Novel Portfolio Construction Based on ESG

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Abstract: As global financial markets continue to grow increasingly complex, and as investors place greater emphasis on sustainable development, the limitations of traditional portfolio theory are becoming more evident. With this in mind, this study examines the impact of incorporating ESG (i.e., Environmental, Social, and Governance) factors into traditional multi-factor models on portfolio optimization, selecting eight stocks from different industries over the period of 2021-2024 as research subjects. By conducting an empirical analysis, the paper assesses the performance of portfolios with ESG factors across varying risk levels and contrasts these with portfolios based on traditional multi-factor models. According to the analysis, the inclusion of ESG factors leads to a significant enhancement in portfolio returns at different risk levels, particularly under high-risk conditions, where ESG factors demonstrate strong capabilities in improving risk-adjusted returns. These results provide valuable empirical support for the integration of ESG factors into modern portfolio optimization, offering fresh insights for the advancement of sustainable investment strategies.

1 INTRODUCTION

The development of portfolio theory has undergone several critical stages, laying the foundation for modern finance. In 1952, Harry Markowitz introduced Modern Portfolio Theory (MPT), which marked the beginning of a scientific approach to asset management by optimizing the balance between risk and return through diversification (Markowitz, 1952). Following this, in 1964, William Sharpe proposed the Capital Asset Pricing Model (CAPM), which incorporated market risk into portfolio optimization, further enriching asset pricing theory (Sharpe, 1964). During the 1970s, Eugene Fama's Efficient Market Hypothesis (EMH) promoted the growth of index investing, allowing investors to achieve long-term returns by holding market indices (Fama, 1970). In the 1980s and 1990s, the derivatives market expanded rapidly, especially with the introduction of the Black-Scholes option pricing model, which facilitated the inclusion of futures, options, and other tools in portfolio construction (Black, 1973). These traditional portfolio theories assumed market efficiency, investor rationality, and normally distributed asset returns, providing a fundamental framework for asset management. However, as financial markets became more complex and globalized, the limitations of these traditional theories became increasingly evident in practice. Firstly, traditional theories assumed that asset returns follow a normal distribution, but real market performance often deviates from this assumption (Mandelbrot, 1863). Secondly, in modern financial markets, investors face increasing uncertainty, especially during extreme events such as global financial crises, where relying solely on traditional mean-variance models is insufficient for effectively mitigating risk (Taleb, 2007). Consequently, both academia and industry have increasingly recognized the need to incorporate additional dimensions into traditional portfolio theory to better adapt to modern market conditions (Lo, 2004).

Currently, portfolio theory is evolving with the introduction of emerging asset classes and advancements in technology, gradually overcoming the limitations of traditional theories. Cryptocurrencies, particularly Bitcoin, have been widely recognized for their potential to enhance portfolio diversification due to their high volatility and low correlation with traditional assets (Brière et al., 2015). Research indicates that incorporating cryptocurrencies into traditional stock and bond portfolios can significantly improve overall performance, particularly in terms of risk management. Further empirical analysis suggests that cryptocurrencies may serve as a safe-haven asset

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under certain market conditions, though their high volatility necessitates caution in practical applications (Corbet et al., 2018). Additionally, private equity, hedge funds, and real estate have increasingly become vital tools for diversifying investment portfolios over the past few years (Anson, 2007; Stulz, 2007). These asset classes have a low correlation with traditional stocks and bonds, enabling them to offer more stable returns during market fluctuations. Studies have shown that including these alternative investments in a portfolio often significantly reduces overall volatility while enhancing long-term returns (Pedersen et al., 2014). This trend further underscores the need for traditional portfolio theory to adapt to modern market conditions by incorporating emerging asset classes and addressing the complexities of financial markets (Ang, 2014). In this context, traditional quantitative investment strategies continue to play a crucial role. These strategies rely on a series of quantifiable factors that can predict the future performance of stocks. The most common factors include momentum, value, and quality factors. With the growing global focus on sustainable development, the application of ESG (Environmental, Social, and Governance) factors in investments has also been increasing. The use of ESG factors is no longer limited to socially responsible investing but is gradually becoming a key consideration for mainstream investors. Research indicates that companies with high ESG ratings tend to perform more steadily over the long term and can effectively reduce portfolio risk. Moreover, ESG factors can help investors avoid potential environmental and social risks, thereby improving risk-adjusted returns in their portfolios. However, despite the increasing importance of ESG factors, their integration into traditional investment strategies remains contentious and under-researched. In recent years, more studies have begun to explore how ESG factors can be combined with traditional quantitative factors to build more comprehensive multi-factor models. For example, research has shown that integrating ESG factors with momentum, value, and quality factors can significantly enhance portfolio performance and reduce investment risk. Some studies have also highlighted that ESG factors perform particularly well during economic downturns, providing investors with a certain degree of downside protection. Nevertheless, existing research has some limitations. Many studies focus only on single markets or short-term performance, lacking analysis of long-term and cross-market effects. Additionally, there is limited research on how to prioritize ESG factors relative to traditional factors within multi-factor models.

The paper aims to construct an innovative portfolio optimization framework by integrating ESG factors with traditional Alpha factors, thereby developing a multi-factor model. Through empirical analysis, the paper seeks to validate the effectiveness of this model in achieving a balance between maximizing financial returns and minimizing risk. By incorporating ESG factors into the traditional multi-factor model, the paper aims to optimize stock selection and trading strategies, creatively combining environmental, social, and governance (ESG) dimensions with momentum, value, and quality Alpha factors. In terms of data processing, the paper will utilize stock and ESG rating data, coupled with empirical analysis, to assess the model's performance across different market environments and to verify its robustness in multi-asset portfolios. Ultimately, the paper aims to provide a comprehensive investment solution that combines financial performance with sustainable development goals, thereby promoting the practical application of ESG investing.

2 DATA AND METHOD

The paper selected weekly price data from the past three years for eight stocks, analysing them to construct an investment portfolio. The data is based on their market performance, ESG ratings, and various factors such as momentum, value, and quality. The eight selected stocks demonstrate strong ESG performance and financial stability, and include Microsoft, Costco, Adobe, NVIDIA, Apple, Walmart, Johnson & Johnson, and Procter & Gamble, covering multiple industries to ensure diversity and representativeness in the portfolio.

ESG factors have increasingly gained importance in the investment field as key indicators for assessing a company's sustainable development capabilities. ESG factors are divided into three components: environmental factors, which focus on a company’s performance in areas such as climate change and resource utilization; social factors, which relate to labor rights, community impact, and other social considerations; and governance factors, which examine a company’s management structure and corporate ethics. By evaluating these factors, investors can identify companies that are stable and low risk over the long term. The inclusion of ESG factors not only helps enhance the sustainability of the investment portfolio but also serves as an effective risk management tool. Typically, ESG

ratings are categorized into high, medium, and low tiers, allowing investors to optimize their portfolios by selecting companies that excel across these areas. Furthermore, integrating ESG factors into a multi-factor investment model can help balance returns and risks amid market fluctuations, contributing to long-term returns.

The Alpha factor model is a financial model used in portfolio management and stock selection. It aims to identify specific factors (Alpha factors) that can explain and predict asset returns, thereby achieving excess returns beyond the market benchmark. Alpha factors represent the performance of individual stocks or assets that are independent of the overall market trend, i.e., the excess returns generated by active management. By capturing the impact of these factors, the model provides a basis for informed investment decisions.

The paper selected three factors: momentum, value, and quality. The momentum factor is based on the historical price trends of assets, typically reflecting the continuation of upward or downward price movements. For the momentum factor, the cumulative return over the past 12 months was used. The value factor measures the pricing of an asset relative to its fundamental value, with the price-to-earnings ratio (P/E) being chosen to identify undervalued or overvalued stocks. The quality factor assesses a company's financial health and operational efficiency, with return on equity (ROE) being selected to identify high-quality companies. Each factor may carry different weights depending on the period and market conditions. The traditional multi-factor model is:

$$R_i = \alpha + \beta_1 \times Momentum + \beta_2 \times Value + \beta_3 \times Quality + \epsilon \quad (1)$$

In the traditional multi-factor model, an ESG factor is introduced to adjust the portfolio's weight distribution. The inclusion of the ESG factor may influence the final portfolio selection, particularly in the analysis of risk-adjusted returns. The multi-factor model with the ESG factor is:

$$R_i = \alpha + \beta_1 \times Momentum + \beta_2 \times Value + \beta_3 \times Quality + \beta_4 \times ESG \quad (2)$$

Table 1: Construction of effective frontier of traditional multi-factor model.

COST	ADBE	NVDA	Portfolio standard deviation	Portfolio return
0.8986	0.2833	-0.1819	0.1849	0.1046
0.8766	0.0614	0.0620	0.2000	0.1750
0.7564	0.0000	0.2436	0.2250	0.2202
0.6243	0.0000	0.3757	0.2500	0.2500
0.5135	0.0000	0.4865	0.2750	0.2750
0.4131	0.0000	0.5869	0.3000	0.2976
0.3191	0.0000	0.6809	0.3250	0.3188
0.2291	0.0000	0.7709	0.3500	0.3391
0.1422	0.0000	0.8578	0.3750	0.3587
0.0574	0.0000	0.9426	0.4000	0.3778
0.0000	0.0000	1.0000	0.4172	0.3908

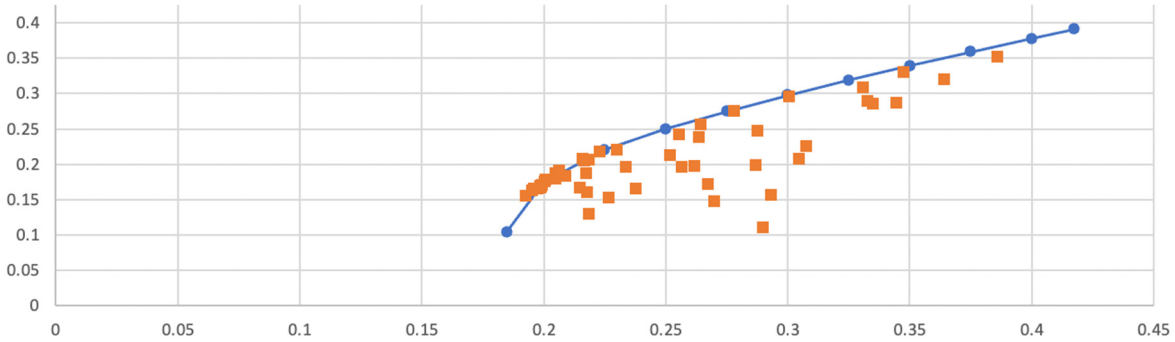

Figure 1: The effective frontier of traditional multi-factor model (Photo/Picture credit: Original).

3 RESULTS AND DISCUSSION

3.1 Effective Frontier

After calculating the weighted average for each stock (listed in Table 1), the paper determined the overall scores for each stock, integrating the weights of momentum, value, quality, and ESG factors. Based on these scores, the top three stocks were selected to construct the investment portfolio. Specifically, the Figure. 1 (traditional multi-factor model) illustrates the efficient frontier for Tesla (TSLA), Adobe (ADBE), and Nvidia (NVDA). The efficient frontier represents the optimal expected returns that investors can achieve at different levels of risk. In this model, the distribution of points is relatively tight, indicating a stable and linear relationship between risk and return. The risk range is mainly concentrated within a portfolio standard deviation of 0.18 to 0.41, reflecting a conservative level of risk. The return at low-risk levels is relatively modest, and the increase in returns is gradual, suggesting that in the traditional multi-factor model, higher expected returns typically require taking on greater risk.

The Figure. 2 shows the efficient frontier after incorporating the ESG factor, with the portfolio comprising Adobe (ADBE), Nvidia (NVDA), and Apple (AAPL), where the parameters are listed in Table 2.. Compared to the traditional model, the inclusion of the ESG factor significantly alters the shape and position of the efficient frontier, shifting the curve upward and to the left. This shift indicates that investors can achieve higher expected returns at the same level of risk. The range of points is broader, particularly in the high-risk area, suggesting that the ESG factor enables the model to better accommodate diversified risk/return combinations. Compared to the traditional model, the risk range under the ESG model expands, with the standard deviation ranging from 0.2489 to 2.5, showing that this portfolio can tolerate higher risk levels while also delivering substantially higher returns. For example, at a standard deviation of 0.35, the return can reach 0.6454, indicating that high returns can still be achieved even at lower risk levels. The maximum portfolio return increases significantly from approximately 0.3907 in the traditional model to 14.0475, with a corresponding portfolio standard deviation also rising to 2.5, indicating that investors can obtain greater returns while accepting higher risks.

Table 2: Effective frontier construction of models incorporating ESG factors.

ADBE	NVDA	AAPL	Portfolio standard deviation	Portfolio return
0.8517	0.2194	-0.0710	0.2489	-0.8316
0.9972	0.0006	0.0023	0.3000	0.1280
0.8347	0.1287	0.0366	0.3500	0.6454
0.8295	0.1046	0.0659	0.4000	1.0481
0.8249	0.0821	0.0929	0.4500	1.4190
0.8203	0.0610	0.1186	0.5000	1.7717
0.8168	0.0397	0.1435	0.5500	2.1128
0.8148	0.0174	0.1678	0.6000	2.4459
0.7853	0.0000	0.2147	0.7000	3.0960
0.7398	0.0000	0.2602	0.8000	3.7315
0.6950	0.0000	0.3050	0.9000	4.3577
0.6506	0.0000	0.3494	1.0000	4.9776
0.6066	0.0000	0.3934	1.1000	5.5930
0.5628	0.0000	0.4372	1.2000	6.2051
0.5191	0.0000	0.4809	1.3000	6.8148
0.4756	0.0000	0.5244	1.4000	7.4225
0.4323	0.0000	0.5677	1.5000	8.0287
0.3890	0.0000	0.6110	1.6000	8.6337
0.3457	0.0000	0.6543	1.7000	9.2376
0.3026	0.0000	0.6974	1.8000	9.8407
0.2594	0.0000	0.7406	1.9000	10.4431
0.2164	0.0000	0.7836	2.0000	11.0449
0.1303	0.0000	0.8697	2.2000	12.2471
0.0015	0.0000	0.9985	2.5000	14.0475

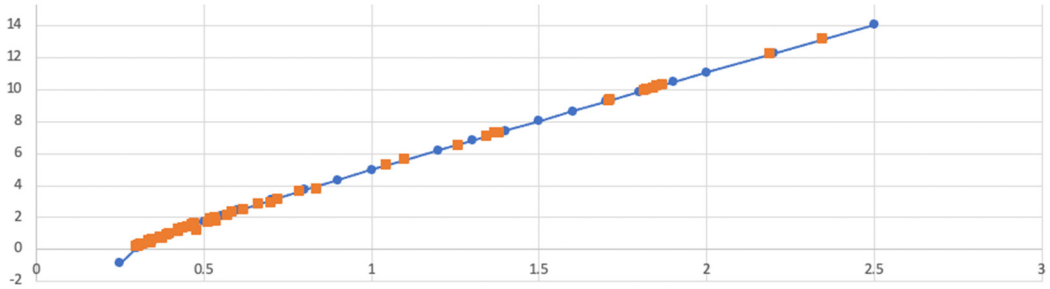

Figure 2: Effective frontier of model incorporating ESG factors (Photo/Picture credit: Original).

Table 3: Optimal risk combination of traditional multi-factor model.

	COST	ADBE	NVDA
	0.57154927	0	0.42845073
Rf	Portfolio	Rf+Portfolio standard deviation	Rf+Portfolio return
-1	2	0.52302755	0.51398898
-0.9	1.9	0.49687617	0.48877611
-0.8	1.8	0.4707248	0.46356325
-0.7	1.7	0.44457342	0.43835038
-0.6	1.6	0.41842204	0.41313752
-0.5	1.5	0.39227066	0.38792465
-0.4	1.4	0.36611929	0.36271178
-0.3	1.3	0.33996791	0.33749892
-0.2	1.2	0.31381653	0.31228605
-0.1	1.1	0.28766515	0.28707318
0	1	0.26151378	0.26186032
0.1	0.9	0.2353624	0.23664745
0.2	0.8	0.20921102	0.21143459
0.3	0.7	0.18305964	0.18622172
0.4	0.6	0.15690827	0.16100885
0.5	0.5	0.13075689	0.13579599
0.6	0.4	0.10460551	0.11058312
0.7	0.3	0.07845413	0.08537025
0.8	0.2	0.05230276	0.06015739
0.9	0.1	0.02615138	0.03494452
1	0	0	0.00973166

3.2 Model Performance

In the first set of results, one can clearly observe the performance of the investment portfolio under different optimization functions. The efficient frontier demonstrates the optimal returns achievable at various levels of risk. For instance, in the minimum variance portfolio, the allocation tends to reduce exposure to highly volatile stocks (such as NVDA) to lower overall risk. This strategy effectively controls the portfolio's volatility, providing relatively stable returns. In the maximum Sharpe ratio portfolio, more weight is allocated to higher-returning stocks (such as COST and NVDA) to maximize risk-adjusted returns. This allocation strategy aims to enhance overall portfolio returns, albeit potentially with higher volatility. The optimal investment portfolio under the traditional model exhibits lower standard deviation and relatively stable returns, with the highest Sharpe ratio recorded at 1.001325, indicating that the portfolio can achieve solid performance under strict risk control. Additionally, this suggests that the traditional factor model is already capable of balancing returns and risks to some extent, though its potential for improvement is limited. The results are listed in Table 3.

Compared to the traditional model, the efficient frontier curve after incorporating the ESG factor is steeper, indicating that as investors are willing to take on more risk, the rate of return increases more significantly. The ESG-enhanced model demonstrates stronger risk tolerance, allowing for optimized investment returns across a broader range of risk levels. Although the risk level increases, the portfolio's returns also rise considerably, reflecting the effectiveness of the ESG factor in portfolio optimization. Notably, the Sharpe ratio significantly improves after the inclusion of the ESG factor, reaching a maximum of 5.619526. This substantial increase indicates that the ESG factor not only enhances portfolio returns but also significantly optimizes risk-adjusted returns, allowing investors to achieve markedly higher returns at the same level of risk. Furthermore, the optimal investment portfolio under the ESG model performs exceptionally well under high-risk conditions, particularly when the risk-free rate is set at 1.0, with a return of 14.06808, far surpassing the performance under the traditional model. This demonstrates that the ESG factor not only boosts the return potential of the portfolio but also offers more attractive returns under high-risk conditions, proving its critical role in long-term investment strategies. The results are shown in Table 4.

3.3 Explanation and Implications

When comparing the traditional multi-factor model with the model incorporating ESG factors, it is evident that the inclusion of ESG factors significantly enhances portfolio performance, particularly under high-risk conditions. The steeper efficient frontier observed after adding ESG factors indicates that as risk increases, the rate of return improves more markedly, highlighting the crucial role of ESG factors in boosting portfolio return potential. Additionally, the ESG factors significantly increase the portfolio's Sharpe ratio, demonstrating a substantial contribution to risk-adjusted returns. These results suggest that

Table 4: Optimal risk mix of models with ESG factors.

	ADBE	NVDA	AAPL
	0	0	1
Rf	Portfolio	Rf+Portfolio standard deviation	Rf+Portfolio return
-1	2	5.006857804	28.12643346
-0.9	1.9	4.756514914	26.72059837
-0.8	1.8	4.506172024	25.31476328
-0.7	1.7	4.255829133	23.90892819
-0.6	1.6	4.005486243	22.5030931
-0.5	1.5	3.755143353	21.09725801
-0.4	1.4	3.504800463	19.69142292
-0.3	1.3	3.254457573	18.28558783
-0.2	1.2	3.004114682	16.87975274
-0.1	1.1	2.753771792	15.47391765
0	1	2.503428902	14.06808256
0.1	0.9	2.253086012	12.66224747
0.2	0.8	2.002743122	11.25641238
0.3	0.7	1.752400231	9.850577288
0.4	0.6	1.502057341	8.444742197
0.5	0.5	1.251714451	7.038907107
0.6	0.4	1.001371561	5.633072017
0.7	0.3	0.751028671	4.227236926
0.8	0.2	0.50068578	2.821401836
0.9	0.1	0.25034289	1.415566746
1	0	0	0.009731655

integrating ESG factors into long-term investment strategies can not only optimize risk management but also lead to more substantial returns. Even if the selected stocks are similar or the same, the inclusion of ESG factors may improve risk-adjusted returns, offering valuable insights for adjusting future investment strategies. This analysis can assist investors in developing more robust and sustainable investment portfolios in the modern market environment. Furthermore, ESG factors provide greater portfolio diversification, enabling investors to adapt strategies flexibly in various market conditions, further enhancing the stability and sustainability of investments.

3.4 Limitations and Prospects

Despite the significant improvement in portfolio performance achieved through the incorporation of ESG factors, this paper has some limitations. Firstly, the time span of the data sample is limited and does not cover longer market cycles, which may affect the generalizability of the results. Secondly, the assignment of weights to ESG factors is somewhat subjective, and the paper does not deeply explore the impact of different weight configurations on portfolio performance. Additionally, this research focuses on a small number of stocks, which limits the applicability of the findings across different markets and industries. Future research should consider expanding the sample to include a broader range of market cycles and asset classes, while also employing more dynamic weight adjustment mechanisms to enhance the reliability and applicability of the results. Furthermore, exploring the integration of ESG factors with other emerging factors, such as big data and artificial intelligence, could provide additional perspectives and innovative opportunities for portfolio optimization.

4 CONCLUSIONS

To sum up, this study significantly advances the traditional multi-factor model by integrating ESG factors, thereby developing a more forward-looking and adaptable framework for portfolio optimization. The research findings indicate that the inclusion of ESG factors not only boosts portfolio returns across various risk levels but also exhibits particularly strong performance under high-risk conditions, showcasing substantial risk-adjusted return capabilities. Moreover, the paper highlights that the integration of ESG factors effectively enhances the portfolio's Sharpe ratio, further optimizing the overall investment performance. Despite these promising results, the research is constrained by a limited time span and a small sample of stocks, which may affect the broader applicability of the findings. Future research could address these limitations by expanding the sample size, utilizing dynamic factor weight adjustments, and incorporating other emerging factors to improve the generalizability and robustness of the results. Overall, this paper provides critical empirical support for incorporating ESG factors into modern portfolio optimization strategies, contributing to the advancement of sustainable investment practices.

REFERENCES

Ang, A. 2014. Asset Management: A Systematic approach to factor investing. OUP Catalogue.

Anson, M., 2007. *Performance Measurement in Private Equity: Another Look.* The Journal of Private Equity, 103, 7–21.

Black, F., Scholes, M., 1973. *The Pricing of Options and Corporate Liabilities.* Journal of Political Economy, 813, 637–654.

Brière, M., Oosterlinck, K., Szafarz, A., 2015. *Virtual currency, tangible return: Portfolio diversification with bitcoin.* Journal of Asset Management, 166, 365–373.

Corbet, S., Meegan, A., Larkin, C., Lucey, B., Yarovaya, L., 2018. Exploring the dynamic relationships between cryptocurrencies and other financial assets. Economics Letters, 165, 28–34.

Fama, E. F., 1970. *Efficient Capital Markets: A Review of Theory and Empirical Work.* The Journal of Finance, 252, 383–417.

Lo, A. W. 2004., The Adaptive Markets hypothesis. The Journal of Portfolio Management, 305, 15–29.

Mandelbrot, B., 1963. *The Variation of Certain Speculative Prices.* The Journal of Business, 364, 394–419.

Markowitz, H., 1952. *Portfolio Selection.* The Journal of Finance, 71, 77–91.

Pedersen, N., Page, S., He, F., 2014. Asset Allocation: Risk Models for Alternative Investments. Financial Analysts Journal, 703, 34–45.

Sharpe, W. F., 1964. *Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk*. The Journal of Finance, 193, 425–442.

Stulz, R. M., 2007. *Hedge Funds: Past, Present, and Future.* The Journal of Economic Perspectives, 212, 175–194.

Taleb, N. N., 2007. *Black Swans and the Domains of Statistics.* The American Statistician, 613, 198–200.