Proceedings of the 8th International Conference on Economic Management and Green Development
DOI: 10.54254/2754-1169/121/20242588

The Influence of ESG Factors on Portfolio Performance

--Based on the Perspective of Markowitz Portfolio Theory

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Abstract: In this paper, the inclusion of Environmental, Social, and Governance (ESG) factors in portfolios is investigated to determine their impact on portfolio performance and its mechanism. Based on the data collected by Bloomberg for 10 stocks from 2003-2023 and Markowitz's portfolio model, it is found that: (1) the inclusion of ESG constraints negatively affects portfolio performance; (2) the inclusion of ESG constraints shifts the GMVP to the right and reduces the convexity of the efficient frontier, thus lowering the portfolio's performance. This study enriches the literature on the factors affecting portfolio performance as well as responsible investment and ESG investment, and is of value to investors or organizations in making investment strategy choices.

Keywords: ESG Investment, Markowitz Portfolio, Responsible Investment.

1. Introduction

The integration of Environmental, Social, and Governance (ESG) factors into investment management has become increasingly significant in contemporary financial markets. With the rise of responsible investing, ESG investing has become a hot topic for investors.

Numerous academic studies have concluded that ESG-rated stocks typically have lower total risk and volatility, and that the consideration of ESG factors can reduce investment risk by increasing transparency and reducing information asymmetry [1]. Moreover, companies with high ESG scores outperform those with low ESG scores over the long term, especially during periods of high market volatility [2]. However, research related to the impact of ESG on portfolios is more limited. How does the inclusion of ESG factors affect portfolio performance? How does the impact of this react?

In order to explore the above issues, this study analyzes the impact of adding ESG factors on portfolio performance and its mechanism based on ten stocks in the U.S. capital market from 2003 to 2023. The U.S. financial market provides a good research scenario for analyzing the above issues because: (1) the U.S. has the largest capital market in the world, with a sound disclosure system and relatively long data records. (2) the ESG concept has been popular in the U.S. for a long time and the scoring mechanism is more mature.

The main findings of this study are: (1) Adding ESG factors to portfolio considerations weakens expected portfolio returns and reduces overall portfolio performance. (2) The addition of ESG constraints shifts the GMVP of Markowitz's portfolio to the right, making the minimum risk of the

DOI: 10.54254/2754-1169/121/20242588

portfolio larger. (3) The addition of ESG constraints makes the effective frontier convexity of MM decrease, which reduces the performance of the portfolio.

The main contributions of this study: (1) This study expands the research on ESG constraints on portfolio performance from the perspective of the U.S. market. ESG investment has been a hot topic in the capital market in recent years, and there has been extensive and in-depth research on it in the academic community, but the research on the level of ESG constraints on portfolio performance is scarce. (2) This study expands the literature in the area of comprehensive performance of Markowitz's portfolio theory from the perspective of adding ESG constraints, and enriches the research results of higher-order laddering theory.

The subsequent structure of this research paper is as follows: Part I is a literature review of corporate ESG performance and investment portfolios and the research hypotheses; Part III is the research theory, including mathematical theories and some constraints; Part IV is the research results; Part V is the analysis and discussion of the research results; Part VI presents the limitations of this paper's research methodology; and Part VII summarizes the research.

2. Literature Review and Research Hypothesis

2.1. Literature Review of Investment Portfolio

Portfolios have played an irreplaceable role in modern asset management, and their role in risk diversification [3], return optimization [4], liquidity management [5], tax optimization [6], and long-term wealth accumulation has been consistently recognized by researchers [7]. As financial literacy advances and develops, more and more factors are being considered for inclusion in portfolio decisions, enriching the choice of underlying assets and the balance of risk-return decisions. Scholars discovered the effect of portfolio time horizon on portfolio returns, using the dynamic programming approach, explicitly derived the optimal strategy and the efficient frontier for the dynamic mean-variance optimization problem [8]. In addition, Macroeconomic events [9] [10], consumer behavior [11] [12] have also added to portfolio management. Further, some researchers used machine learning regression algorithms to forecast stock values for the next period [13].

Based on Markowitz's portfolio theory, numerous scholars have optimized and added to it. Mei et al [14] considered the portfolio optimization problem for single-period investors facing different types of transaction costs, and adds desirable properties such as sparsity and stability to the trading strategy by transforming the rebalancing problem into a linear regression framework. Uberti, P. [15] incorporated the consideration of kurtosis and skewness and proposed an optimal portfolio selection method that combines expected return, variance, degree and kurtosis. The eigenvalue compression method proposed by Ortiz et al. [16] significantly improves the out-of-sample performance of Markowitz's model and reduces the volatility of the optimal weights. Besides, other scholars have extended Markowitz's portfolio theory to make it more effective and relevant to contemporary financial markets.

Currently, only a relatively small number of scholars have added ESG factors to the optimization of Markowitz's portfolios, so whether ESG factors affect the strategy and through what mechanism is subject to further research.

2.2. Literature Review of Corporate ESG Performance

Studies have found that companies with good ESG performance are good guides to their economic performance, brand image and long-term success due to their overall performance in environmental, social and corporate governance dimensions. Yuan and Xiong [17] conducted an empirical study using a sample of A-share listed companies in China from 2011-2019 and found that firms with high ESG scores tend to exhibit better performance levels. From a corporate innovation perspective, Li et

DOI: 10.54254/2754-1169/121/20242588

al. [18] found that corporate ESG performance and its three dimensions can significantly enhance corporate innovation; Fang and Hu [19] also found that ESG performance not only improves the quantity of corporate innovation output, but also helps to improve the quality of innovation. Furthermore, Lian et al. [20] and Chen et al. [21] found that firms with better ESG performance have a lower cost of debt financing, but ESG performance has a significant negative effect on the cost of equity financing. Meanwhile, corporate ESG performance has a significant inhibitory effect on corporate fraud [22].

Most of the recent research on ESG has focused on the firm's perspective, focusing on the impact of ESG performance on the firm. Academic research on the use of ESG as a stock selection indicator is scarce, and there is less research on how it further affects portfolio performance.

2.3. Research Hypothesis

This study will analyze the impact of ESG factors on portfolios in terms of the efficient frontier, the global minimum variance portfolio in Markowitz's portfolio theory.

The efficient frontier for portfolios proposed by Markowitz's model of portfolio theory is an arc from the lower left to the upper right representing all optimal portfolios, i.e., those with the highest income at a given level of risk, and those with the least risk at a given level of income. Based on a capital market perspective, Giese et al. [23] found that ESG factors can significantly affect stock valuation, risk, and performance: companies with high ESG scores typically have higher valuations and lower risk, and provide more stable returns over the long term. An G, J. [24] claimed that ESG performance, as a comprehensive assessment index of corporate green development, has been emphasized by market investors, and at the same time, research on the correlation between ESG performance and financial returns has become a hot issue in the field of ESG investment, and many studies in the international arena have shown that good ESG performance can bring good financial returns. Moreover, considering ESG utility can change investors' investment behavior and asset portfolio choices, the higher the ESG rating of an asset, the higher its allocation weight [25]. Therefore, the inclusion of ESG factors in the portfolio strategy is a reflection of the risk aversion of investors, and because of the lower level of risk they are willing to take on, the risk premium they are expected to receive will fall accordingly, which will lead to an overall decrease in the expected return. Based on the above analysis and discussion, this paper proposes the first research hypothesis:

H_1: Other things being equal, the addition of ESG factors may cause the convexity of the Markowitz portfolio model to decrease.

The second aspect relates to the global minimum variance portfolio point. Kempf et al. [26] claimed empirical studies show that an investment in the global minimum variance portfolio often yields better out-of-sample results than does an investment in the tangency portfolio and suggest investing in the global minimum variance portfolio. Besides, Clarke et al. [27] concluded that the minimum-variance portfolio at the left-most tip of the efficient frontier has the unique property that optimal security weights are solely dependent on the security covariance matrix without regard to expected returns. Furthermore, the minimum variance tends to hold low beta and low residual risk stocks [28]. With the development of financial theory and the application of mathematics, Bodnar et al. [29] based on the sample estimator and the shrinkage estimator of the GMVP weights, creatively constructed two tests for the weights of the GMVP in a high-dimensional setting, whose sample size tends to infinity. Therefore, this paper proposes the second hypothesis:

H_2: Other things being equal, the inclusion of ESG considerations in the portfolio would shift the global minimum variance portfolio point to the left.

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3. Methodology

3.1. Mean-Variance Theory

Mean-variance theory is a central part of Modern Portfolio Theory (MPT), introduced by Harry Markowitz in 1952.

3.1.1. Expected Return

The expected return of the portfolio is the weighted average of the expected returns of each asset. The formula is shown below:

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

where w_i is the weight of asset i in the portfolio, and $E(R_i)$ is the expected return on asset i. In addition, each sum of the weight of the assets in the portfolio follows:

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

3.1.2. Variance and Standard Deviation

The risk of a portfolio is measured by the variance or standard deviation of its returns. The formula for the variance of a portfolio is given below:

$$\sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_{ij} \tag{3}$$

where σ_{ij} is the covariance between asset i and asset j, following calculation methodology:

$$\sigma_{ij} = Cov(X_i, X_j) = \sigma_i \sigma_j \rho_{ij} \tag{4}$$

and ρ_{ij} is the correlation coefficient between variable X_i and variable X_j.

3.2. Setting ESG Constraint

In this paper, environmental, social and governance factors are introduced into the investment decision-making process to achieve more holistic and sustainable investment objectives, which in turn reduce risk, improve long-term returns and satisfy investor values. Therefore, this study sets up the ESG Constraint:

$$\sum_{i=1}^{n} (E_i + S_i + G_i) w_i \leq 0.9 \times \sum_{i=1}^{n} (E_i + S_i + G_i)\, \hat{w}_i \tag{5}$$

This constraint indicates that the weighted sum of the new portfolios on the ESG score cannot exceed 90% of the effective risk portfolio without the ESG constraint. It means that during the optimization process, the ESG performance of the portfolio cannot be too low, and a certain ESG standard needs to be maintained relative to the original ESG-constrained portfolio without ESG constraint.

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3.3. Setting limits on Percentage of Investor's Equity

In order to limit the exposure due to leverage and to ensure sufficient equity, the research sets constraint on percentage of investor's equity. This study mimicked the Regulation T, administered by the Federal Reserve, primarily addresses the initial margin requirements for purchasing securities. Based on the above, the constraint allows broker-dealers to allow their customers to have positions, 50% or more of which are funded by the customer's account equity:

$$\sum_{i=1}^{n} |w_i| \leq 2 \tag{6}$$

In conjunction with the above, the ESG constraints and financing constraints will be added into Markowitz portfolios, combined with the use of the Solver Table (an excel plug-in) tool to analyze and study the changes in the efficient frontier and global least-squares of the portfolios before and after the constraint is added in order to draw conclusions from the study.

4. Results

The Study will use Bloomberg to obtain 20 years (2003~2023) of daily data of total returns for the S&P 500 index (ticker symbol "SPX"), and for ten stocks (ticker symbols see the Table1 below) such that there are three sectors of stocks with stocks in each group belonging to one (Yahoo!finance) sector and an instrument representing risk-free rate, 1-month annual Fed Funds rate (ticker symbol "FEDL01"). The contemporaneous ESG [ESG3] scores data also from Bloomberg for all of companies with detailed explanations to them.

Table 1: Underlying Stocks in The Portfolio

Stock	Stock #1	Stock #2	Stock #3	Stock #4	Stock #5	Stock #6	Stock #7	Stock #8	Stock #9	Stock #10
Firm	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUK	ALK	HA

This study firstly simulates the typical limitations existing in the U.S. mutual fund industry: A U.S. open-ended mutual fund is not allowed to have any short positions. Therefore, the constraint will ensure that all the weights must be larger than zero. Then the study uses Solver to process the weights of stocks in the portfolio when the portfolio variance is minimized and weights of stocks when the Sharpe ratio is maximized. The results are presented in Table 2 below.

Table 2: Mutual Fund Portfolio without ESG Constraint

	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUK	ALK	HA
MinVar	2.93%	34.63%	5.93%	0.00%	0.00%	5.71%	47.62%	2.12%	1.06%	0.00%
MaxSharpe	33.18%	0.00%	5.00%	0.00%	0.00%	0.00%	42.14%	0.00%	13.73%	5.96%
	Return			Std			Sharpe Ratio			
MinVar	10.02%			15.97%			0.628			
MaxSharpe	16.01%			19.35%			0.828			

After that, the ESG constraint mentioned in methodology 3.2 will be applied to the portfolio and use the same methodology to derive the asset weights for the minimum variance of the portfolio under

DOI: 10.54254/2754-1169/121/20242588

the ESG constraint as well as the asset weights under the maximum Sharpe ratio, respectively. The results are demonstrated in Table 3.

Table 3: Mutual Fund Portfolio with ESG Constraint

	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUK	ALK	HA
MinVar	1.77%	32.45%	5.65%	0.00%	0.00%	6.02%	52.55%	1.57%	0.00%	0.00%
MaxSharpe	26.43%	0.00%	1.50%	0.00%	0.00%	0.00%	59.42%	0.00%	6.39%	6.27%
	Return			Std			Sharpe Ratio			
MinVar	10.00%			16.00%			0.625			
MaxSharpe	15.09%			18.57%			0.813			

Similarly, in the absence of the ESG constraint, the model will add the constraint mentioned in the methodology that allows brokers to allow their clients to hold 50% or more of their positions that are funded from the client's account equity, allowing investors to short the stocks. The result is shown in Table 4.

Table 4: Equity Ensuring Portfolio without ESG Constraint

	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUK	ALK	HA
MinVar	6.11%	31.43%	8.21%	6.18%	-5.87%	32.00%	55.59%	10.48%	-0.30%	-3.82%
MaxSharpe	34.30%	-0.08%	12.93%	4.28%	-3.35%	21.74%	58.12%	-6.54%	10.41%	8.19%
	Return			Std			Sharpe Ratio			
MinVar	12.07%			15.60%			0.774			
MaxSharpe	20.45%			18.60%			1.099			

Finally, this research will add the ESG constraint to the strategy and use Solver to produce financial data under that condition. The result is shown in Table 5.

Table 5: Equity Ensuring Portfolio with ESG Constraint

	ADBE	IBM	SAP	BAC	C	WFC	TRV	LUK	ALK	HA
MinVar	7.08%	27.65%	8.07%	8.85%	-36.34%	31.89%	64.66%	-10.32%	1.79%	-3.33%
MaxSharpe	28.70%	-2.20%	9.93%	2.52%	-41.52%	22.61%	73.87%	-6.28%	3.86%	8.52%
	Return			Std			Sharpe Ratio			
MinVar	12.07%			15.60%			0.774			
MaxSharpe	20.45%			18.60%			1.099			

The study then uses SolverTable to draw the above four mean-variance images and group the portfolios constrained with mutual fund constraint and ESG limitation, which named Portfolio Series A, and the portfolios constrained with equity constraint and ESG limitation, named Portfolio Series B. The images are then used to take the next step in the analysis.

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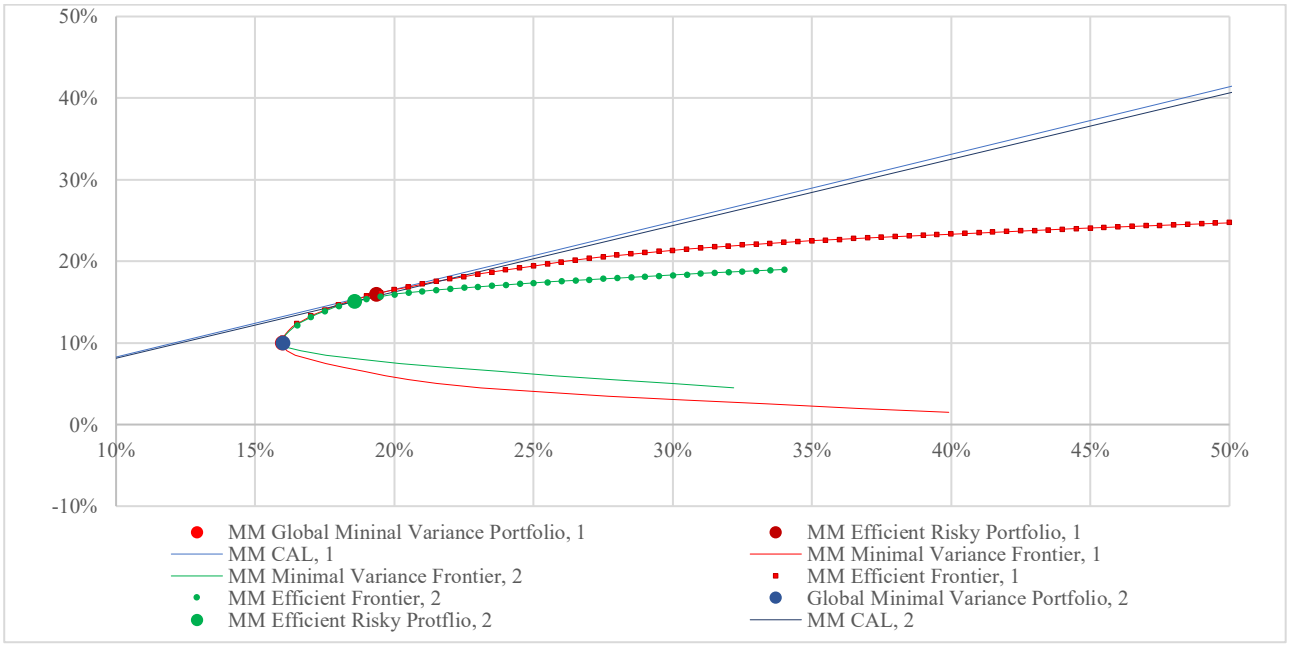

Figure 1: The mean-variance image of Portfolio Series A

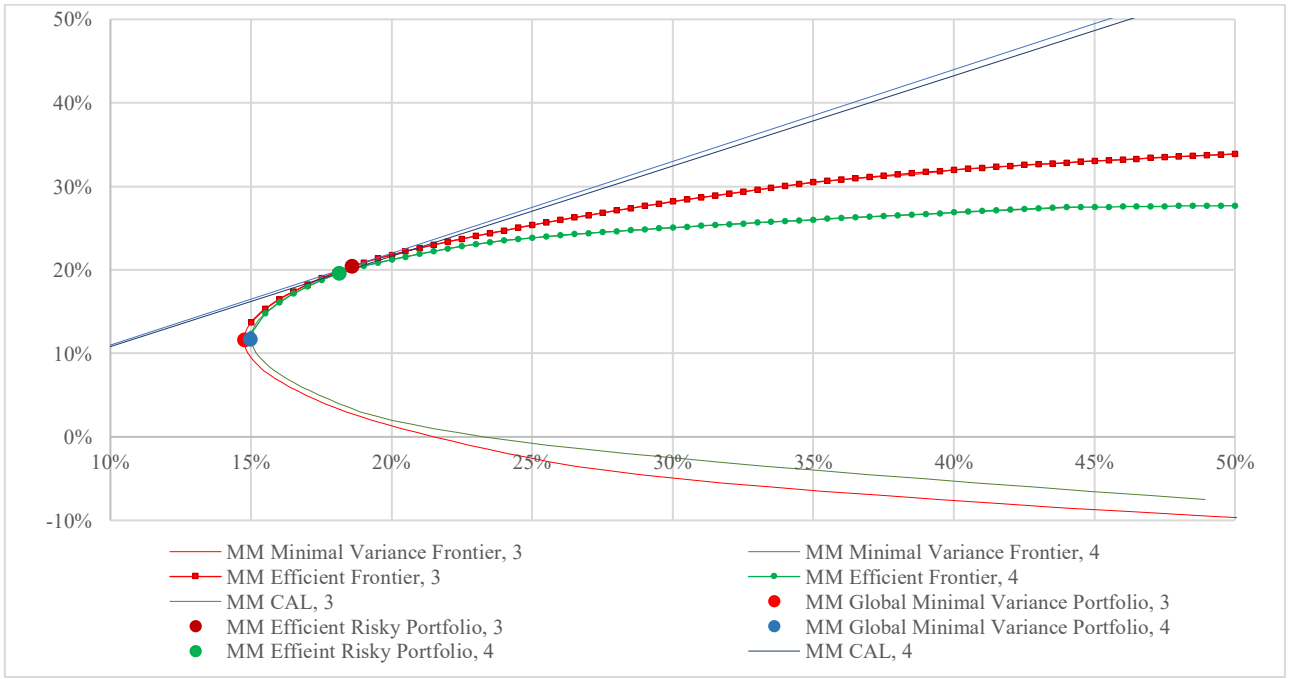

Figure 2: The mean-variance image of portfolio Series B

Figure1 demonstrates that the convexity of the red curve is smaller than that of the green curve, i.e., the addition of the ESG constraint reduces the convexity of the effective frontier. In the Figure2, the effective frontier with ESG constraint reflects similar results to the Figure1, showing the less convexity compared to the constraint without ESG factor.

Combined with the information reflected in the above graphs, the inclusion of ESG constraint does make the convexity of the MM's efficient frontier smaller. Therefore, the results confirm H_1.

DOI: 10.54254/2754-1169/121/20242588

From the perspective of global minimal variance portfolio, it can be observed that the addition of ESG constraint shifts the global minimum variance portfolio point rightward, increasing the minimum variance of the portfolios, which rejects H_2.

5. Discussion

The results above indicate that the inclusion of ESG constraint reduces the investment performance of Markowitz's model, not only making the model's efficient frontier less convex, but also shifting the portfolio's point of minimum risk to the right. In the following paragraphs, this study will analyze in depth the root causes of the above phenomenon.

5.1. The Analysis on Global Minimizing Portfolio

Given that the variance of the portfolio can be expressed as:

$$\sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_{ij} \tag{7}$$

The inclusion of ESG constraints changes the covariance matrix between the remaining assets due to the fact that the excluded assets typically have different return and risk characteristics. The new covariance matrix may reflect higher correlations, as assets with high ESG scores may be concentrated in particular industries, which leads rise to σ_{ij} and $w_i w_j$, reduces diversification effects and increases portfolio risk. Therefore, the GMVP moves rightward.

5.2. The Analysis of Effective Frontier

Covariance Matrix is a matrix that describes the covariance of returns between different assets. In portfolio optimization, the covariance matrix is used to calculate the overall risk of a portfolio. Moreover, the basis for constructing the efficient frontier is to compute the expected return and covariance matrix for each asset. As ESG constraint is added to the investment, it has an impact on the weighting of each stock in the portfolio. Therefore, in this study, enhancing the overall ESG performance of the portfolio comes at the expense of portfolio diversification, causing some stocks to fall to zero as a percentage of the portfolio. The decline in number of underlying assets causes the dimensionality of the covariance matrix to decrease and thus the shape of the efficient frontier to change, shifting downward.

In addition, the decrease in dimensionality of the covariance matrix shrinks the feasible region covered by the efficient frontier. Also, certain extreme combinations (e.g., high-risk, high-return or low-risk, low-return) that would otherwise be achievable through certain underlying investments are no longer feasible with fewer of those stocks.

The reason for the rightward shift of the GMVP has been analyzed in 5.1, due to the rightward shift of the GMVP and the downward shift of the effective frontier curve, both of which together make the convexity of the effective frontier curve decrease, thus failing to achieve the desired results.

5.3. The Discussion on Long-term Effect vs. Short-time Effect

It may be that the results of the study discourage investors who value responsibility, but the trade-off between long-term and short-term returns on investments should still not be ignored. It has been shown that companies that emphasize ESG usually perform better in the long run. Besides, investors can get a more comprehensive understanding of the potential risks of the enterprise [30] [31]. These are because they are more sustainable and better able to cope with external shocks and market changes.

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So, if the time effect is considered through adding ESG constraints to portfolio returns, investors may want to hold these assets for a longer period of time.

The results of this study in no way exhort investors to focus on the temporary negative impact of the inclusion of ESG constraint on their portfolios, but rather to look at the long-term returns of their portfolios in a sustainable light.

6. Limitation

6.1. Overfitting Problem

In the Markowitz portfolio model, in-sample data are used for model construction and optimization to determine the optimal asset allocation by estimating the expected return and covariance of assets from historical data. Overfitting occurs due to the use of too many historical data points and complex model parameters that cause the model to fit random fluctuations and anomalies in the data. Overfitting occurs when the model overfits the features and noise of the historical data rather than capturing the true trends and patterns of the data.

6.2. Representativeness of Historical Data Problem

This study uses stock data from the past 20 years to construct portfolios. Since certain stocks have performed exceptionally well in the past, the model may give these stocks a higher weighting. However, the performance of these stocks may have been due to specific historical events or market conditions that may not necessarily be repeated in the future. If market conditions change, such as a deterioration in the macroeconomic environment or increased competition in the industry, the performance of these stocks may decline significantly, resulting in an overall underperformance of the portfolio.

7. Conclusion

The empirical results indicate that the inclusion of ESG factors tends to reduce the convexity of the efficient frontier, thereby leading to lower expected returns for a given level of risk and higher risk for a given level of return. Specifically, the addition of ESG constraint was found to shift the GMVP rightward, suggesting an increase in the portfolio's minimum risk level.

The ESG constraint may result in short-term performance trade-offs, the long-term benefits could outweigh these drawbacks. Companies with high ESG scores generally exhibit better risk management capabilities, higher resilience to external shocks, and more sustainable performance over time. These attributes can ultimately enhance long-term financial returns and stability, aligning with the growing investor emphasis on responsible and sustainable investing.

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