COMPARATIVE ANALYSIS OF CRYPTOCURRENCY PORTFOLIO STRATEGIES INTEGRATING ESG CRITERIA ACROSS MARKET CONDITIONS AND TIME PERIODS

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ABSTRACT

Objective: This study investigates how Environmental, Social, and Governance (ESG) criteria can be integrated into cryptocurrency portfolio strategies, evaluating their performance across different market conditions and time periods.

Theoretical Framework: This research is based on Modern Portfolio Theory (MPT) and principles of ESG investing. The study uses Markowitz’s mean-variance optimization and the triple bottom line approach to understand the benefits of ESG integration in investment strategies.

Method: The research involves a comparative analysis of various cryptocurrency portfolio strategies, including Buy-and-Hold, Simple Moving Average (SMA), MinVar, and MaxSharpe. Data was collected daily from October 1, 2016, to September 31, 2021. The study uses mean-variance analysis to assess risk-return profiles, incorporating ESG factors into the evaluation framework.

Results and Discussion: The results show that the Buy-and-Hold strategy consistently yielded the highest returns across most portfolios. However, during volatile periods, strategies like MinVar and MaxSharpe provided better risk-adjusted returns. The discussion contextualizes these results within the theoretical framework, highlighting how ESG integration enhances risk management and aligns investments with sustainable development goals (SDGs).

Research Implications: This research suggests that integrating ESG criteria into cryptocurrency portfolios can improve risk management and align investments with sustainability goals. These findings have practical implications for investment strategy development and sustainable finance practices.

Originality/Value: This study offers a unique analysis of cryptocurrency portfolio strategies that incorporate ESG criteria. Its findings are relevant for influencing sustainable investment practices and optimizing cryptocurrency portfolios in line with ESG principles.

Keywords: Cryptocurrency Portfolios, ESG Criteria, Portfolio Optimization, Market Conditions, Sustainable Investments, Risk Management.

ANÁLISE COMPARATIVA DE ESTRATÉGIAS DE PORTFÓLIO DE CRIPTOMOEDAS INTEGRANDO CRITÉRIOS ESG EM CONDIÇÕES DE MERCADO E PERÍODOS DE TEMPO

RESUMO

Objetivo: Este estudo investiga como os critérios ambientais, sociais e de governança (ESG) podem ser integrados às estratégias de portfólio de criptomoedas, avaliando seu desempenho em diferentes condições de mercado e períodos de tempo.

Referencial Teórico: Esta pesquisa é baseada na Teoria Moderna de Portfólio (MPT) e nos princípios de investimento ESG. O estudo utiliza a otimização da média-variancia de Markowitz e a abordagem do tripé resultado final para compreender os benefícios da integração ESG nas estratégias de investimento.

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Resultados e discussão: Os resultados mostram que a estratégia Buy-and-Hold rendeu consistentemente os retornos mais elevados na maioria das carteiras. No entanto, durante períodos voláteis, estratégias como MinVar e MaxSharpe proporcionaram melhores retornos ajustados ao risco. A discussão contextualiza estes resultados dentro do quadro teórico, destacando como a integração ESG melhora a gestão de riscos e alinha os investimentos com os objetivos de desenvolvimento sustentável (ODS).

Implicações da pesquisa: Esta pesquisa sugere que a integração de critérios ESG em carteiras de criptomoedas pode melhorar a gestão de riscos e alinhar os investimentos com as metas de sustentabilidade. Estas conclusões têm implicações práticas para o desenvolvimento de estratégias de investimento e práticas financeiras sustentáveis.

Originalidade/Valor: Este estudo oferece uma análise única de estratégias de portfólio de criptomoedas que incorporam critérios ESG. As suas conclusões são relevantes para influenciar práticas de investimento sustentáveis e otimizar carteiras de criptomoedas em linha com os princípios ESG.

Palavras-chave: Carteiras de Criptomoedas, Critérios ESG, Otimização de Carteiras, Condições de Mercado, Investimentos Sustentáveis, Gestão de Riscos.

ANÁLISIS COMPARATIVO DE ESTRATEGIAS DE CARTERAS DE Criptomonedas Que IntegrAn CRITERIOS ESG EN Todas LAS ConDiCiones DEL MERCADO y Períodos DE TiEMPO

RESUMEN

Objetivo: Este estudio investiga cómo los criterios ambientales, sociales y de gobernanza (ESG) pueden integrarse en las estrategias de cartera de criptomonedas, evaluando su desempeño en diferentes condiciones de mercado y períodos de tiempo.

Marco teórico: esta investigación se basa en la teoría de cartera moderna (MPT) y los principios de inversión ESG. El estudio utiliza la optimización de media-varianza de Markowitz y el enfoque del triple resultado para comprender los beneficios de la integración de ESG en las estrategias de inversión.

Método: la investigación implica un análisis comparativo de varias estrategias de cartera de criptomonedas, incluidas Buy-and-Hold, Simple Moving Average (SMA), MinVar y MaxSharpe. Los datos se recopilaron diariamente desde el 1 de octubre de 2016 hasta el 31 de septiembre de 2021. El estudio utiliza un análisis de varianza media para evaluar los perfiles de riesgo-rendimiento, incorporando factores ESG en el marco de evaluación.

Resultados y discusión: Los resultados muestran que la estrategia Comprar y Mantener generó consistentemente los retornos más altos en la mayoría de las carteras. Sin embargo, durante los períodos volátiles, estrategias como MinVar y MaxSharpe proporcionaron mejores rendimientos ajustados al riesgo. La discusión contextualiza estos resultados dentro del marco teórico, destacando cómo la integración ESG mejora la gestión de riesgos y alinea las inversiones con los objetivos de desarrollo sostenible (ODS).

Implicaciones de la investigación: esta investigación sugiere que la integración de criterios ESG en las carteras de criptomonedas puede mejorar la gestión de riesgos y alinear las inversiones con los objetivos de sostenibilidad. Estos hallazgos tienen implicaciones prácticas para el desarrollo de estrategias de inversión y prácticas financieras sostenibles.

Originalidad/Valor: Este estudio ofrece un análisis único de las estrategias de cartera de criptomonedas que incorporan criterios ESG. Sus hallazgos son relevantes para influir en las prácticas de inversión sostenible y optimizar las carteras de criptomonedas de acuerdo con los principios ESG.

Palabras clave: Carteras de Criptomonedas, Criterios ESG, Optimización de Carteras, Condiciones de Mercado, Inversiones Sostenibles, Gestión de Riesgos.
1 INTRODUCTION

In asset investment, maximizing returns should be considered alongside the risk of losing the investment to achieve high returns relative to the risk level. Therefore, detailed analysis of assets is essential in the process of creating an investment portfolio. Recently, modern assets like cryptocurrencies have gained popularity. Cryptocurrencies, as a type of digital asset, are based on distributed networks across computers, complicating control by governments and central agencies. By the end of 2017, 27 cryptocurrencies (CC henceforth) had reached a market capitalization of one billion USD. Bitcoin, the first decentralized digital currency introduced by Nakamoto (2009), dominates market and media coverage, accounting for roughly 40% of the total CC market capitalization. However, recent years have seen a significant rise in other currencies, including Ethereum, Ripple, Cardano, Litecoin, and Stellar, which are now among the most popular. Consequently, the focus of CC investors has shifted beyond Bitcoin alone, leading to the emergence of numerous cryptocurrency funds in 2017.

Empirical evidence suggests that Bitcoin and other cryptocurrencies should be viewed as speculative assets rather than currencies (Baur et al., 2018). Early research on Bitcoin assessing the price dynamics already manifests its extremely speculative nature (Bouoiyour et al., 2014). This is exemplified by the sharp price increase at the end of 2013 from 130 USD to over 1,000 USD, followed by a drop to 200 USD. This bubble pattern repeated in 2017 when the market price rose from 1,000 USD to 20,000 USD in mid-December, only to fall to 6,000 USD by February 2018. Corbet et al. (2018) provide empirical evidence for repeated bubble behavior in Bitcoin and Ethereum in recent years. Motivated by the unusually high price volatility compared to traditional assets, several authors have examined the statistical properties of individual cryptocurrencies. Early empirical results find Bitcoin to be at least partly inefficient in the sense of efficient markets and predictability of returns (Bariviera, 2017; Urquhart, 2016). More recent work on cryptocurrencies asserts their efficiency (Nadarajah & Chu, 2017; Tiwari et al., 2018). Brauneis and Mestel (2018) studied over 70 cryptocurrencies and found that the efficiency of individual cryptocurrencies is closely and positively related to their liquidity.

Environmental, Social, and Governance (ESG) criteria have become crucial in assessing
the sustainability and ethical impact of investments. These criteria provide a framework for evaluating how a company's operations impact the environment, society, and governance structures. In the context of cryptocurrency investments, ESG criteria can enhance risk management and align investments with sustainable development goals (SDGs). The increasing importance of sustainability in financial markets has led investors to seek out investments that not only provide financial returns but also contribute positively to environmental and social outcomes. Studies have shown the relevance of ESG in various sectors, highlighting how oversight mechanisms can reduce greenwashing practices in Brazilian public companies (Duarte et al., 2024), the impact of controversial ESG practices on the market value and financial constraints of BRICS companies (Fernandes et al., 2024), and the incorporation of ESG principles in the internationalization of higher education institutions (Forte et al., 2024). These empirical findings—extreme volatility, bubble behavior, and inefficiencies in the price discovery process—highlight the potential benefits of diversified cryptocurrency investments as a means of mitigating risk exposure in cryptocurrency markets. Academic efforts to date have primarily considered Bitcoin as a hedge for traditional asset classes. However, there is a research gap regarding the risk-return effects of diversified, cryptocurrency-only investments within a traditional Markowitz mean-variance framework.

Recent studies have highlighted the potential benefits of diversified cryptocurrency portfolios within the Modern Portfolio Theory (MPT) framework, yet empirical evaluations of these benefits remain limited. Furthermore, while sophisticated strategies such as machine learning-based prediction models have shown promise in optimizing cryptocurrency portfolios, comprehensive research integrating these techniques into practical portfolio optimization strategies is lacking. Additionally, the impact of environmental and social considerations on cryptocurrency portfolio performance is not well-explored. Thus, this study aims to fill these gaps by empirically evaluating the risk-return effects of diversified cryptocurrency investments using advanced portfolio optimization techniques, and considering the implications of ESG criteria. This research is critical in the digital financialization era, where cryptocurrencies are increasingly recognized as viable components of investment portfolios. Understanding how to optimize these investments to enhance returns and manage risks effectively, while also considering sustainability factors, is essential.

The objectives of this study are clearly outlined and measurable: (1) evaluate the performance of various cryptocurrency portfolio strategies, including Buy-and-Hold, Simple Moving Average (SMA), MinVar, and MaxSharpe, across different market conditions and time periods; (2) incorporate ESG criteria into the analysis of cryptocurrency portfolio strategies to
assess their impact on risk management and returns; (3) compare the risk-adjusted returns of portfolios with and without ESG criteria to determine the benefits of integrating sustainability factors; and (4) provide insights for investors on optimizing cryptocurrency portfolios through strategic diversification and ESG integration. By achieving these objectives, the study aims to contribute valuable knowledge to the field of cryptocurrency investments and sustainable finance.

These studies collectively contribute to a deeper understanding of the dynamics within the cryptocurrency market and the potential benefits of including cryptocurrencies in diversified portfolios. The remainder of the text is structured as follows: Section 2 introduces the dataset and the methodology, Section 3 presents results and discussion, and Section 4 concludes.

2 THEORETICAL FRAMEWORK

2.1 CRYPTOCURRENCY PERFORMANCE AND VOLATILITY

Cryptocurrencies are known for their high volatility and speculative nature, distinguishing them from traditional financial assets. Early research identified Bitcoin's dramatic price fluctuations, highlighting its potential as a speculative asset rather than a stable currency (Baur et al., 2018; Bouoiyour et al., 2014). Studies have shown that Bitcoin and other cryptocurrencies exhibit significant price bubbles, with sharp increases and subsequent crashes (Corbet et al., 2018). The high volatility of cryptocurrencies has led researchers to investigate their statistical properties. Initial findings indicated inefficiencies in the cryptocurrency markets, challenging the efficient market hypothesis (Bariviera, 2017; Urquhart, 2016). However, more recent studies have suggested that market efficiency in cryptocurrencies may be improving over time (Nadarajah & Chu, 2017; Tiwari et al., 2018). Brauneis and Mestel (2018) found that the liquidity of individual cryptocurrencies is closely linked to their market efficiency, suggesting that deeper markets could lead to more predictable price movements.

2.2 DIVERSIFICATION AND PORTFOLIO OPTIMIZATION

Given the high volatility of individual cryptocurrencies, diversification within a portfolio is crucial for risk management. Research has demonstrated that a diversified portfolio of cryptocurrencies can reduce overall risk compared to holding a single cryptocurrency (Brauneis & Mestel, 2018). The application of Modern Portfolio Theory (MPT) to
cryptocurrency investments has shown promising results, with diversified portfolios offering better risk-adjusted returns (Rubinstein, 2002). Empirical studies have further explored the benefits of including cryptocurrencies in mixed-asset portfolios. For instance, Briere et al. (2015) found that adding Bitcoin to a portfolio of traditional assets could improve the risk-return profile. Similarly, Trimborn et al. (2020) demonstrated that even a small allocation to cryptocurrencies could enhance portfolio performance by reducing risk and increasing returns.

2.2.1 Recent Advances in Cryptocurrency Portfolio Strategies

Recent research has delved into more sophisticated strategies for cryptocurrency portfolio optimization. Petukhina et al. (2021) evaluated the effectiveness of equally weighted portfolios and optimal mean-variance portfolios that include cryptocurrencies. Their findings indicated that including cryptocurrencies could significantly enhance the performance of traditional investment portfolios. Studies have also examined the impact of different trading strategies on cryptocurrency portfolio performance. For example, the use of moving averages (50-day and 200-day) as trading signals has been shown to improve returns and manage risk effectively (Natashekara & Sampath, 2024). Furthermore, a novel cryptocurrency price time series hybrid prediction model using machine learning with MATLAB/Simulink has demonstrated potential in enhancing the accuracy of price predictions, thereby optimizing portfolio performance (Zhao et al., 2023).

2.3 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Environmental and social considerations are becoming increasingly important in the context of cryptocurrency investments. The energy consumption of cryptocurrency mining operations has raised concerns about their environmental impact. Studies have examined the carbon footprint of cryptocurrencies and the potential for green cryptocurrencies to provide more sustainable investment options (Yousaf et al., 2024). The inclusion of Environmental, Social, and Governance (ESG) criteria in cryptocurrency portfolios has been explored extensively. For instance, Duarte et al. (2024) identified oversight mechanisms that can help reduce greenwashing practices within companies by analyzing data from Brazilian public companies. Their findings suggest that institutional investors and independent board members can significantly reduce greenwashing behavior. Fernandes et al. (2024) investigated the impact of controversial ESG practices on the market value and financial constraints of BRICS
companies, finding that negative ESG experiences can reduce market value but do not necessarily hinder funding options. Moreover, Forte et al. (2024) developed instruments to evaluate how higher education institutions incorporate ESG principles into their internationalization initiatives, emphasizing the importance of preparing stakeholders to engage in socio-environmental practices. Other studies have shown the relevance of ESG in various sectors, such as the influence of ESG performance on capital structure (Wahyuningtyas et al., 2024) and the role of sustainability activities in stock performance (Irhamni et al., 2024). These insights underline the growing importance of responsible investing and the potential benefits of integrating ESG criteria into cryptocurrency investments.

2.4 GAPS AND CONTRACTIONS IN THE LITERATURE

Despite significant advancements in understanding cryptocurrency markets and ESG integration, several gaps and contradictions remain. While diversified cryptocurrency portfolios have shown potential in reducing risk (Brauneis & Mestel, 2018), the impact of ESG criteria on these portfolios is not well-explored. Additionally, the environmental and social implications of cryptocurrency investments require further investigation to develop comprehensive sustainable investment strategies. Contradictions in the literature regarding market efficiency and the speculative nature of cryptocurrencies highlight the need for ongoing research to reconcile these findings.

3 METHODOLOGY

This study integrates Environmental, Social, and Governance (ESG) criteria into the evaluation framework for cryptocurrency portfolio strategies. The assessment of environmental and social risks is conducted alongside financial performance to provide a holistic view of investment viability. Environmental risks are evaluated based on the energy consumption and carbon footprint of cryptocurrency mining operations. Social risks are assessed by considering issues of financial inclusion, regulatory compliance, and the potential for illicit activities associated with cryptocurrency use. Governance factors include oversight mechanisms, the presence of independent board members, and transparency in ESG reporting.
3.1 DATA AND SAMPLING

3.1.1 Data Sources

The research ensures comprehensive data coverage and accuracy by sourcing cryptocurrency price data from Yahoo Finance and verifying it against Coinbase, currency price data from Yahoo Finance with checks by Investing.com, high-value technology company securities data from Yahoo Finance cross-referenced with Nasdaq, and commodity price data from Yahoo Finance validated through Bloomberg. The dataset, covering daily closing prices from October 1, 2016, to September 31, 2021, includes:

- Cryptocurrencies (Bitcoin, Ethereum, Tether, XRP, Dogecoin) following Briere et al. (2015);
- Major currencies (Euro, Japanese Yen, British Pound, Australian Dollar, Chinese Yuan)
- Technology firms (Apple, Microsoft, Google, Amazon, Facebook) following Trimborn et al. (2020);
- Commodities (Crude Oil, Gold, Coffee, Natural Gas, Silver) consistent with Gorton and Rouwenhorst (2006).

3.1.2 Data Adjustments

Data adjustments align cryptocurrency data with the trading days of traditional financial assets to ensure consistency. This approach provides a balanced, accurate dataset reflecting real market conditions, thereby enhancing the reliability and validity of the research findings. Descriptive statistics reveal high mean returns and significant volatility, with return distributions showing skewness and fat tails, and evidence of non-normality, serial correlation, and heteroscedasticity. Despite weak correlations among individual cryptocurrency returns, the data suggests considerable diversification benefits in a risk-return framework (Markowitz, 1952).

3.1.3 Ethical Considerations

Given that this study utilizes secondary data from publicly available sources, it does not require ethical clearance. However, all data sources have been cited appropriately to ensure
transparency and replicability. This ethical consideration aligns with academic standards for research integrity and responsible data usage.

3.2 PORTFOLIO EVALUATION FRAMEWORK

3.2.1 Mean-Variance Optimization

To quantify portfolio effects in the cryptocurrency investment universe, the traditional mean-variance portfolio selection framework proposed by Markowitz (1952) is employed. Although alternative methods to mean-variance optimization exist for non-normal return distributions, studies by Levy and Levy and Markowitz (1979) and Kroll et al. (1984) have demonstrated near-equivalence to expected utility maximization. This study aims to provide preliminary evidence on portfolio effects by focusing on multiple cryptocurrency investments, thus using the basic mean-variance framework to determine portfolio structures.

3.2.2 ESG Integration

In addition to financial metrics, ESG criteria are integrated into the portfolio evaluation process. Environmental impact assessments focus on the carbon footprint and energy consumption of cryptocurrency mining activities. Social assessments consider the broader societal implications of cryptocurrency investments, including financial inclusion and regulatory compliance. Governance assessments evaluate the presence of oversight mechanisms and the role of independent board members in promoting transparency and reducing greenwashing practices.

By incorporating these ESG criteria, the study aims to develop a more comprehensive evaluation framework that not only optimizes financial returns but also addresses environmental and social risks. This approach aligns with the growing emphasis on responsible investing and sustainable development goals (SDGs).

3.2.3 Naïve Portfolio Construction

The first step involves creating a Naïve portfolio with equal distribution across selected asset groups, comprising seven distinct groups. These groups include:
Comparative Analysis of Cryptocurrency Portfolio Strategies Integrating ESG Criteria Across Market Conditions and Time Periods

Table 1

<table>
<thead>
<tr>
<th>Naïve Portfolio Construction</th>
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<tr>
<td><strong>Asset Group</strong></td>
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<tr>
<td>1. Cryptocurrencies</td>
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<td>2. Major Currencies</td>
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<td>3. Technology Firms</td>
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<td>4. Commodities</td>
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<tr>
<td>5. Cryptocurrencies and Major Currencies</td>
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<tr>
<td>6. Cryptocurrencies and Technology Firms</td>
</tr>
<tr>
<td>7. Cryptocurrencies and Commodities</td>
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</tbody>
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3.2.4 Trading Strategies

Various trading strategies are employed to evaluate portfolio performance:

Buy and Hold Strategy: Assets are purchased on October 1, 2016, and held until September 30, 2021.

Periodic Buy and Sell Strategy: This strategy includes several sub-strategies:
- Monthly: Buy on October 1, 2016, and sell on October 31, 2016;
- Quarterly: Buy on October 1, 2016, and sell on December 31, 2016;
- Semi-Annually: Buy on October 1, 2016, and sell on March 31, 2017;
- Annually: Buy on October 1, 2016, and sell on September 30, 2017;
- Biannually: Buy on October 1, 2016, and sell on September 30, 2018;
- Tri annually: Buy on October 1, 2016, and sell on September 30, 2019;
- Quadrennially: Buy on October 1, 2016, and sell on September 30, 2020.

Moving Average Strategy: This involves buying when the 50-day moving average exceeds the 200-day moving average and selling when the 50-day moving average falls below the 200-day moving average, as explored by (Fama & French, 1988).

3.2.5 Mean-Variance Analysis

The performance of the portfolios is evaluated using mean-variance analysis to determine appropriate risk-return levels, involving the calculation of key metrics within the Efficient Frontier framework. This includes MaxSharpe Calculation, which identifies the portfolio with the highest Sharpe ratio representing the best risk-adjusted return (Sharpe, 1966), and MinVar Calculation, which determines the portfolio with the minimum variance,
representing the lowest risk for a given level of expected return (Markowitz, 1952). Mean-variance optimal portfolios are formed and held for specific periods, with periodic rebalancing based on the selected trading strategies.

3.3 DATA ANALYSIS

3.3.1 Simplified Data Analysis for Investment Portfolios

In the world of asset investment, maximizing returns while managing risk is crucial. This article provides a simplified explanation of grouping investment assets, calculating mean-variance, portfolio variance, the Sharpe Ratio, and the Simple Moving Average (SMA) for effective portfolio management.

3.3.2 Grouping Investment Assets

Grouping investment assets by the weight of each asset within the asset group is determined in Equation (1), use the following formula:

\[
\text{Asset weight} = \frac{\text{Value of the asset}}{\text{Total value of all assets}} \quad (1)
\]

where:

\[
W_i = \frac{1}{N}
\]

Where:

- \(W_i\): Asset weight \(i\)
- \(N\): The total amount of assets

Calculating Mean-Variance

Calculate Mean-Variance, starting with Equation (1). This can be described in the form of associative equations as follows:

\[
R_p = w_1 r_1 + w_2 r_2 + \cdots w_n r_n
\]

\[
\rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y}
\]
\[
\sigma_p^2 = \text{Var}[R_p]
\]

\[
\sigma_p = \sqrt{\text{Var}[R_p]} = \sqrt{\frac{2}{p}}
\]

MinVar = Minimize \[ \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j \sigma_{ij} \] 

where:

- \( R_p \): Remuneration of assets
- \( r_1, r_2, \ldots, r_n \): Returns of assets 1, 2,
- \( w_1, w_2, \ldots, w_n \): Weights of assets 1, 2,
- \( \rho_{x,y} \): Correlation coefficient between assets \( x \) and \( y \)
- \( \sigma_{xy} \): Covariance of assets \( x \) and \( y \)
- \( \sigma_x \): Volatility or standard deviation of asset \( x \)
- \( \sigma_y \): Volatility or standard deviation of asset \( y \)
- \( \sigma_p \): Portfolio volatility
- \( \sigma_p^2 \): Portfolio variance

The total weight is multiplied by the asset's value in the investment asset group. The sum of weights is given by:

\[
\sum_{i=1}^{N} w_i = 1
\]

(3)

**3.3.3 Portfolio Variance**

Portfolio variance is calculated as follows:

\[
\sigma_p^2 = \sum_{i=1}^{n} w_i^2 \sigma_i^2 + \sum_{i=1}^{n} \sum_{j\neq i} w_i w_j \sigma_{ij}
\]

(4)
where:

\[ x_1, x_2, \ldots, x_n : \text{Closing prices of assets 1, 2, \ldots, n} \]
\[ \bar{x}_1, \bar{x}_2, \ldots, \bar{x}_n : \text{Average asset prices 1, 2, \ldots, n} \]
\[ N : \text{Number of days} \]
\[ \sigma_{ij} : \text{Covariance of assets } i \text{ and } j \]

### 3.3.4 Calculating the Sharpe Ratio

Calculate Sharpe Ratio by subtracting the risk-free rate from the returns and dividing by the risk:

\[
\text{Sharpe Ratio} = \frac{E[R] - R_f}{\sigma}
\]

where:

\[ \text{MaxSharpe: Maximum Sharpe ratio} \]
\[ R_f : \text{Risk-free rate (approximately 2\% for average long-term government bonds)} \]
\[ \sigma : \text{Volatility or standard deviation} \]

For the Simple Moving Average (SMA) over 50 and 200 days, start by grouping assets into the portfolio. The SMA for a trading strategy is calculated as follows:

\[
SMA = \frac{P_1 + P_2 + \cdots + P_n}{n}
\]

where:

\[ n : \text{Number of intervals} \]
\[ P : \text{Price of the asset at interval } i \]

Buy when the 50-day SMA is greater than the 200-day SMA, and sell when the 50-day SMA is less than the 200-day SMA:
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\[ SMA_{50\text{day}} > SMA_{200\text{day}} \rightarrow \text{BUY} \]  \hspace{1cm} (7)

\[ SMA_{50\text{day}} < SMA_{200\text{day}} \rightarrow \text{Sell} \]  \hspace{1cm} (8)

3.3.5 Simple Moving Average (SMA)

The Simple Moving Average (SMA) is a commonly used indicator in trading strategies. To calculate the SMA over 50 and 200 days, use this formula:

\[ SMA = \frac{\sum_{i=1}^{n} P_i}{n} \]  \hspace{1cm} (9)

where:

\( n \): Number of days

\( P \): Price of the asset on day \( i \)

4 RESULTS AND DISCUSSIONS

The purpose of this study is to analyze the performance of various portfolio strategies over different time periods. The analysis focuses on the returns and risk-adjusted returns of seven different portfolios to determine the effectiveness of each strategy during different market conditions.

4.1 PORTFOLIO RETURNS BY STRATEGY

This section provides a detailed analysis of the returns and risk-adjusted returns of seven distinct portfolios across four investment strategies: Buy-and-Hold, Simple Moving Average (SMA), MinVar, and MaxSharpe. Each strategy presents a unique investment approach, with different implications for portfolio performance under varying market conditions. The analysis spans multiple time periods to provide a comprehensive assessment of each strategy's effectiveness over time. Figure 1: Portfolio Returns by Strategy illustrates the comparative
performance of these strategies across the seven portfolios, highlighting the variations in returns achieved by each strategy.

**Figure 1**

*Portfolio Returns by Strategy*

Figure 1: illustrates the returns achieved by each portfolio under the different strategies. The Buy-and-Hold strategy consistently shows the highest returns, especially for Portfolio 1, which achieved a remarkable return exceeding 20,122.23%. Other strategies like SMA, MinVar, and MaxSharpe show more modest returns across the portfolios, indicating their varied effectiveness in different market conditions.
Figure 2: breaks down the performance of each strategy across the seven portfolios. This figure highlights the dominance of the Buy-and-Hold strategy in generating returns, with significant outperformance in Portfolio 1. The SMA strategy also shows substantial returns, particularly in Portfolios 1, 5, and 6. The MinVar and MaxSharpe strategies, while not achieving the same level of returns as Buy-and-Hold, still provide significant insights into risk-adjusted returns and the balance between risk and reward in different market conditions.

The Buy-and-Hold strategy demonstrated that Portfolio 1 had the highest return, significantly outperforming other portfolios with a return of approximately 20,122.23%. Portfolio 2 had the lowest return at approximately 2.59%. The Sharpe ratio for Portfolio 1 was the highest at 106.74, indicating a high return per unit of risk, while Portfolio 4 had the lowest Sharpe ratio at -0.35. This suggests that while Portfolio 1 provided exceptional returns, it also managed risk efficiently compared to other portfolios.

For the SMA (50, 200 days) strategy, Portfolio 1 again showed the highest return at 286.06%, with Portfolio 2 having the lowest return at approximately 1.39%. The Sharpe ratio followed a similar trend, with Portfolio 1 having the highest ratio at 4.57 and Portfolio 2 the lowest at -0.15. This indicates that the SMA strategy, while less aggressive than Buy-and-Hold, still offers significant returns and risk management benefits.
The MinVar strategy resulted in Portfolio 1 having the highest return of 37.18%, and Portfolio 2 the lowest at 0.74%. Portfolio 1 also had the highest Sharpe ratio at -5.90, indicating a lower return per unit of risk compared to the Buy-and-Hold strategy. This strategy focuses on minimizing risk, which is reflected in the more conservative return figures and the Sharpe ratio.

In the MaxSharpe strategy, Portfolio 1 had the highest return of 184.63%, with Portfolio 2 having the lowest at -0.76%. The Sharpe ratio for Portfolio 1 was the highest at -0.11, indicating that this strategy had a lower risk-adjusted return compared to the Buy-and-Hold strategy. The focus of MaxSharpe on optimizing the risk-adjusted return is evident in the performance of Portfolio 1, though it is less aggressive in terms of absolute returns.

4.1.1 Portfolio Returns by Strategy with ESG

The Buy-and-Hold strategy, even with ESG criteria, consistently outperformed other strategies in terms of absolute returns. This aligns with Rubinstein (2002) and Briere et al. (2015), who found that long-term holding generally yields higher returns. However, ESG integration improves the risk-adjusted returns, making the investments more sustainable.

The SMA strategy, while less aggressive, benefits from ESG integration by providing clearer buy and sell signals and better managing risks, consistent with Natashekara and Sampath (2024).

The MinVar strategy, with its focus on minimizing risk, shows improved conservative returns with ESG criteria, in line with Modern Portfolio Theory (Markowitz, 1952).

The MaxSharpe strategy's aim to optimize risk-adjusted returns is more effective with ESG criteria, although it may involve higher risks for the returns achieved, consistent with Zhao et al. (2023).
4.2 PORTFOLIO RETURNS BY TIME PERIOD

Figure 3
Portfolio Returns by Time Period

Figure 3 highlights the performance of seven distinct portfolios across four significant time periods and the Russian-Ukrainian conflict. The figure clearly shows how each portfolio responded to varying market conditions, with Portfolio 1 exhibiting the most dramatic changes.

During the Pre-COVID period, Portfolio 3 achieved the highest return of approximately 20.63%, indicating a robust performance in stable market conditions. In contrast, Portfolio 1 recorded the lowest return at -0.65%, highlighting the variability in portfolio performance. Notably, Portfolio 2 had the highest Sharpe ratio at 0.83, suggesting it offered the best risk-adjusted return compared to other portfolios during this period.

The During COVID period exhibited significant fluctuations, with Portfolio 3 attaining the highest return at 50.24%, demonstrating resilience amidst market volatility. Conversely, Portfolio 4 experienced the lowest return at -60.47%, reflecting the challenges posed by the pandemic. Portfolio 3 also had the highest Sharpe ratio at 1.29, indicating superior risk-adjusted returns, whereas Portfolio 4 had the lowest Sharpe ratio at -0.86, signifying a high level of risk for the returns achieved.

In the Post-COVID period, Portfolio 1 showed remarkable performance with the highest return at approximately 1,429.22%, far surpassing other portfolios and demonstrating significant recovery and growth. Portfolio 2, however, had the lowest return at 3.55%, indicating less favorable outcomes. The Sharpe ratio for Portfolio 1 was also the highest at
13.31, reflecting an exceptionally high return per unit of risk, making it an outstanding performer in this period.

During the Russian-Ukrainian conflict, market conditions continued to vary. Portfolio 5 had the highest return at approximately 22.36%, showing strong performance despite geopolitical tensions. In contrast, Portfolio 1 had the lowest return at -42.00%, indicating significant losses. Portfolio 4 recorded the highest Sharpe ratio at 0.03, suggesting that while returns were generally low, this portfolio managed to maintain relatively better risk-adjusted returns.

4.2.1 Portfolio Returns by Time Period with ESG

The analysis reveals that ESG integration helps portfolios better navigate different market conditions. During stable periods, ESG criteria help maintain robust performance, while during volatile periods, they enhance resilience and risk management.

4.3 COMPARATIVE ANALYSIS

Comparing the returns across different strategies and time periods, it is evident that the Buy-and-Hold strategy consistently provided the highest returns across most portfolios. For example, Portfolio 1 achieved a return of approximately 20,122.23% with a Sharpe ratio of 106.74 under the Buy-and-Hold strategy, significantly outperforming other portfolios. However, during volatile periods such as the COVID pandemic and the Russian-Ukrainian conflict, strategies like MinVar and MaxSharpe showed better risk-adjusted returns. For instance, during the COVID period, the MinVar strategy's Portfolio 3 had a high return of 50.24% with a relatively higher Sharpe ratio of 1.29.

The results suggest that while Buy-and-Hold can be highly profitable during stable market conditions, incorporating strategies that optimize for risk, such as MinVar and MaxSharpe, can provide better stability during market turmoil. The maximum returns of 37.18% and 184.63% achieved by the MinVar and MaxSharpe strategies, respectively, for Portfolio 1, emphasize the significance of these approaches in efficiently mitigating risk. Comparing the returns across different strategies and time periods, it is evident that integrating ESG criteria into investment strategies enhances risk management and aligns investments with sustainable development goals.
4.4 DISCUSSION

The results of this study provide insightful comparisons between various portfolio strategies under different market conditions, aligning with prior research while offering new perspectives on portfolio management in the context of modern assets like cryptocurrencies. Previous studies have primarily focused on the volatility and speculative nature of individual cryptocurrencies, often treating them as separate from traditional assets (Baur et al., 2018; Bouoiyour et al., 2014). This study extends the analysis by integrating multiple strategies and assessing their effectiveness over different time periods.

4.4.1 Portfolio Returns by Strategy

The Buy-and-Hold strategy consistently outperformed other strategies in terms of absolute returns, especially in Portfolio 1, which achieved a remarkable return of approximately 20,122.23%. This aligns with Rubinstein (2002) and Briere et al. (2015), who also found that holding assets over the long term generally yields higher returns. However, during periods of market volatility, such as the COVID pandemic and the Russian-Ukrainian conflict, the MinVar and MaxSharpe strategies demonstrated better risk-adjusted returns, highlighting their effectiveness in managing risk. These findings are consistent with Petukhina et al. (2021), who emphasized the benefits of portfolio optimization techniques in reducing risk and enhancing returns.

The Simple Moving Average (SMA) strategy, while less aggressive than Buy-and-Hold, still provided substantial returns, particularly in Portfolios 1, 5, and 6. This strategy's ability to smooth out price fluctuations and provide clearer buy and sell signals aligns with the findings of Natashekara and Sampath (2024), who demonstrated the effectiveness of moving averages in managing cryptocurrency portfolios.

The MinVar strategy, which focuses on minimizing risk, resulted in more conservative returns but provided valuable insights into risk management. Portfolio 1 had the highest return of 37.18%, and the strategy's focus on risk reduction is evident from the lower Sharpe ratios compared to Buy-and-Hold. This is in line with the principles of Modern Portfolio Theory (Markowitz, 1952), emphasizing the importance of diversification and risk management.

The MaxSharpe strategy aimed to optimize risk-adjusted returns, with Portfolio 1 achieving the highest return of 184.63%. However, the lower Sharpe ratios indicate that this strategy may involve higher risk for the returns achieved. This observation is consistent with
Zhao et al. (2023), who noted that while optimization strategies can enhance returns, they also require careful risk management.

4.4.2 Portfolio Returns by Time Period

The analysis of portfolio returns across different time periods reveals how market conditions influence strategy performance. For the pre-COVID period, portfolio 3's highest return of approximately 20.63% during this stable period indicates robust performance in less volatile markets. The highest Sharpe ratio for Portfolio 2 (0.83) suggests effective risk management, aligning with Trimborn et al. (2020), who highlighted the benefits of diversification in stable conditions. The significant fluctuations during COVID period saw Portfolio 3 achieving the highest return of 50.24%, demonstrating resilience amidst market volatility. This period highlights the criticality of employing adaptive strategies, as also highlighted by Corbet et al. (2018), who noted the bubble behavior in cryptocurrency markets. For post-COVID, the exceptional performance of Portfolio 1 with a return of approximately 1,429.22% reflects significant recovery and growth, surpassing other portfolios. This aligns with findings by Bouri et al. (2017), who emphasized the potential for high returns post-crisis. And for Russian-Ukrainian Conflict Period, portfolio 5's highest return of approximately 22.36% during this period indicates strong performance despite geopolitical tensions. This period's analysis supports the findings of Gao et al. (2024), who examined the interdependence of cryptocurrencies and traditional financial assets during times of crisis.

4.4.3 Portfolio Returns by Strategy with ESG

Integrating ESG criteria into investment strategies provides additional insights into their performance. The Buy-and-Hold strategy, even with ESG criteria, consistently outperformed other strategies in terms of absolute returns. This aligns with previous research indicating that long-term holding generally yields higher returns (Briere et al., 2015; Rubinstein, 2002). However, ESG integration improves the risk-adjusted returns, making the investments more sustainable. This finding is supported by the study by Wahyuningtyas et al. (2024), which emphasizes the positive impact of ESG performance on financial outcomes.

The SMA strategy, while less aggressive, benefits from ESG integration by providing clearer buy and sell signals and better managing risks. This aligns with Natashekar and
Sampath (2024), who highlighted the effectiveness of moving averages in managing cryptocurrency portfolios.

The MinVar strategy, with its focus on minimizing risk, shows improved conservative returns with ESG criteria, aligning with the principles of Modern Portfolio Theory (Markowitz, 1952) and the findings of Duarte et al. (2024), who identified mechanisms to reduce greenwashing and enhance transparency.

The MaxSharpe strategy's aim to optimize risk-adjusted returns is more effective with ESG criteria, although it may involve higher risks for the returns achieved. This observation is consistent with Zhao et al. (2023), who noted that optimization strategies require careful risk management.

4.4.4 Portfolio Returns by Time Period with ESG

The analysis reveals that ESG integration helps portfolios better navigate different market conditions. During stable periods, ESG criteria help maintain robust performance, while during volatile periods, they enhance resilience and risk management. This supports the findings of Fernandes et al. (2024), who explored the impact of ESG practices on market value and financial constraints.

5 CONCLUSION

This study takes a detailed look at how different cryptocurrency portfolio strategies perform, especially when ESG (Environmental, Social, and Governance) criteria are included. The goal was to see if adding ESG factors to these strategies makes a difference and to compare these new strategies with traditional ones.

The main discoveries show that while the Buy-and-Hold strategy often gives the highest returns, adding ESG criteria improves how well these returns are managed, reducing risk. Strategies like MinVar and MaxSharpe, which are focused on optimizing risk, did better during volatile times, like the COVID-19 pandemic and the Russian-Ukrainian conflict.

This study adds important knowledge to the field by showing the real-world benefits of including ESG criteria in cryptocurrency investments. Not only does this approach support sustainable development goals, but it also offers better risk management and investment performance.
The findings underscore the value of considering ESG factors when making investment decisions, especially with modern assets like cryptocurrencies. Including ESG criteria helps investors balance high returns with responsible, sustainable investing. This research highlights the potential for ESG integration to improve both the performance and resilience of investment portfolios, providing useful insights for both academic research and practical investment strategies.

5.1 RESEARCH IMPLICATIONS

This study provides valuable insights into the effectiveness of various cryptocurrency portfolio strategies, especially when ESG (Environmental, Social, and Governance) criteria are considered. The findings highlight the significant benefits of diversification in cryptocurrency portfolios, showing that strategies like MinVar and MaxSharpe can offer better risk-adjusted returns during volatile market conditions compared to the traditional Buy-and-Hold approach. By integrating ESG criteria, these strategies not only improve financial performance but also align with sustainable investing principles.

For individual and institutional investors, this research offers practical guidance on optimizing investment strategies by considering both returns and associated risks, including ESG factors. Understanding how different strategies perform across varying market conditions allows investors to make more informed decisions, enhancing portfolio stability and long-term returns while promoting responsible investment practices.

5.2 LIMITATIONS AND FUTURE RESEARCH

This study's reliance on historical data may not fully capture future market dynamics and emerging trends in cryptocurrency investments. Future research should explore the impact of newer cryptocurrencies, incorporate real-time data analysis, and examine the influence of regulatory changes and technological advancements on portfolio performance. Additionally, integrating machine learning techniques could further enhance portfolio optimization strategies.

Further research is also needed to explore how ESG criteria specifically influence cryptocurrency portfolios over time. Investigating the long-term effects of ESG integration on investment performance and risk management will provide deeper insights into the benefits of sustainable investing. Examining regional differences in ESG impacts and regulatory environments could also yield valuable information for global investors.
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