Impact of ESG Risk on Portfolio Optimization and Returns: An Analysis Using the Markowitz Model

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Abstract. This paper explores the integration of Environmental, Social, and Governance (ESG) factors into portfolio optimization using the Markowitz Model, focusing on two groups of ten stocks each from the Technology, Media, and Telecom (TMT) sectors. These stocks are categorized into low and high ESG risk groups according to established ESG rating agencies. Employing historical data, the study computes key financial metrics such as annualized returns, standard deviation, and Sharpe ratios to conduct various portfolio optimizations including the minimal risk frontier, efficient frontier, and inefficient frontier, while also applying five specific operational constraints reflective of real-world investment limits. The analysis distinctly highlights the superior performance of the low ESG risk group, which demonstrated higher returns and better risk-adjusted return profiles, as evidenced by elevated Sharpe ratios. These findings suggest that ESG integration not only aligns with broader societal goals but also enhances financial performance, especially under diverse regulatory and strategic constraints. This research enriches the discourse on sustainable investing by providing empirical evidence on how ESG factors influence traditional portfolio management strategies, potentially guiding future investor decisions and promoting a shift towards more sustainable investment practices.

Keywords: Markowitz Model, Portfolio Optimization, ESG, TMT, Constraints.

1. Introduction

The integration of Environmental, Social, and Governance (ESG) factors into investment management represents a significant paradigm shift within the financial industry. As global awareness of sustainability issues grows, investors and fund managers are increasingly considering the broader societal and environmental impacts of their investment choices, alongside traditional financial metrics. This shift reflects an understanding that ESG factors can substantially influence the long-term profitability and risk profiles of investments, potentially affecting an organization's sustainability and ethical footprint.

Historically, portfolio optimization has been guided by the principles developed by Harry Markowitz in 1952, represents a seminal advancement in the field of portfolio theory, introducing the concept of portfolio optimization based on the trade-off between risk and return [1]. Central to the Markowitz Model is the idea that an investor can achieve optimal portfolio allocation by maximizing returns for a given level of risk, or equivalently, by minimizing risk for a given level of expected return. This is accomplished through diversification, where the combined variance of the portfolio assets provides a measure of the overall risk. Markowitz's formulation uses mean-variance analysis, which has become a foundational concept in both theoretical finance and practical investment strategy [2]. This model not only underscored the importance of asset correlation in portfolio design but also laid the groundwork for modern portfolio theory (MPT). The mathematical representation of parametric optimization of Markowitz Model is shown as follows

$$\max E(r_p) = \max \sum_{i=1}^{n} \omega_i \mu_i \tag{1}$$

$$\min \sigma_P = min \sqrt{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_i \omega_j \sigma_{ij}} \tag{2}$$

$$0 \leq \omega_i \leq 1, i = 1, \ldots, n \tag{3}$$

$$\sum_{i=1}^{n} \omega_i = 1 \quad (4)$$

Where ω_i is a percentage of capital that will be invested in asset i; r^i is the return on asset i; μ_i the expected return on asset i; μ_{ij} is the covariance between the return on assets i and j; $E(r_P)$ is the expected return of the portfolio; σ_P is the risk of the portfolio [3].

The Markowitz Model revolutionized portfolio management by formalizing the trade-off between risk and return, but it did so without accounting for the non-financial impacts encapsulated by ESG considerations. With the evolution of financial markets and the increasing complexity of factors influencing them, there is a compelling need to adapt traditional financial models to incorporate these broader considerations.

This paper explores the impact of ESG risk on portfolio optimization and returns by applying an adapted Markowitz Model to analyze how ESG factors influence the risk-return profile of investment portfolios. The study utilizes a decade of historical daily total return data from two distinct groups of 10 stocks each, categorized based on their ESG risk ratings provided by Sustainalytics. These stocks, all from the Technology, Media, and Telecom (TMT) sectors, are divided into groups with 'low' (ESG risk score less than 10) and 'high' (ESG risk score greater than 16) ESG risk ratings.

Through a detailed comparative analysis, this paper aims to uncover whether different levels of ESG risk influence investor decisions and alter portfolio returns. Specifically, it seeks to determine whether portfolios composed of stocks with lower ESG risks not only comply with ethical and sustainable investing criteria but also outperform their higher-risk counterparts in financial terms. This analysis is intended to contribute to the ongoing discourse in sustainable investing by quantifying the impacts of ESG factors on traditional portfolio optimization approaches, offering valuable insights for investors striving to align ethical practices with financial performance.

2. Literature Review

2.1. Evolution and Adaptation of Portfolio Theory

Markowitz's model for portfolio optimization is a foundational framework in finance, highlighting the critical balance between risk and return and guiding investment strategies under diverse market conditions. Ivanova & Dospatliev detailed the model's practical implementation in the Bulgarian stock market from 2013 to 2016, demonstrating its adaptability and continued relevance by identifying efficient frontiers and optimal portfolios under varied market scenarios [3]. Extending this, G. A. Pogue incorporated real-world considerations into the Markowitz Portfolio Selection Model, such as variable transaction costs, short sales, leverage options, and taxes, which are crucial yet often overlooked in theoretical models [4].

Özyeşil applied the Markowitz model to the Borsa Istanbul-30 National Stock Index (BIST-30), reaffirming the essential relationship between risk and return in financial investments. This approach highlights the shortcomings of conventional portfolio management, which typically prioritizes maximizing returns without adequate risk consideration, potentially leading to poor risk management outcomes [5]. Similarly, W. Sharpe critiqued mutual funds for their inability to surpass market benchmarks, attributing this underperformance to high expense ratios rather than market inefficiencies. His study suggests a shift towards investment strategies that emphasize diversification, risk evaluation, and the pursuit of low costs [6].

In a related vein, George Chacko and Luis M. Viceira explored optimal consumption and portfolio choices under varying risk conditions, providing solutions tailored to investors with specific consumption preferences. Their findings indicate a negative hedging demand in portfolios for highly risk-averse investors, especially when stock returns are inversely related to volatility, as commonly observed in U.S. markets [7].

2.2. Impact and Integration of ESG Factors:

The integration of Environmental, Social, and Governance (ESG) factors into the mean-variance framework marks a significant evolution in investment strategies, emphasizing ethical, social, and governance issues as core to portfolio management. Kaurissaari highlighted the trade-offs between return and responsibility, demonstrating a negative relationship between ESG scores and risk, suggesting a shift in investment objectives towards sustainability and responsibility [8]. Schmidt further emphasized that incorporating ESG criteria significantly alters portfolio performance and risk profiles, requiring a nuanced balance between traditional financial goals and sustainable investment objectives [9].

Additionally, Riedl & Smeets investigated how ESG factors enhance portfolio diversification, potentially altering portfolio volatility and performance. Their research supports the notion that ESG integration not only impacts financial outcomes but also enhances risk management processes, aligning investments with broader ethical standards [10]. Kempf and Osthoff found that implementing socially responsible investment screens can result in abnormal returns, reinforcing the financial viability of ethically focused investing strategies [11].

Emerging research by Pedersen, Fitzgibbons, & Pomorski introduces new metrics and strategies for ESG assessment, crucial for investors aiming to achieve a dual mandate of financial performance and social impact. This indicates a trend towards more comprehensive and balanced investment approaches [12]. Friede, Busch, & Bassen predict that future portfolio management will increasingly incorporate ESG factors, driven by improvements in data quality and analytical methods, which will enhance the evaluation of ESG impacts on financial performance [13].

Contemporary studies, such as those by Chen et al., use sophisticated models incorporating ESG criteria to optimize portfolios, demonstrating potential outperformance over traditional investment strategies in the US stock market from 2005 to 2017 [14]. Lapanan's exploration of investor behavior towards Socially Responsible Investments (SRIs) reveals a strong alignment with investor values, indicating a nuanced relationship between investor loyalty and financial outcomes [15]. Renneboog et al. provided a comprehensive review of SRIs, highlighting a significant trend where investors are increasingly drawn to these investments despite potential lower returns, focusing on ethical practices and good governance [16].

3. Methodology

3.1. Data Collection and Preparation

For this study, the author utilized historical daily total return data spanning a recent 10-year period for two distinct groups of ten stocks in TMT sector, with a specific focus on technology companies. These companies were selected based on the Sustainalytics ESG Risk Ratings. As shown in table 1 and table 2, the first group consists of stocks with low ESG risk scores (less than 10), while the second comprises stocks with high ESG risk scores (greater than 16). Each stock in our dataset is identified by its NAS code, ensuring a consistent framework for data retrieval and analysis.

Table 1: Low ESG Risk Companies List.

	Low ESG Risk Stocks	NAS	ESG Risk
1	Avnet, Inc.	AVT	7.7
2	CDW Corp.	CDW	8.7
3	Flex Ltd.	FLEX	9.3
4	Itron, Inc.	ITRI	9.2
5	Novanta, Inc.	NOVT	7.9
6	Plexus Corp.	PLXS	7.2
7	Sanmina Corp.	SANM	8.6
8	ScanSource, Inc.	SCSC	8.9
9	TTM Technologies, Inc.	TTMI	7.9
10	Universal Display Corp.	OLED	7.4

Table 2: High ESG Risk Companies List.

	High ESG Risk Stocks	NAS	ESG Risk
1	Yandex NV	YNDX	25.4
2	Apple, Inc.	AAPL	16.7
3	Bel Fuse, Inc.	BELFB	18.2
4	JOYY	YY	24.3
5	Extreme Networks, Inc.	EXTR	17.1
6	Meta Platforms, Inc.	META	33.9
7	Alphabet, Inc.	GOOGL	24.2
8	ViaSat, Inc.	VSAT	19.8
9	Wix.com	WIX	20.7
10	IAC, Inc.	IAC	24.8

To mitigate the effects of non-Gaussian distributions typically observed in daily financial data, we aggregated the returns into monthly observations. This aggregation not only stabilizes the variance but also simplifies the computational processes involved in subsequent analyses. For each of the 10 stocks under consideration, several fundamental metrics have been computed, including the annual average return, annual standard deviation, beta, alpha, residual standard deviation, and correlation, which are shown in the table 3-6.

Table 3: Low ESG Risk Companies Parameters.

	SPX	AVT	CDW	FLEX	ITRI	NOVT	OLED	PLXS	SANM	SCSC	TTMI
Annual Average Return	11.05%	7.85%	26.87%	19.20%	13.55%	32.90%	29.54%	13.49%	16.83%	6.00%	14.57%
Annual StDev	15.17%	27.87%	23.94%	33.65%	38.38%	31.88%	48.89%	25.50%	33.77%	33.28%	39.24%
Beta	1	1.2699	1.0737	1.3475	1.3250	1.3692	1.4481	0.9712	1.0348	1.2914	1.6244
Alpha	0	-0.0618	0.1501	0.0431	-0.0109	0.1777	0.1354	0.0276	0.0539	-0.0827	-0.0338
Residual StDev	0.00%	20.15%	17.55%	26.73%	32.70%	24.18%	43.68%	20.81%	29.90%	26.90%	30.54%

Table 4: Low ESG Risk Companies Correlation.

	SPX	AVT	CDW	FLEX	ITRI	NOVT	OLED	PLXS	SANM	SCSC	TTMI
SPX	1.0000	0.6911	0.6802	0.6073	0.5236	0.6515	0.4492	0.5777	0.4647	0.5886	0.6279
AVT	0.6911	1.0000	0.6306	0.5830	0.4750	0.4812	0.2778	0.6149	0.5893	0.6041	0.5217
CDW	0.6802	0.6306	1.0000	0.5145	0.5007	0.5039	0.3451	0.5509	0.3611	0.5598	0.5225
FLEX	0.6073	0.5830	0.5145	1.0000	0.5038	0.5055	0.4008	0.5651	0.4661	0.4934	0.6154
ITRI	0.5236	0.4750	0.5007	0.5038	1.0000	0.4449	0.2067	0.3795	0.3261	0.4221	0.4350
NOVT	0.6515	0.4812	0.5039	0.5055	0.4449	1.0000	0.4317	0.5863	0.3903	0.4513	0.5025
OLED	0.4492	0.2778	0.3451	0.4008	0.2067	0.4317	1.0000	0.4044	0.2550	0.2924	0.3905
PLXS	0.5777	0.6149	0.5509	0.5651	0.3795	0.5863	0.4044	1.0000	0.5330	0.6065	0.5418
SANM	0.4647	0.5893	0.3611	0.4661	0.3261	0.3903	0.2550	0.5330	1.0000	0.4722	0.4178
SCSC	0.5886	0.6041	0.5598	0.4934	0.4221	0.4513	0.2924	0.6065	0.4722	1.0000	0.5265
TTMI	0.6279	0.5217	0.5225	0.6154	0.4350	0.5025	0.3905	0.5418	0.4178	0.5265	1.0000

Table 5: High ESG Risk Companies Parameters.

	SPX	AAPL	YNDX	VSAT	BELFB	EXTR	WIX	GOOGL	IAC	META	YY
Annual Average Return	11.05%	29.22%	3.83%	0.78%	26.74%	24.52%	28.62%	18.46%	19.81%	23.01%	8.33%
Annual StDev	15.17%	27.54%	43.99%	40.74%	51.26%	56.30%	54.11%	23.76%	38.37%	32.81%	48.41%
Beta	1	1.2597	1.2560	1.2588	1.4442	1.7247	1.4169	1.0588	1.2880	1.0914	0.6599
Alpha	0	0.1530	-0.1005	-0.1313	0.1078	0.0547	0.1296	0.0676	0.0558	0.1095	0.0104
Residual StDev	0.00%	19.83%	39.65%	35.99%	46.35%	49.85%	49.66%	17.51%	33.03%	28.32%	47.37%

Table 6: High ESG Risk Companies Correlation.

	SPX	AAPL	YNDX	VSAT	BELFB	EXTR	WIX	GOOGL	IAC	META	YY
SPX	1.0000	0.6938	0.4331	0.4687	0.4273	0.4647	0.3972	0.6760	0.5091	0.5046	0.2067
AAPL	0.6938	1.0000	0.2474	0.1986	0.3025	0.3054	0.2546	0.4720	0.4541	0.4030	0.1282
YNDX	0.4331	0.2474	1.0000	0.1199	0.0731	0.2018	0.3876	0.3024	0.3091	0.3996	0.2723
VSAT	0.4687	0.1986	0.1199	1.0000	0.2697	0.2979	0.1687	0.3406	0.2148	0.0832	0.0796
BELFB	0.4273	0.3025	0.0731	0.2697	1.0000	0.2922	0.1675	0.2461	0.1505	0.0409	0.0914
EXTR	0.4647	0.3054	0.2018	0.2979	0.2922	1.0000	0.0882	0.3080	0.2202	0.1366	0.1278
WIX	0.3972	0.2546	0.3876	0.1687	0.1675	0.0882	1.0000	0.3599	0.4624	0.3334	0.1418
GOOGL	0.6760	0.4720	0.3024	0.3406	0.2461	0.3080	0.3599	1.0000	0.4603	0.5266	0.1967
IAC	0.5091	0.4541	0.3091	0.2148	0.1505	0.2202	0.4624	0.4603	1.0000	0.3983	0.2273
META	0.5046	0.4030	0.3996	0.0832	0.0409	0.1366	0.3334	0.5266	0.3983	1.0000	0.2664
YY	0.2067	0.1282	0.2723	0.0796	0.0914	0.1278	0.1418	0.1967	0.2273	0.2664	1.0000

3.2. Markowitz Model Optimization

Utilizing the fundamental data, the author calculated all necessary inputs for a comprehensive application of the full Markowitz Model (MM). This process involved setting up the model to find the minimum risk frontier (minimum variance frontier), efficient frontier, minimum return frontier (inefficient frontier), and the Capital Allocation Line (CAL), incorporating five specific constraints that are often used in real cases. The models are built in Excel, using Solver and SolverTable to obtain the return and the standard deviation needed to construct three frontiers for each of the five constraints. Additionally, the paper determined the minimum risk portfolio and the maximum Sharpe ratio for the portfolios. The five constraints include, $\sum_{i=1}^{11}|w_i| \leq 2$; $|w_i| \leq 1, for\ \forall i$; $no\ constraints$; $w_i \geq 0, for\ \forall i$; $w_1 = 0$.

The five constraints outlined for portfolio optimization address various regulatory and strategic considerations to define permissible investment strategies. First, the Regulation T constraint by FINRA requires the absolute sum of portfolio weights not to exceed 200%, ensuring that no more

than half of the investment is on margin. Second, an arbitrary box constraint limits individual asset weights to no more than 100%, preventing any single investment from dominating the portfolio. Third, a "free" problem allows for unrestricted portfolio construction to observe the theoretical limits of permissible portfolios and the efficient frontier. Fourth, consistent with the U.S. mutual fund industry regulations under the Investment Company Act of 1940, no negative weights (short positions) are allowed, ensuring all investments are long-only. Lastly, an additional constraint is applied to explore the impact of excluding a broad index (specified by $w_1 = 0$, testing its influence on the portfolio's performance. These constraints collectively shape the portfolio's risk and return characteristics by imposing limits on leverage, diversification, and investment direction (long-only).

3.3. Comparative Analysis and Impact Assessment

Upon establishing the optimal portfolios under each set of constraints, the paper conducted a comparative analysis of the results from the two groups of stocks—those with high and low ESG risks. The aim was to discern the influence of ESG risk scores on portfolio returns and to assess any potential implications on investor decision-making. By comparing the performance metrics and portfolio compositions across different ESG risk levels, the author provides insights into how ESG considerations might affect investment strategies and outcomes.

This methodology ensures a rigorous examination of the interplay between ESG factors and traditional financial metrics within the framework of portfolio optimization, enabling a detailed exploration of the strategic implications of ESG risk in investment decision-making.

4. Result and Discussion

The analysis of the Markowitz Model optimization outcomes for two groups of stocks, categorized by their ESG risk ratings, provides insightful contrasts in their respective portfolio performances. The author computed the minimum variance (minVar) and maximum Sharpe ratio (maxSharp) portfolios for both the high ESG risk and low ESG risk groups.

Table 7: Min Var& Max Sharpe Portfolios for Low ESG Risk Companies.

	SPX	AVT	CDW	FLEX	ITRI	NOVT	OLED	PLXS	SANM	SCSC	TTMI	**Return**	**StDev**	**Sharpe**
Min Var	125.4%	-16.3%	4.3%	-2.5%	-1.8%	-12.2%	-3.8%	18.8%	4.8%	-6.0%	-10.6%	9.3%	13.5%	0.69
Max Sharpe	6.4%	-64.0%	132.3%	14.9%	-15.9%	58.2%	3.4%	-12.4%	32.3%	-36.2%	-19.0%	50.9%	31.7%	1.61

Table 8: Min Var& Max Sharpe Portfolios for High ESG Risk Companies.

	SPX	AAPL	YNDX	VSAT	BELFB	EXTR	WIX	GOOGL	IAC	META	YY	**Return**	**StDev**	**Sharpe**
Min Var	139.6%	-14.3%	-4.3%	-5.3%	-4.1%	-5.7%	-2.6%	-1.0%	-2.9%	-4.0%	4.7%	6.5%	13.9%	0.47
Max Sharpe	-81.4%	104.6%	-25.6%	-20.5%	16.6%	12.2%	20.1%	50.5%	-10.2%	33.5%	0.2%	48.6%	38.0%	1.28

The Low ESG Risk group's Min Var portfolio primarily leverages SPX (S&P 500 Index) with a substantial allocation of 125.4%, suggesting an aggressive use of leverage to minimize portfolio variance. In the Max Sharpe scenario, the allocation significantly shifts with SPX reduced to 6.4% and a notable increase in the weight of CDW and NOVT to 132.3% and 58.2% respectively, highlighting a strategic shift to capitalize on specific stock performances for maximizing risk-adjusted

returns. Performance metrics reveal a return of 9.3% and a standard deviation of 13.5% in the Min Var setup, resulting in a Sharpe ratio of 0.69. This shifts dramatically in the Max Sharpe setup to a return of 50.9% with a higher standard deviation of 31.7%, yielding a Sharpe ratio of 1.61. This indicates a substantial increase in risk to achieve higher returns.

For the High ESG Risk group, the Min Var portfolio shows an even higher allocation to SPX at 139.6%. The Max Sharpe scenario, however, displays a diverse strategy with a strong focus on AAPL and GOOGL at 104.6% and 50.5% respectively, balancing the portfolio with investments in sectors likely perceived as stable or high-growth. The High ESG Risk portfolio in the Min Var configuration registers a lower return of 6.5% and a standard deviation of 13.9%, culminating in a Sharpe ratio of 0.47. In the Max Sharpe scenario, the portfolio performance dramatically improves with a return of 48.6% and a standard deviation of 38.0%, leading to a Sharpe ratio of 1.28. This reflects a high-risk strategy but with better returns, showcasing effective risk management and return optimization.

Both portfolios employ substantial leveraging in their Min Var configurations with over-allocations to SPX. However, the strategies in the Max Sharpe configurations show significant differences. The Low ESG Risk group focuses on specific stocks like CDW and NOVT to maximize returns, whereas the High ESG Risk group opts for a more diversified approach, particularly focusing on large-cap tech stocks like AAPL and GOOGL.

It should be noticed that the Low ESG Risk portfolio, in both configurations, demonstrates a higher Sharpe ratio and return, compared to the High ESG Risk portfolio. The Min Var scenario shows a more conservative risk profile for both groups, but the Max Sharpe scenarios indicate a more aggressive pursuit of higher returns.

The analysis highlights differing strategic approaches between the Low and High ESG Risk portfolios under the Markowitz Model, emphasizing their respective focus on maximizing returns through distinct risk management strategies. The Low ESG Risk portfolio, particularly in its Max Sharpe configuration, emerges as providing potentially more lucrative opportunities for investors seeking high returns coupled with favorable risk-adjusted performance metrics. Conversely, the High ESG Risk portfolio, though also pursuing a high-return strategy, balances its approach by investing in more diversified and perceived stable sectors, offering a safer but potentially less rewarding investment profile. This study underlines the importance of strategic asset allocation and the influence of ESG considerations in achieving desired financial outcomes in investment portfolios.

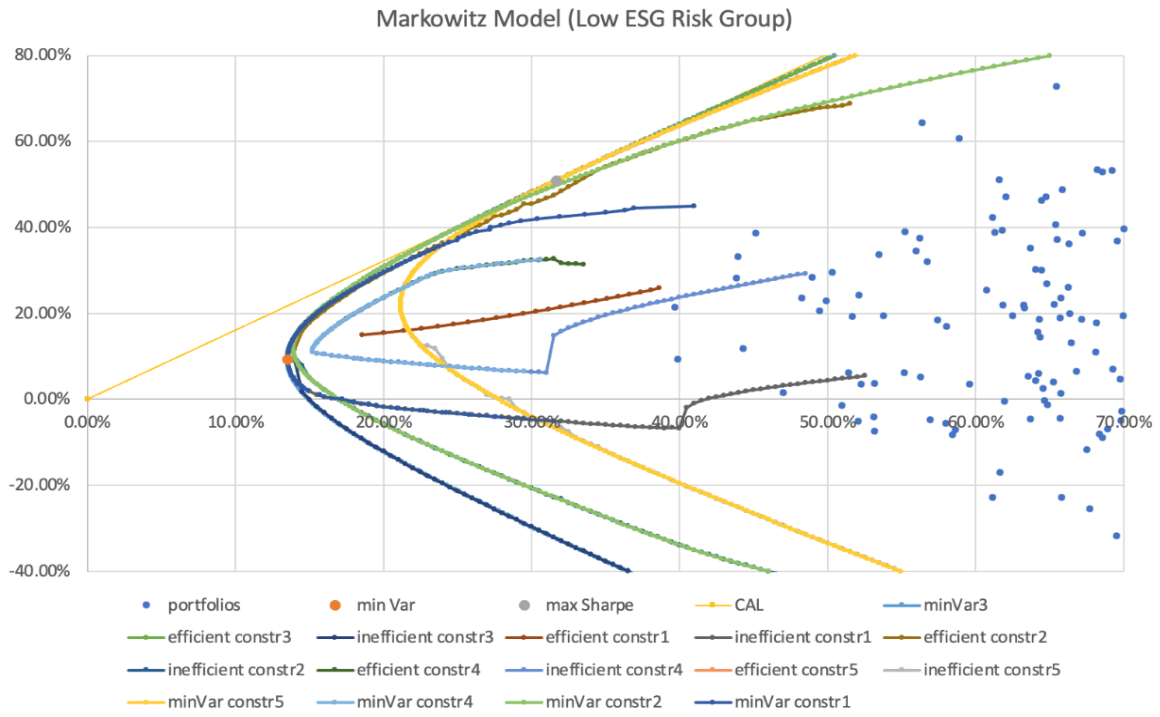

Figure 1: Markowitz Model for the Low ESG Risk Group.

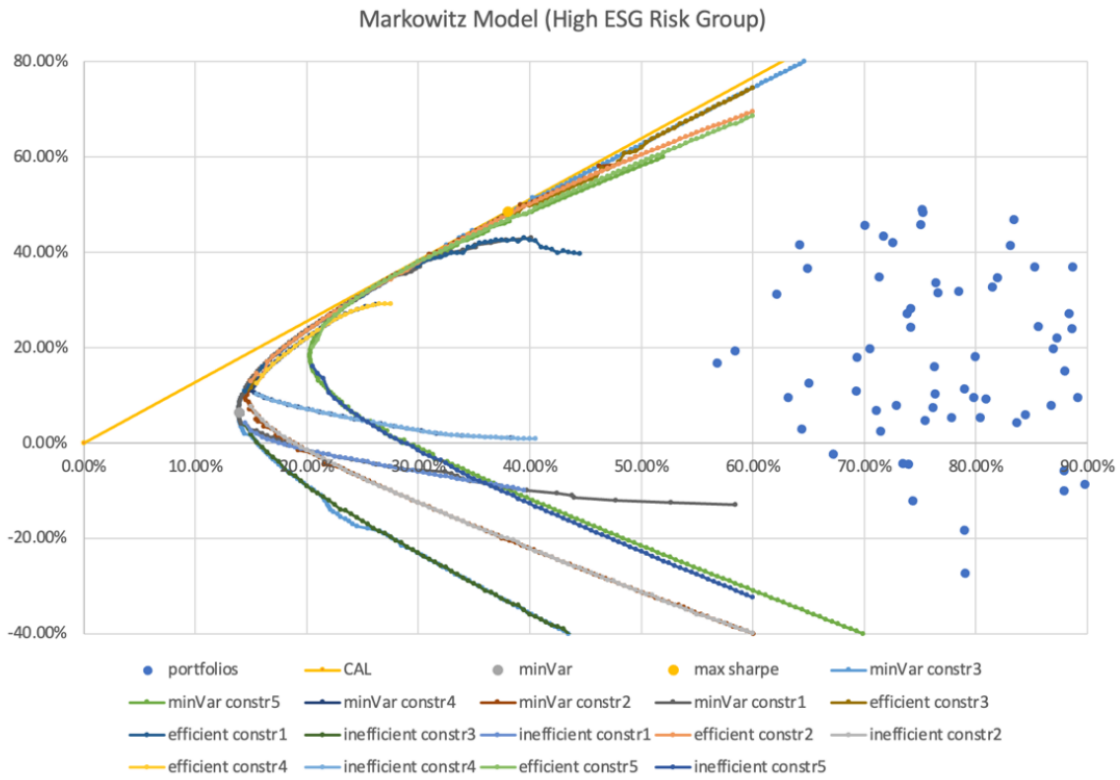

Figure 2: Markowitz Model for the Low ESG Risk Group.

Therefore, it is reasonable for investors to consider the ESG risk of their portfolios, based on the result that the Low ESG Risk group has higher returns and Sharpe ratios. The frontiers with constraints are shown in Figures 1 and 2. Figure 1, which represents the Markowitz Model for the Low ESG Risk Group, demonstrates multiple efficient frontiers under different constraints, each showing a unique trade-off between risk and return. Figure 2, depicting the High ESG Risk Group, shows similar patterns. However, the shifts in the efficient frontiers are less pronounced than in the Low ESG Risk group. This group's portfolios also display efficient and inefficient frontiers but with generally lower returns and Sharpe ratios across similar risk levels compared to the Low ESG Risk group.

5. Conclusion

This paper examined the integration of Environmental, Social, and Governance (ESG) factors into portfolio optimization using the Markowitz Model, revealing both the model's utility and limitations in the context of modern sustainable investing. The application of this classical framework highlighted the advantages of comprehensive risk analysis and diversification, demonstrating that non-correlated ESG-focused assets could significantly reduce overall portfolio risk while potentially enhancing returns. Such integration proved effective in developing portfolios that adhere not only to financial metrics but also to elevated ESG standards.

The result of the Markowitz Model supports the conclusion that the Low ESG Risk group not only provides higher returns but also better Sharpe ratios, reflecting more favorable risk-adjusted returns compared to the High ESG Risk group. This underlines the importance of ESG risk consideration in portfolio management, where lower ESG risks can lead to more efficient and potentially lucrative investment opportunities, particularly under varied regulatory and strategic constraints.

In conclusion, the findings of this study suggest that ESG considerations are more than just ethical constraints; they can be significant enhancers of portfolio performance. By adopting ESG integration, investors do not only align with broader societal values but also position themselves to potentially improve their financial outcomes. The variability in performance across different ESG risk categories

emphasizes the necessity of precise and thoughtful integration of these factors into the investment process. While the Markowitz Model offers valuable insights into ESG portfolio diversification and optimization, it also necessitates enhanced computational techniques and improved data accuracy.

Future research could expand on this by exploring the specific elements within ESG that most significantly influence portfolio performance, thus providing more detailed guidelines for asset selection and risk management. This would further solidify ESG investing as a prudent choice not only from an ethical standpoint but also from a financial perspective.

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