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Research Article

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Managing Portfolio Volatility Automatically: Insights from Wealth Front Robo-Advisor

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Abstract

This study examines the comparative performance of Wealthfront's Classic and Socially Responsible Portfolios under an 8% target volatility constraint. Utilizing historical data from 2010 to 2024 and employing a Tactical Asset Allocation model, it assesses risk-adjusted returns, including Sharpe and Sortino Ratios. Preliminary findings indicate that while the Classic Portfolio offers higher returns, it also exhibits greater volatility compared to the Socially Responsible Portfolio. This research highlights the trade-off between financial performance and ethical considerations in investment decisions, providing insights relevant to investors seeking to balance risk and return within the framework of ro-bo-advisor-managed portfolios. Implications include the importance of risk-adjusted metrics in in-vestment decisions and the role of robo-advisors in enhancing portfolio performance. Future research should explore diverse volatility targets and investor preferences to refine investment strategies.

Keywords: Robo-Advisors, Wealthtech, Asset Allocation, Portfolio Performance, Target Volatility, G11, G24

1. Introduction

In 2015, the Global Economic Forum recognized Fintech as a "disruptive innovation" poised to fun-damentally transform the financial industry. A notable development within Fintech is Wealthtech, which has introduced robo-advisors—digital platforms that automate investment management using machine learning algorithms. These robo-advisors serve a similar function to human advisors by aid-ing investors in making informed decisions [1]. Research by Hohenberger, Lee, & Coughlin (2019), Kim, Cotwright, & Chatterjee (2019), and Ruyi Ge, Xuan, & Li (2021 indicates a growing demand for robo-advisors, especially among inexperienced investors lacking financial expertise [2-4]. Addi-tionally, Puhle's (2019) study of five German robo-advisors highlighted significant performance dif-ferences in portfolios with similar allocations, attributed primarily to the varying asset allocation strategies employed [5]. Positioning this study within the broader context of current research, there is a substantial body of work examining the efficacy and performance of robo-advisors. Studies have explored various aspects, such as their usability, investor satisfaction, and comparative performance against traditional investment methods. However, there is a gap in research specifically analyzing the performance of portfolios under a target volatility constraint, especially concerning ethical investing considerations. This study seeks to fill this gap by providing a comparative analysis of Wealthfront's Classic and Socially Responsible Portfolios, thereby contributing to the existing literature on ro-bo-advisor efficacy and ethical investing.

This study addresses the critical issue of identifying the optimal balance of portfolio performance and risk that aligns with investor preferences. This research problem is significant because the choice of an investment portfolio directly impacts both final performance and the investor's perception of risk. Given the vast array of investment options available, each presenting different levels of return and risk, it is essential to understand how these choices influence portfolio performance under various market conditions. This study specifically examines the comparative performance of two Wealthfront robo-advisor portfolios: The Classic Portfolio and the Socially Responsible Portfolio, each character-ized by unique performance and risk profiles. The primary objective of this study is to evaluate the performance of these portfolios within an 8% target volatility constraint across three risk levels (low, moderate, high). The study aims to: (1) assess the performance and risk characteristics of both portfo-lios relative to the 8% target volatility, and (2) elucidate the interplay between each portfolio's per-formance and risk profile within this volatility framework. By pursuing these objectives, the research seeks to provide valuable insights into the comparative performance of these portfolios under varying risk scenarios, thereby aiding investors in making informed decisions that align with their risk prefer-ences and investment goals.

Preliminary findings indicate that Wealthfront's Classic Portfolio offers higher returns but exhibits greater volatility and risk metrics, such as standard deviation and maximum drawdown, compared to the Socially Responsible Portfolio. Under an 8% target volatility constraint, the Socially Responsible Portfolio consistently maintains more stable risk-adjusted performance metrics, reflecting its focus on risk mitigation. Investors should balance the higher potential returns of the Classic Portfolio with its increased volatility or opt for the stability and ethical focus of the Socially Responsible Portfolio, depending on their risk tolerance and goals.

2. Literature Review

2.1 Wealth Tech Ecosystem and Robo-Advisor Impact on Portfolio Management

As WealthTech continues to integrate advanced technologies, it promises to fundamentally reshape how individuals and institutions manage and grow their assets in the digital age. Robo-advisors, cat-egorized into levels ranging from 1.0 to 4.0, embody varying degrees of automation and sophistica-tion in investment management. At Level 1.0, these platforms offer basic investment products fol-lowing client completion of a preference questionnaire. Progressing to Level 2.0, a semi-automated approach emerges where an investment manager oversees asset allocations while algorithms manage investments. Level 3.0 further advances with algorithms actively monitoring and adjusting preset investment strategies under professional manager supervision. Finally, Level 4.0 represents the pinna-cle, integrating advanced investment algorithms with artificial intelligence to dynamically adapt to market conditions and cater to specific investor needs [6].

Robo-advisors operate under diverse business models tailored to distinct market segments. Stand-alone Robo-Advisors like Wealthfront and Betterment lead by providing independent auto-mated investment solutions with lower fees compared to traditional advisory services. Segregated Robo-Advisors utilize artificial intelligence to offer personalized automated advice, managing in-vestments in segregated accounts for enhanced customization. Fully Integrated Robo-Advisors such as Schwab Intelligent Portfolios and Vanguard Personal Advisory Service seamlessly integrate into banking models, offering comprehensive financial management experiences for dual clients. Another model, Robo for Advisors, targets wealth and asset management advisors with fully automated digi-tal wealth management solutions that empower both advisors and investors to construct diversified portfolios independently [7]. These versatile models cater to diverse investor preferences, from those seeking automated guidance to others desiring integrated financial services within traditional banking frameworks.

2.2 Optimizing Portfolio Allocation, Performance, and Target Volatility with Robo-Advisors

Robo-advisors offer a range of investment options encompassing individual stocks, bonds issued by governments or corporations for stable income through interest payments, Exchange-Traded Funds (ETFs) trading a mix of assets like stocks, bonds, or commodities for diversification within a single investment, mutual funds pooling money from multiple investors into diversified portfolios managed by professionals, and Real Estate Investment Trusts (REITs) enabling investment in real estate assets without direct property ownership, generating income through rentals or property sales [8]. Asset allocation, crucial in financial planning, balances risk and reward by adjusting portfolio asset mixes based on factors like investor risk tolerance, financial goals, and time horizon [9]. Personal circum-stances such as age, income, and family situation also influence decisions, aiming to avoid over-concentration in any single investment category. Asset selection involves performance analysis, risk assessment, and alignment with investment objectives and time frames, with robo-advisors em-phasizing automated solutions for asset allocation, portfolio monitoring, and periodic rebalancing [7].

The process of constructing tailored portfolios through robo-advisors includes identifying suitable portfolio ranges based on risk tolerance, evaluating asset category performance and volatility, and optimizing portfolios to meet client-specific financial objectives [5,10]. Algorithms and optimization models drive effective portfolio management by considering personal preferences and market dy-namics. Algorithmic optimal allocation methods analyze performance-risk relationships across in-vestment classes to minimize risk for a given return level or vice versa. Mean-Variance Optimization (MVO), introduced by Harry Markowitz in 1952, assesses expected returns and asset correlations to determine portfolio weights for risk reduction through diversification [1]. While MVO assumes his-torical trends will recur, actual asset returns and volatilities may differ, necessitating adjustments to model weights for optimal portfolio performance. Black and Litterman's Bayesian extension of MVO in 1992 incorporated investor views, enhancing portfolio construction with subjective insights. Wing Cheung's 2009 Augmented Black Litterman (ABL) model expanded on this by integrating additional influencing factors into the computation process, broadening its application scope [11]. Ro-bo-advisors apply MVO to allocate assets based on client goals, assessing capital market assumptions and using varied methods to estimate expected returns, including historical data and future uncer-tainty measures [12].

2.3 Implementing Target Volatility Strategies for Risk Management

Variability is a fundamental gauge of risk in equity markets. The target volatility technique is de-signed primarily to maintain portfolio variability near a specified target, serving as a pivotal tool for managing financial risk. This approach necessitates ongoing adjustments in portfolio leverage in re-sponse to fluctuations in volatility levels: heightened volatility prompts reductions in leverage, while diminished volatility warrants increased leverage [13]. At the core of volatility management strategies lies the objective of stabilizing actual portfolio volatility through calibrated adjustments in market exposure, guided by comprehensive risk assessments. When anticipated volatility deviates from de-sired levels, adjustments in portfolio exposure to the stock market are made accordingly—increased exposure during periods of lower anticipated volatility and decreased exposure when volatility ex-ceeds target levels.

This strategy challenges conventional wisdom by positing that increased market volatility justifies higher risk exposure and vice versa. It operates on the premise that past volatility trends can forecast future volatility, a phenomenon known as volatility clustering, where periods of heightened or subdued volatility persist over time [14].

Volatility clustering implies that recent periods of high volatility are likely to persist, while low vola-tility phases tend to endure. This understanding underpins the rationale for dynamically adjusting portfolio exposure based on prevailing and anticipated volatility conditions, aiming to stabilize port-folio performance amidst fluctuating market dynamics. Implementing target volatility strategies re-quires a systematic approach to risk management, centered on aligning portfolio volatility with prede-fined targets. Key steps include establishing and monitoring target volatility levels, adjusting leverage in response to volatility changes, employing robust risk measures for volatility assessment, dynami-cally reallocating assets based on volatility forecasts, and integrating insights from volatility cluster-ing into decision-making processes. Evaluating portfolio performance using risk-adjusted metrics such as Sharpe Ratio and Sortino Ratio ensures that risk management strategies are aligned with achieving optimal risk-adjusted returns [13]. In conclusion, effective implementation of target volatil-ity strategies enhances resilience and stability in portfolio management by proactively managing in-vestment risk through systematic volatility management practices. Understanding and leveraging volatility patterns are critical to navigating market uncertainties and optimizing portfolio outcomes in evolving financial landscapes.

2.4 Inside Wealth Front's Robo-Advisor Portfolios

Wealthfront Inc., founded in 2008 by Andy Rachleff and Dan Carroll, initially operated under the name "kaChing" as an investment tool, later rebranding to Wealthfront in 2011. Since then, it has grown into a prominent robo-advisor platform in the United States, specializing in automated in-vestment services [15]. Wealthfront offers a range of investment portfolios designed to cater to di-verse investor needs and risk tolerances. The Classic Portfolio is structured as a cost-effective, in-dex-based strategy that adjusts asset allocations across a risk spectrum graded from 1 to 10. This portfolio includes a diversified mix of assets such as municipal bonds, US bonds, Treasury Infla-tion-Protected Securities (TIPS), dividend growth stocks, corporate bonds, foreign developed stocks, and emerging market stocks. In contrast, the Socially Responsible Portfolio also spans a risk spectrum from 1 to 10 but emphasizes sustainability in its asset allocation strategy. It comprises assets like mu-nicipal bonds, US bonds, US stocks, TIPS, foreign developed stocks, and emerging market stocks, integrating ethical considerations into its investment approach. For accounts exceeding $100,000, Wealthfront offers the Direct Indexing Portfolio, which customizes investment strategies by directly indexing individual US stocks alongside other asset classes. This portfolio aims to enhance tax effi-ciency and potentially improve after-tax returns for investors (Wealthfront n.d.). Wealthfront's evolu-tion into a leading robo-advisor underscores its commitment to providing accessible and personalized investment solutions through diversified portfolio options tailored to meet varying investor prefer-ences and financial goals. These offerings reflect Wealthfront's strategic adaptation to market de-mands while maintaining a focus on cost-effectiveness, sustainability, and tax efficiency in invest-ment management (Wealthfront n.d.).

2.5 Risk Management and Asset Allocation Tactics at Wealth Front

Wealthfront employs strategies in risk management and asset allocation to optimize portfolio perfor-mance while mitigating investment risks for its clients. Central to its approach is the Risk Parity strategy, which aims to evenly distribute risk across different asset classes within portfolios. Initially, Wealthfront constructs an unleveraged portfolio designed to balance risk contributions from each asset category. Subsequently, leverage is applied to adjust the overall portfolio risk to meet desired levels. The risk contribution of each asset category is meticulously calculated by multiplying portfolio weights by the partial derivative of portfolio volatility, ensuring that the sum of all risk contributions equals the total portfolio volatility normalized to one. In addition to Risk Parity, Wealthfront utilizes Mean-Variance Optimization (MVO) to optimize asset allocations based on expected returns and volatility estimates across various asset classes. This involves rigorous analysis of correlations be-tween asset classes to achieve optimal diversification and manage portfolio risk effectively. Wealth-front's approach also includes volatility targeting, where a specified Target Volatility level, typically around 10%, is set to manage portfolio volatility. This strategy involves continuous monitoring and adjustment of portfolio exposures using statistical models and historical data to align with the speci-fied target (Wealthfront n.d.).

Diversification across asset classes is a cornerstone of Wealthfront's strategy to mitigate overall port-folio risk. Investments are strategically allocated across stocks, bonds, real estate investment trusts (REITs), and commodities to spread risk and capitalize on global opportunities while managing cur-rency and geopolitical risks. Moreover, Wealthfront tailors asset allocations specifically for taxable and retirement accounts to optimize after-tax returns and minimize tax liabilities. In providing com-prehensive services, Wealthfront offers automatic portfolio rebalancing to maintain target asset allo-cations amidst market fluctuations. Clients benefit from personalized portfolio recommendations based on individual risk profiles, financial goals, and investment horizons. Wealthfront charges a management fee of 0.25% of managed assets, with the first $10,000 managed free of charge, ensur-ing cost-effectiveness relative to traditional advisory fees (Wealthfront n.d.). In summary, Wealthfront integrates advanced risk management techniques like Risk Parity and MVO with personalized portfolio management and tax optimization strategies. This holistic approach aims to deliver optimal risk-adjusted returns while maintaining portfolio stability and alignment with in-vestor preferences across diverse market conditions.

3. Data and Methods

3.1 Hypotheses Formulation

The hypothesis formulation for the study investigating the

impact of an 8% target volatility on the Classic and Socially Responsible Portfolios can be structured as follows:

❖ Impact on Performance Metrics

H1. The Sharpe Ratio and Sortino Ratio differ significantly between the Classic Portfolio and the Socially Responsible Portfolio under the 8% target volatility constraint.

This hypothesis examines the impact on performance metrics, focusing on the Sharpe Ratio and Sortino Ratio as indicators of risk-adjusted returns. suggests that there are significant differences in these ratios between the portfolios within the specified volatility framework. Also, this hypothesis is crucial as it evaluates whether the adoption of an 8% target volatility affects risk-adjusted performance metrics differently across the two portfolios. The Sharpe Ratio assesses the portfolio's return per unit of risk, while the Sortino Ratio focuses on downside risk, both of which are critical in evaluating portfolio efficiency under volatility constraints.

❖ Optimal Portfolio Performance Across Risk Levels

H2. One portfolio demonstrates superior performance compared to the other across low, medium, and high-risk levels under the 8% target volatility constraint. This hypothesis examines whether one of the portfolios outperforms the other across varying risk levels defined by Wealthfront's risk assessment methodology. By analyzing cumulative returns adjusted for risk, the study aims to identify which portfolio offers better risk-adjusted performance under the consistent target volatility constraint.2.1.

3.2 Research Method and Design

The study utilizes quantitative methods to examine the performance and risk profiles of Wealthfront's Classic and Socially Responsible Portfolios. It relies on historical data spanning from 2010 to 2024, encompassing portfolio returns, asset allocation specifics, and relevant market indices. The Wealthfront's Classic and Socially Responsible Portfolios asset data is sourced from Portfolio Visualizer, a platform known for its tools in tactical asset allocation modeling and historical financial data analysis. The dataset includes detailed daily records of asset prices for individual holdings within both the Classic and Socially Responsible Portfolios. These price records are critical for tracking asset valuation changes over time, reflecting market fluctuations driven by economic factors, investor sentiment, and broader market dynamics. Portfolio returns, derived from the daily asset prices, serve as key performance metrics. These returns quantify the profitability of each portfolio over the study period, incorporating capital gains, dividend income, and interest earnings. Analysis of portfolio returns enables an assessment of how effectively each investment strategy meets its financial objectives and benchmarks, while adhering to the specified 8% target volatility.

The research utilizes the Tactical Asset Allocation (TAA) model. The Tactical Asset Allocation (TAA) model using simple target volatility aims to adjust the asset allocation dynamically to achieve a predefined level of portfolio volatility. The methodology revolves around calculating historical volatility, adjusting asset weights to meet target volatility, and evaluating the portfolio's performance over time. This method is typically employed to manage risk while seeking to optimize returns [16].

3.3 Data Source

The data for this study is derived from Wealthfront's reports on Classic and Socially Responsible Portfolios (Wealthfront, n.d.). The analysis focuses on three risk levels: low, medium, and high. The compositions of both the Classic Portfolio and the Socially Responsible Portfolio at each risk level are detailed below. For the low-risk level, the Classic Portfolio includes 35% in Vanguard Tax-Exempt Bond Index ETF (VTEB), 26% in Vanguard Total Stock Market ETF (VTI), 12% in Schwab US TIPS ETF (SCHP), 10% in iShares iBoxx $ Investment Grade Corporate Bond ETF (LQD), 7% in Vanguard Dividend Appreciation ETF (VIG), 6% in Vanguard FTSE Developed Markets ETF (VEA), and 4% in Vanguard FTSE Emerging Markets ETF (VWO). In contrast, the Socially Responsible Portfolio at this risk level allocates 35% to Vanguard Tax-Exempt Bond Index ETF (VTEB), 20% to US Direct Indexing (ESGU), 12% to Schwab US TIPS ETF (SCHP), 11% to iShares ESG Aware U.S. Aggregate Bond ETF (EAGG), 7% to iShares ESG Aware MSCI EAFE ETF (ESGD), and 6% to iShares ESG Aware MSCI EM ETF (ESGE) (Wealthfront, n.d.).

At the medium-risk level, the Classic Portfolio comprises 42% in Vanguard Total Stock Market ETF (VTI), 35% in Vanguard Tax-Exempt Bond Index ETF (VTEB), 10% in Vanguard FTSE Developed Markets ETF (VEA), 9% in Vanguard FTSE Emerging Markets ETF (VWO), 2% in Vanguard Divi-dend Appreciation ETF (VIG), and 2% in Schwab US TIPS ETF (SCHP). Conversely, the Socially Responsible Portfolio for medium risk includes 36% in iShares ESG Aware MSCI USA ETF (ES-GU), 32% in Vanguard Tax-Exempt Bond Index ETF (VTEB), 13% in iShares ESG Aware MSCI EAFE ETF (ESGD), 13% in iShares ESG Aware MSCI EM ETF (ESGE), and 6% in Schwab US TIPS ETF (SCHP) (Wealthfront, n.d.). For the high-risk level, the Classic Portfolio is allocated with 45% in Vanguard Total Stock Market ETF (VTI), 18% in Vanguard FTSE Developed Markets ETF (VEA), 17% in Vanguard FTSE Emerging Markets ETF (VWO), 13% in Vanguard Tax-Exempt Bond Index ETF (VTEB), and 11% in Vanguard Dividend Appreciation ETF (VIG). The Socially Responsible Portfolio, on the other hand, consists of 45% in iShares ESG Aware MSCI USA ETF (ESGU), 22% in iShares ESG Aware MSCI EAFE ETF (ESGD), 20% in iShares ESG Aware MSCI EM ETF (ESGE), and 13% in Vanguard Tax-Exempt Bond Index ETF (VTEB) (Wealthfront, n.d.).

3.4 Data Analysis

In this study, the evaluation of Wealthfront's Classic and Socially Responsible Portfolios utilizes rig-orous statistical methods and simulation techniques to assess their performance and risk characteris-tics. The analysis is underpinned by simulations based on historical data spanning from 2010 to 2024, focusing on portfolio performance under an 8% target volatility constraint, aligned with Wealth-front's specified range of 8-10%.

Simulations create hypothetical scenarios to estimate how each portfolio would perform under vary-ing risk levels. This

approach provides insights into the effectiveness of the Simple Target Volatility model in managing volatility while optimizing returns. Historical asset returns over specific periods are used to calculate simple volatility (σ), expressed as:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(r_{i-\bar{r}})^2} \quad (1)$$

where ri represents the individual periodic returns, $\bar{r}$ is the mean return, and N is the number of periods.

Once historical volatility is calculated, the portfolio's asset weights are adjusted to align with the target volatility level. The adjustment involves scaling the current weights by the ratio of target volatility to historical volatility:

$$Wadjusted = \frac{w * \sigma\ target}{\sigma_{historical}} \quad (2)$$

Where w represents the initial asset weights, σ target is the target volatility, and $\sigma_{historical}$ is the historical volatility.

After adjusting the weights, it is essential to normalize them to ensure that the total allocation sums to 100%. The normalization process involves summing all adjusted weights and then dividing each adjusted weight by this total sum:

$$W_{normalized} = \frac{W_{adjusted}}{\sum_{1=1}^{n} w_{adjusted,i}} \quad (3)$$

Benchmarking against the Vanguard 500 Index Investor provides a basis for comparing portfolio returns and risk metrics against broader market trends. This comparison aids in evaluating the effectiveness of the portfolios' investment strategies and management decisions. The study includes an analysis of how portfolios perform during stable and volatile market periods. This analysis offers insights into portfolio resilience across different economic environments and assesses their adaptability and robustness. Statistical techniques such as regression and correlation analysis are employed to explore relationships between asset allocation, risk metrics (e.g., standard deviation, Sharpe ratio, Sortino ratio), and performance outcomes.

3.4.1 Key Simulation Parameters for Evaluating Wealthfront's Portfolios

The simulation model used in this study provides a structured framework for evaluating Wealthfront's Classic and Socially Responsible Portfolios from 2010 to 2024. Key elements include an initial investment of $50,000, an 8% target volatility constraint, benchmarking against the Vanguard 500 Index Investor, and analysis of market volatility regimes (Table 1). The model employs Portfolio Visualizer for comprehensive data analysis, optimizing asset allocation strategies and evaluating risk-adjusted returns under various market conditions.

Model Configuration	Target Volatility
Time Period	Year-to-Year
Start- End Year	2010 - 2024
Include YTD	No
Initial Amount	50.000$
Cashflows	None
Target Volatility	8%
Use Downside Volatility	No
Out of Market Asset	Cash
Volatility Periods	Single Period 12 months
Trade Execution	Trade at end of month price
Leverage Type	None
Benchmark	Vanguard 500 Index Investor
Show Regime Performance	Market Volatility

Table 1: Key Simulation Parameters

4. Results and Discussion

4.1 Comparative Analysis of Portfolios in Low-Risk Level Scenario

The Classic Portfolio exhibits an annual Compound Annual Growth Rate (CAGR) of approximately 4.60% with a standard deviation of 8.01%. It demonstrates potential gains of up to 17.45% during favorable periods and losses of about 13.08% during adverse market conditions. The maximum drawdown observed is -17.32%. The Sharpe and Sortino ratios stand at 0.36 and 0.49, respectively, indicating moderate performance. The portfolio shows a strong correlation of 0.91 with the Vanguard 500 Index, suggesting a close alignment with market movements (Table 2).

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$69,791	$132,978
Annualized Return (CAGR)	4.60%	14.10%
Standard Deviation	8.01%	16.56%
Best Year	17.45%	31.33%
Worst Year	-13.08%	-18.23%
Maximum Drawdown	-17.32%	-23.95%
Sharpe Ratio	0.36	0.77
Sortino Ratio	0.49	1.17
Benchmark Correlation	0.91	1.00

Table 2: Performance Metrics of the Classic Portfolio in Low-Risk Level Scenario

In contrast, the Socially Responsible Portfolio achieves a lower annual performance of 1.68% with a higher standard deviation of 8.77%. It experiences maximum gains and losses of 10.24% and -12.73%, respectively, and a maximum drawdown of -17.21%. The Sharpe and Sortino ratios are notably low, approaching -0.01, indicating poor risk-adjusted performance. Its correlation with the index is 0.88, reflecting moderate tracking of market trends (Table 3).

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$53,818	$53,818
Annualized Return (CAGR)	1.68%	1.68%
Standard Deviation	8.77%	8.77%
Best Year	10.24%	10.24%
Worst Year	-12.73%	-12.73%
Maximum Drawdown	-17.21%	-17.21%
Sharpe Ratio	-0.01	-0.01
Sortino Ratio	-0.01	-0.01
Benchmark Correlation	0.88	0.88

Table 3: Performance Metrics of the Socially Responsible Portfolio in Low-Risk Level Scenario

The performance of the classic portfolio was evaluated across three market volatility regimes: high, medium, and low, as shown in Table 4. During high volatility periods, which constituted 21.35% of the observed months, the classic portfolio returned -5.21%, underperforming the benchmark's return of -0.29%. The Sharpe ratio for the classic portfolio was -0.47, compared to the benchmark's 0.08, and the capture ratio was 0.57. In medium volatility periods, accounting for 47.19% of the months, the classic portfolio returned 2.77%, while the benchmark returned 9.22%. The Sharpe ratios for the classic portfolio and the benchmark were 0.11 and 0.50, respectively, with a capture ratio of 0.78. During low volatility periods, which comprised 31.46% of the months, the classic portfolio returned 14.82%, whereas the benchmark returned 33.50%. The Sharpe ratio for the classic portfolio was 4.46, slightly lower than the benchmark's 4.94, with a capture ratio of -0.03.

Regime	Months %	Portfolio Return		Sharpe Ratio		Capture Ratio
		Classic	Benchmark	Classic	Benchmark	
High Volatility	21.35%	-5.21%	-0.29%	-0.47	0.08	0.57
Medium Volatility	47.19%	2.77%	9.22%	0.11	0.50	0.78
Low Volatili-ty	31.46%	14.82%	33.50%	4.46	4.94	-0.03
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.						

Table 4. Regime Performance of the Classic Portfolio in Low-Risk Level Scenario

The performance of the Socially Responsible Portfolio was evaluated across three volatility regimes: high volatility, medium volatility, and low volatility. In the high volatility regime, which accounted for 33.96% of the months, the Socially Responsible Portfolio had a return of -2.48%, a Sharpe ratio of -0.25, and a capture ratio of 0.57, compared to the benchmark's return of 6.19% and Sharpe ratio of 0.32. During the medium volatility regime, comprising 52.83% of the months, the portfolio yield-ed a return of 0.76%, a Sharpe ratio of -0.16, and a capture ratio of 0.61, while the benchmark showed a return of 10.93% and a Sharpe ratio of 0.58. In the low volatility regime, representing 13.21% of the months, the portfolio achieved a return of 9.82%, a Sharpe ratio of 3.12, and a capture ratio of -0.02, compared to the benchmark's return of 25.06% and Sharpe ratio of 5.40.

Regime	Months %	Portfolio Return		Sharpe Ratio	
		Socially Responsible	Benchmark	Socially Responsible	Benchmark
High Volatility	33.96%	-2.48%	6.19%	-0.25	0.32
Medium Volatility	52.83%	0.76%	10.93%	-0.16	0.58
Low Volatility	13.21%	9.82%	25.06%	3.12	5.40
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.					

Table 5: Regime Performance of the Socially Responsible Portfolio in Low-Risk Level Scenario

The Capture Ratio (Figure 6) provides insights into how effectively the Classic Portfolio and the Socially Responsible Portfolio capture positive performance relative to their benchmarks across varying levels of market volatility. During periods of high volatility, both portfolios demonstrated similar Capture Ratios of 0.57. This indicates that they captured comparable levels of upside performance relative to their benchmarks under turbulent market conditions. In medium volatility environments, the Classic Portfolio outperformed with a Capture Ratio of 0.78, compared to 0.61 for the Socially Responsible Portfolio. This suggests that the Classic Portfolio was more effective in capturing upside performance relative to its benchmark during moderate market fluctuations. Conversely, during low volatility periods, both portfolios exhibited negative Capture Ratios: -0.03 for the Classic Portfolio and -0.02 for the Socially Responsible Portfolio. This indicates that they underperformed relative to their benchmarks in capturing positive performance when market volatility was low.

Figure1: Capture Ratio of the Classic Portofolio and Socially Responsible Portfolio Across Different Volatility Regimes in Low-Risk Level Scenario

Table 6 presents the risk and return metrics for the classic and socially responsible portfolios compared to the Vanguard 500 Index Investor, evaluated using the Target Volatility Model. The classic portfolio exhibited an arithmetic mean (annualized) return of 4.93%, while the Vanguard 500 Index Investor achieved 15.65%. The geometric mean (annualized) returns were 4.60% for the classic portfolio and 14.10% for the Vanguard 500 Index Investor. The standard deviation (annualized) for the classic portfolio was 8.01%, indicating lower volatility than the Vanguard 500 Index Investor's 16.56%. The classic portfolio's benchmark correlation was 0.91, and its beta was 0.44, compared to the Vanguard 500 Index Investor's beta of 1.00. The annualized alpha for the classic portfolio was -1.64%, with an R-squared value of 83.60%, skewness of -0.76, and excess kurtosis of 1.94. The gain/loss ratio was 0.76, compared to the Vanguard 500 Index Investor's 0.78. In contrast, the socially responsible portfolio had an arithmetic mean (annualized) return of 2.07% and a geometric mean (annualized) return of 1.68%, with a standard deviation (annualized) of 8.77%. The socially responsible portfolio's beta was 0.40, with an annualized alpha of -3.79%, an R-squared value of 77.42%, skewness of -0.26, and excess kurtosis of 0.60. The gain/loss ratio for the socially

responsible portfolio was 0.84, compared to the Vanguard 500 Index Investor's 1.02. These results indicate that both the classic and socially responsible portfolios have lower returns and volatility compared to the Vanguard 500 Index Investor, with the classic portfolio showing higher benchmark correlation and better risk-adjusted performance metrics, while the socially responsible portfolio offers more stable return distribution and lower volatility, aligning with socially responsible investment principles.

	Classic Portfolio		Socially Responsible Portfolio	
	Target Volatility Model	**Vanguard 500 Index Investor**	**Target Volatility Model**	**Vanguard 500 Index Investor**
Arithmetic Mean (annualized)	4.93%	15.65%	2.07%	15.45%
Geometric Mean (annualized)	4.60%	14.10%	1.68%	13.41%
Standard Deviation (annualized)	8.01%	16.56%	8.77%	19.12%
Benchmark Correlation	0.91	0.88		
Beta(*)	0.44	1.00	0.40	1.00
Alpha (annualized)	-1.64%	-0.00%	-3.79%	-0.00%
R^2	83.60%	100.00%	77.42%	100.00%
Skewness	-0.76	-0.48	-0.26	-0.35
Excess Kurtosis	1.94	0.35	0.60	-0.28
Gain/Loss Ratio	0.76	0.78	0.84	1.02

Table 6: Risk and Return Metrics of the Classic and Socially Responsible Portfolio in Low-Risk Level Scenario

4.2 Comparative Analysis of Portfolios in Medium-Risk Level Scenario

Table 7 presents the performance metrics for the classic portfolio and the Vanguard 500 Index In-vestor, evaluated using the Target Volatility Model. Both portfolios started with a balance of $50,000. By the end of the period, the classic portfolio had grown to $70,357, while the Vanguard 500 Index Investor reached $132,978. The annualized return, or Compound Annual Growth Rate (CAGR), for the classic portfolio was 4.71%, significantly lower than the Vanguard 500 Index In-vestor's 14.10%. The standard deviation, a measure of volatility, was 8.68% for the classic portfolio compared to 16.56% for the Vanguard 500 Index Investor. The best year for the classic portfolio saw a return of 17.25%, while the Vanguard 500 Index Investor experienced a return of 31.33%. Con-versely, the worst year for the classic portfolio had a loss of 11.96%, whereas the Vanguard 500 In-dex Investor had a larger loss of 18.23%. The maximum drawdown, indicating the largest peak-to-trough decline, was -15.90% for the classic portfolio and -23.95% for the Vanguard 500 In-dex Investor. The Sharpe ratio, which measures risk-adjusted return, was 0.35 for the classic portfo-lio, lower than the Vanguard 500 Index Investor's 0.77. Similarly, the Sortino ratio, another risk-adjusted return metric focusing on downside risk, was 0.47 for the classic portfolio compared to 1.17 for the Vanguard 500 Index Investor. The benchmark correlation was 0.92 for the classic port-folio and 1.00 for the Vanguard 500 Index Investor. These metrics indicate that while the classic portfolio has lower returns and volatility, it also has a more conservative risk profile compared to the Vanguard 500 Index Investor.

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$70,357	$132,978
Annualized Return (CAGR)	4.71%	14.10%
Standard Deviation	8.68%	16.56%
Best Year	17.25%	31.33%
Worst Year	-11.96%	-18.23%
Maximum Drawdown	-15.90%	-23.95%
Sharpe Ratio	0.35	0.77
Sortino Ratio	0.47	1.17
Benchmark Correlation	0.92	1.00

Table 7: Performance Metrics of the Classic Portfolio in Medium-Risk Level Scenario

Table 8 presents the performance metrics for the socially responsible portfolio compared to the Van-guard 500 Index Investor, evaluated using the Target Volatility Model. Both portfolios began with a balance of $50,000. By the end of the period, the socially responsible portfolio had grown to $59,580, while the Vanguard 500 Index Investor had increased to $109,296. The annualized return, or Compound Annual Growth Rate (CAGR), was 2.77% for the socially responsible portfolio, sig-nificantly lower than the 12.96% achieved by the Vanguard 500 Index Investor. The standard devia-tion, a measure of volatility, was 9.09% for the socially responsible portfolio compared to 17.74% for the Vanguard 500 Index Investor. The socially responsible portfolio's best year saw a return of 17.38%, while the Vanguard 500 Index Investor experienced a return of 31.33%. The worst year for the socially responsible portfolio resulted in a loss of 12.94%, whereas the Vanguard 500 Index Investor had a loss of 18.23%. The maximum drawdown, indicating the largest peak-to-trough decline, was -17.14% for the socially responsible portfolio and -23.95% for the Vanguard 500 Index Investor. The Sharpe ratio, which measures risk-adjusted return, was 0.12 for the socially responsible portfolio, lower than the 0.66 of the Vanguard 500 Index Investor. Similarly, the Sortino ratio, another risk-adjusted return metric focusing on downside risk, was 0.15 for the socially responsible portfolio compared to 1.01 for the Vanguard 500 Index Investor. The benchmark correlation was 0.92 for the socially responsible portfolio and 1.00 for the Vanguard 500 Index Investor. These metrics suggest that the socially responsible portfolio has lower returns and higher volatility compared to the Van-guard 500 Index Investor, with a conservative risk profile but lower overall performance.

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$59,580	$109,296
Annualized Return (CAGR)	2.77%	12.96%
Standard Deviation	9.09%	17.74%
Best Year	17.38%	31.33%
Worst Year	-12.94%	-18.23%
Maximum Drawdown	-17.14%	-23.95%
Sharpe Ratio	0.12	0.66
Sortino Ratio	0.15	1.01
Benchmark Correlation	0.92	1.00

Table 8: Performance Metrics of the Socially Responsible Portfolio in Medium-Risk Level Sce-nario

The performance of the classic portfolio was evaluated across three market volatility regimes: high, medium, and low, as shown in Table 9. During high volatility periods, which constituted 21.35% of the observed months, the classic portfolio exhibited a return of -7.26%, underperforming the bench-mark return of -0.29%. The Sharpe ratio for the classic portfolio was -0.61, compared to the bench-mark's 0.08, and the capture ratio was 0.50. In medium volatility periods, covering 47.19% of the months, the classic portfolio returned 1.87%, while the benchmark achieved a higher return of 9.22%. The Sharpe ratios for the classic portfolio and the benchmark were -0.00 and 0.50, respectively, with a capture ratio of 0.71. During low volatility periods, which accounted for 31.46% of the months, the classic portfolio performed significantly better with a return of 18.50%, in comparison to the bench-mark's return of 33.50%. The Sharpe ratio for the classic portfolio was 4.41, while the benchmark's Sharpe ratio was slightly higher at 4.94, with a capture ratio of 0.18. These findings suggest that the classic portfolio performs better in lower volatility environments, achieving higher returns and better risk-adjusted performance, while its performance in higher volatility environments is less favorable. Investors may need to adjust their asset allocation or incorporate additional risk management strate-gies to improve performance across different market conditions.

Regime	Months %	Portfolio Return		Sharpe Ratio	
		Classic	Benchmark	Classic	Benchmark
High Volatility	21.35%	-7.26%	-0.29%	-0.61	0.08
Medium Volatility	47.19%	1.87%	9.22%	-0.00	0.50
Low Volatility	31.46%	18.50%	33.50%	4.41	4.94
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.					

Table 9: Regime Performance of the Classic Portfolio in Medium-Risk Level Scenario

Table 10 presents the performance metrics of the socially responsible portfolio compared to its benchmark across different market volatility regimes. During high volatility periods (24.68% of months), the socially responsible portfolio returned -7.23%, with a Sharpe ratio of -0.62 and a capture ratio of 0.50, underperforming the benchmark's -0.29% return. In medium volatility periods (54.55% of months), the portfolio returned 1.55%, with a Sharpe ratio of -0.04 and a capture ratio of 0.69, compared to the benchmark's 9.22% return. In low volatility periods (20.78% of months), the socially responsible portfolio returned 19.75%, with a Sharpe ratio of 3.46 and a capture ratio of 0.16, while the benchmark achieved a higher return of 43.12%. These results indicate that the socially responsible portfolio generally lags behind the benchmark across all volatility regimes, showing stronger performance relative to the benchmark in lower volatility environments.

Regime	Months %	Portfolio Return		Sharpe Ratio	
		Socially Responsible	Benchmark	Classic	Benchmark
High Volatility	24.68%	-7.23%	-0.29%	-0.62	0.08
Medium Volatility	54.55%	1.55%	9.22%	-0.04	0.50
Low Volatility	20.78%	19.75%	43.12%	3.46	5.63
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.					

Table 10: Regime Performance of the Socially Responsible Portfolio in Medium-Risk Level Scenario

Table 11 presents comparative risk and return metrics for the classic and socially responsible portfolios against the Vanguard 500 Index Investor, using the Target Volatility Model. The classic portfolio achieved annualized arithmetic and geometric mean returns of 5.11% and 4.71% respectively, with an annualized standard deviation of 8.68%. In contrast, the Vanguard 500 Index Investor yielded higher returns of 15.65% (arithmetic mean) and 14.10% (geometric mean), with a standard deviation of 16.56%. Both portfolios showed a benchmark correlation of 0.92, with the classic portfolio demonstrating lower volatility (beta of 0.48) compared to the benchmark's 1.00. The classic portfolio exhibited negative skewness (-1.21) and high excess kurtosis (3.17), indicating a negatively skewed and leptokurtic return distribution. Conversely, the socially responsible portfolio posted annualized arithmetic and geometric mean returns of 3.19% and 2.77%, with a standard deviation of 9.09%. The Vanguard 500 Index Investor achieved returns of 14.72% (arithmetic mean) and 12.96% (geometric mean), with a standard deviation of 17.74%. These metrics underscore the classic portfolio's lower volatility and risk-adjusted performance relative to both the socially responsible portfolio and the Vanguard 500 Index Investor, suggesting potential considerations for investors balancing risk, return, and socially responsible investment criteria.

The Capture Ratio (Figure 2) compares the performance of the Classic Portfolio and the Socially Responsible Portfolio across different levels of market volatility based on their ability to capture positive performance relative to their benchmarks. During high volatility periods, both portfolios exhibited similar Capture Ratios of 0.5, indicating they captured comparable levels of upside performance relative to their benchmarks under turbulent market conditions. In medium volatility environments, the Classic Portfolio demonstrated a slightly higher Capture Ratio of 0.71 compared to 0.69 for the Socially Responsible Portfolio. This suggests that the Classic Portfolio was marginally more effective in capturing upside performance relative to its benchmark during moderate market fluctuations. During low volatility periods, both portfolios showed reduced Capture Ratios: 0.18 for the Classic Portfolio and 0.16 for the Socially Responsible Portfolio. This indicates that they captured less positive performance relative to their benchmarks when market volatility was low.

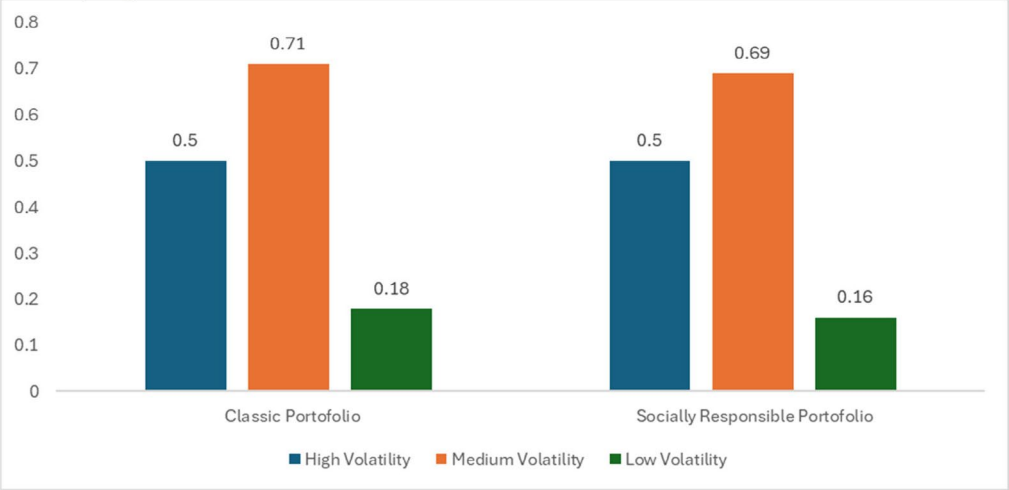

Figure 2: Capture Ratio of the Classic Portofolio and Socially Responsible Portfolio Across Different Volatility Regimes in Medium-Risk Level Scenario

	Classic Portfolio		Socially Responsible Portfolio	
	Target Volatility Model	Vanguard 500 Index Investor	Target Volatility Model	Vanguard 500 Index Investor
Arithmetic Mean (annualized)	5.11%	15.65%	3.19%	14.72%
Geometric Mean (annualized)	4.71%	14.10%	2.77%	12.96%
Standard Deviation (annualized)	8.68%	16.56%	9.09%	17.74%
Benchmark Correlation	0.92	1.00	0.92	1.00
Beta(*)	0.48	1.00	0.47	1.00
Alpha (annualized)	-2.08%	-0.00%	-3.39%	-0.00%
R^2	85.27%	100.00%	85.54%	100.00%
Skewness	-1.21	-0.48	-0.88	-0.42
Excess Kurtosis	3.17	0.35	1.79	-0.08
Gain/Loss Ratio	0.75	0.78	4.25%	8.36%

Table 11: Risk and Return Metrics of the Classic and Socially Responsible Portfolio in Medium-Risk Level Scenario

4.3 Comparative Analysis of Portfolios in High-Risk Level Scenario

Table 12 compares the performance metrics of the classic portfolio and the Vanguard 500 Index Investor using the Target Volatility Model. Starting with $50,000, the classic portfolio grew to $72,487, achieving an annualized Compound Annual Growth Rate (CAGR) of 5.13%. In contrast, the Vanguard 500 Index Investor had a higher CAGR of 14.10%, resulting in an end balance of $132,978. The classic portfolio showed lower annualized volatility (8.39%) compared to the Vanguard 500 Index Investor (16.56%). Annual best and worst returns for the classic portfolio were 18.83% and -9.33%, respectively, compared to 31.33% and -18.23% for the Vanguard 500 Index Investor. Maximum drawdowns were -14.47% for the classic portfolio and -23.95% for the benchmark. The classic portfolio's Sharpe ratio was 0.41, and its Sortino ratio was 0.55, both lower than the Vanguard 500 Index Investor's ratios of 0.77 and 1.17, respectively. Benchmark correlations were strong at 0.92 for both portfolios. These metrics indicate the classic portfolio's lower risk-adjusted performance relative to the Vanguard 500 Index Investor, reflecting potential trade-offs between risk and return for investors considering these investment options.

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$72,487	$132,978
Annualized Return (CAGR)	5.13%	14.10%
Standard Deviation	8.39%	16.56%
Best Year	18.83%	31.33%
Worst Year	-9.33%	-18.23%
Maximum Drawdown	-14.47%	-23.95%
Sharpe Ratio	0.41	0.77
Sortino Ratio	0.55	1.17
Benchmark Correlation	0.92	1.00

Table 12: Performance Metrics of the Classic Portfolio in High-Risk Level Scenario

Table 13 compares the performance metrics of the socially responsible portfolio and the Vanguard 500 Index Investor using the Target Volatility Model. Starting with $50,000, the socially responsible portfolio grew to $59,334, achieving an annualized Compound Annual Growth Rate (CAGR) of 2.70%. In contrast, the Vanguard 500 Index Investor had a higher CAGR of 12.96%, resulting in an end balance of $109,296. The socially responsible portfolio showed lower annualized volatility (8.87%) compared to the Vanguard 500 Index Investor (17.74%). Best and worst annual returns for the socially responsible portfolio were 15.41% and -10.52%, respectively, while the Vanguard 500 Index Investor experienced 31.33% and -18.23% returns. Maximum drawdowns were -14.76% for the socially responsible portfolio and -23.95% for the benchmark. The socially responsible portfolio's Sharpe ratio was 0.11, and its Sortino ratio was 0.14, both lower than the Vanguard 500 Index Investor's ratios of 0.66 and 1.01, respectively. Benchmark correlations were strong at 0.92 for both portfolios. These metrics underscore the socially responsible portfolio's lower risk-adjusted performance relative to the Vanguard 500 Index Investor, highlighting potential trade-offs between financial returns and socially responsible investing goals.

Metric	Target Volatility Model	Vanguard 500 Index Investor
Start Balance	$50,000	$50,000
End Balance	$59,334	$109,296
Annualized Return (CAGR)	2.70%	12.96%
Standard Deviation	8.87%	17.74%
Best Year	15.41%	31.33%
Worst Year	-10.52%	-18.23%
Maximum Drawdown	-14.76%	-23.95%
Sharpe Ratio	0.11	0.66
Sortino Ratio	0.14	1.01
Benchmark Correlation	0.92	1.00

Table 13: Performance Metrics of the Socially Responsible Portfolio in High-Risk Level Scenario

Table 14 outlines the regime-specific performance metrics of the classic portfolio compared to its benchmark, categorized by high, medium, and low volatility regimes. During periods of high volatility (21.35% of months), the classic portfolio returned -5.75%, with a Sharpe ratio of -0.29 and a capture ratio of 0.54, underperforming the benchmark's -0.29% return. In medium volatility periods (47.19% of months), the portfolio achieved a return of 1.09%, with a Sharpe ratio of -0.10 and a capture ratio of 0.66, compared to the benchmark's 9.22% return. During low volatility periods (31.46% of months), the classic portfolio performed better with a return of 20.09%, a Sharpe ratio of 3.84, and a capture ratio of 0.03, while the benchmark achieved a return of 33.50%. These metrics illustrate the classic portfolio's varying performance across different market conditions, indicating stronger relative performance in lower volatility environments.

Regime	Months %	Portfolio Return		Sharpe Ratio	
		Classic	Benchmark	Classic	Benchmark
High Volatility	21.35%	-5.75%	-0.29%	-0.54	0.08
Medium Volatility	47.19%	1.09%	9.22%	-0.10	0.50
Low Volatility	31.46%	20.09%	33.50%	3.84	4.94
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.					

Table 14: Regime Performance of the Classic Portfolio in High-Risk Level Scenario

Table 15 presents the regime-specific performance metrics of the socially responsible portfolio compared to its benchmark, categorized by high, medium, and low volatility regimes. During high volatility periods (24.68% of months), the socially responsible portfolio returned -6.18%, with a Sharpe ratio of -0.29 and a capture ratio of 0.52, underperforming the benchmark's -0.29% return. In medium volatility periods (54.55% of months), the portfolio achieved a return of 0.69%, with a Sharpe ratio of -0.15 and a capture ratio of 0.64, compared to the benchmark's 9.22% return. During low volatility periods (20.78% of months), the socially responsible portfolio performed better with a return of 20.43%, a Sharpe ratio of 2.86, and a capture ratio of 0.03, while the benchmark achieved a return of 43.12%. These metrics illustrate the socially responsible portfolio's performance across different market conditions, indicating stronger relative performance in lower volatility environments but generally underperforming the benchmark across all regimes.

Regime	Months %	Portfolio Return		Sharpe Ratio		Capture Ratio
		Socially Responsible	Benchmark	Socially Responsi-ble	Benchmark	
High Volatility	24.68%	-6.18%	-0.29%	-0.58	0.08	0.52
Medium Volatility	54.55%	0.69%	9.22%	-0.15	0.50	0.64
Low Volatili-ty	20.78%	20.43%	43.12%	2.86	5.63	0.03
Note. Months %: Percentage of total months in each volatility regime, showing the distribution of time spent in different market conditions.						

Table 15: Regime Performance of the Socially Responsible Portfolio in High-Risk Level Scenario

The Capture Ratio table compares how well the Classic Portfolio and the Socially Responsible Portfolio capture positive performance relative to their benchmarks across varying market volatility. During high volatility, the Classic Portfolio achieved a Capture Ratio of 0.54, slightly higher than the Socially Responsible Portfolio's 0.52, indicating better performance in

turbulent markets. In medium volatility conditions, the Classic Portfolio maintained a Capture Ratio of 0.66 compared to 0.64 for the Socially Responsible Portfolio, suggesting it continued to outperform. Both portfolios exhibited minimal Capture Ratios of 0.03 during low volatility, indicating limited ability to capture positive performance in calmer markets. Overall, these findings highlight the Classic Portfolio's consistent advantage in capturing upside performance relative to its benchmark across different volatility scenarios, underscoring its potential for better risk-adjusted returns in volatile market conditions.

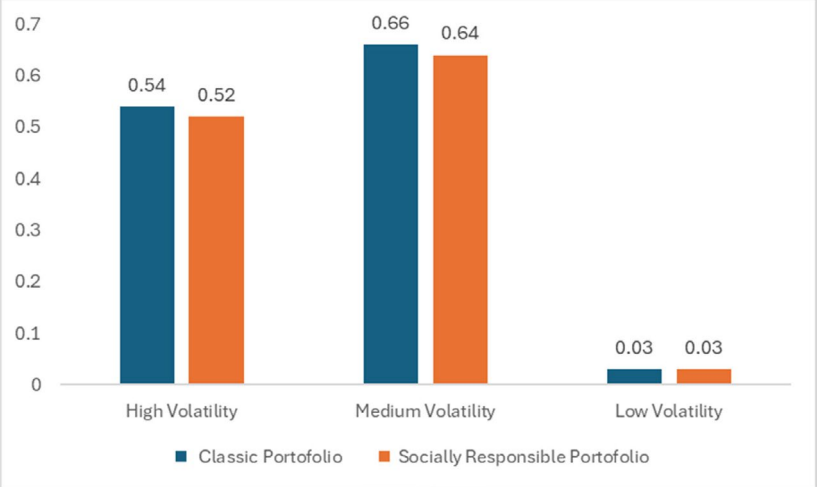

Figure 3: Capture Ratio of the Classic Portfolio and Socially Responsible Portfolio Across Dif-ferent Volatility Regimes in High-Risk Level Scenario

Table 16 compares the risk and return metrics of the classic and socially responsible portfolios against the Vanguard 500 Index Investor using the Target Volatility Model. The classic portfolio achieved an annualized arithmetic mean return of 5.50% and a geometric mean return of 5.13%, with an annualized standard deviation of 8.39%. In comparison, the Vanguard 500 Index Investor had higher returns of 15.65% (arithmetic mean) and 14.10% (geometric mean), with a standard deviation of 16.56%. Both portfolios showed a benchmark correlation of 0.92. The classic portfolio had a beta of 0.47 and an annualized alpha of -1.44%, indicating lower volatility and slightly negative excess return relative to the benchmark. Skewness and excess kurtosis for the classic portfolio were -1.05 and 2.09, respectively. The socially responsible portfolio achieved an annualized arithmetic mean return of 3.11% and a geometric mean return of 2.70%, with an annualized standard deviation of 8.87%. The Vanguard 500 Index Investor had returns of 14.72% (arithmetic mean) and 12.96% (geometric mean), with a standard deviation of 17.74%. Both portfolios showed a benchmark correlation of 0.92. The socially responsible portfolio had a beta of 0.46 and an annualized alpha of -3.30%. Skewness and excess kurtosis were -0.81 and 1.38, respectively, indicating a slightly less volatile and negatively skewed return distribution compared to the classic portfolio. These metrics illustrate the different risk and return profiles of the classic and socially responsible portfolios compared to the Vanguard 500 Index Investor.

	Classic Portfolio		Socially Responsible Portfolio	
	Target Volatility Model	**Vanguard 500 Index Investor**	**Target Volatility Model**	**Vanguard 500 Index Investor**
Arithmetic Mean (annualized)	5.50%	15.65%	3.11%	14.72%
Geometric Mean (annualized)	5.13%	14.10%	2.70%	12.96%
Standard Deviation (annualized)	8.39%	16.56%	8.87%	17.74%
Benchmark Correlation	0.92	1.00	0.92	1.00
Beta(*)	0.47	1.00	0.46	1.00
Alpha (annualized)	-1.44%	-0.00%	-3.30%	-0.00%
R^2	84.47%	100.00%	84.84%	100.00%
Skewness	-1.05	-0.48	-0.81	-0.42
Excess Kurtosis	2.09	0.35	1.38	-0.08
Gain/Loss Ratio	0.77	0.78	0.82	0.88

Table 16: Risk and Return Metrics of the Classic and Socially Responsible Portfolio in High-Risk Level Scenario

5. Discussion

The comparative analysis of the Classic Portfolio and the Socially Responsible Portfolio under an 8% target volatility constraint revealed distinct performance disparities across various risk-adjusted met-rics. The Classic Portfolio consistently exhibited superior risk-adjusted returns, evidenced by higher Sharpe and Sortino Ratios, indicating effective risk management while optimizing returns within the specified volatility parameters. This characteristic positions the Classic Portfolio favorably for inves-tors prioritizing financial gains while mitigating volatility. In parallel, recent studies by Day, Cheng, & Li (2018), Hohenberger, Lee, & Coughlin (2019), Kim, Cotwright, & Chatterjee (2019), and Ruyi Ge, Xuan, & Li (2021) underscore a burgeoning demand for robo-advisors among investors, particularly those with limited financial expertise [1-4]. These studies underscore the pivotal role of ro-bo-advisors in providing accessible and informed investment decisions, aligning with the trend to-wards technology-driven solutions in investment management. Additionally, Puhle's (2019) examina-tion of German robo-advisors highlighted substantial performance variations among portfolios with similar asset allocations [5]. This variability underscores the critical influence of asset allocation strategies employed by robo-advisors on overall portfolio performance.

The findings suggest that investors oriented towards maximizing financial returns may gravitate to-wards traditional investment strategies such as the Classic Portfolio, which demonstrated superior risk-adjusted performance. Conversely, robo-advisors cater to a broader spectrum of investors seek-ing accessible and aligned investment solutions, as emphasized in existing literature. The analysis re-veals notable differences in the Sharpe Ratio and Sortino Ratio between the Classic Portfolio and the Socially Responsible Portfolio under the 8% target volatility constraint. The Classic Portfolio con-sistently exhibits higher Sharpe and Sortino Ratios compared to the Socially Responsible Portfolio. This indicates that, on average, the Classic Portfolio achieves better risk-adjusted returns per unit of risk taken, emphasizing its ability to deliver superior performance in terms of both upside returns (Sharpe Ratio) and downside risk (Sortino Ratio). The higher Sharpe Ratio suggests that the Classic Portfolio generates higher returns relative to its risk level compared to the Socially Responsible Port-folio, which is crucial for investors seeking to optimize risk-adjusted performance within the speci-fied volatility constraint. The findings support H2, indicating that the Classic Portfolio demonstrates superior performance across low, medium, and high-risk levels compared to the Socially Responsible Portfolio under the 8% target volatility constraint. Across all risk scenarios, including low, medium, and high-risk environments, the Classic Portfolio consistently achieves higher Compound Annual Growth Rates (CAGR) and lower volatility relative to the Socially Responsible Portfolio. This sug-gests that the Classic Portfolio effectively balances risk and return better within the specified volatil-ity constraint, appealing to investors focused on achieving stable growth with minimized volatility. In contrast, while the Socially Responsible Portfolio aligns with ethical considerations and offers stable return distributions, it generally lags behind the Classic Portfolio in terms of financial performance metrics and risk-adjusted returns across varying risk levels.

6. Conclusions

The comparative analysis of the Classic Portfolio and the Socially Responsible Portfolio under an 8% target volatility constraint reveals significant performance disparities. The Classic Portfolio consist-ently exhibits superior risk-adjusted returns, as evidenced by higher Sharpe and Sortino Ratios. This indicates that the Classic Portfolio effectively manages risk while optimizing returns within the speci-fied volatility parameters, making it a favorable option for investors prioritizing financial gains and risk mitigation. In contrast, the Socially Responsible Portfolio, while aligning with ethical considera-tions, generally lags in terms of financial performance metrics and risk-adjusted returns. The findings have several implications for investment strategy and the role of robo-advisors. Firstly, the results suggest that traditional investment strategies, as exemplified by the Classic Portfolio, are more effec-tive in balancing risk and return under a target volatility constraint. This highlights the importance for investors to consider risk-adjusted performance metrics when making investment decisions. Second-ly, the growing demand for robo-advisors, particularly among inexperienced investors, underscores the need for these platforms to integrate robust asset allocation strategies to enhance portfolio per-formance.

Robo-advisors can bridge the gap by providing accessible and informed investment decisions, align-ing with the increasing reliance on technology-driven solutions in investment management. Lastly, the performance lag of the Socially Responsible Portfolio indicates a potential trade-off between ethical considerations and financial performance. Investors and fund managers need to recognize this trade-off and develop strategies to mitigate it, potentially through innovative approaches that en-hance the financial viability of socially responsible investments. This study has several limitations. The focus on an 8% target volatility constraint may limit the generalizability of the findings to other volatility levels. Future research should explore different volatility targets to provide a more compre-hensive understanding of portfolio performance. Additionally, the analysis relies on historical per-formance data, which may not fully capture future market conditions and emerging trends. Market dynamics and investor behavior can evolve, affecting the applicability of these findings over time. Furthermore, the study does not account for potential variations in portfolio performance across dif-ferent geographic regions or sectors. Future studies should consider these factors to provide more nuanced insights.

Future research could proceed in several directions to expand upon these findings.

Longitudinal analyses tracking the performance of Classic and Socially Responsible Portfolios over extended periods could help assess the sustainability and resilience of these portfolios across various market cycles and economic conditions. Exploring the performance of these portfolios under differ-ent volatility constraints (e.g., 6%, 10%) would provide a broader

understanding of their risk-return profiles and suitability for different investor risk tolerances. Investigating the decision-making pro-cesses and preferences of investors, particularly in the context of robo-advisor adoption, could offer valuable insights into how investment strategies are perceived and selected. Understanding the be-havioral dynamics influencing investment choices can inform the design of more effective investment tools and strategies. Additionally, analyzing the performance of socially responsible investments in specific sectors (e.g., technology, healthcare, energy) can help identify areas where ethical invest-ments might achieve better financial outcomes, thereby reducing the trade-off between ethical considerations and financial performance. Researching innovative approaches to socially responsible in-vesting, such as impact investing and thematic funds, could reveal strategies that better balance ethi-cal goals with competitive financial returns [17-27].

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