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RETHINKING MULTI-ASSET PORTFOLIO OPTIMISATION FOR A TURBULENT BUSINESS ENVIRONMENT: NEW INSIGHTS

Financial asset portfolio optimisation is the primary objective of all fund managers managing multiple asset classes for international investors. Multi-asset portfolios across global markets are regarded as well-rounded financial portfolios. This research paper employs three different financial portfolio optimisation techniques encompassing a diverse range of assets, namely the S&P 500, Emerging Equity Market Index, Gold, Emerging Market Bonds, Crude Oil, REITs, and Bitcoin.

The portfolios developed through the traditional Optimal Risky Portfolio (ORP) method demonstrate superior performance compared to alternative portfolio optimisation techniques, specifically the Equal Risk Contribution (ERC) and the Most Diversified Portfolio (MDP) methods, as evidenced by key metrics such as the Sharpe Ratio and Value at Risk (VaR). These findings are consistent across distinct periods, including crisis phases such as the stock market crisis of 2018, the COVID-19 pandemic, the Russia-Ukraine conflict, and the US Fed rate hikes in 2023. The study encompasses all these events within an extensive timeframe from January 2018 to June 2023.

The research underscores the importance of single-asset selection during tumultuous market conditions, identifying Bitcoin, Crude Oil, and Gold as viable options. The results reveal that MSCI Emerging Market Equities, Bonds, the S&P 500, and REITs did not significantly enhance risk-adjusted returns during the 2018–2023 period. Notably, the ORP method demonstrated significantly superior Sharpe Ratios and Value at Risk compared to the ERC and MDP methods. Conversely, no significant differences were observed in the Sharpe Ratios and Value at Risk between the ERC and MDP portfolios.

This study contributes to the existing body of literature by reaffirming the dominance of the ORP method over the ERC and MDP approaches in volatile market conditions during the turbulent financial period from 2018 to 2023.

Keywords: Equal Risk Contribution, Most Diversified Portfolio, Multi-Asset Portfolio, Optimal Risky Portfolio, Portfolio, Sharpe Ratio, Value at Risk

JEL classification: ***G11, G1, G58, G61***

Оптимізація портфеля фінансових активів є метою всіх керуючих фондами, які управляють кількома класами активів для міжнародних інвесторів. Портфелі з кількома активами на світових ринках вважаються всебічно збалансованими фінансовими портфелями. У цій дослідницькій роботі використовуються три різні методи оптимізації фінансового портфеля, що охоплюють широкий спектр активів, а саме: S&P 500, індекс ринків акцій, що розвиваються, золото, облігації ринків, що розвиваються, сиру нафту, інвестиційні фонди нерухомості (REIT) та біткойни. Портфелі, розроблені за допомогою традиційного методу оптимального ризикованого портфеля (ORP), демонструють вищу ефективність порівняно з альтернативними методами оптимізації портфеля, зокрема рівний внесок ризику та максимально диверсифікований портфель, про що свідчать такі критичні показники, як коефіцієнт Шарпа та Value at Risk. Ці висновки підтверджуються протягом різних періодів, включаючи кризові фази, такі як криза фондового ринку 2018 р., COVID-19, російсько-українська криза та підвищення ставки ФРС США у 2023 р. Дослідження охоплює всі ці події протягом тривалого періоду з січня 2018 р. по червень 2023 р. Дослідження підкреслює важливість вибору одного активу під час бурхливих ринкових умов серед потенційних кандидатів, включаючи біткойни, сиру нафту та золото як життєздатні варіанти. Дослідження показує, що акції MSCI ринків, що розвиваються, облігації, S&P 500 та REITS суттєво не підвищили скориговану на ризик доходність протягом 2018-2023 рр. Примітно, що метод ORP продемонстрував значно вищі коефіцієнти Шарпа та Value at Risk порівняно з методом Equal Risk Portfolio (ERC) та MDP. І навпаки, суттєвих відмінностей у коефіцієнтах Шарпа та Value at Risk портфелів ERC та MDP не спостерігалося. Це дослідження доповнює існуючу літературу, підтверджуючи гегемонію методу ORP над методами ERC та MDP в умовах волатильного ринку в період волатильного фінансового ринку з 2018 по 2023 р.

Ключові слова: рівний внесок ризику, найбільш диверсифікований портфель, портфель з кількома активами, оптимальний ризикований портфель, портфель, коефіцієнт Шарпа, вартість під ризиком

JEL classification: ***G11, G1, G58, G61***

Introduction

Some headwinds, including US-China trade tensions, the reintroduction of sanctions on Iran, the NAFTA rebrand, the slide in crude oil prices, and the 18-month mark after Brexit, characterised the financial markets in 2018. These events contributed to a volatile market environment, with investors grappling with geopolitical uncertainty and worries about worldwide economic growth. The marketplace became risky throughout the 12 months, with sharp selloffs in the fourth quarter because of concerns about a potential recession.

The unprecedented outbreak of COVID-19 triggered a global crisis, swiftly changing the world's landscape. It presented a worldwide health emergency and led to a substantial global economic decline. The pandemic significantly disrupted the international financial market. While the world adjusted to the pandemic's "new normal," the conflict between Russia and Ukraine and the surging prices of Brent and WTI crude Oil added to the crisis. During these challenging times, diversifying the wealth of international investors across asset classes to yield positive risk-adjusted returns became daunting for portfolio managers. Consequently, portfolio managers had to transition towards alternative asset classes, regions, and portfolio construction approaches to boost portfolio returns and achieve outstanding performance.

The effective allocation of wealth across various assets remains a crucial concern for portfolio managers, highlighting the amalgamation of assets to optimise risk-adjusted returns – a fundamental aspect of both academic research and practical investment management. Numerous portfolio construction methods have emerged, each presenting a unique approach to balancing risk and return. Markowitz's [1] traditional mean-variance optimisation has historically played a vital role in constructing portfolios by maximising expected returns relative to risk, as initially proposed in 1952. His pioneering work laid the groundwork for Modern Portfolio Theory (MPT), emphasising diversification and introducing the efficient frontier concept.

In contemporary portfolio theory, progress has led to innovative strategies integrating alternative risk metrics, such as the Equal Risk Contribution (ERC) portfolio introduced by Maillard et al. [2]. This inventive approach aims to allocate asset weights to achieve equal contributions to the overall portfolio risk. Another advancement is the Maximum Diversified Portfolio (MDP) technique, developed by Choueifaty [3], which prioritises diversification across asset classes while considering underlying risk elements and their correlations. The Diversification Ratio (D.R.), proposed by Choueifaty et al. [4], serves a cornerstone of the MDP framework, defining the ratio between the portfolio's weighted average individual asset risk and its overall portfolio risk.

This research paper explores portfolio construction using three prominent methodologies: the optimal risky portfolio, the equal risk contribution portfolio, and the most diversified portfolio. The paper offers valuable insights through a comparative examination of these strategies, shedding light on their implications for asset allocation choices, returns, and risk profiles. Additionally, it examines key performance metrics such as the Sharpe ratio, introduced by Sharpe [5], and the Value at Risk (VaR), developed by J.P. Morgan in the early 1990s [42]. These metrics are indispensable for assessing risk-adjusted returns and managing risks within investment portfolios.

In the context outlined in the introduction, the current study aims to address the following research objectives:

1. To investigate the concentration levels of portfolio weights under three distinct portfolio construction methods from 2018 to 2023.

2. To determine the maximum risk-adjusted returns achievable for these portfolios.

3. To assess the portfolio value in scenarios of extreme shortfall in portfolio value.

4. To evaluate any significant differences in risk-adjusted returns among the three methods.

5. To examine and analyse potential significant differences in the portfolios' Value at Risk (VaR) across the three methods.

The subsequent sections of this paper are structured as follows. The literature review provides a comprehensive overview of the selected multi-assets and traces the evolution of portfolio construction strategies within the three methods: the Optimal Risky Portfolio (ORP), the Equal Risk Contribution (ERC), and the Most Diversified Portfolio (MDP). The materials and methods segment elucidates the data sources, selection criteria, and the mathematical underpinnings of the portfolio construction techniques under investigation. The results segment presents the outcomes obtained by applying each approach to the dataset, followed by a comparative analysis highlighting the similarities and differences between the portfolios constructed using the three methods. The discussion section interprets the findings, delving into the practical implications of employing diverse techniques and investigating the statistical significance of observed differences in risk-adjusted returns and the Value at Risk (VaR) of the portfolios. Finally, the conclusion summarises the essential findings, acknowledges certain limitations, and underscores the importance of informed portfolio construction decisions within the investment landscape.

Literature Review

Previous research has extensively explored the repercussions of pandemics, including the Spanish flu of 1918 by Correia et al. [6], as well as more recent pandemics such as the 1968 flu, 2003 SARS, 2009 H1N1, 2012 MERS, 2014 Ebola, and 2016 Zika virus studied by Ma et al. [7], on financial markets, particularly in the context of diverse asset portfolios. Froot [8] emphasised the necessity of incorporating tangible assets into multi-asset portfolios to enhance diversification, given the strong negative correlation between extensively diversified stock and bond portfolios and inflation. During crises such as the subprime crisis and the Euro sovereign debt crisis of 2015, heterogeneous global portfolios, which consist of portfolios comprising various

asset classes, demonstrated superior returns compared to homogeneous portfolios. Bratis et al. [9] agreed that strategies involving commodities should be integrated into multi-asset portfolios.

However, Lombardi et al. [10] presented contrasting findings, while Buyuksahin et al. [11] observed that including commodities in a multi-asset portfolio alongside equity stocks led to increased volatility. Furthermore, the correlation between equities and commodities experienced an upswing during the Global Financial Crisis of 2008, suggesting that adding commodities may not necessarily enhance the Sharpe ratios within equity portfolios. Aliu et al. [12] found that combining stocks in a portfolio with cryptocurrencies, forex, and commodities reduced portfolio risk before and during the COVID-19 pandemic. Trichilli et al. [13] highlighted the inclusion of Bitcoins within a multi-asset portfolio comprising stocks and commodities, both pre-COVID-19 and during the pandemic. The inclusion of Bitcoins in a portfolio of stocks and commodities not only improved risk-adjusted returns but also provided hedging properties. Sa-Aadu et al. [14] revealed that the optimal risky portfolio preferred equity REITs, precious metals, and Treasury bonds during economic downturns. In contrast, throughout intervals of economic prosperity, the optimal risky portfolio tilted closer to domestic US stocks (21%), corporate bonds (19%), and stock REITs (4%). In dire financial situations, the portfolio allocation favoured government bonds (42%), stock REITs (38%), and commodities (20%).

Kyriazis [15] found that Bitcoin exhibited safe-haven properties during the Russia-Ukraine conflict. Studies by Su et al. [16-17] corroborated these findings, suggesting that Bitcoin can serve as a financial tool for optimising portfolios during periods of heightened geopolitical risk. Selmi et al. [18] also noted that the inclusion of gold in a portfolio could act as a safe haven against underperforming assets during geopolitical instability. Several studies, including those by [19-21], have acknowledged the potential for positive portfolio gains by integrating cryptocurrency with traditional financial assets. Specifically, Bouri et al. [22] observed that Bitcoin is an imperfect hedge against stock and bond indices, making it a suitable diversification instrument. Tiwari et al. [23] replicated similar findings for the S&P 500. However, Conlon and McGee's study in 2020 [17] suggested that Bitcoin did not serve as a hedge during the extreme bear market triggered by the COVID-19 pandemic for the S&P 500. In contrast, Corbet et al. [24] found that cryptocurrencies like Bitcoin tended to amplify contagion during periods of severe financial and economic turbulence.

Some of the gaps observed in the literature are as follows: firstly, most studies have focused on customary assets such as stocks, bonds, and commodities. However, there is a growing interest in alternative assets such as cryptocurrencies and REITs. Our paper includes Bitcoin and REITs ETFs as representatives of cryptocurrencies and real estate in multi-asset portfolios. Secondly, pandemics and wars can lead to significant market volatility and unexpected losses. It is essential to understand the expected loss in the value of such multi-asset portfolios during turbulent times. Our paper attempts to fill this research gap. Thirdly, our paper employs the Equal Risk Contribution and the Most Diversified Portfolio methods in addition to the popular Markowitz mean-variance optimisation, also known as the Optimal Risky Portfolio. Very few papers have used the former two methods in creating multi-asset portfolios. Our paper compares the risk-adjusted returns and the expected shortfall in the portfolio's value under all three methods.

Materials and Methods

The authors have meticulously gathered daily stock index data for various assets, including the S&P 500, MSCI Emerging Market equity, emerging market bonds, Brent crude oil futures prices in USD, gold prices in USD, Bitcoin, REITs, and risk-free bonds (Table 1). The data was collected from January 3, 2018, to June 14, 2023, from an open source – investing.com. Exhibit I provides a detailed tabulation of the assets considered in this research. The study duration was subdivided into six

distinct sub-periods encompassing 1,179 observations. Portfolio rebalancing was conducted at regular intervals of every 197th day. Consequently, the entire study period was stratified into six sub-periods as follows: January 3, 2018 – December 10, 2018 (representing the financial market crisis of 2018); December 11, 2018 – November 22, 2019 (the pre-COVID-19 phase); November 25, 2019 – October 29, 2020 (COVID-19 Phase 1); October 30, 2020 – September 29, 2021 (COVID-19 Phase 2); September 30, 2021 – August 16, 2022 (the Russo-Ukraine war); and finally, August 17, 2022 – June 14, 2023 (the US Fed rate hike). The 1,179 observations were evenly distributed across these sub-periods, resulting in 196 observations in each period.

This research constructed multi-asset portfolios utilising the Optimal Risky, Equal Risk Contribution, and Most Diversified Portfolio methods. Microsoft Excel version 2007 Solver, an add-in tool, was used to design the portfolios. The GRG Nonlinear method with non-negativity constraints was applied as a standard practice for optimisation. Integrating diverse portfolio construction methods and employing risk-adjusted measures such as the Sharpe Ratio and the Value at Risk (VaR) method has significantly enhanced the robustness of this study.

Portfolio Construction Methods Used

Optimal Risky Portfolio (ORP):

Creating the optimal risky portfolio necessitates estimating the expected return, variance, and covariance of the portfolio's assets. These estimates are often derived from historical data or other statistical methods. A portfolio that maximises the risk-adjusted return, also known as the Sharpe Ratio, can be determined using mathematical optimisation techniques such as linear programming or quadratic programming.

The basic Markowitz mean variance-optimal model, also called the Optimal Risky Portfolio, finds a vector **w** which maximises the Sharpe Ratio: [25]

$$\max_{w} f^T w - \frac{1}{2} w^T \sum w \qquad (1)$$

f represents the estimated expected return, and **Σ** is the covariance matrix.

The asset allocation procedure involves assigning optimal investment weights to different risky assets. The weights become optimal when the portfolio achieves projected utility maximisation and risk minimisation for risk-averse investors [26].

Equal risk contribution Portfolio (ERC):

The Equal Risk Contribution (ERC) portfolio is an optimisation technique designed to ensure that each asset bears an equal share of the portfolio's risk. This strategy guarantees that no single asset dominates the portfolio's risk and promotes effective asset diversification. To construct an ERC portfolio, the standard deviation of each asset must first be determined. The formula

Table 1

Variables used in the study

Asset	Representation	Source	Symbol
US Broad-Based Equity Index	S&P 500 in USD	www.investing.com	S&P500
Emerging Market Equity Index	MSCI Emerging Market Index in USD	www.investing.com	MSCI
Gold	Gold Futures Prices in USD	www.investing.com	GOLD
Emerging Market Bond Index	iShares JP Morgan USD Emerging Markets Bond ETF	www.yahoofinance.com	EMB
Crude	Brent Crude oil futures prices in USD	www.investing.com	CRUDE
Cryptocurrency	Bitcoin prices in USD	www.investing.com	BITCOINS
Real Estate	Vanguard Real Estate ETF in USD	www.investing.com	REITS

Source: Author's compilation

above is then applied to calculate the portfolio weights. The optimisation process typically involves solving a constrained optimisation problem to minimise the differences between the risk contributions of each asset.

The naïve portfolio tends to invest equal dollar amounts in each constituent. At the same time, the ERC allocates *risk equally* among all the asset classes.

$$\sigma_i \equiv \omega_i \frac{\partial \sigma(w)}{\partial_{\omega_i}} \quad (2)$$

Where:

w_i represents the weight of the i-th asset,

σ_i is the standard deviation of the ith asset,

$\partial\sigma/\partial\omega_i$ Is the marginal risk contribution.

The ERC method aims to set $\sigma_i = \sigma_j$ for all assets *i* and *j* in the given portfolio, all assets should contribute equally to risk.

$$\min_w \sum_{i,j} \left[\omega_i (\sum w)_i - \omega_j (\sum w)_j\right]^2 \quad (3)$$

The risk contribution is set to w = 0, so it is typical to write $\omega_i \geq 0 \; and \; \sum_i \omega_i = 1$

Most Diversified Portfolio (MDP):

The most diversified portfolio, sometimes referred to as the minimum variance portfolio, focuses on reducing the volatility of the entire portfolio. It is designed to maximise diversification benefits by allocating weights based on the assets' marginal contributions to portfolio risk. By assigning greater weight to assets with lower volatility, this strategy emphasises diversification. To construct the most diversified portfolio possible, one must calculate the standard deviation of each asset in the portfolio. The formula used above in Equation 3 is then applied to determine the portfolio weights. The optimisation procedure minimises the portfolio's total volatility by solving a constrained optimisation problem (Tables 2-5).

$$DR(w) = \frac{\langle W|\sigma \rangle}{\sigma(w)} \quad (4)$$

Where:

D.R. (*w*) represents the Diversification Ratio

w represents the weight of the ith asset,

$\sigma(w)$ is the volatility of the ith asset,

$\langle w|\sigma \rangle$ is the average volatility of the asset

Results

Table 2

Risk Weights as per Optimal Risky Portfolio

Assets	Financial Market Crisis 2018	Pre Covid-19	COVID-19 Phase 1	COVID-19 Phase 2	Russo-Ukrainian War	US Fed Rate Hike 2023 Phase
EMB	0%	0%	0%	0%	0%	0%
Gold	0%	0%	0%	0%	0%	100%
Crude	0%	0%	0%	0%	100%	0%
MSCI	0%	0%	0%	0%	0%	0%
S&P	0%	0%	0%	0%	0%	0%
REITs	0%	0%	0%	0%	0%	0%
Bitcoins	100%	100%	100%	100%	0%	0%
Sharpe Ratio	-0.3689	-0.0987	-0.0145	0.0099	-0.2603	-1.4454

Source: Author's Calculations

Table 3

Risk Weights as per Equal Risk Contribution Portfolio

Assets	Financial Market Crisis 2018	Pre Covid-19	COVID-19 Phase 1	COVID-19 Phase 2	Russo-Ukraine War	US Fed Rate Hike 2023 Phase
EMB	30%	31%	20%	30%	24%	19%
Gold	25%	20%	30%	19%	26%	20%
Crude	9%	6%	5%	8%	7%	10%
MSCI	10%	15%	18%	14%	18%	22%
S&P	10%	11%	12%	13%	10%	12%
REITs	14%	14%	10%	13%	11%	12%
Bitcoins	3%	3%	7%	3%	4%	6%
Sharpe Ratio	-2.4275	-1.8841	-0.2139	-0.7191	-1.2285	-1.8386

Source: Author's calculations

Table 4

Asset Weights as per MDP

Assets	Financial Market Crisis 2018	Pre Covid-19	Covid-19 Phase1	COVID-19 Phase 2	Russo-Ukraine War	US Fed Rate Hike 2023 Phase
EMB	58%	56%	12%	68%	40%	26%
Gold	23%	13%	62%	14%	32%	20%
Crude	6%	6%	9%	8%	9%	13%
MSCI	0%	12%	13%	4%	14%	27%
S&P	0%	0%	0%	0%	0%	2%
REITS	7%	8%	0%	1%	0%	3%
Bitcoins	6%	5%	4%	6%	6%	10%
Sharpe Ratios	-2.6325	-1.9022	-0.2057	-0.7767	-1.2571	-1.7598
Diversification Ratio	9	11.18	5.63	7.9	5.07	3.93

Source: Author's calculations

Table 5

Results of T-tests

ORP & ERC (Sharpe Ratio)	**ORP & ERC (VaR)**
P value: 0.03216	**P value: .004663**
ERC & MDP (Sharpe Ratio)	ERC & MDP (VaR)
P Value: 0.937	P Value: 0.953
MDP & ORP (Sharpe Ratio)	**MDP & ORP (VaR)**
P Value: 0.0348	**P Value: 0.0069**

Source: Author's calculations

A two-sample test of means of Sharpe ratios and Value at Risk was conducted between the paired portfolio construction methods. The results of the ANOVA hypothesis were -

Null hypothesis: Ho: $\mu orp = \mu erc = \mu mdp$

There is no significant difference in the means of the Sharpe ratios and Value at Risk of ORP, ERC and MDP methods.

Alternative Hypothesis: H1: $\mu orp \neq \mu erc \neq \mu mdp$

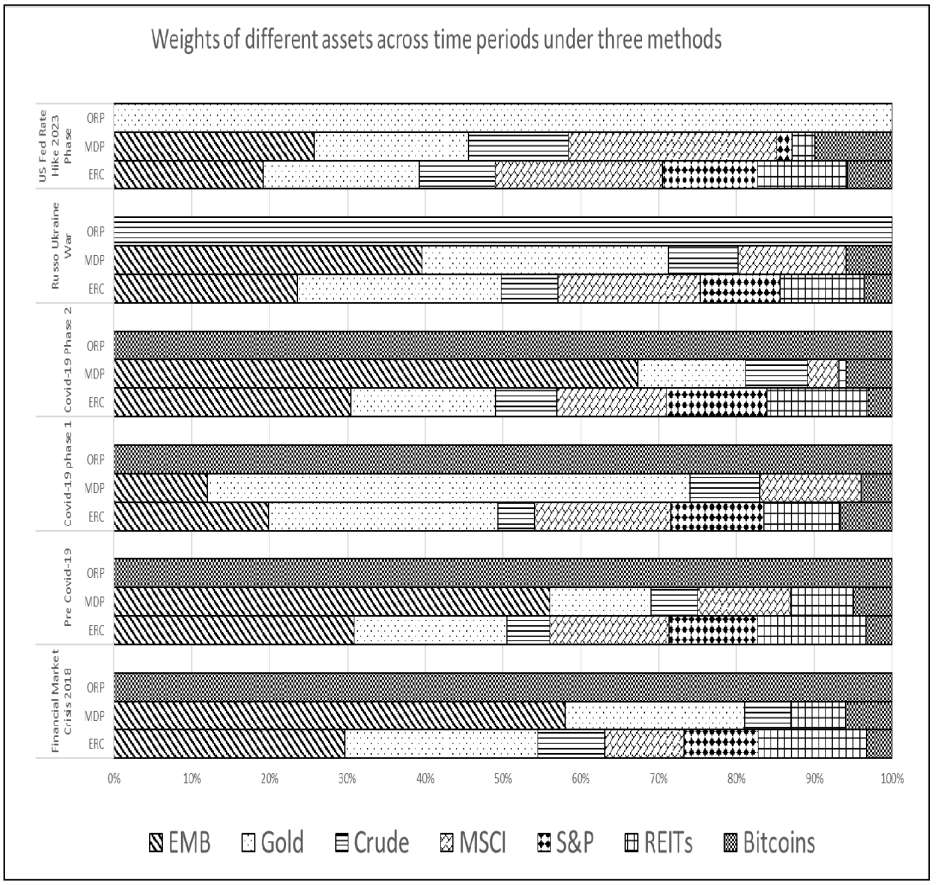

Fig.1. Wights of different assets across time periods under three methods
Source: Author's Creation

The means of the Sharpe ratios and Value at Risk of the ORP, ERC, and MDP methods differ significantly.

Discussions

Fig. 1 exhibits the tapestry of portfolio allocation weights across different risky assets under the three optimisation methods: ORP, ERC, and MDP.

Table 2 represents the weights of the seven different assets across the six periods under study using the Optimal Risky Portfolio Method (ORP). The portfolio composition from January 2018 to September 2021 shows Bitcoin receiving a 100% weight in the multi-asset portfolio, having the best Sharpe ratio. The findings of our paper are consistent with those of Briere et al. [27], whose study found that portfolios funded with cryptocurrencies perform better. Bouri et al. [22] also found that Bitcoin serves as a good diversifier in a multi-asset portfolio. Similarly, studies by Koziuk and Akyildirim et al. [28-29] concluded that including cryptocurrencies in multi-asset portfolios improves risk-adjusted return performance. The period from October 2021 to mid-August 2022 was marked by the onset of the Russia-Ukraine war. In our ORP portfolio, crude oil received a 100% allocation. The beginning of 2022 was characterised by this conflict, which led to extreme volatility in global crude oil prices, coupled with surging demand in the oil and gas sector in the post-COVID-19 period. Previous studies by Bessler et al. [30] suggested that using crude futures improves the performance of bond-stock portfolios. The ongoing Russia-Ukraine war and the

US Fed interest rate tightening marked the last period from mid-August 2022 to mid-June 2023. Gold once again emerged as a safe haven for international investors amidst the U.S. Fed interest rate tightening and the continuing geopolitical tensions between Russia and Ukraine. This represents an extreme market condition, and our results align with previous studies by Bredin et al. [31] (who found gold to be a safe haven during financial crises), Aboura et al. [32] (for the period between 1988 and 2013 in multi-asset portfolios), Tiwari et al. [33] (for the period between 1985 and 2017), and Ren et al. [34] (during the pre-COVID-19 phase).

Table 3 presents the weights obtained under the Equal Risk Contribution (ERC) method, which aims to distribute risk evenly across all asset classes. By visualising the portfolio across six different periods, it can be observed that Emerging Market Bonds and Gold contribute approximately 40–50% of the total portfolio, while Bitcoin and Crude have significantly lower contributions throughout. During the COVID-19 pandemic, Gold substantially dominated the portfolio in COVID-19 Phase I, acting as a hedge against all other asset classes. In the period corresponding to the US Fed rate hike, the portfolio exhibits an almost equal weighting across all asset classes. Additionally, there is a notable increase in the contribution of the MSCI Index to the overall portfolio. Examining the Sharpe ratios of the portfolios across the six different periods, the risk-adjusted returns are lower than those achieved through the Optimal Risky Portfolio Method. However, the COVID-19 Phases I and II display higher Sharpe ratios than any other periods under the Equal Risk Contribution method.

Table 4 presents the portfolio results obtained under the Most Diversified Portfolio (MDP) method. The analysis indicates that from January 2018 to mid-August 2022, the MDP method emphasised Emerging Market Bonds (EMBs) and Gold, which together accounted for approximately 60-80% of the portfolio. However, in the final phase of the analysis, the combined contribution of EMBs and Gold declined to below 50%. It is challenging to interpret the performance of assets such as the S&P and REITs because, under the MDP method, these two assets consistently hold weights between 0% and 13%. In contrast, the weights of assets such as Crude, MSCI, and Bitcoin fluctuate between approximately 3% and 27% across the six phases. During the COVID-19 pandemic, the results obtained under the ORP method were completely opposite to those derived from the MDP method. The ORP results placed 100% emphasis on Bitcoin.

In contrast, the results provided under the diversified method leaned more toward Gold, with an allocation of around 62%, which acted as a hedge against other assets during that period. Furthermore, as the markets began to recover in 2021, the Emerging Market Bonds (EMBs) started outperforming once again. The data reveal that the diversification ratio fluctuated across different periods, with both increases and decreases observed, indicating significant variation in the portfolio's overall diversification level.

Table 5 depicts a statistically significant difference in the Sharpe ratios between the ORP and ERC methods, as well as between the ORP and MDP methods. This suggests that the risk-adjusted returns of the portfolios constructed using the ORP method are superior to those achieved through the ERC and MDP methods. However, no statistically significant difference in the Sharpe ratios was observed between the ERC and MDP methods.

A similar pattern is observed in the Value at Risk (VaR) metrics. There is a statistically significant difference in the expected shortfall in portfolio value between the ORP and ERC methods, as well as between the ORP and MDP methods. This indicates that the portfolios constructed using the ORP method experience a smaller shortfall in portfolio value compared to those created using the ERC and MDP methods. However, no statistically significant difference in the Sharpe ratios was observed between the ERC and MDP methods.

This study used various portfolio construction methods to examine a diverse portfolio over five years. Interestingly, all

six phases of the study showed negative Sharpe ratios, as depicted in Table 2. This underperformance relative to the risk-free rate can be attributed to a combination of external factors. The study's timeframe coincided with several significant events that led to market downturns, such as the COVID-19 pandemic, the Russia-Ukraine conflict, and the US Fed tightening of interest rates. These events directly impacted the portfolio's performance, causing asset prices to drop and resulting in negative returns for investors. During the period analysed, the potential rise in the risk-free rate may have contributed to the negative Sharpe ratios. The Sharpe ratio is a measure used to assess a portfolio's performance by considering its level of risk. It evaluates how much additional return a portfolio generates compared to the risk-free rate relative to its volatility. If the risk-free rate increases, it can make it more challenging for a portfolio to achieve a positive Sharpe ratio. Jacobsen et al. [35] agreed that even assets with negative returns can be included in a diversified portfolio due to the generally sufficient conditions for risk parity portfolios to be Sharpe ratio optimal, based on the diversification features of assets.

Paramitha et al. [36] also noted that when evaluating the performance of a portfolio's assets over different time frames, it is possible that the portfolio experienced high overall volatility. This high volatility, measured by the standard deviation of portfolio returns, can result in a negative Sharpe ratio. While a negative Sharpe ratio suggests underperformance compared to the risk-free rate during a specific period, it does not necessarily indicate that the portfolio will continue to underperform. Additional factors must be considered to fully understand the portfolio's performance. One crucial factor is the benchmark used to calculate the Sharpe ratio, as different benchmarks can lead to varying results. It is also essential to take into account the investment objectives of the portfolio. Negative Sharpe ratios may be of lesser concern if the goal is to achieve high returns in volatile markets.

Various factors, including industry relationships, market conditions, and the number of assets considered, can influence the composition of an optimal portfolio. It is widely accepted in both the finance industry and academic literature that even small portfolios, carefully selected with optimal assets, can achieve a high level of diversification. Furthermore, the concept of optimal portfolios consisting of only one asset, despite multiple assets being considered in the optimisation process, has been explored in several studies.

Lei [37] and Janabi [38] examined the construction of optimal portfolios, with [37] focusing on inter-industry relationships and [38] considering investable portfolios under crisis market conditions. Korn [39] extended this discussion to a multi-asset setting by introducing the worst-case optimal portfolio approach. Maringer [40] addressed the challenge of identifying an optimal portfolio with a limited number of assets, highlighting the use of heuristic methods in this context. Collectively, these studies underscore the dynamic nature of portfolio optimisation and the numerous factors that can influence the composition of an optimal portfolio.

Conclusion

In conclusion, this research examined the construction of multi-asset portfolios utilising seven distinct assets from January 2018 to June 2023. The portfolio construction methods employed were the Optimal Risky Portfolio, Equal Risk Contribution Portfolio, and Most Diversified Portfolio. The findings of this study provide valuable insights into the dynamics of portfolio allocation and asset weightings under varying market conditions.

The observations revealed several key points. Firstly, REITs consistently received negligible or low portfolio weights across all periods under the ORP, MDP, and ERC methods. In contrast, Bitcoin dominated the Optimal Risky Portfolio from 2018 to 2021, covering four major financial market phases: the 2018 crisis, the pre-COVID-19 period, and COVID-19 Phases 1 and 2. The appeal of Bitcoin was later replaced by Crude Oil, which experienced a surge in prices and received a 100% allocation during the Russia-Ukraine war period.

The end of 2022 and the beginning of 2023 were marked by a steady rise in US interest rates, leading to an increase in Treasury yields. During this time, Gold re-emerged as a safe haven, receiving a 100% asset weight in the portfolio. None of the other four assets – S&P 500, MSCI Emerging Market Equities Index, Emerging Market Bond Index, and REITs – received any representation in Markowitz's mean-variance optimisation of the Optimal Risky Portfolio.

The ERC and MDP results clearly indicate that Emerging Market Bonds and Gold dominated portfolio weights in each period, while Bitcoin, REITs, and Crude Oil received only minimal representation due to their higher risk levels. Under the ORP method, Bitcoin, Crude Oil, and Gold emerged as assets that significantly enhanced the Sharpe ratios. Similar findings were reported by Gupta et al. [41], who examined three periods – pre-COVID-19, COVID-19, and the Ukraine war – using portfolios that included BRICS indices, Gold, Crude, and bonds.

Statistical tests, including the test of means and ANOVA, underscored the superiority of the Optimal Risky Portfolio in generating higher Sharpe ratios and minimising portfolio value shortfalls based on Value at Risk. The findings highlight the Optimal Risky Portfolio's durability and profitability in constructing multi-asset allocations. This research underscores the importance of dynamic asset allocation and portfolio construction methods in adapting to evolving market conditions. The Optimal Risky Portfolio approach emerges as a robust strategy for building resilient multi-asset portfolios, offering valuable guidance for investors and portfolio managers seeking to optimise risk-adjusted returns and navigate turbulent financial environments. Furthermore, this research opens avenues for future studies to incorporate factors such as transaction costs and dynamic rebalancing techniques into the construction and evaluation of multi-asset portfolios.

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RETHINKING MULTI-ASSET PORTFOLIO OPTIMISATION FOR A TURBULENT BUSINESS ENVIRONMENT: NEW INSIGHTS

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Financial asset portfolio optimisation is the primary objective of all fund managers managing multiple asset classes for international investors. Multi-asset portfolios across global markets are regarded as well-rounded financial portfolios. This research paper employs three different financial portfolio optimisation techniques encompassing a diverse range of assets, namely the S&P 500, Emerging Equity Market Index, Gold, Emerging Market Bonds, Crude Oil, REITs, and Bitcoin.

The portfolios developed through the traditional Optimal Risky Portfolio (ORP) method demonstrate superior performance compared to alternative portfolio optimisation techniques, specifically the Equal Risk Contribution (ERC) and the Most Diversified Portfolio (MDP) methods, as evidenced by key metrics such as the Sharpe Ratio and Value at Risk (VaR). These findings are consistent across distinct periods, including crisis phases such as the stock market crisis of 2018, the COVID-19 pandemic, the Russia-Ukraine conflict, and the US Fed rate hikes in 2023. The study encompasses all these events within an extensive timeframe from January 2018 to June 2023.

The research underscores the importance of single-asset selection during tumultuous market conditions, identifying Bitcoin, Crude Oil, and Gold as viable options. The results reveal that MSCI Emerging Market Equities, Bonds, the S&P 500, and REITs did not significantly enhance risk-adjusted returns during the 2018–2023 period. Notably, the ORP method demonstrated significantly superior Sharpe Ratios and Value at Risk compared to the ERC and MDP methods. Conversely, no significant differences were observed in the Sharpe Ratios and Value at Risk between the ERC and MDP portfolios.

This study contributes to the existing body of literature by reaffirming the dominance of the ORP method over the ERC and MDP approaches in volatile market conditions during the turbulent financial period from 2018 to 2023.

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