УДК 336.322

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DOI: 10.32702/2306-6814.2024.3.124

COMBINING TRADITIONAL AND ALTERNATIVE INVESTMENTS: PORTFOLIO RISK ASSESSMENT BASED ON COPULA MODEL

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ПОЄДНАННЯ ТРАДИЦІЙНИХ ТА АЛЬТЕРНАТИВНИХ ІНВЕСТИЦІЙ: ОЦІНКА РИЗИКУ ПОРТФЕЛЯ НА ОСНОВІ ПІДХОДУ ІЗ ЗАСТОСУВАННЯМ КОПУЛ

The exponential growth of the alternative assets market over the past decade has unveiled new strategic opportunities for investors. This progress gives rise to challenges associated with optimizing the capital allocation between traditional and alternative assets. The article explores the economic problem of constructing an optimal investment portfolio using the specification method of Markowitz's theoretical approach to combining these two groups of assets. The starting stage of the research was a correlation analysis applied to the statistical series of index returns for the period 2015—2019. The analysis revealed the heterogeneity of the correlation dependency within the studied group. A "rolling window" of 47 weeks was analyzed to calculate correlations within this framework between indices representing alternative investments and the traditional S&P500 index. The rolling window provides lines of correlation values. Significant fluctuations in these lines indicate instability in interdependencies, indirectly justifying the limitations of using classical correlation and providing a basis for considering other measures, including copulas. The classical Markowitz approach was applied to find portfolios with minimal risk and an alternative interpretation. The capital requirements for covering potential losses were calculated for portfolios selected from traditional investments, alternatives, and their combinations using two approaches. Within the Markowitz approach, the problem of finding the optimal portfolio in constructing and analyzing three efficient sets was structured. The obtained results, from a risk perspective, visualize the potential combination of assets. Based on this, an optimal portfolio was constructed from a combination of alternative and traditional assets (a portfolio with cryptocurrencies is also considered). The capital requirements were analyzed using a paired copula construction. The underestimation of the potential risk of critical losses when calculating CVaR based on historical data was identified. The obtained results were verified based on historical return data of optimal portfolios from 2020 to 2022.

Експоненційний розвиток ринку альтернативних активів протягом останнього десятиріччя розкриває нові стратегічні можливості для інвесторів. Цей прогрес породжує проблеми, пов'язані з оптимізацією розподілу капіталу між традиційними та альтернативними активами. В статті досліджується економічна задача побудови оптимального інвестиційного портфеля методом специфікації теоретичного підходу Марковіца до комбінації цих двох груп активів. Вихідним етапом дослідження виступив кореляційний аналіз, застосований до статистичних рідів доходностей індексів за період 2015—2019 рр. Аналіз показав неоднорідність кореляційної залежності в середині досліджуваної групи. Проаналізовано "рухоме вікно" довжиною 47 тижнів для розрахунку кореляції в цих межах між індексами що представляють альтернативні інвестиції та традиційний індекс S&P500. Значні коливання цих ліній показують нестабільнсть взаємозалежностей та, опосередковано, слугує обгрунтуванням обмеженості використання класичної кореляції та є підгрунтям для розгляду інших мір, зокрема, копули. Застосовано класичний підхід Марковіца для знаходження портфелів з мінімальним ризиком та альтернативну інтерпритацію. Розраховано потребу в капіталі для покриття можливих збитків при виборі портфелей з традиційних інвестицій, альтернативних та їх комбінацій за двома підходами. В межах застосування підходу Марковіца було структуровано задачу знаходження оптимального портфеля в побудову та аналіз трьох ефективних множин. Отримані резуль-

тати з точки зору ризику візуалізують потенціал комбінації активів. На цій основі побудований оптимальний портфель з комбінації альтернативних та традиційних активів (окремо розглянуто портфель з криптовалютами). Проаналізовано потребу в капіталі за допомогою застосування конструкції із парних копул. Визначено недооцінку потенційного ризику критичних втрат при розрахунку CVaR на основі історичних даних. Верифіковано отримані результати на основі історичних даних доходності оптимальних портфелей в 2020—2022 роках.

Key words: alternative investment assets, diversification, portfolio optimization, CVaR, copula, Bitcoin, cryptocurrency.

Ключові слова: альтернативні інвестиційні активи, диверсифікація, оптимізація портфелю, CVaR, копула, Біткоін, криптовалюта.

PROBLEM STATEMENT

In the modent stock market, there is a persistent trend of expanding the investment spectrum, driven by the increasing needs of investors. Traditional assets such as stocks, bonds, and cash equivalents are now being actively complemented by alternative assets. Moreover, the development of Exchange Traded Funds (ETFs) tools enables the utilization of alternative assets in an ETF form. As a result, investors have broader opportunities to combine traditional and alternative assets, creating diversified investment portfolios. It generates rise new challenges associated with constructing such portfolios. The analysis of dependencies between the returns of traditional and alternative assets often reveals non-standard patterns. This is explained by the fact that the response of returns from different traditional and alternative assets to market factors can be quite diverse. Under the manifestation of certain market factors, returns move in the same direction, while under the manifestation of others, they move in opposite directions. Based on this, there arises a need for an extensive investigation of interdependencies compared to correlation. This underscores the relevance of employing more advanced measures of return interdependence. One such measure is copulas, which provide a more accurate assessment of risk by modeling complex dependencies between random variables. The copula approach allows for the consideration of nonlinear relationships and how the risk of one asset affects the risk of others in a diversified portfolio. This creates conditions for better analyze for extreme situations and enables a more precise determination of capital requirement to cover risks.

ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

Recent publications have explored the topic of alternative investment assets by M. Anson [1], L. Swedroe, D. Kizer [2], and V. Debski [3], who presented varying perspectives on defining the concept of alternative investment assets. A. Dorsey [4], D. Chorafas [5], F. Stefanini [6], T. Schneeweis, and D. Pescatore [7] developed their classifications of assets falling into this category. In their works, K. Leitner [8] and E. Sokolowska [9] highlighted the peculiarities of such investment instruments. The specifics of investing in alternative investment assets were investigated by Mundi, Kumar [10] Fischer, Lind-Braucher [11] J. Mulvey, Woo Chang Kim [12], A. Clark [13]. R. Darabi, M. Baghban [14]. Allen, McAleer and Singh applying Vine copula to Risk Measurement and Risk Modelling [15].

FORMULATION OF THE OBJECTIVES OF THE ARTICLE (TASK STATEMENT)

The purpose of the article is to study the nature and effectiveness of diversification through the combination of alternative and traditional investments. This research aims to establish the efficiency of such diversification by employing advanced econometric and mathematical tools, specifically copulas, to provide a more accurate assessment of capital requirements for risk coverage in these diversified portfolios. This approach aims to enhance our understanding of the quantitative aspects of diversified investment strategies and contribute to the development of more precise risk management methodologies in the financial domain.

SUMMARY OF THE MAIN RESEARCH MATERIAL

The alternative investment market has demonstrated growth over the past decade. For instance, the research company Preqin [16] claims that the overall value of alternative assets more than doubled between 2015 and 2021 and is projected to reach $23 trillion by 2026 (representing 12% of the global investment market in 2021). The growth occurs both overall and within each specific class of alternative investment assets. According to the specialized platform Propel(X) [17], the average return on such assets is 9% annually.

The examination of alternative assets gives rise to discussions regarding the conceptualization of this term. The analysis of the concept of alternative investments reveals differences in scientific and professional literature. In literature, two main approaches are most commonly used to define this concept. The first approach involves defining alternative assets from an "excluding" perspective: alternative investment assets are those that do not belong to traditional asset classes (stocks, bonds, and depositary bank instruments) [9]. The second approach defining alternative assets from an "including". In particular, five main groups of alternative investments are identified: real assets, hedge funds, commodities, private equity, and structured products [3].

As mentioned earlier, investing in alternative assets is complicated for investors due to the partial connection with physical assets. This has led to the creation of a special investment instrument — Exchange-Traded Fund (ETF), which formally corresponds to traditional stock assets in operational management. These funds provide investors with the opportunity to access various markets and sectors by investing in a single financial instrument

Table 1. Correlation matrix of traditional and alternative investment assets

	S&P 500	S&P 600	S&P 400	S&P GSCI	S&P GSCI Energy & Metals	S&P United States REIT (USD)	S&P GSCI Precious Metals	S&P Oil & Gas	S&P Listed Private Equity Index	S&P GSCI Agriculture
S&P 500	100,00%									
S&P 600	86,73%	100,00%								
S&P 400	92,91%	96,57%	100,00%							
S&P GSCI	39,91%	42,66%	41,54%	100,00%						
S&P GSCI Energy & Metals	39,37%	41,10%	40,30%	98,83%	100,00%					
S&P United States REIT (USD)	78,58%	78,48%	83,20%	32,45%	31,07%	100,00%				
S&P GSCI Precious Metals	2,56%	2,66%	1,71%	18,14%	16,54%	7,87%	100,00%			
S&P Oil & Gas Exploration & Production	61,12%	70,55%	68,79%	71,25%	70,78%	49,86%	3,45%	100,00%		
S&P Listed Private Equity	84,91%	82,97%	87,08%	41,32%	40,60%	76,71%	2,62%	63,75%	100,00%	
S&P GSCI Agriculture	12,15%	17,50%	15,08%	41,69%	29,04%	13,31%	13,50%	24,75%	13,80%	100,00%

Source: compiled and calculated by the author based on [18].

that represents a diverse portfolio of assets. One of the key advantages of using ETFs for investing in alternative assets is easy access to these markets without the need for direct acquisition or management of individual assets. This makes investing in alternative assets more accessible and convenient for a wide range of investors, as ETFs are traded on the stock exchange and can be bought and sold just like shares of traditional companies.

To analyze interdependencies between traditional and alternative investment assets, S&P agency indices representing each category were used. Using indices only from S&P allows you to get a comprehensive view of the stock market through the use of standardized and widely recognized indicators that reflect the movements of various sectors and companies as a whole. We chose 3 indices representing traditional assets and 7 alternative ones. Their list can be found in Table 1 [18].

The period chosen for the study is from 2015 to 2019. This selection was based on several objective factors that determined the optimality and adequacy of the investigated time frame. Firstly, the use of weekly data for the specified period allows for the formation of a sample of values for each of the included indexes. Weekly data provide a clearer picture of overall trends and patterns, assisting investors in synthesizing and understanding price movements over a more weighted time period. Secondly, the selected period is characterized by relative economic stability and lacks anomalous periods, such as unforeseen financial or economic crises, like the COVID-19 pandemic.

Alternative investment assets may have lower correlation with traditional financial markets, such as stocks and bonds. This means that their prices may react differently to economic and market changes compared to traditional assets. Including alternative assets in a portfolio allows investors to reduce overall risk. Such differences are caused by the varied nature of income for these assets. As a result of the distinct origin and species diversity, alternative assets have a low correlation with traditional asset classes, meaning they demonstrate less dependence on the market movements of stocks or bonds. Thus, investors use alternative investments to allocate their investments across different asset classes to reduce overall portfolio risk and balance profit potential under various market conditions. First of all, it is necessary to analyze the degree of correlation between the selected indices, both in individual cases and across the "traditional" and "alternative" categories. Table 1 represents it.

Correlations between assets are calculated based on the weekly returns of the relevant indices for a 10-year period (November 2013 — November 2023). Thus, the average correlation between traditional indices was 0,9207. At the same time, this indicator for exclusively alternative assets is 0,3625. The average indicator for the entire sample is 0,4725. This indicates not only a significantly lower dependence between traditional and alternative investment assets as a whole, but also the multidirectional nature of returns between individual classes of alternative assets. If we consider the sliding correlation between the series of alternative investment assets and the most popular traditional S&P 500 index with a step of 47 (which corresponds to the average number of weekly data points available from 2015 to 2022), as presented in Figure 1, it can be asserted that the correlation in these pairs is not constant throughout the entire investigated period. Moreover, some series exhibit significant periods of negative correlation.

In our analysis, we consider two major categories of assets: traditional and alternative. For each category, we will construct an efficient set of portfolios consisting of assets from that class and determine the risk level for each of the return levels.One of the key tools for analyzing portfolios is the Markowitz model, which allows you to determine the optimal balance between risk and profitability based on statistical data on the movement of asset prices. This model is used to construct efficient sets of portfolios representing different combinations of assets [19].

After determining the characteristics of individual assets, we proceed to the construction of the two-factor Markowitz optimization problem [19]. With the help of this optimization, we determine the portfolio that minimizes the risk (standard deviation of the return) at a given level of return.

The Markowitz model is based on a quadratic formula for portfolio risk:

$$\sigma^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j p_{ij} \quad (1),$$

σ^2 — the variance of the portfolio;

w_i та w_j — the weights of assets in the portfolio;

σ_i та σ_j — the standard deviations of individual assets;

p_{ij} — the coefficient of covariance between assets.

The Markowitz theory practically enables the construction of a portfolio with minimal risk by minimizing standard deviation. Another alternative target indicator to determine the required capital reserve is to consider a more representative metric — VaR (Value at Risk) or CVaR (Conditional Value at Risk).

Value at Risk determines the amount of money that an investor can lose with a certain probability for a certain period of time. It is a measure of risk that indicates the maximum possible loss in a given time interval and at a certain level of confidence. Conditional Value at Risk is an extension of VaR that determines the average value of losses if they exceed the VaR value at a certain confidence level. CVaR expresses the conditional average value of losses, assuming that they exceed the calculated VaR value. Both metrics are used to assess risk in financial instruments, but VaR simplistically indicates the potential maximum loss, while CVaR complements this by looking at the average loss if the VaR level is exceeded. These metrics help make risk management decisions and build the necessary capital reserve [22]. In our case, the calculated indicators mean what value with a probability of 95% will not exceed the losses from investing in these investment portfolios. For the purposes of our study, CVaR more accurately describes the capital reserve levels. Therefore, it is more appropriate to choose CVaR as the target metric. To determine the capital reserve under risk, we will construct portfolios with minimal risk separately for traditional and alternative investment assets. A practical calculation of the shares of each asset in the portfolio with the lowest risk is carried out with the help of the "Solver" add-in for Microsoft Excel, based on the above-mentioned Markowitz approach. The target indicator of the portfolio, which we minimize, is standard deviation in first approach and CVaR in second (maximize).

Despite the risk assessment methodology provided by the Markowitz model, it has certain drawbacks that do not fully account for interdependencies among assets within the portfolio, especially in specific parts of the distribution. This may lead to insufficient accuracy in estimating the overall portfolio risk. To obtain a more precise and realistic risk assessment, it is proposed to use an approach based on copulas. A copula is a statistical tool that allows modeling dependencies between different variables in probability distributions. In mathematical terms, a copula is expressed through the probability distribution function for each variable and their joint distribution function, reflecting their mutual dependence. The copula formula looks as follows:

$$C(u_1, u_2, u_3 \dots u_n) = C(F_1(x_1), F_2(x_2), \dots, F_n(x_n)) \quad (2),$$

C — formula of copula;

$u_1, u_2, u_3 \dots u_n$, — marginal distribution functions;

$F_1(x_1), F_2(x_2), \dots, F_n(x_n)$ — probabilities of the values of the respective variables.

Vine copulas utilize a parameter system based on the sequential application of bivariate copulas. Typically, this parameter system is represented in the form of a tree, reflecting the relationships between variables. In each node of the tree, a bivariate copula is defined to model the dependence between variables. Usually, a different type of copula is used for each node, allowing for a better representation of diverse forms of dependence between variables. There is no formal universal formula for vine copulas due to their complexity and variability. Each copula in vine copulas is represented by its parameters, which account for the specific relationship between particular variables. This forms a construction of pairwise copulas — an approach to modeling dependence between many variables using a set of multivariate copulas, allowing for a better modeling of complex dependencies between different pairs of variables. This approach considers the variety of dependencies between variables in complex data, making the model more flexible and accurate. Using the pairwise copula construction for calculating CVaR provides more accurate and reliable portfolio risk results. This is explained by the fact that CVaR calculated based on copulas more accurately captures the dependencies between assets in the portfolio than the traditional Markowitz method. Therefore, its use allows for a more comprehensive and realistic depiction of the overall risk of the investment portfolio, enabling a more accurate assessment of the capital reserve amount. A

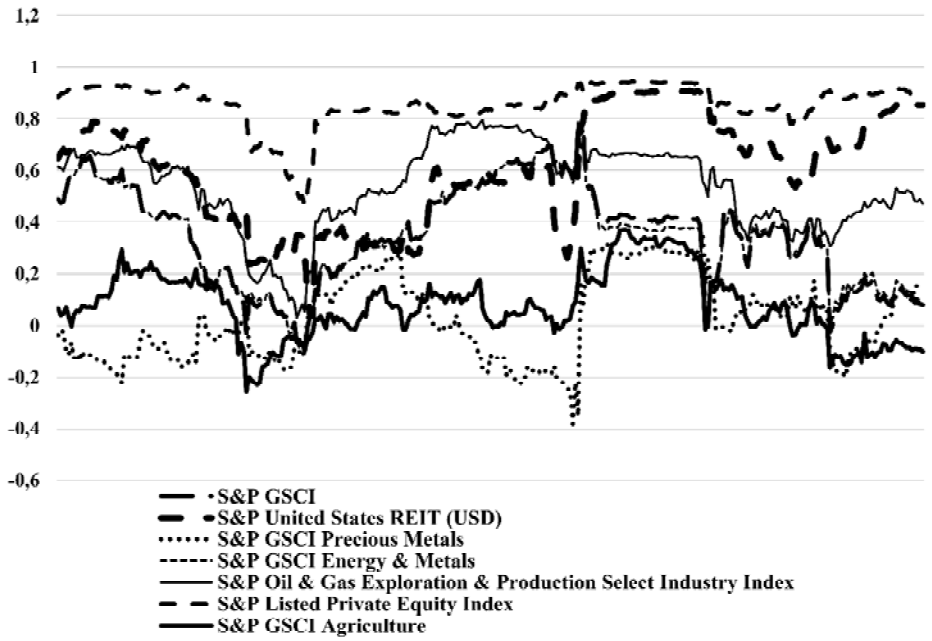

Fig. 1. Sliding correlation of alternative investment assets and S&P 500 index with a step of 47.

Source: Calculated by the author based on [18].

Table 2. Risk indicators of low risk portfolios (optimized by standard deviation) by class of included assets

	Traditional (Portfolio 1)	Alternatives (Portfolio 2)	Portfolio1+ Portfolio2	Combination with low risk (of all indexes)
Mean	0,21%	0,10%	0,11%	0,11%
95% CVaR Markowitz Approach	-5,65%	-2,52%	-2,49%	-2,50%
95% CVaR Copula Approach	-5,78%	-3,38%	-3,34%	-3,29%

Source: calculated by the author based on [18].

Table 3 Risk indicators of low risk portfolios (optimized by CVaR) by class of included assets

	Traditional (Portfolio 1)	Alternatives (Portfolio 2)	Portfolio1+ Portfolio2	Combination with low risk (of all indexes)
Mean	0,21%	0,09%	0,10%	0,13%
95% CVaR Markowitz Approach	-5,65%	-2,46%	-2,46%	-2,44%
95% CVaR Copula Approach	-5,78%	-3,39%	-3,36%	-3,26%

Source: calculated by the author based on [18].

portfolio of traditional assets with minimal risk is 100% composed of the S&P500 index. A potfolio of alternative investments assets consists of REIT, agriculture, precious metals and privat equity indexes. At the same time, the relative novelty of the alternative assets category is often accompanied by a lack of full understanding of which assets belong to traditional and which to alternative. In view of this, it is advisable to consider a minimum risk portfolio not by separately selecting a portfolio based on all available components, but based on a combination of portfolios 1 and 2. This optimal portfolio will consist of 11.08% from portfolio 1 and 82.98% from portfolio 2 based on alternative investments. The calculated risk indicators for the three portfolios with minimal risk are shown in Table 2.

The application of such an approach provides investors with transparency in the relationship between selected portfolios of traditional and alternative assets. Additionally, calculating CVaR based on a copula approach allows for a more accurate assessment of the capital at risk. As seen in the table, even the application of a simple combination of two portfolios with minimal risk allows for a more effective diversification of the traditional investment portfolio. However, the approach of constructing a minimum-risk portfolio based on 10 available assets shows an even more efficient result.

When CVaR value is used as a target indicator, the trend in general remains similar. This indicates a positive effect of diversification regardless of the chosen measure of risk (Table 3).

However, a more traditional task from the point of view of investors is the construction of so-called "optimal" portfolios. We optimized investment portfolios of relevant samples using the Sharpe ratio. The Sharpe ratio is a metric used to assess the risk-return of a portfolio or a specific asset. It measures the excess of return over the risk-free rate relative to the total risk of an investment.

$$\text{Sharpe Ratio} = \frac{R_p - R_0}{\sigma_p} \qquad (3),$$

R_p — portfolio (or asset) return;

R_0 — risk-free rate (the return rate of bonds with a long-term maturity is usually used);

σ_p — the standard deviation of a portfolio's (or asset's) return.

This ratio compares the level of return an investor receives with the level of risk he takes and takes into account the risk-free rate, which is considered the main relative measure [20]. The higher the value of the Sharpe ratio, the better the investor compensates for the risk by accepting this level of profitability in the portfolio. Practically, the maximization of the Sharpe ratio was also carried out through the "Solver" add-on. Maximization of the Sharpe ratio allows finding optimal combinations of investment portfolios. We built optimal portfolios from the point of view of the risk/return ratio for each of the individual asset categories (traditional, alternative and their combinations). The optimal portfolios for alternative assets consists of precious metals and private equity indexes. The combined optimal portfolio consists of S&P500 and precious metals indexes. The optimal portfolio based on traditional assets is unchanged and is 100% of the S&P500. Also, we have formed an optimal portfolio with the possibility of investing in cryptocurrencies (Bitcoin or BTC). The obtained result significantly increases the average profitability of the portfolio, but at the same time — causes significantly higher capital requirments (determined by both approaches). Risk indicators for optimal portfolios are shown in Table 4.

Therefore, the value of CVaR calculated on the basis of copulas for each of the individual portfolios is greater than the similar indicator determined on the basis of the Markowitz approach. Thus, the amount of capital at risk that must be reserved is higher. The least significant difference is characteristic of the portfolio of traditional assets, however, it should be noted that the portfolio consists of a single asset, so the application of the copula approach is not fully relevant for this specific case. To check the practicality of this calculation, the expected risk indicators were compared with the historical CVaR values of these portfolios in 2020—2022. This period is quite indicative, as it equates to a significant crisis period in the economy associated with the COVID-19 pandemic and the Russian-Ukrainian war. The calculation of the required amount of capital reserve is carried out using CVaR. Thus, for the optimal portfolio of traditional assets, this value was -(-8.86%), for alternative — (-8.49%), for the combined portfolio — (-5.48%), for the combined portfolio with BTC — (-8,55%). This difference for the combined portfolio is caused by the low correlation between alternative and traditional assets in COVID-19. (Fig.1)

Although these values exceeded the expected risk under both approaches, the CVaR value calculated on the basis of the copula approach is closer for all three individual portfolios, and the significant difference is caused by the suddenness of the crisis period. Separately, we note that

the indicator for the combined portfolio showed significantly better results, which emphasizes the effectiveness of diversifying portfolios with the help of alternative investment assets even in crisis periods. The application of a copula-based approach allowed for a more accurate assessment of capital needs for each of the portfolios reviewed, which was confirmed by comparing with the corresponding CVaR values for the years 2020—22. Thus, the approach based on copulas is characterized by a lower tolerance for risk, so it is more suitable for calculating the capital requirement [21].

Conclusions and prospects for further research in this area. The market of alternative investments has been actively developing in recent years — both quantitatively — towards the growth of capitalization of already existing assets, and qualitatively — due to the appearance of technically new investment objects. The reason for this development is the growing need for them from investors. The reason for such popularity lies in the opportunities for portfolio diversification that these assets provide. The article analyzes the dependence of returns on individual indices representing traditional and alternative investment assets. Two approaches were used for this. The first approach is to build a general correlation matrix on the basic interval of the study. The obtained results confirm that the dependence between traditional and alternative investment assets is quite low. Also, low correlation is characteristic of the relationships between individual classes of alternative assets. In addition, a 47-week "rolling window" was considered to calculate the correlation within these ranges between the S&P500 index and each of the alternative indices. Rolling of such window provides lines fo correlations value. Significant fluctuations in the graphs of sliding correlation and significant periods for certain indices with its negative value show the instability of interdependencies, which indirectly serves as a justification for the limitations of using classical correlation for portfolio diversification and future risk assessment. This is the basis for considering other measures, in particular, the copula. Based on the indices mentioned above, efficient sets of portfolios with minimal risk from traditional and alternative assets were constructed. To build such portfolios, the principle of Markowitz optimization with the minimization of the standard deviation and the approach based on the maximization of the CVaR value were used. Two approaches to building a combined portfolio with minimal risk were analyzed separately: through combining portfolios with minimal risk from traditional and alternative assets and based on the available set of all assets. For all four resulting portfolios, the construction of paired copulas was applied, which allows for a more accurate assessment of the relationship between individual assets included in the portfolio and, accordingly, the value of the capital requirement.

The obtained results confirm the positive effect of diversification, as the CVaR values for the combined portfolios (both according to the historical and copula approaches) are better than the corresponding values of the portfolios of traditional and alternative investment assets separately. Also, for all portfolios, the value of CVaR calculated using the copula approach is less than

Table 4. Risk indicators of optimized portfolios by class of included assets

	Traditional	Alternatives	Combination	Combination with BTC
Mean	0,21%	0,14%	0,17%	0,53%
95% CVaR Markowitz Approach	-5,65%	-3,08%	-3,01%	-5,25%
95% CVaR Copula Approach	-5,78%	-4,99%	-4,15%	-7,14%

Source: calculated by the author based on [18].

the historical value, which indicates a possible underestimation of the risk of these portfolios. Additionally, four optimal portfolios were constructed using the Sharpe ratio: based on traditional assets, alternative assets, their combination and combitaion with cryptocurrency. As with the portfolios with minimal risk, the trends towards a lower CVaR value for the copula approach persist. To verify the obtained results, we calculated the value of the capital requirement for optimal portfolios in 2020—2022. The verification showed that the value of CVaR, estimated using the copula approach, determined the capital requirement in the described periods much more accurately, which indicates the higher accuracy of this method of evaluation. Additionally, we note that the inclusion of cryptocurrency assets in the portfolio significantly increases the profitability of the portfolio, but at the same time, due to significant volatility, increases capital requirements. Further research should be directed to the development of portfolio optimization methods directly using the copula approach.

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Стаття надійшла до редакції 23.01.2024 р.