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INVESTIGATION OF THE FEASIBILITY OF INCLUDING DIFFERENT CRYPTOCURRENCIES IN THE INVESTMENT PORTFOLIO FOR ITS DIVERSIFICATION

Lina JUŠKAITĖ, Laura GUDELYTĖ-ŽILINSKIENĖ *

Department of Financial Engineering, Faculty of Business Management, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223, Vilnius, Lithuania

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Abstract. *Purpose* – the main aim of this article is to identify cryptocurrencies suitable for investment and portfolio diversification.

Research methodology – the methodology of empirical research includes methods of scientific literature analysis, statistical data analysis, multicriteria evaluation, correlation analysis.

Findings – Bitcoin is the leading cryptocurrency, but this result could have been due to an exceptionally high market capitalization. Based on the results of the analysis, the inclusion of Bitcoin, Etherium and Dogecoin in the investment portfolio of S&P500, Euro Stoxx 50, DAX and CAC 40 indexes could be considered. Terra could be an interesting investment when considering the benefits of diversification.

Research limitations – based on the results of the study, the inclusion of all studied cryptocurrencies in the investment portfolio could be considered in order to diversify the portfolio, taking into account their investment attractiveness.

Practical implications – Cryptocurrencies attract investors not only because of the returns they receive, but also because of the absence of intermediaries, which allows them to reduce transaction costs. High returns are associated with high risks, so it is necessary to conduct as much research as possible to identify the benefits of cryptocurrencies and to find risk management strategies. One such benefit of cryptocurrencies highlighted in research is diversification.

Originality/Value – the novelty of the study lies in evaluat*ion of* 10 selected cryptocurrencies according to different criteria using a multi-criteria valuation method to identify cryptocurrencies *that are* non-correlated or weakly correlated with traditional assets *and* the most suitable for investment and for portfolio diversification.

Keywords: diversification, cryptocurrencies, investment, traditional assets.

JEL Classification: G11.

*Corresponding author. E-mail: *laura.gudelyte-zilinskiene@vilniustech.lt*

Introduction

Cryptocurrencies are one of the alternative investments that have recently attracted both experienced and inexperienced investors for their returns as well as researchers (Binda, 2020; Corbet et al., 2018; Demiralay & Bayracı, 2021; Goodell & Goutte, 2021), who try to understand and explain the cryptocurrency market. Although there are currently many differing views on whether cryptocurrencies can be considered a separate asset class and what their similarities are to stocks, bonds, or foreign currency. Demiralay and Bayracı (2021) note that cryptocurrencies are considered an alternative asset class, but very little known about the results of the cryptocurrency portfolio. In recent years, the rapidly evolving cryptocurrency market has attracted an increasing investor interest, not only in terms of potential returns, but also in terms of the absence of intermediaries, which allows for low transaction costs and sometimes avoids these costs altogether. The types of cryptocurrencies are endless: some exist from the beginning of their creation until now, others are created and disappear, others result from the diverges of blockchain. Many investors tend to invest in cryptocurrencies, especially for investors with high risk tolerance (Andrianto, 2017), so finding the right strategy is relevant for investors. Cryptocurrencies are considered a new asset class because of the additional benefits they provide. One such benefit is diversification. Research studies (Inci & Lagasse, 2019; Lee et al., 2018; Liew et al., 2019) observe that cryptocurrencies are weakly correlated with traditional assets, and the possibility of using them to diversify an investment portfolio is being explored. However, despite the strong growth of the cryptocurrency market, research on the cryptocurrency diversification portfolio is limited (W. Liu, 2019). The question of whether it is possible to diversify stocks with cryptocurrencies is unsolved (Goodell & Goutte, 2021). Investing in cryptocurrency involves high risks due to unpredictable price changes and security. The prices of cryptocurrencies are difficult to define because the literature emphasizes that cryptocurrencies have no underlying assets, so their prices depend on investors' expectations for the future. The risks posed by cryptocurrencies call for more in-depth research to find the most appropriate cryptocurrency investment strategy. Properly assessing the diversification feature of cryptocurrencies, they could become a full and useful part of the investment portfolio in the future.

It is important to note that the world is currently experiencing a health crisis that is affecting the financial markets. Goodell and Goutte (2021) argue that the COVID-19 period is expected to change the dynamics of financial markets, so that even the topics explored in detail need to be updated, so it is crucial that researchers study cryptocurrency correlations, hedging, and diversification during this crisis.

Problem of the research. Is it suitable to use cryptocurrency to invest in portfolio diversification?

Research objects. Investment portfolio diversification in cryptocurrencies.

Aim of the article. To identify cryptocurrencies suitable for investment and portfolio diversification.

Tasks of the research:

1. To analyze the theoretical aspects of investment portfolio diversification in cryptocurrencies;
2. To make the research methodology;
3. To study the suitability of different cryptocurrencies for portfolio diversification.

Research methods. Scientific literature analysis, statistical data analysis, multicriteria evaluation, correlation analysis.

1. Theoretical analysis of investment portfolio diversification in cryptocurrencies

The financial sector is undergoing fundamental changes due to globalization processes, technologies and increasing social needs, along with the growing popularity of cryptocurrencies (Binda, 2020). Cvetkova (2018) identifies the cryptocurrency as the new product of historical development and progress that will become an integral part of a market economy in the near future. In many parts of the world, the question remains whether cryptocurrencies are money because they exist only in cyberspace, have no physical counterpart, and are based on computer code (Bondarenko et al., 2019). Encrypted data cannot be copied, so it can be said that the cryptocurrency is protected against counterfeiting (Bondarenko et al., 2019). The primary reason for creating Bitcoin was the motivation to create digital cash: a payment system that would be similar to cash, incorporate the useful features of cash, and allow electronic transactions (Berentsen & Schär, 2018). Bitcoin is generally considered to be the main decentralized digital currency (Maleki et al., 2020), which has become popular due to its proposed anonymity in transactions and independence from traditional financial service providers (David et al., 2021).

Inci and Lagasse (2019) define cryptocurrency as online cash that can be considered as valuable digital information as long as no one else has access to value-added information, and its creation is based on the need for online cash and the pursuit of anonymity. A cryptocurrency can be defined as a virtual currency created to act as an exchange medium using cryptography and is based on electronic connection (İçellioğlu & Öner, 2019). Binda (2020) writes that cryptocurrencies are a limited-circulation digital or virtual currency that is secured by cryptographic solutions, not controlled by central authorities, and protected from government interference and manipulation. According to Saksonova and Kuzmina-Merlin (2019), Tapscott and Tapscott (2017), Berentsen and Schär (2018), Inci and Lagasse (2019), the following main features of cryptocurrencies can be distinguished:

- Decentralized – there is no central authority with the exclusive right to manage and supervise the accounts;
- Transaction privacy – users can choose to remain anonymous;
- No guarantees – no conditions of protection and liability, and no insurance;
- Blockchain technology – transaction records are linked to each previous record;
- Use of nicknames – nicknames allow users to remain anonymous;
- Unregulated – no government or organization controls any cryptocurrency;
- Anonymous – an anonymous system of operations without bank accounts.

The pursuit of anonymity in financial transactions has not led to very good associations, and such transactions are often associated with fraud or crime. Currently, cryptocurrencies have left their dark side and become the object of research in asset and portfolio management (Trimborn et al., 2020). Cryptocurrencies differ mainly in their value, transaction speed, usage and volatility (Inci & Lagasse, 2019). Cryptocurrencies have become the subject of discussion on the Internet and in the media, attracting the attention of scientists, investors, and the government (Mohammed, 2018). Cryptocurrencies have become a profitable object to invest and this has led to their development (Bondarenko et al., 2019). Cryptocurrencies are attractive to investors because of the benefits they provide, although the primary purpose of creating them was not to invest. According to Inci and Lagasse (2019), Trimborn et al. (2020), Mohammed (2018) can be identified the main benefits of investing in cryptocurrencies:

- As a hedging instrument;
- The advantage of diversification;
- Improves risk and return ratio;
- High return on investment;
- There are no fees that are normally charged in the presence of financial intermediaries.

Alternative investments are popular and used in portfolio management, including real estate, commodities, private equity funds, hedge funds due to lower correlation with traditional asset classes: stocks, bonds and cash equivalents for good portfolio diversification (Lee et al., 2018). The scientific literature discusses whether cryptocurrencies could be one of the alternatives to improve portfolio risk management. Although cryptocurrencies have huge market capitalization and investors' willingness to invest, some important strategic issues still need to be solved that cryptocurrencies would play an important role in the financial world (Mohammed, 2018). Cryptocurrencies are receiving a lot of attention from investors and analysts as a new form of investment offering high returns, but can also lead to high losses (Kyriazis et al., 2019). Cryptocurrencies, as a form of investment, are preferred for resilience control and any intervention (Kyriazis et al., 2019). Investors in cryptocurrencies understand that such an investment involves high risk. Although academic research shows the benefits of Bitcoin for portfolio efficiency, investors are still skeptical about such an investment (Inci & Lagasse, 2019). According to Inci and Lagasse (2019), Trimborn et al. (2020) the main risks of investing in cryptocurrencies are:

- Illiquidity;
- Thefts;
- Fraud;
- Ransomware attacks / hacking;
- Strict government regulation is possible;
- Price volatility;
- Operational risk.

When including cryptocurrencies in a portfolio, it is necessary to pay attention to their low liquidity compared to traditional assets; if you want to include cryptocurrencies based on market capitalization and stocks in the same portfolio, over-weighting cryptocurrencies should be avoided (Trimborn et al., 2020). The cryptocurrency market is highly volatile, so it is important for investors to understand the risk structure of cryptocurrency returns before investing and that the high volatility of the cryptocurrency market is based on investors

sentiment rather than on the chang of fundamental factors (Mohammed, 2018). It is also important need to evaluate other factors: storage security, reporting, a decentralized and autonomous cryptocurrency management structure, the complexity of managing an unregulated system (Mohammed, 2018).

Trimborn et al. (2020) reveal that the inclusion of cryptocurrencies in a portfolio increases returns compared to portfolios that consist only of traditional assets and can certainly improve the risk and return ratio. Although there is insufficient research, these studies reveal that cryptocurrencies have the advantage of diversification in the short term because they are separated from common financial markets (Inci & Lagasse, 2019). Corbet et al. (2018) reveal the benefits of diversification provided by cryptocurrencies in the investment portfolio as they are decoupled from underlying assets, but notes the dependence of cryptocurrency market behavior on monetary policy and regulated arbitrage. Cryptocurrencies may be a good choice for diversifying portfolio risk due to the weak correlation between cryptocurrencies and traditional assets, but it should be understood that cryptocurrencies are still in an experimental stage (Lee et al., 2018) and the role of cryptocurrencies in future financial markets remains unclear (Huynh et al., 2020). Investors in cryptocurrencies need more information to be able to make sure they are investing properly and mitigating risk (David et al., 2021). Cryptocurrencies have weak correlation with each other in terms of market capitalization and are unrelated to traditional assets, making them interesting for the diversification effect (Trimborn et al., 2020).

Research related to investing in cryptocurrencies aims to determine whether cryptocurrencies can be used for investment, assessing their benefits and risks. The ratio of returns to risk, how they correlate with traditional investment assets, the benefits of risk diversification in the investment portfolio, the probability that cryptocurrencies will remain valid in the future, and the most suitable investment horizon, are assessed. The process of evaluating highly volatile cryptocurrencies is complex and depends on many parameters (Kyriazis et al., 2019). Investors and financial analysts are constantly looking for a simple and informative indicator to measure asset prices. Recent efforts have focused on cryptocurrencies to discover how to price cryptocurrency assets in order not only to understand prices but also to suggest practical investment strategies (Y. Liu & Zhang, 2021) The found optimal indicator should reflect the cryptocurrency market – it is overvalued or undervalued (Y. Liu & Zhang, 2021). Lee et al. (2018) reveal a very small correlation between the cryptocurrency index CRIX and traditional assets, on that basis cryptocurrencies are a good diversifier of traditional assets. Brauneis and Mestel (2019) note the high risk mitigation potential when using more than one cryptocurrency, this approach may attract investors to cryptocurrencies who are reluctant to take on too much risk inherent in the cryptocurrency market. Bondar et al. (2020) conducted a study on the efficiency of the use of cryptocurrencies as investment resources, hypothesizing that the inclusion of CRIX currency index components in the investment portfolio improves its quality, which has been confirmed. Given the different characteristics of cryptocurrencies, investors can take advantage of the potential benefits of diversification (Demiralay & Bayracı, 2021).

Goodell and Goutte (2021) point to the COVID-19 period that affects financial markets, so even well researched topics should be updated to reflect how they have changed

during this crisis. Goodell and Goutte (2021) studied cryptocurrencies: Bitcoin, Ethereum, Litecoin and Tether, and stock indices: SWISS index, IBEX 35, DAX, CAC 40, FTSE 100, EUROSTOXX and S&P 500 and observed changes in the interaction of some cryptocurrencies due to COVID-19, however, a small role for Bitcoin, Ethereum and Litecoin was found in diversifying shares during the period before COVID-19 and during COVID-19 period. The possibility of diversifying the investment portfolio in different cryptocurrencies should be further and more explored, as there is still no consensus. Also, no single model has been found and presented on how the benefits of diversification in the investment portfolio can be properly assessed.

2. Research methodology

The research methodology is based on the research methods described in the scientific literature. The aim of the research is to identify cryptocurrencies suitable for investment and portfolio diversification. The scheme of this research is shown in Figure 1. Calculations are performed with Excel and SPSS programs.

In the first stage of the research, a matrix of 10 cryptocurrencies and 6 evaluable criteria is formed, according to which the data ranking is performed. The daily returns of the selected 10 cryptocurrencies, which make up the B10 BITA CRYPTO 10 INDEX, are calculated in order to further evaluate the cryptocurrencies according to the selected criteria.

The first criterion chosen is average market capitalization, because according to Saksonova and Kuzmina-Merlino (2019), the main economic indicators of cryptocurrencies are exchange rate and capitalization. Saksonova and Kuzmina-Merlino (2019) note that the cryptocurrency market is still a small part of the total financial market, so the capitalization of the cryptocurrency market is a maximizing criterion in this assessment. The second criterion reflecting market liquidity is the average daily volume of cryptocurrencies. Brauneis et al.

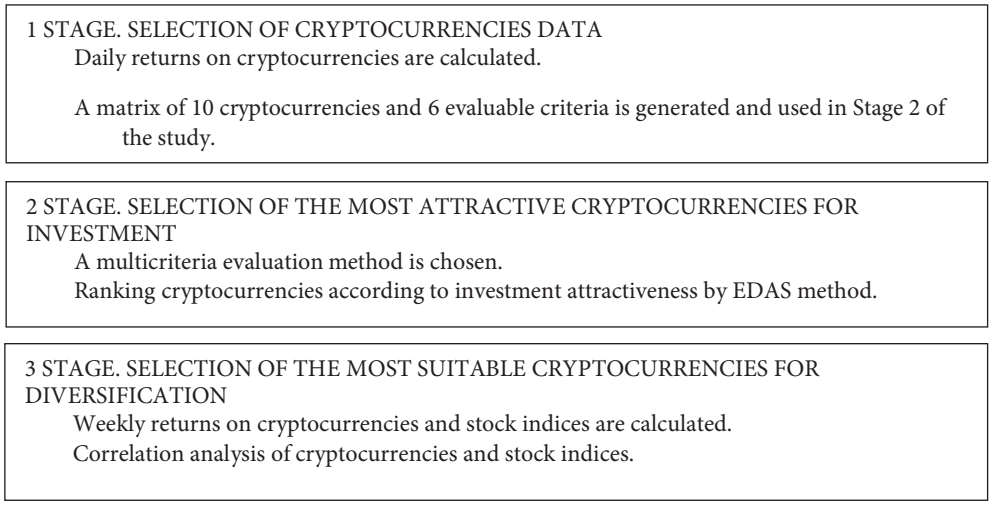

Figure 1. Research scheme (source: compiled by the authors)

(2021) argue that the volume of cryptocurrencies is one of the factors strongly affecting the liquidity of cryptocurrencies. Cryptocurrencies due to high liquidity – high volume is identified as an investment opportunity (Bonneau et al., 2015), so the daily volume of a cryptocurrency is a maximizing criterion in this assessment. Other criteria are chosen taking into account that the goal of the investment portfolio is to achieve the optimal combination of risk and return (Saksonova & Kuzmina-Merlino, 2019). According to Inci and Lagasse (2019), cryptocurrencies are valued as a separate investment opportunity based on risk and return characteristics. Thus, the remaining four criteria for the cryptocurrencies under research were selected: daily average return, daily maximum return, daily minimum return – maximizing criteria, as investors seek the highest possible return, and risk reflecting daily return standard deviation – minimizing criteria because investors typically avoid risk. The cryptocurrency evaluation criteria are distributed equally in the matrix. Based on Inci and Lagasse (2019), the following equation is used to calculate the daily returns on cryptocurrencies:

$$r_t = \ln\left(P_t\right) - \ln\left(P_{t-1}\right), \tag{1}$$

where: r_t – daily return on the cryptocurrency; P_t – cryptocurrency day closing price; P_{t-1} – the closing price of the cryptocurrency of the previous day.

Based on Dasman (2021), the following equation is used to calculate the standard deviation of the daily return on cryptocurrencies:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(r_i - r\right)^2}, \tag{2}$$

where: σ – standard deviation (risk) of the cryptocurrency daily return; r_i – daily return of the cryptocurrency; r – average daily return of the cryptocurrency; n – number of observations.

In the second stage of the reseach, ranking using the EDAS (Evaluation based on Distance from Average Solution) method is performed (Ghorabaee et al., 2015). According to Ghorabaee et al. (2015), this newly proposed assessment method is useful when conflicting criteria are used in the study. The EDAS method is useful in this research because cryptocurrencies have quite contradictory properties. Investing in cryptocurrencies involves high profits and losses. High returns are always associated with high risk, and investors are also interested in other criteria for cryptocurrencies, which makes it quite difficult to optimally select cryptocurrencies for investment. This method is also more efficient compared to alternative multicriteria evaluation methods because it is related to the distance from the average solution (AV) (Ghorabaee et al., 2015). The EDAS evaluation method, based on a matrix of cryptocurrencies selected in the first step and their criteria, consists of eight main steps and the ranking in the last 9 steps.

Step 1. The average solution AV_j is sought according to the following equation (Ghorabaee et al., 2015):

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}, \tag{3}$$

where: AV_j – the average of the criteria; X_{ij} – primary evaluation; n – the number of primary evaluations.

Step 2. If criterion *j* is maximizing, the positive distance from the average PDA_{ij} is calculated by the following equation (Ghorabaee et al., 2015):

$$PDA_{ij} = \frac{\max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j}, \tag{4}$$

where: PDA_{ij} – positive distance from the average; X_{ij} – primary evaluation; AV_j – the average of the criteria.

If criterion *j* is minimizing, then the positive distance from the average PDA_{ij} is calculated according to the following equation (Ghorabaee et al., 2015):

$$PDA_{ij} = \frac{\max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j}, \tag{5}$$

where: PDA_{ij} – positive distance from the average; X_{ij} – primary evaluation; AV_j – the average of the criteria.

Step 3. If criterion *j* is maximizing, the negative distance from the average NDA_{ij} is calculated by the following equation (Ghorabaee et al., 2015):

$$NDA_{ij} = \frac{\max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j}, \tag{6}$$

where: NDA_{ij} – negative distance from the average; X_{ij} – primary evaluation; AV_j – the average of the criteria.

If criterion *j* is minimizing, then the negative distance from the average NDA_{ij} is calculated according to the following equation (Ghorabaee et al., 2015):

$$NDA_{ij} = \frac{\max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j}, \tag{7}$$

where: NDA_{ij} – negative distance from the average; X_{ij} – primary evaluation; AV_j – the average of the criteria.

Step 4. Calculate the weighted PDA_{ij} sum SP_i according to the following equation (Ghorabaee et al., 2015):

$$SP_i = \sum_{j=1}^{m} \omega_j \cdot PDA_{ij}, \tag{8}$$

where: SP_i – the weighted sum of the positive distances from the average; PDA_{ij} – positive distance from the average; ω_j – criteria weights.

Step 5. Calculate the weighted NDA_{ij} sum SN_i according to the following equation (Ghorabaee et al., 2015):

$$SN_i = \sum_{j=1}^{m} \omega_j \cdot NDA_{ij}, \tag{9}$$

where: SN_i – the weighted sum of the negative distances from the average; NDA_{ij} – negative distance from the average; ω_j – criteria weights.

Step 6. The normalization of SP_i is performed according to the following equation (Ghorabaee et al., 2015):

$$NSP_i = \frac{SP_i}{\max_i\left(SP_i\right)}, \tag{10}$$

where: NSP_i – the normalized weighted sum of the positive distances from the average; SP_i – the weighted sum of the positive distances from the average.

Step 7. The normalization of SN_i is performed according to the following equation (Ghorabaee et al., 2015):

$$NSN_i = 1 - \frac{SN_i}{\max_i\left(SN_i\right)}, \tag{11}$$

where: NSP_i – the normalized weighted sum of the negative distances from the average; SN_i – the weighted sum of the negative distances from the average.

Step 8. The score AS_i is calculated according to the following equation (Ghorabaee et al., 2015):

$$AS_i = \frac{1}{2}\left(NSP_i + NSN_i\right), \tag{12}$$

where: AS_i – evaluation score; NSP_i – the normalized weighted sum of the positive distances from the average; NSN_i – the normalized weighted sum of the negative distances from the average.

Step 9. Ranking is performed according to the evaluation score of AS_i. The higher the value of AS_i, the higher the rank of the evaluated cryptocurrencies.

In the third stage of the study, a correlation analysis is performed. The correlation coefficient shows the strength of the linear dependence of the studied variables (Čekanavičius & Murauskas, 2004). According to Schober and Schwarte (2018), the Pearson correlation coefficient is commonly used for generally normally distributed data. If the assumption of normality of the variables is incorrect or the data sample is less than 20 observations, the Spearman correlation coefficient is applied (Čekanavičius & Murauskas, 2004).

Based on Čekanavičius and Murauskas (2001), the following equation is used to calculate the Pearson correlation coefficient between two investment assets:

$$R_P = \frac{\left(n-1\right)\sum r_i r_j - \left(\sum r_i\right)\left(\sum r_j\right)}{\sqrt{\left(\left(n-1\right)\sum r_i^2 - \left(\sum r_i\right)^2\right)\left(\left(n-1\right)\sum r_j^2 - \left(\sum r_j\right)^2\right)}}, \tag{13}$$

where: R_P – Pearson correlation coefficient; r_i and r_j return on investment assets; n is the number of observations.

The correlation is considered very strong when R is from 0.90 to 1; strong – R from 0.70 to 0.89; medium strength – R from 0.40 to 0.69; weak – R from 0.10 to 0.39; very weak (insignificant) – R from 0.00 to 0.10 (Schober & Schwarte, 2018). The strength of the correlation is appropriate for the same negative estimates. The negative correlation coefficient shows the inverse dependence of the variables (Čekanavičius & Murauskas, 2004). Based on

Čekanavičius and Murauskas (2004), the following equation is used to calculate the Spearman correlation coefficient between two investment assets:

$$R_S = \frac{\sum_{i,j=1}^{n}\left(R_{ri} - \frac{n+1}{2}\right)\left(R_{rj} - \frac{n+1}{2}\right)}{\sqrt{\sum_{i,j=1}^{n}\left(R_{ri} - \frac{n+1}{2}\right)^2}\sqrt{\sum_{i,j=1}^{n}\left(R_{rj} - \frac{n+1}{2}\right)^2}}, \quad (14)$$

where: R_S – the Spearman correlation coefficient; R_{ri} and R_{rj} – rates of return on investment assets; n is the number of observations.

The Spearman correlation coefficient is the same Pearson correlation coefficient is only calculated not for the values of the variables, but for their ranks (Čekanavičius & Murauskas, 2004).

The statistical significance of this correlation coefficient needs to be determined. Two hypotheses are used to test significance: H_0 – correlation coefficient is zero; H_1 – correlation coefficient is not zero (Bilevičienė & Jonušauskas, 2011). If the significance level p value is lower than the selected significance level, then the hypothesis H_0 is rejected and the correlation is considered significant, if the p value is higher or the same as the significance level, then the correlation is insignificant (Bilevičienė & Jonušauskas, 2011).

To determine whether the sample has a normal distribution, "it is possible to apply the criteria of Kolmogorov-Smirnov and Shapiro-Wilk (when data are less than 50)" (Bilevičienė & Jonušauskas, 2011, p. 93). If the observed significance level is lower than the significance level of 0.05, it can be concluded that the distribution is not normal (Bilevičienė & Jonušauskas, 2011).

According to Ankenbrand and Bieri (2018), the weak correlation between cryptocurrencies and well-established asset classes promotes the potential for portfolio diversification, resulting in a more favorable risk and return ratio for such portfolios. The correlation of the selected 10 cryptocurrencies with the traditional asset – stock indices is studied. Correlation analysis is performed by SPSS program.

3. Research results

In the first stage of reseach, ten leading cryptocurrencies are selected which are traded during 2021: Bitcoin (BTC), Ethereum (ETH), Cardano (ADA), Binance Coin (BNB), Dogecoin (DOGE), Litecoin (LTC), Chainlink (LINK), Bitcoin Cash (BCH), Terra (LUNA), XRP (XRP). These cryptocurrencies are included in the B10 BITA CRYPTO 10 INDEX (BITA, n.d.).

Criteria with equal weights are selected to evaluate cryptocurrencies as an investment vehicle: average market capitalization (max), average daily volume of cryptocurrencies (max), daily average return (max), daily maximum return (max), daily minimum return (max) and daily returns standard deviation (min). The resulting matrix of cryptocurrencies and criteria is presented in Table 1.

Table 1. Cryptocurrencies and Criteria Matrix (source: compiled by the authors based on CoinMarketCap, n.d.)

2021	Average market capitalization (Market Cap) $	Average volume (24 h) $	Daily average return	Daily maximum return	Daily minimum return	Daily returns standard deviation
	max	max	max	max	max	min
Weights	0.17	0.17	0.17	0.17	0.17	0.17
Bitcoin	889783910133	47155742196	0.00125	0.17182	–0.14811	0.04210
Ethereum	325038670844	27280819104	0.00444	0.23070	–0.31746	0.05623
Cardano	48422576869	4216065822	0.00553	0.27944	–0.30111	0.06689
Binance Coin	61106456287	2851188715	0.00715	0.52924	–0.40443	0.07320
Dogecoin	26745065748	4142663711	0.00934	1.51621	–0.51493	0.13251
Litecoin	12499754980	4349674456	0.00041	0.24841	–0.44119	0.06275
Chainlink	11589439351	2241870849	0.00138	0.27562	–0.46602	0.07426
Bitcoin Cash	11383281686	3727390027	0.00063	0.42082	–0.43461	0.06870
Terra	9407722157	821744133	0.01341	0.64099	–0.48774	0.10125
XRP	39640149532	6086639830	0.00344	0.44461	–0.39608	0.07708

In the second stage of the study, ranking using the EDAS method is performed. In the first step of this method, the average solution AV_j according to Eq. (3) is calculated. The calculated values are given in Table 2.

Table 2. AV_j values (source: compiled by the authors)

2021	Average market capitalization (Market Cap) $	Average volume (24 h) $	Daily average return	Daily maximum return	Daily minimum return	Daily returns standard deviation
AV_j	143561702759	10287379884	0.00470	0.47579	–0.39117	0.07550

In the second step, for the maximizing criteria, the positive distance from the average PDA_{ij} is calculated according to Eq. (4), for the minimizing criteria, the positive distance from the average PDA_{ij} is calculated according to Eq. (5). The calculated values are given in Table 3.

In the third step, for the maximizing criteria, the negative distance from the average NDA_{ij} is calculated according to Eq. (6), for the minimizing criteria, the negative distance from the average NDA_{ij} is calculated according to Eq. (7). The calculated values are given in Table 4.

Table 3. PDA_{ij} (source: compiled by the authors)

2021	Average market capitalization (Market Cap) $	Average volume (24 h) $	Daily average return	Daily maximum return	Daily minimum return	Daily returns standard deviation
	max	max	max	max	max	min
Weights	0.17	0.17	0.17	0.17	0.17	0.17
Bitcoin	5.1979	3.5838	0.0000	0.0000	–0.6214	0.4424
Ethereum	1.2641	1.6519	0.0000	0.0000	–0.1884	0.2552
Cardano	0.0000	0.0000	0.1761	0.0000	–0.2302	0.1141
Binance Coin	0.0000	0.0000	0.5218	0.1124	0.0000	0.0304
Dogecoin	0.0000	0.0000	0.9887	2.1867	0.0000	0.0000
Litecoin	0.0000	0.0000	0.0000	0.0000	0.0000	0.1688
Chainlink	0,0000	0.0000	0,0000	0.0000	0.0000	0.0163
Bitcoin Cash	0.0000	0.0000	0.0000	0.0000	0.0000	0.0900
Terra	0.0000	0.0000	1.8535	0.3472	0.0000	0.0000
XRP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4. NDA_{ij} (source: compiled by the authors)

2021	Average market capitalization (Market Cap) $	Average volume (24 h) $	Daily average return	Daily maximum return	Daily minimum return	Daily returns standard deviation
	max	max	max	max	max	min
Weights	0.17	0.17	0.17	0.17	0.17	0.17
Bitcoin	0.0000	0.0000	0.7338	0.6389	0.0000	0.0000
Ethereum	0.0000	0.0000	0.0540	0.5151	0.0000	0.0000
Cardano	0.6627	0.5902	0.0000	0.4127	0.0000	0.0000
Binance Coin	0.5744	0.7228	0.0000	0.0000	–0.0339	0.0000
Dogecoin	0.8137	0.5973	0.0000	0.0000	–0.3164	0.7552
Litecoin	0.9129	0.5772	0.9129	0.4779	–0.1279	0.0000
Chainlink	0.9193	0.7821	0.7070	0.4207	–0.1913	0.0000
Bitcoin Cash	0.9207	0.6377	0.8652	0.1155	–0.1111	0.0000
Terra	0.9345	0.9201	0.0000	0.0000	–0.2469	0.3411
XRP	0.7239	0.4083	0.2672	0.0655	–0.0125	0.0210

In the fourth step, the weighted sum of $PDA_{ij} - SP_i$ is calculated according to Eq. (8). In the fifth step, the weighted sum of $NDA_{ij} - SN_i$ is calculated according to Eq. (9). In the sixth step, normalization of SP_i is performed according to formula 10 to obtain NSP_i. In the seventh step, normalization of SN_i is performed according to Eq. (11) to obtain NSN_i. In the eighth step, the evaluation score AS_i is calculated according to Eq. (12). In the ninth step, the

ranking according to the evaluation score of AS_i is performed, the higher the value of AS_i the higher the ranking. The results are shown in Table 5.

Table 5. Cryptocurrencies ranking (source: compiled by the authors)

2021	SP_i	SN_i	NSP_i	NSN_i	AS_i	Ranking
Bitcoin	1.4338	0.2288	1.0000	0.5014	0.7507	1
Ethereum	0.4971	0.0948	0.3467	0.7933	0.5700	2
Cardano	0.0100	0.2776	0.0070	0.3950	0.2010	7
Binance Coin	0.1108	0.2105	0.0773	0.5411	0.3092	4
Dogecoin	0.5292	0.3083	0.3691	0.3281	0.3486	3
Litecoin	0.0281	0.4588	0.0196	0.0000	0.0098	10
Chainlink	0.0027	0.4396	0.0019	0.0419	0.0219	9
Bitcoin Cash	0.0150	0.4047	0.0105	0.1180	0.0642	8
Terra	0.3668	0.3248	0.2558	0.2921	0.2740	5
XRP	0.0000	0.2456	0.0000	0.4648	0.2324	6

Ranking using the EDAS method showed that the leading cryptocurrency according to 2021 data is Bitcoin. This result only confirms that investor interest in Bitcoin remains strong. This result may have led to Bitcoin to have the highest average market capitalization in 2021. Bitcoin accounted for 70% of the total cryptocurrency market on January 1, 2021 (CoinMarketCap, n.d.). In terms of average volume, which shows cryptocurrency liquidity, Bitcoin is also first, although in terms of average daily return of 0.13%, Bitcoin is in eighth place, but it is important to note that the risk factor – the daily returns standard deviation was the smallest of all 10 cryptocurrencies – 4.21% in 2021. In second place – Ethereum. This may have led, that this cryptocurrency is second only to Bitcoin in terms of market capitalization. The ranking results obtained only confirm that these cryptocurrencies can be found in the first and second place in the cryptocurrency indices. In third place – Dogecoin. This result may have been due to the observed higher average return on this cryptocurrency than on the remaining cryptocurrencies, but it is important to note that this cryptocurrency had the highest risk. In the third stage of the research, a correlation analysis of the selected cryptocurrencies is performed.

The correlation of 10 cryptocurrencies with traditional assets – stock indices – is investigated. The American stock market is represented by the S&P 500 index, the European stock market by Euro Stoxx 50, the German stock market by DAX index, the French stock market by CAC 40 index (Yahoo Finance, n.d.). Cryptocurrencies are traded daily but stocks are traded only on work days, so it was chosen to assess the correlation between the weekly returns of cryptocurrencies and stocks. Weekly returns are calculated according to formula 1: r_t – weekly return; P_t – weekly closing price; $P_{(t-1)}$ is the closing price of the previous week. The weekly closing prices of cryptocurrencies and stock indices are obtained from Yahoo Finance (n.d.).

Table 6. Correlation (source: compiled by the authors)

2021	S&P 500	Euro Stoxx 50	DAX	CAC 40
Bitcoin	0.266	0.293*	0.157	0.349*
Ethereum	0.300*	0.156	0.088	0.252
Cardano	0.021	0.093	0.024	0.132
Binance Coin	0.249	0.262	0.123	0.363**
Dogecoin	0.101	0.151	0.181	0.148
Litecoin	0.183	0.214	0.091	0.294*
Chainlink	0.143	0.169	0.078	0.251
Bitcoin Cash	0.187	0.157	0,060	0.235
Terra	–0.039	0.074	–0.031	0.100
XRP	0.238	0.198	0.186	0.227

Note: ** – The correlation is statistically significant at the 0.01 level; * – The correlation is statistically significant at the 0.05 level.

The Kolmogorov-Smirnov test (52 observations) was performed to determine which correlation coefficient to use. The results of the normal distribution test showed that the distribution of Bitcoin, Cardano, Litecoin, Chainlink, Bitcoin Cash, Terra, S&P 500 index and DAX index was normal. Based on these results, a Pearson correlation coefficient can be applied between these assets. Ethereum, Binance Coin, Dogecoin, XRP, Euro Stoxx 50, and CAC 40 index normality test results indicated that the distribution was not normal. The Spearman correlation coefficient is used to assess the correlation with these assets. The correlation results are presented in Table 6.

Correlation analysis showed that all the cryptocurrencies studied could be used to diversify the investment portfolio, as they had a very weak or weak and in most cases statistically insignificant correlation with traditional assets. Terra had a very weak and statistically insignificant correlation with all stock indices under study. The inclusion of non-correlated assets in the investment portfolio leads to better diversification, a better combination of expected returns and risk, and more efficient management of the entire portfolio. The analysis showed that the returns on cryptocurrencies are not related to the stock indices under study, so it is feasibility to include all the cryptocurrencies under study in the investment portfolio for diversification.

Conclusions

Based on the literature review, it can be stated that cryptocurrencies are still controversial. Although cryptocurrencies are viewed negatively because of the risks they pose, they are increasingly being considered for the benefits of diversifying their investment portfolios. When considering a cryptocurrency as an investment and portfolio diversification tool, it is important to note that investors are not insured in any way in the event of a loss, which would result in a lack of government intervention and regulation at this point. More importantly, however, government intervention should be very careful and prudent so as not

to cause major illiquidity problems and destroy the cryptocurrencies as a new investment vehicle, or worse, to disrupt this market.

The application of the EDAS method in this study allows for the optimal selection of the most attractive cryptocurrencies for investment. Due to the contradictory characteristics of cryptocurrencies and the goals pursued by investors, such as high return on investment, low risk and liquidity, this is usually quite difficult to do. The application of correlation analysis provides an opportunity to select cryptocurrencies suitable for portfolio diversification. Cryptocurrencies valued in these two aspects could be considered for inclusion in the investment portfolio.

A multicriteria assessment revealed that Bitcoin is, as might be expected, the leading cryptocurrency, but this result could have been due to an exceptionally high market capitalization that would be difficult to compare with other cryptocurrencies. Assessing the correlation of all studied cryptocurrencies confirms the unique feature of cryptocurrencies highlighted in studies – a weak or very weak correlation with traditional assets. All 10 cryptocurrencies had a very weak or weak correlation with all stock indices under study.

Based on the results of this study, the inclusion of all studied cryptocurrencies in the investment portfolio could be considered for diversification, but it is necessary to take into account the ranking results obtained and select from the most attractive for investment. Based on the results of the ranking and correlation analysis, the inclusion of Bitcoin, Etherium and Dogecoin in the investment portfolio based on S&P500, Euro Stoxx 50, DAX and CAC 40 could be considered. Terra could be an interesting investment when considering the benefits of diversification, although this cryptocurrency ranks fifth, but has a very weak and insignificant relationship with all the stock indices analyzed.

References

Andrianto, Y. (2017). The effect of cryptocurrency on investment portfolio effectiveness. *Journal of Finance and Accounting*, *5*(6), 229. https://doi.org/10.11648/j.jfa.20170506.14

Ankenbrand, T., & Bieri, D. (2018). Assessment of cryptocurrencies as an asset class by their characteristics. *Investment Management and Financial Innovations*, *15*(3), 169–181. https://doi.org/10.21511/imfi.15(3).2018.14

Berentsen, A., & Schär, F. (2018). A short introduction to the world of cryptocurrencies. *Federal Reserve Bank of St. Louis Review*, *100*(1), 1–16. https://doi.org/10.20955/r.2018.1-16

Bilevičienė, T., & Jonušauskas, S. (2011). *Statistinių metodų taikymas rinkos tyrimuose*. Mykolo Romerio universitetas.

Binda, J. (2020). Cryptocurrencies – problems of the high-risk instrument definition. *Investment Management and Financial Innovations*, *17*(1), 227–241. https://doi.org/10.21511/imfi.17(1).2020.20

BITA. (n.d.). *The Index Technology Company*. Retrieved December 5, 2021, from https://www.bitadata.com/

Bondar, M. I., Stovpova, A. S., Ostapiuk, N. A., Biriuk, O. H., & Tsiatkovska, O. V. (2020). Efficiency of using cryptocurrencies as an investment asset. *International Journal of Criminology and Sociology*, *9*, 2944–2954. https://www.lifescienceglobal.com/pms/index.php/ijcs/article/view/8078

Bondarenko, O., Kichuk, O., & Antonov, A. (2019). The possibilities of using investment tools based on cryptocurrency in the development of the national economy. *Baltic Journal of Economic Studies*, *5*(2), 10. https://doi.org/10.30525/2256-0742/2019-5-2-10-17

Bonneau, J., Miller, A., Clark, J., Narayanan, A., Kroll, J. A., & Felten, E. W. (2015). SoK: Research perspectives and challenges for bitcoin and cryptocurrencies. In *Proceedings – IEEE Symposium on Security and Privacy* (pp. 104–121). IEEE. https://doi.org/10.1109/SP.2015.14

Brauneis, A., & Mestel, R. (2019). Cryptocurrency-portfolios in a mean-variance framework. *Finance Research Letters*, *28*, 259–264. https://doi.org/10.1016/j.frl.2018.05.008

Brauneis, A., Mestel, R., & Theissen, E. (2021). What drives the liquidity of cryptocurrencies? A long-term analysis. *Finance Research Letters*, *39*. https://doi.org/10.1016/j.frl.2020.101537

Čekanavičius, V., & Murauskas, G. (2001). *Statistika ir jos taikymai, I*. TEV.

Čekanavičius, V., & Murauskas, G. (2004). *Statistika ir jos taikymai, II*. TEV.

Corbet, S., Meegan, A., Larkin, C., Lucey, B., & Yarovaya, L. (2018). Exploring the dynamic relationships between cryptocurrencies and other financial assets. *Economics Letters*, *165*, 28–34. https://doi.org/10.1016/j.econlet.2018.01.004

CoinMarketCap. (n.d.). *Cryptocurrency prices, charts and market capitalizations*. Retrieved December 5, 2021, from https://coinmarketcap.com/

Cvetkova, I. (2018). Cryptocurrencies legal regulation. *BRICS Law Journal*, *5*(2), 128–153. https://doi.org/10.21684/2412-2343-2018-5-2-128-153

Dasman, S. (2021). Analysis of return and risk of cryptocurrency bitcoin asset as investment instrument. *Accounting and Finance Innovations*. https://doi.org/10.5772/intechopen.99910

David, S. A., Inacio, C. M. C., Nunes, R., & Machado, J. A. T. (2021). Fractional and fractal processes applied to cryptocurrencies price series. *Journal of Advanced Research*, *32*, 85–98. https://doi.org/10.1016/j.jare.2020.12.012

Demiralay, S., & Bayracı, S. (2021). Should stock investors include cryptocurrencies in their portfolios after all? Evidence from a conditional diversification benefits measure. *International Journal of Finance and Economics*, *26*(4), 6188–6204. https://doi.org/10.1002/ijfe.2116

Ghorabaee, M. K., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica*, *26*(3), 435–451. https://doi.org/10.15388/Informatica.2015.57

Goodell, J. W., & Goutte, S. (2021). Diversifying equity with cryptocurrencies during COVID-19. *International Review of Financial Analysis*, *76*. https://doi.org/10.1016/j.irfa.2021.101781

Huynh, T. L. D., Hille, E., & Nasir, M. A. (2020). Diversification in the age of the 4th industrial revolution: The role of artificial intelligence, green bonds and cryptocurrencies. *Technological Forecasting and Social Change*, *159*. https://doi.org/10.1016/j.techfore.2020.120188

İçellioğlu, C. S., & Öner, S. (2019). An Investigation on the Volatility of Cryptocurrencies by means of Heterogeneous Panel Data Analysis. *Procedia Computer Science*, *158*, 913–920. https://doi.org/10.1016/j.procs.2019.09.131

Inci, A. C., & Lagasse, R. (2019). Cryptocurrencies: applications and investment opportunities. *Journal of Capital Markets Studies*, *3*(2), 98–112. https://doi.org/10.1108/JCMS-05-2019-0032

Kyriazis, N. A., Daskalou, K., Arampatzis, M., Prassa, P., & Papaioannou, E. (2019). Estimating the volatility of cryptocurrencies during bearish markets by employing GARCH models. *Heliyon*, *5*(8). https://doi.org/10.1016/j.heliyon.2019.e02239

Lee, D. K. C., Guo, L., & Wang, Y. (2018). Cryptocurrency: A new investment opportunity? *Journal of Alternative Investments*, *20*(3), 16–40. https://doi.org/10.3905/jai.2018.20.3.016

Liew, J., Li, R., Budavári, T., & Sharma, A. (2019). Cryptocurrency investing examined. *The Journal of the British Blockchain Association*, *2*(2), 1–12. https://doi.org/10.31585/jbba-2-2-(2)2019

Liu, W. (2019). Portfolio diversification across cryptocurrencies. *Finance Research Letters*, *29*, 200–205. https://doi.org/10.1016/j.frl.2018.07.010

Liu, Y., & Zhang, L. (2021). *Cryptocurrency valuation: An explainable AI approach*. https://doi.org/ 10.2139/ssrn.3657986

Maleki, N., Nikoubin, A., Rabbani, M., & Zeinali, Y. (2020). Bitcoin price prediction based on other cryptocurrencies using machine learning and time series analysis. *Scientia Iranica*. https://doi.org/10.24200/SCI.2020.55034.4040

Mohammed, I. (2018). *Crypto currency as an Emerging Investment Instrument: The Missing Link*……. SSRN. https://doi.org/10.2139/ssrn.3144187

Saksonova, S., & Kuzmina-Merlino, I. (2019). Cryptocurrency as an investment instrument in a modern financial market. *St Petersburg University Journal of Economic Studies*, *35*(2), 269–282. https://doi.org/10.21638/spbu05.2019.205

Schober, P., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia and Analgesia*, *126*(5), 1763–1768. https://doi.org/10.1213/ANE.0000000000002864

Tapscott, A., & Tapscott, D. (2017). How blockchain is changing finance. *Harvard Business Review*. https://capital.report/Resources/Whitepapers/40fc8a6a-cdbd-47e6-83f6-74e2a9d36ccc_finance_topic2_source2.pdf

Trimborn, S., Li, M., & Härdle, W. K. (2020). Investing with cryptocurrencies – a liquidity constrained investment approach. *Journal of Financial Econometrics*, *18*(2), 280–306. https://doi.org/10.1093/jjfinec/nbz016

Yahoo Finance. (n.d.). *Stock market live, quotes, business & finance news*. Retrieved January 16, 2022, from https://finance.yahoo.com/