Portfolio with a number and calculates the minimum capital required. Conditional VaR is an extension of VaR. CVaR helps calculate the average of losses that occur beyond the Value-at-Risk point in a distribution. The smaller the CVaR, the better.



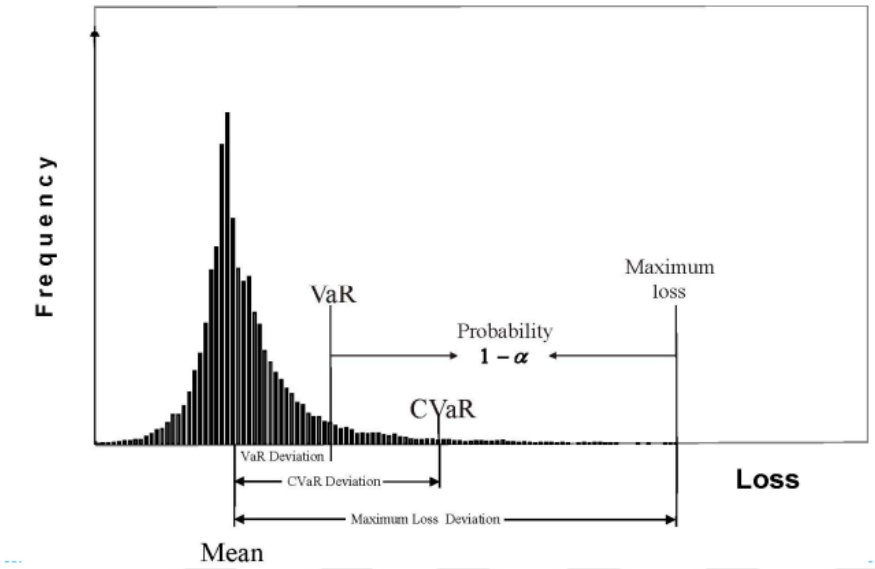


Figure 1 Var and CVaR Deviation

VaR is not a coherent measure of risk because it violates the property of subadditivity, which reads:

If X,Y ∈ L then $\rho(X+Y) \leq \rho(X) + \rho(Y)$

But it may be limited by coherent risk measures such as conditional value-at-risk (CVaR) or entropic value-at-risk (EVaR).

The CVaR is defined by the average of the VaR values for confidence levels between 0 and α. Since CVaR uses data generated by VaR, it's important to first calculate VaR. When a fund manager creates a VaR, they can use that data to create a CVaR using the following formula:

$$CVaR = \frac{1}{1-c} \int_{-1}^{VaR} xp\,(x)dx$$

Eq.12 CVar Formula

p(x)dx = probability density of obtaining a return at "x"

c = VaR limit

VaR = calculated level of VaR

The CVaR calculation provides a more prudent view of managing risk, especially over a longer time horizon. Not only does it take into account a broader spectrum of volatility, but it also measures risk in real dollars beyond the expected worst-case scenarios.

VaR, unlike CVaR, has the property of being a robust statistic. A related class of risk measures is range value at risk (RVaR), which is a robust version of CVaR.

For X € $L_M +$ with $L_M +$

the set of all measurable Borel functions whose moment generating function exists for all positive real values) we have ;

$$VaR_{1-\infty}(X) \leq RVaR_{\alpha,\beta}(X) \leq CVaR_{1-\infty}(X) \leq EVaR_{1-\infty}(X)$$

where

$$\begin{aligned}
\mathrm{VaR}_{1-\alpha}(X) &:= \inf_{t\in\mathbf{R}}\{t : \Pr(X \leq t) \geq 1-\alpha\},\\
\mathrm{CVaR}_{1-\alpha}(X) &:= \frac{1}{\alpha}\int_0^{\alpha} \mathrm{VaR}_{1-\gamma}(X)d\gamma,\\
\mathrm{RVaR}_{\alpha,\beta}(X) &:= \frac{1}{\beta-\alpha}\int_{\alpha}^{\beta} \mathrm{VaR}_{1-\gamma}(X)d\gamma,\\
\mathrm{EVaR}_{1-\alpha}(X) &:= \inf_{z>0}\{z^{-1}\ln(M_X(z)/\alpha)\},
\end{aligned}$$

Eq.13 VaR, CVaR and EVaR Formula

in which case $M_X(z)$ is the moment-generating function of X at z. In the above equations, the variable X denotes financial loss and not wealth, as is usually the case.

A portfolio manager's job is to make decisions that serve both to generate profits and to hedge against risk. Fund managers can monitor volatility and work with risk managers to determine VaR and CVaR. The use of this information can range from hedging to rebalancing the portfolio.

While it is impossible to predict the future, there are always ways to protect against it. Contingent Value at Risk gives funds the ability to identify protective measures and understand their loss potential. This can remove some of the uncertainty from future investments.

CHAPTER 4

4. EMPIRICAL RESULTS

Both cryptocurrencies in question have close to zero or negative correlations with index, exchange rates, commodities and mutual funds. Therefore, based on these correlation coefficients and relations, at first glance, it is possible to say that cryptocurrencies can be used in portfolio diversification. In the continuation of the study, different portfolios were created within the framework of the previously mentioned strategies and using the historical data of the assets. First of all, index, exchange rate and commodities are included in the portfolios and the returns, risks and Sharpe ratios of these portfolios are calculated. In order to create the minimum risk portfolio, we need to make the variance, which is the risk indicator, the lowest.

In order to make this value the lowest, we need to be able to change the weights of the assets in the portfolio. For this reason, the combination that changes the weights of the assets in the portfolio and minimizes the variance of the portfolio is calculated by using the "Solver" add-in of Excel. Some constraints were used while calculating this combination. The first of these constraints is that the weights of cryptocurrencies in the portfolio are >=0. This constraint has been determined considering that no assets in the portfolio can be short-sold and have a negative weight. The second constraint is that the sum equals 100%. It is also aimed to reduce the risk by minimizing the variance.

Table 3 about here

In Table 3, return and risk metrics are reported for two-asset optimal portfolios. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index

(BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio alternately to see their effect.

All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023. Without any weight constraint, optimization process may tend to concentrate all money in some single asset, which may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio.

Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively For each MSR Portfolio, Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

According to Table 3, Sharpe ratio has the highest between BIST30-USD. This indicates a larger return in proportion to the risk taken. At the same time the expected risk adjusted returns all else being equal Sortino ratio has higher the between BIST30-ETH. If we prefer an optimal portfolio with 2 assets with the highest return, we can look at BISt30-USD or BIST30-ETH.

Return and risk metrics are reported for three-asset optimal portfolios. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added in pairs to the diversified portfolio to see their effect. All data are daily and obtained from investing.com for the period of 05/04/21 – 28/04/23.

Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio.

Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each MSR Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Table 4 about here

Table 4 reports return and risk metrics are reported for three-asset optimal MSR portfolios similar to Table 3. Table 3 was for two-asset portfolios. In Table 4 we have three-asset portfolios.

According to Table 4, again, if we maximize the return, we can choose BIST30-USDTRY-ETH in the portfolio with the highest Sharpe and Sortino ratio adjusted for risks is considered good and indicates an increased return against volatility. We will get the maximum annual return with BIST30 and ETH have diversified portfolio weight constraints of 10%.

Table 5 about here

Table 5 shows results from four asset optimal portfolios which is the most complex portfolio relative to toher cases. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio to see their effect.

All data are daily and obtained from investing.com for the period of 05/04/21 – 28/04/23, which is the “main sample” period. The “post-Covid-19 era” includes the sub-sample period of 29/04/22 – 28/04/23. The “post-Covid-19 pre-Feb 6” period covers 29/04/22 – 03/02/23, which

excludes the period of the Feb. 6, 2023 great earthquake disaster in Turkey. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio.

Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each MSR Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

When we create a portfolio containing 4 assets, Sharpe and Sortino ratio is among the highest BIST30-USDTRY-GOLD-ETH and the portfolio has the highest annual return. The returns are lower in portfolios that include BTC.

Next, we repeated our analyses for global minimum variance portfolios instead of maximum Sharpe ratio portfolios. Optimization based on the maximum Sharpe ratio would return the asset weights in the portfolio that would give the highest Sahrpe ratio for the potfolio. For the following global minimum variance portfolio cases, optimization is made based on the asset weights that would give the minimum portfolio variance.

Table 6 about here

In Table 6, return and risk metrics are reported for two-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio alternately to see their effect.

All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023. Without any weight constraint, optimization process may tend to concentrate all money in some single asset, which may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio.

Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively For each GMV Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returns) and Conditional VaR values reported.

When we prefer minimum risk, Sharpe and Sortino ratio is the highest BIST30-USDTRY in a 2-asset portfolio. The asset with the highest annual return is BIST30. When a stand-alone portfolio is created, it is 0.9501 per year, while when we include USDTRY, the return drops to 0.9115. We reach a high return portfolio with little risk.

Table 7 about here

Table 7 illustrates return and risk metrics for three-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added in pairs to the diversified portfolio to see their effect.

Similar to Table 6, in Table 7, all data are daily and obtained from investing.com for the period of 05/04/21 – 28/04/23. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since

we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio.

Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each GMV Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returns) and Conditional VaR values reported. When we minimize the risk of a portfolio containing 3 assets, the Sharpe and Sortino ratio is the highest, BIST30-USDTRY-ETH. When we increase their weight in the portfolio, that is, when we increase it to 90%, we reach the highest return.

Table 8 about here

Table 8 presents the most complex potfolio comparisons where we have four assets. In Table 8, return and risk metrics are reported for four-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio to see their effect.

Since this is the most compe case compared to other GMV portolios, in Table 8 we examine post-Covid and pre-earthquake periods as an addition to the main sample period. As it was mentioned before, all data are daily and obtained from investing.com for the period of 04/05/21 - 04/28/23, which is the "main sample" period. The "post-Covid-19 era" includes the sub-sample period of 29/04/22 – 28/04/23. The "post-Covid-19 PRE-Feb. 6" period covers 29/04/22 – 03/02/23, which excludes the period of the Feb. 6, 2023 great earthquake disaster in Turkey. Similar to previous cases, since without any weight constraint, optimization process ma tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Thus, Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10%

weight constraint. For each GMV Portfolio, Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

In Table 8, when we look at the Post-Covid–Pre-Feb 6 (pre-earthquake) period, we see that a portfolio with 4 assets, which we can obtain with minimum risk, is between the highest BIST30-GOLD-USDTRY-ETH when Sharpe and Sortino ratios are taken into account. Based on the annual return, we see that high returns are achieved with the same assets. However, we observe a decrease in Sharpe and Sortino ratio when we increase their weights.

CHAPTER 5

5. CONCLUSIONS

Looking at the portfolios created using six different models, it is seen that inclusion of cryptocurrencies in portfolios positively affects portfolio performances. This finding is in line with the results of various studies in literature suggesting that cryptocurrencies can be good instruments for portfolio diversification in general. Especially, ETH has the higher return than BTC in the diversified portfolio. Cryptocurrencies, in general, have the effect of increasing the returns and reducing the risks of portfolios, enabling higher returns at lower risk levels, the same returns at lower risk levels, or higher returns at the same risk levels. From this point of view, it has been concluded that cryptocurrencies are good portfolio diversifiers because they both show negative or low correlations with traditional assets. Therefore, cryptocurrencies can be used for portfolio diversification and keeping them in portfolios even in small amounts may provide benefits in this regard.

It is possible to develop and expand this work by increasing the number of assets and asset types, using different cryptocurrencies and different portfolio strategies. In this way, more comprehensive information on the benefits of cryptocurrencies for portfolio diversification will be obtained. It should also be taken into account that the study was carried out using historical data, and it should not be forgotten that the situations that occurred in the past may not be a mirror of the future as the future is full of uncertainties.

Recently, cryptocurrencies have almost collapsed due to the tightening policies implemented around the world to combat inflation, reducing liquidity from global markets. With the Fed's interest rate hike move and announcing that it would narrow the balance sheet, cryptocurrencies began to decline. The decline that started first with Bitcoin spread to other cryptocurrencies. The wave of sales in crypto assets causes panic among investors as the atmosphere of recession spreads, inflation, interest rates and cost of living increase. Stock markets are also on the decline: The S&P 500 index in the USA has lost 20 percent since its last peak. For many, it is too risky to invest in hard-to-predict instruments like cryptocurrencies during such period. The lack of a regulatory agency and the lack of a guarantee given by financial institutions make investing in cryptocurrencies even more difficult.

However, starting with the pandemic, investment preferences as well as social life have changed. Not only in Turkey, but also in many countries around the world, people have increased their interest in investment instruments that are 'new' for them. While some were interested in cryptocurrencies, others started to invest in stocks. The number of domestic investors investing in the stock market, which was around 1.2 million before the pandemic, exceeded 2 million. It is estimated that the number of people who trade in cryptocurrencies is around 3 million. Looking at the general profiles of those who have recently been interested in such 'moving' markets, one can say that those who think short-term are in the majority.

In this study, inline with the previous work, the diversification effect of cryptos on the portfolio is found positive during our sample period. Rather than just building a diversified portfolio or a portfolio of cryptos, investing in a variety of assets can both reduce risk and increase returns.

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APPENDIX: TABLES

Table 1. Descriptive Statistics

Mean, median, standard deviation, miniöuö, maximum values are reported. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). GOLD (XAU/USD), USDTRY, BTC_USD and ETH_USD are Gold-Dollar, U.S. Dollars-Turkish Lira, Bitcoin Dollar and Etherium Dollar, respectively. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023.

	BIST30	GOLD	USDTRY	BTC	ETH
Mean	0.002665	0.000349	0.001866	-0.00021	0.001462
Median	0.003	0.0006	0.0014	-0.0014	0.0007
Standard Deviation	0.020383	0.008986	0.01542	0.038544	0.049938
Minimum	-0.0907	-0.0297	-0.173	-0.1563	-0.1757
Maximum	0.0997	0.0359	0.0836	0.1459	0.2646
Number of Observations	513	513	513	513	513

Table 2. Correlation Table

Pairwise correlations are reported. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). GOLD (XAU/USD), USDTRY, BTC_USD (BTC) and ETH_USD (ETH) are Gold-Dollar, U.S. Dollars-Turkish Lira, Bitcoin Dollar and Etherium Dollar, respectively. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023.

	BIST30	GOLD	USDTRY	BTC	ETH
BIST30	1				
GOLD	0.06654	1			
USDTRY	0.020374	-0.07261	1		
BTC	0.113305	0.081512	-0.38601	1	
ETH	0.125264	0.102907	-0.3608	0.853965	1

Table 3. Return and Risk Metrics for Optimal (MSR) Portfolios: Two-Asset Case

Return and risk metrics are reported for two-asset optimal portfolios. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio alternately to see their effect. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023. Without any weight constraint, optimization process may tend to concentrate all money in some single asset, which may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively For each MSR Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portofolio	BIST30	BIST30-GOLD			BIST30-USDTRY			BIST30-BTC			BIST30-ETH		
Model		1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9000	0.5000	0.1000	0.9000	0.5000	0.1000
Expected Daily Portfolio Return	0.0027	0.0006	0.0015	0.0024	0.0019	0.0023	0.0026	0.0001	0.0012	0.0024	0.0016	0.0021	0.0025
Daily Standard Deviation	0.0204	0.0085	0.0114	0.0184	0.0141	0.0129	0.0184	0.0350	0.0228	0.0192	0.0452	0.0281	0.0196
Expected Annual Portfolio Return	0.9501	0.1567	0.4592	0.8403	0.6290	0.7646	0.9116	0.0197	0.3605	0.8147	0.4872	0.6776	0.8923
Annualized Standard Deviation	0.3229	0.1342	0.1807	0.2919	0.2229	0.2044	0.2922	0.5542	0.3612	0.3037	0.7168	0.4456	0.3106
Annualized Downside Risk	0.2510	0.0896	0.1323	0.2252	0.1997	0.1660	0.2255	0.3899	0.2451	0.2315	0.4881	0.2971	0.2327
Sharpe Ratio	2.8903	1.0425	2.4475	2.8209	2.7466	3.6580	3.0626	0.0052	0.9517	2.6276	0.6563	1.4831	2.8186
Sortino Ratio	3.7183	1.5619	3.3440	3.6560	3.0648	4.5040	3.9675	0.0074	1.4022	3.4476	0.9637	2.2244	3.7617
VaR (95%, daily)	-0.0335	-0.0139	-0.0188	-0.0303	-0.0231	-0.0212	-0.0303	-0.0575	-0.0375	-0.0315	-0.0744	-0.0463	-0.0322
CVaR (95%, daily)	-0.0548	-0.0180	-0.0282	-0.0493	-0.0574	-0.0418	-0.0503	-0.0905	-0.0560	-0.0506	-0.1060	-0.0638	-0.0514

Table 4. Return and Risk Metrics for Optimal (MSR) Portfolios: Three-Asset Case

Return and risk metrics are reported for three-asset optimal portfolios. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added in pairs to the diversified portfolio to see their effect. All data are daily and obtained from investing.com for the period of 04/05/21 - 04/28/23. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each MSR Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portfolio	BIST30-GOLD-USDTRY			BIST30-GOLD-BTC			BIST30-GOLD-ETH			BIST30-USDTRY-BTC			BIST30-USDTRY-ETH		
Model	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.0000	0.0000	0.0000	0.8000	0.4000	0.1000	0.1000	0.1000	0.1000	0.8000	0.4000	0.1000	0.8000	0.4000	0.1000
Expected Daily Portfolio Return	0.0007	0.0017	0.0026	0.0001	0.0013	0.0024	0.0007	0.0016	0.0026	0.0003	0.0014	0.0026	0.0016	0.0021	0.0027
Daily Standard Deviation	0.0077	0.0111	0.0185	0.0312	0.0195	0.0193	0.0096	0.0128	0.0197	0.0306	0.0190	0.0191	0.0397	0.0231	0.0196
Expected Annual Portfolio Return	0.2016	0.5157	0.9283	0.0341	0.3797	0.8306	0.1895	0.5005	0.9089	0.0742	0.4332	0.9015	0.5024	0.6947	0.9828
Annualized Standard Deviation	0.1214	0.1763	0.2934	0.4946	0.3094	0.3051	0.1525	0.2023	0.3122	0.4844	0.3014	0.3032	0.6295	0.3663	0.3098
Annualized Downside Risk	0.0809	0.1303	0.2249	0.3470	0.2084	0.2314	0.0965	0.1404	0.2325	0.3396	0.2028	0.2304	0.4281	0.2425	0.2320
Sharpe Ratio	1.5226	2.8294	3.1072	0.0349	1.1729	2.6671	1.1323	2.3908	2.8575	0.1185	1.3818	2.9177	0.7714	1.8505	3.1182
Sortino Ratio	2.2843	3.8291	4.0526	0.0498	1.7415	3.5164	1.7900	3.4454	3.8368	0.1691	2.0538	3.8394	1.1342	2.7958	4.1638
VaR (95%, daily)	-0.0126	-0.0183	-0.0305	-0.0514	-0.0321	-0.0317	-0.0158	-0.0210	-0.0324	-0.0503	-0.0313	-0.0315	-0.0654	-0.0380	-0.0322
CVaR (95%, daily)	-0.0164	-0.0286	-0.0515	-0.0806	-0.0452	-0.0497	-0.0223	-0.0320	-0.0514	-0.0776	-0.0435	-0.0516	-0.0942	-0.0507	-0.0534

Table 5. Return and Risk Metrics for Optimal (MSR) Portfolios: Four-Asset Case

Return and risk metrics are reported for four-asset optimal portfolios. Optimatization is based on maximizimg the Sharpe ratio. MSR stands for Maximum Sharpe Ratio. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio to see their effect. All data are daily and obtained from investing.com for the period of 04/05/21 - 04/28/23, which is the "main sample" period. The "post-Covid-19 era" includes the sub-sample period of 04/29/22 - 04/28/23. The "post-Covid-19 pre-Feb 6" period covers 04/29/22 – 02/03/23, which excludes the period of the Feb. 6, 2023 great earthquake disaster in Turkey. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each MSR Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portfolio	BIST30-GOLD-USDTRY-BTC MAIN SAMPLE			BIST30-GOLD-USDTRY-BTC POST-COVID-19 ERA			BIST30-GOLD-USDTRY-BTC POST-COVID-19 PRE-FEB. 6			BIST30-GOLD-USDTRY-ETH MAIN SAMPLE			BIST30-GOLD-USDTRY-ETH POST-COVID-19 ERA			BIST30-GOLD-USDTRY-ETH POST-COVID-19 PRE-FEB. 6		
Model	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.7000	0.3000	0.1000	0.7000	0.3000	0.1000	0.7000	0.3000	0.1000	0.1000	0.1000	0.1000	0.7000	0.3000	0.1000	0.7000	0.3000	0.1000
Expected Daily Portfolio Return	0.0003	0.0015	0.0026	0.0001	0.0014	0.0027	-0.0006	0.0016	0.0035	0.0008	0.0018	0.0028	0.0006	0.0017	0.0028	0.0001	0.0019	0.0036
Daily Standard Deviation	0.0268	0.0160	0.0192	0.0253	0.0171	0.0216	0.0259	0.0171	0.0210	0.0087	0.0123	0.0196	0.0332	0.0196	0.0219	0.0359	0.0205	0.0215
Expected Annual Portfolio Return	0.0894	0.4534	0.9182	0.0137	0.4334	0.9698	-0.1479	0.5005	1.4265	0.2356	0.5586	1.0002	0.1755	0.5272	1.0118	0.0306	0.6276	1.4930
Annualized Stand. Dev.	0.4250	0.2540	0.3046	0.4013	0.2713	0.3424	0.4104	0.2708	0.3330	0.1371	0.1954	0.3113	0.5264	0.3105	0.3472	0.5681	0.3243	0.3411
Annualized Downside Risk	0.2969	0.1714	0.2305	0.3087	0.1732	0.2269	0.3421	0.1888	0.2324	0.0869	0.1374	0.2320	0.3946	0.2013	0.2275	0.4294	0.2214	0.2339
Sharpe Ratio	0.1707	1.7189	2.9591	-0.0076	1.5353	2.7836	-0.4012	1.7864	4.2339	1.5957	2.7729	3.1589	0.3016	1.6439	2.8653	0.0243	1.8837	4.3283

Sortino Ratio	0.2444	2.5474	3.9100	-0.0099	2.4057	4.1999	-0.4813	2.5618	6.0666	2.5177	3.9436	4.2386	0.4023	2.5351	4.3740	0.0321	2.7592	6.3103
VaR (95%, daily)	-0.0441	-0.0264	-0.0316	-0.0417	-0.0282	-0.0355	-0.0426	-0.0281	-0.0346	-0.0142	-0.0203	-0.0323	-0.0546	-0.0322	-0.0361	-0.0590	-0.0337	-0.0354
CVaR (95%, daily)	-0.0703	-0.0358	-0.0505	-0.0664	-0.0398	-0.0564	-0.0713	-0.0400	-0.0503	-0.0204	-0.0312	-0.0523	-0.0853	-0.0433	-0.0515	-0.0879	-0.0466	-0.0484

Table 6. Return and Risk Metrics for GMV Portfolios: Two-Asset Case

Return and risk metrics are reported for two-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio alternately to see their effect. All data are daily and obtained from investing.com for the period of April 5, 2021 to April 28, 2023. Without any weight constraint, optimization process may tend to concentrate all money in some single asset, which may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively For each GMV Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portofolio	BIST30	BIST30-GOLD			BIST30-USDTRY			BIST30-BTC			BIST30-ETH		
Model		1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000	0.1895	0.5000	0.1000	0.1085	0.5000	0.1000
Expected Daily Portfolio Return	0.0027	0.0007	0.0015	0.0024	0.0022	0.0023	0.002585	0.0021	0.0012	0.0024	0.0025	0.0021	0.0025
Daily Standard Deviation	0.0204	0.0084	0.0114	0.0184	0.0124	0.0129	0.018441	0.0188	0.0228	0.0192	0.0196	0.0281	0.0196
Expected Annual Portfolio Return	0.9501	0.1875	0.4592	0.8403	0.7164	0.7646	0.911555	0.7016	0.3605	0.8147	0.8875	0.6776	0.8923
Annualized Standard Deviation	0.3229	0.1333	0.1807	0.2919	0.1967	0.2044	0.292154	0.2979	0.3612	0.3037	0.3105	0.4456	0.3106

Annualized Downside Risk	0.2510	0.0886	0.1323	0.2252	0.1699	0.1660	0.225523	0.2169	0.2451	0.2315	0.2313	0.2971	0.2327
Sharpe Ratio	2.8903	1.2810	2.4475	2.8209	3.5560	3.6580	3.062612	2.2985	0.9517	2.6276	2.8038	1.4831	2.8186
Sortino Ratio	3.7183	1.9264	3.3440	3.6560	4.1179	4.5040	3.967468	3.1566	1.4022	3.4476	3.7650	2.2244	3.7617
VaR (95%, daily)	-0.0335	-0.0138	-0.0188	-0.0303	-0.0204	-0.0212	-0.030332	-0.0309	-0.0375	-0.0315	-0.0322	-0.0463	-0.0322
CVaR (95%, daily)	-0.0548	-0.0181	-0.0282	-0.0493	-0.0402	-0.0418	-0.050342	-0.0447	-0.0560	-0.0506	-0.0511	-0.0638	-0.0514

Table 7. Return and Risk Metrics for GMV Portfolios: Three-Asset Case

Return and risk metrics are reported for three-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added in pairs to the diversified portfolio to see their effect. All data are daily and obtained from investing.com for the period of 04/05/21 - 04/28/23. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each GMV Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portfolio	BIST30-GOLD-USDTRY			BIST30-GOLD-BTC			BIST30-GOLD-ETH			BIST30-USDTRY-BTC			BIST30-USDTRY-ETH		
Model	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.0000	0.0000	0.0000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1076	0.1000	0.1000
Expected Daily Portfolio Return	0.0010	0.0017	0.0026	0.0006	0.0015	0.0024	0.0007	0.0016	0.0026	0.0023	0.0021	0.0026	0.0020	0.0022	0.0027
Daily Standard Deviation	0.0072	0.0111	0.0185	0.0089	0.0122	0.0193	0.0096	0.0128	0.0197	0.0171	0.0122	0.0191	0.0111	0.0126	0.0196
Expected Annual Portfolio Return	0.2697	0.5405	0.9283	0.1525	0.4389	0.8306	0.1989	0.5005	0.9089	0.7788	0.6752	0.9015	0.6619	0.7469	0.9828
Annualized Standard Deviation	0.1140	0.1759	0.2934	0.1406	0.1925	0.3051	0.1524	0.2023	0.3122	0.2716	0.1940	0.3032	0.1760	0.2004	0.3098
Annualized Downside Risk	0.0806	0.1309	0.2249	0.0920	0.1370	0.2314	0.0960	0.1404	0.2325	0.2055	0.1518	0.2304	0.1540	0.1548	0.2320
Sharpe Ratio	2.2193	2.9772	3.1072	0.9652	2.1923	2.6671	1.1944	2.3908	2.8575	2.8060	3.3948	2.9177	3.6643	3.6439	3.1182
Sortino Ratio	3.1371	3.9991	4.0526	1.4752	3.0798	3.5164	1.8975	3.4454	3.8368	3.7074	4.3372	3.8394	4.1880	4.7167	4.1638
VaR (95%, daily)	-0.0118	-0.0183	-0.0305	-0.0146	-0.0200	-0.0317	-0.0158	-0.0210	-0.0324	-0.0282	-0.0201	-0.0315	-0.0183	-0.0208	-0.0322

CVaR (95%, daily)	-0.0163	-0.0294	-0.0515	-0.0202	-0.0298	-0.0497	-0.0222	-0.0320	-0.0514	-0.0459	-0.0350	-0.0516	-0.0417	-0.0349	-0.0534

Table 8. Return and Risk Metrics for GMV Portfolios: Four-Asset Case

Return and risk metrics are reported for four-asset global minimum risk (GMV) portfolios. Optimatization is based on minimizing portfolio risk. BIST30 represents the diversified porfolio, the market portfolio based on Borsa Istanbul 30 Index (BIST30). Gold (XAU/USD), USDTRY, BTC_USD and ETH_USD added to the diversified portfolio to see their effect. All data are daily and obtained from investing.com for the period of 04/05/21 - 04/28/23, which is the "main sample" period. The "post-Covid-19 era" includes the sub-sample period of 04/29/22 - 04/28/23. The "post-Covid-19 PRE-Feb. 6" period covers 04/29/22 – 02/03/23, which excludes the period of the Feb. 6, 2023 great earthquake disaster in Turkey. Without any weight constraint, optimization process may tend to concentrate all money in a single asset that may be other than the diversified portfolio, and since we want to see the effect of the cryptocurencies on the diversified portfolio, we put alternative weight constraints on the diversified portfolio. Models 1, 2 and 3 have diversified portfolio weight constraints of 10%, 50% and 90%, respectively while other assets have 10% weight constraint. For each GMV Portfolio,Weight of the Crypto Asset, Expected Daily Portfolio Return, Daily Standard Deviation, Expected Annual Portfolio Return, Annualized Standard Deviation, Annualized Downside Risk, Sharpe Ratio, Sortino Ratio, VaR (Value at risk based on 95% confidence level and daily returnsy) and Conditional VaR values reported.

Assets in Portfolio	BIST30-GOLD-USDTRY-BTC MAIN SAMPLE			BIST30-GOLD-USDTRY-BTC POST-COVID-19 ERA			BIST30-GOLD-USDTRY-BTC POST-COVID-19 PRE-FEB. 6			BIST30-GOLD-USDTRY-ETH MAIN SAMPLE			BIST30-GOLD-USDTRY-ETH POST-COVID-19 ERA			BIST30-GOLD-USDTRY-ETH POST-COVID-19 PRE-FEB. 6		
Model	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Weight of the Crypto Asset	0.7000	0.3000	0.1000	0.7000	0.3000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.7000	0.3000	0.1000	0.1000	0.1000	0.1000
Expected Daily Portfolio Return	0.0003	0.0015	0.0026	0.0001	0.0014	0.0027	0.0012	0.0022	0.0035	0.0008	0.0018	0.0028	0.0006	0.0017	0.0028	0.0013	0.0023	0.0036
Daily Standard Deviation	0.0268	0.0160	0.0192	0.0253	0.0171	0.0216	0.0047	0.0122	0.0210	0.0087	0.0123	0.0196	0.0332	0.0196	0.0219	0.0052	0.0128	0.0215

Expected Annual Portfolio Return	0.0894	0.4534	0.9182	0.0137	0.4334	0.9698	0.3501	0.7488	1.4265	0.2356	0.5586	1.0002	0.1755	0.5272	1.0118	0.3872	0.7969	1.4930
Annualized Standard Deviation	0.4250	0.2540	0.3046	0.4013	0.2713	0.3424	0.0751	0.1931	0.3330	0.1371	0.1954	0.3113	0.5264	0.3105	0.3472	0.0819	0.2022	0.3411
Annualized Downside Risk	0.2969	0.1714	0.2305	0.3087	0.1732	0.2269	0.0538	0.1335	0.2324	0.0869	0.1374	0.2320	0.3946	0.2013	0.2275	0.0568	0.1376	0.2339
Sharpe Ratio	0.1707	1.7189	2.9591	-0.0076	1.5353	2.7836	4.4388	3.7916	4.2339	1.5957	2.7729	3.1589	0.3016	1.6439	2.8653	4.5200	3.8574	4.3283
Sortino Ratio	0.2444	2.5474	3.9100	-0.0099	2.4057	4.1999	6.1932	5.4843	6.0666	2.5177	3.9436	4.2386	0.4023	2.5351	4.3740	6.5190	5.6705	6.3103
VaR (95%, daily)	-0.0441	-0.0264	-0.0316	-0.0417	-0.0282	-0.0355	-0.0078	-0.0200	-0.0346	-0.0142	-0.0203	-0.0323	-0.0546	-0.0322	-0.0361	-0.0085	-0.0210	-0.0354
CVaR (95%, daily)	-0.0703	-0.0358	-0.0505	-0.0664	-0.0398	-0.0564	-0.0137	-0.0287	-0.0503	-0.0204	-0.0312	-0.0523	-0.0853	-0.0433	-0.0515	-0.0116	-0.0283	-0.0484