The Role of Solar Equity Investments for Sustainable Portfolio Diversification in the Post-Pandemic Era

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Abstract

This paper investigates the role of solar equity investments, particularly solar Exchange-Traded Funds (ETFs) such as TAN, in the context of portfolio diversification post-COVID-19. It aims to elucidate the potential of these investments in enhancing portfolio resilience and contributing to sustainable economic growth. The objectives include analyzing the market performance, risk-return dynamics, and diversification benefits of solar investments in the wake of the pandemic.

The study covers the period from January 2020 to March 2024, analyzing three key ETFs: TAN (Invesco Solar ETF), SPY (SPDR S&P 500 ETF Trust), and EFA (iShares MSCI EAFE ETF). The research utilizes daily logarithmic returns and employs financial modeling techniques within the R programming environment for performance visualization, maximum drawdown evaluation, and portfolio optimization. By simulating 5,000 portfolio scenarios, the study identifies the optimal combinations for Minimum Variance and Maximum Sharpe Ratio Portfolios.

The findings indicate that the solar ETF, while contributing to diversification, holds a marginal position in optimized portfolios when contrasted with traditional equity investments. The Maximum Sharpe Ratio Portfolio showed an overwhelming preference for SPY, and the Minimum Variance Portfolio was predominantly weighted towards EFA, with both portfolios assigning a minimal role to TAN.

This study contributes original insights into the post-pandemic investment landscape by specifically focusing on solar equity investments within the realm of sustainable finance. It underscores the nuanced role of these investments in portfolio strategy formulation.

For investors and portfolio managers, the research provides evidence-based guidance on the strategic incorporation of solar investments into portfolios, highlighting the balance between embracing the clean energy transition and managing investment risk. Policymakers may derive value from understanding how solar investments interact with broader market dynamics, which can inform the development of supportive regulatory frameworks for sustainable finance.

Keywords

Solar Equity Investments, Portfolio Diversification, Portfolio Optimization, Sustainable Finance

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Introduction

The transition towards renewable energy has gained unprecedented momentum in recent years (Solomon and Krishna, 2011; Gielen et al., 2019; Guliyev, 2023; Hieu and Mai, 2023; Nijsse et al., 2023), spurred by increasing environmental concerns and the global commitment to sustainable development (Lamb and Steinberger, 2017; Yang et al., 2023).

Renewable energy technologies, including a wide variety of sources such as solar, wind, and hydro, along with practices enhancing energy efficiency and breakthrough innovations, are bolstered by policy-driven incentives. This integration is fundamental to the landscape of renewable energy investments. With continuous improvements that amplify their cost-effectiveness and operational efficiency, these technologies have begun to draw substantial investment flows, thereby facilitating the growth and sophistication of the renewable energy market (Tolliver et al., 2020; Liu et al., 2021; Madaleno et al., 2022; Li, 2023).

Among renewable energy sources, solar power stands out due to its vast potential, technological advancements, and policy support. In the investment domain, solar energy equity investments, especially through Exchange-Traded Funds (ETFs), have attracted significant attention from investors seeking to capitalize on the clean energy transition while aiming for portfolio diversification and sustainability.

The COVID-19 pandemic underscored the need for resilient and sustainable investment strategies. The ensuing volatility highlighted the vulnerabilities in traditional investment portfolios and sparked a reevaluation of investment priorities towards more sustainable and resilient assets. In this context, solar energy investments, with their inherent sustainability benefits and growth potential, present an attractive opportunity for investors. However, the pandemic presented unique challenges and opportunities for the clean energy sector (Hassan, 2022; Tudor, 2023).

This paper aims to explore the viability and benefits of solar equity investments, with a specific focus on solar ETFs, in the context of portfolio diversification and sustainability. By examining the market performance of solar ETFs, particularly TAN, and analyzing their risk-return dynamics, we aim to provide insights into how these investments can enhance portfolio resilience and contribute to sustainable economic recovery. Furthermore, we will examine the diversification benefits from incorporating solar equity investments into diversified equity portfolios, assessing their potential to mitigate risks and improve returns in the post-pandemic era. Consequently, this study seeks to offer valuable perspectives for investors, portfolio managers, and policymakers on the strategic importance of solar equity investments in navigating the evolving landscape of renewable energy finance and sustainable investment.

The paper is organized as follows: Section 2 offers a brief review of the related literature; Section 3 details the data and methodology employed in the study; Section 4 presents and discusses the main results; the final section provides conclusions.

2. Review of the scientific literature

To date, a broad spectrum of research has focused on the profound impact of the COVID-19 pandemic on energy markets, encompassing both the overall energy sector and specifically targeted studies on green energy markets. As such, previous studies shed light on how the pandemic has disrupted global supply chains, altered demand and supply dynamics of energy resources, and influenced investor behaviors and market volatility.

Among others, Shaikh (2022) provides a thorough analysis of the impact of the COVID-19 pandemic on the energy markets, with a particular focus on the crisis's effects on stock market volatility. It effectively models the volatility of energy markets, demonstrating the significant effects that various phases of the pandemic have had on these markets and showing that COVID-19-induced uncertainty factors have had pronounced effects on the historical volatility of energy markets.

Dutta et al. (2021) analyze the behavior of socially responsible (SR) investments, specifically focusing on green stocks within the Indian market amidst the evolving landscape of socially responsible investing. The study highlights the increasing traction of green investing, accelerated by global initiatives such as the Paris Agreement, and the ambitious renewable energy targets set by the Indian government. It also underscores the unique challenges faced by green stocks, particularly their heightened volatility and susceptibility to risk transmission from broader financial markets during uncertain times, exacerbated by the COVID-19 pandemic.

Hassan (2022) additionally investigates the impact of carbon market price fluctuations on the volatility of NASDAQ clean energy stock returns, employing GARCH (1,1)-X and EGARCH (1,1)-X models. The study reveals significant insights into the relationship between technology and clean energy stocks. It shows that fluctuations in technology stock prices, which represent the use of new and potentially risky technologies in clean energy production, contribute significantly to the ARCH term of the volatility models, thus highlighting the inherent risks associated with deploying emerging technologies in the clean energy sector.

Furthermore, Tudor (2023) provides a multifaceted exploration of the risk-return characteristics of green hydrogen exchange-traded funds (ETFs) compared to conventional equity and broader green energy portfolios within the framework of socially responsible investing (SRI). It reveals that green hydrogen investments underperformed in the aftermath of the COVID-19 pandemic, with lower returns and higher risk compared to conventional equity from April 2021 to May 2023. Moreover, the study underscored that a substantial portion of their returns were due to systematic market risk.

3. Materials and Methods

3.1 Data

This study encompasses the period from January 2020 to March 2024, focusing on three key exchange-traded funds (ETFs): TAN (solar energy), SPY (SPDR S&P 500 ETF Trust), and EFA (iShares MSCI EAFE, i.e., Europe, Australia, Asia, and the Far East). TAN is chosen for its focus on the burgeoning solar energy sector, encapsulating the performance of companies actively involved in solar energy production and technologies and thus highlighting the performance of the sector. SPY, tracking the S&P 500, serves as a benchmark for the overall US stock market performance, while EFA, tracking the MSCI EAFE index, provides insights into over 900 stocks listed on international equity markets outside of the U.S. and Canada. This selection enables a comprehensive analysis that not only underscores the dynamics within the clean energy sector, particularly solar energy, but also facilitates a broader understanding of solar investments' relative performance and resilience in comparison to major market indices. Data for all ETFs were sourced from Yahoo Finance, ensuring accuracy and consistency in the analysis. Daily price series, adjusted for dividends and other corporate actions, were transformed into logarithmic returns for a detailed performance evaluation.

3.2 Method

Utilizing the R programming environment, this analysis exploits R's extensive libraries designed for financial modeling and portfolio optimization, focusing on performance visualization and risk assessment.

3.2.1. Portfolio Construction and Optimization

The study simulates 5.000 scenarios to scrutinize the optimized combinations of the following two distinct portfolio strategies:

1. Optimized SPY-EFA Portfolio: This strategy, focusing exclusively on equity investments without sector-specific concentration, merges the broad U.S. stock market with diversified international equities, intending to harness the benefits of global market exposure.

2. Optimized TAN-SPY-EFA Portfolio: Enhancing the diversified equity strategy by incorporating solar energy investments, this approach examines the potential of sector-specific diversification alongside global equity exposure to optimize portfolio performance.

A uniform distribution determined the asset allocation within these portfolios, allowing for an equitable exploration of asset combinations. The optimization distinguished portfolios that minimized risk or maximized the Sharpe ratio, pinpointing those offering an optimal balance between risk and return.

The critical examination between the two portfolio strategies aims to illustrate the impact of integrating solar energy investments on the risk-return profile and the diversification benefits within a global equity context.

This research makes use of the **tidyquant** and **tidyverse** packages for efficient data handling and visualization. It creates multiple portfolios—specifically, 5,000 of them—through a looped process. The details such as weights, returns, risks, and Sharpe ratios for these portfolios are systematically stored in matrices and vectors for further examination. For easier interpretation, the collected data are neatly organized into a tibble. Following this method, the analysis is visualizing the efficient frontier, graphically representing the risk versus return for all generated portfolios and identifying the Minimum Variance Portfolio (MVP) and the Tangency Portfolio (TP) through mean-variance optimization (Markowitz, 1952; Sharpe, 1963; Sharpe, 1966).

4. Results and discussion

Figure 1 charts the equity returns of the three equity investments from January 2020 to March 2024. The trajectories depicted underline the disparate performance and volatility inherent to each fund, reflecting their sensitivity to macroeconomic shifts and sector-specific developments, and reveal that TAN is the most volatile of the three, with sharp increases and decreases in returns. The SPY, which tracks the broader US stock market, exhibits a relatively steady growth pattern with minor fluctuations, suggesting a stable investor sentiment and a resilient response to market conditions over the period. This consistent performance characterizes the SPY as a potentially reliable foundation in an investment portfolio, particularly appealing to those seeking steady growth with moderate risk.

In contrast, TAN, the solar energy-focused ETF, demonstrates considerable volatility, with sharp ascents and descents indicative of a sector experiencing rapid growth and frequent market reassessments. The pronounced peak in returns suggests periods of heightened investor optimism and possible sector-specific catalysts, while the subsequent troughs may reflect market corrections or reactions to policy and technological changes impacting the solar industry. TAN's performance thus presents an interesting case study for investors attracted to high-growth sectors, albeit with an acceptance of higher risk and a strategy to navigate its cyclical nature.

EFA, representing international equity markets, showcases a more tempered performance curve, with lesser volatility compared to TAN but also lesser returns compared to SPY. Its moderate and more predictable pattern could be interpreted as a reflection of diverse market influences outside of the US, offering potential stability but with capped growth prospects in comparison to its US counterparts. The distinct movements among the ETFs underscore the imperative for investors to evaluate sector-specific trends and integrate diversified investment approaches. TAN's performance, in particular, invites further scrutiny to discern the drivers of its dramatic shifts, with implications for strategic positioning within the clean energy sector. Overall, the divergence observed in this chart calls for an intricate investment strategy that balances the growth potential of high-energy sectors with the stability offered by broader market indices.

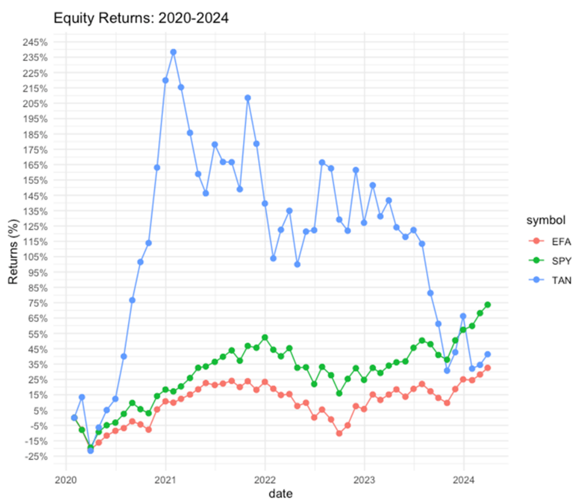

Figure no. 1. **Cumulative returns of the three ETFs (1.01.2020 – 31.03.2024)**

Next, statistics displayed in Figure 2 delineate a clear disparity in the risk profiles of the three ETFs: EFA, SPY, and TAN. TAN, representing the solar energy sector, exhibits significantly higher volatility in its downside metrics compared to the more diversified EFA and the broad US market SPY. This is particularly evident in its semi deviation, a measure of the fluctuation of negative returns, which is more than double that of EFA and SPY. Furthermore, TAN's maximum drawdown—a metric that captures the largest single drop from peak to trough—is markedly higher, suggesting that an investment in TAN could potentially experience substantial short-term losses. Both the historical Value at Risk (VaR) and Expected Shortfall (ES) at the 95% confidence level underscore TAN's higher risk, with its values indicating a greater potential for extreme losses in adverse market conditions. Conversely, SPY and EFA maintain closer risk profiles to each other, with SPY slightly edging out as the riskier of the two, albeit not nearly as much as TAN. The modified VaR and ES metrics, which adjust for the skewness and kurtosis in the returns distribution, also reflect this pattern, with TAN bearing the most risk. These insights are critical for investors when calibrating the risk-return balance of their portfolios, particularly underlining the enhanced risk associated with sector-specific investments like TAN.

DownsideRisk Statistics

	EFA	SPY	TAN
Semi Deviation	0.0099	0.0104	0.0208
Gain Deviation	0.0086	0.0094	0.0194
Loss Deviation	0.011	0.0117	0.0199
Downside Deviation (MAR=0%)	0.0098	0.0102	0.0206
Downside Deviation (Rf=0%)	0.0098	0.0102	0.0206
Downside Deviation (0%)	0.0098	0.0102	0.0206
Maximum Drawdown	0.3572	0.3575	0.7453
Historical VaR (95%)	-0.0175	-0.0202	-0.0435
Historical ES (95%)	-0.0312	-0.0343	-0.0652
Modified VaR (95%)	-0.0218	-0.0222	-0.0476
Modified ES (95%)	-0.0573	-0.0514	-0.0753

Figure no. 2. Downside risk statistics

The covariance matrix in Table 1 presents the degree to which the returns of EFA, SPY, and TAN move together. EFA and SPY have the smallest covariance, suggesting that their return movements are less strongly related compared to the other pairs. TAN has a notably higher covariance with both EFA and SPY, with the highest being with SPY. This indicates that TAN's returns are more closely related to the movements in the broader US market represented by SPY.

Table no. 1. Covariance matrix

	EFA	SPY	TAN
EFA	0.0441	0.0411	0.0590
SPY	0.0411	0.0493	0.0633
TAN	0.0590	0.0633	0.2164

Proceeding with the analysis, the study will now shift focus towards portfolio optimization between the diversified equity funds, EFA and SPY, to assess their combined performance in the aftermath of the COVID-19 pandemic. By constructing and evaluating a multitude of portfolios—this time with an expansive approach of simulating 5,000 scenarios—the research aims to uncover the optimal mix of these two ETFs. This phase will seek to determine the strategic asset allocation that minimizes risk while maximizing risk-adjusted returns, shedding light on the diversification benefits within a global equity context as the world emerges from the pandemic-induced economic volatility. Table 2 summarizes the optimization results.

Table no. 2. Optimization of EFA-SPY investments

	EFA	SPY	Return	Risk	SharpeRatio
Maximum Sharpe Allocation	0.0000419	1.00	0.137	0.222	0.615
Minimum Variance Allocation	0.732	0.268	0.0793	0.208	0.381

The maximum Sharpe allocation, favoring a heavy concentration in SPY with minimal exposure to EFA, yields a notably higher return of 13.7% but comes with a proportionally increased risk of 22.2%. This results in a Sharpe ratio of 0.615, indicating a relatively favorable risk-adjusted return. Conversely, the minimum variance allocation opts for a more balanced distribution between EFA and SPY, with a majority allocation to EFA. While this allocation generates a lower return of 7.93%, it also entails a lower risk of 20.8%. Consequently, the Sharpe ratio decreases to 0.381, reflecting a less favorable risk-return profile compared to the maximum Sharpe allocation.

The last stage of the analysis aims to optimize portfolios between the diversified equity funds EFA and SPY, alongside the solar energy-focused ETF, TAN. This investigation seeks to uncover the most efficient asset allocation strategies within the observed period spanning January 2020 to March 2024. Employing a similar mean-variance optimization framework utilized previously, the study generates 5,000 random portfolios for each distinct scenario, exploring the potential benefits of integrating TAN into portfolios predominantly composed of EFA and SPY. By evaluating the risk-return characteristics of these portfolios, the research aims to elucidate the diversification advantages and risk-reward trade-offs associated with incorporating TAN, a sector-specific asset, into broader equity portfolios.

Figures 3 and 4 depict the weights of the three ETFs within the Minimum Variance Portfolio (MVP) and the Tangency Portfolio (TP), thus revealing the optimal compositions derived from the portfolio optimization process.

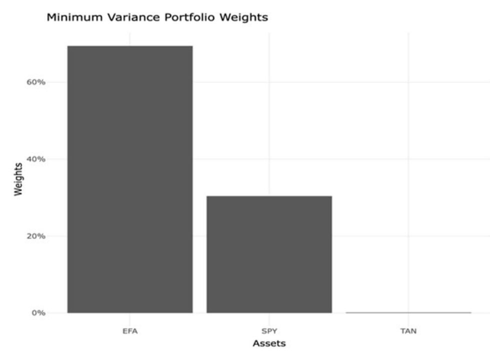

Figure no. 3. Asset Weights in MVP

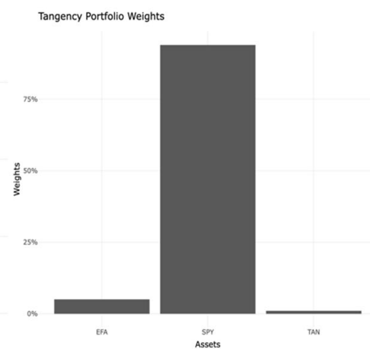

Figure no. 4. Asset Weights in the TP

In the MVP (Figure 3), the largest weight is assigned to EFA, followed by a substantial allocation to SPY, with TAN having a very small representation. This suggests that, within the historical data used for the optimization, EFA and SPY together provided the lowest variance, or risk, for the portfolio.

The TP (Figure 4), on the other hand, shows an overwhelming preference for SPY, with almost negligible allocations to EFA and TAN. This indicates that SPY is considered to contribute most to the portfolio's excess return per unit of risk, as measured by the Sharpe ratio.

Figure 5 visualizes the efficient frontier of the 5,000 portfolios constructed from a combination of EFA, SPY, and TAN, displaying the trade-off between annualized risk (volatility) and returns, where the color gradient represents the Sharpe Ratio. Of note, most portfolios cluster towards the bottom of the triangle, indicating a range of lower-return, lower-risk combinations. The red dots identify the Minimum Variance Portfolio (MVP), offering the lowest risk at that return level, and the Tangency Portfolio (TP), which has the highest Sharpe Ratio, denoting the optimal risk-adjusted return.

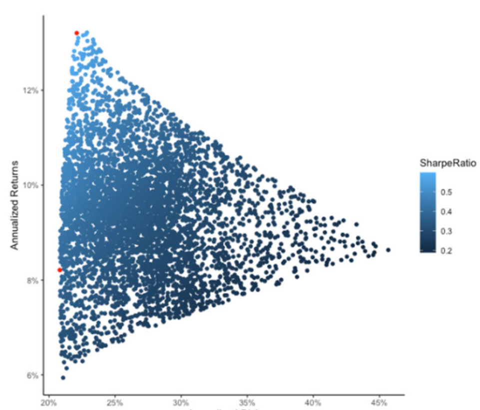

Figure no. 5. Efficient frontier

More details about the optimization results are presented in Table 3.

Table no. 3. Optimization of EFA-SPY-TAN investments

	EFA	SPY	TAN	Return	Risk	SharpeRatio
Maximum Sharpe Allocation	0.00650	0.985	0.00814	0.136	0.222	0.610
Minimum Variance Allocation	0.767	0.232	0.000823	0.0766	0.208	0.368

The Maximum Sharpe Ratio Allocation suggests a portfolio composition where nearly all of the weight is placed on the SPY ETF (98.5%), with very marginal allocations to EFA (0.65%) and TAN (0.814%), indicating a strong preference for SPY as the primary driver of returns. This portfolio strategy focuses on maximizing the return per unit of risk, achieving a portfolio return of 13.6% with an associated risk (as measured by standard deviation) of 22.2%, resulting in a Sharpe Ratio of 0.61. In contrast, the Minimum Variance Allocation shifts the focus towards risk minimization, predominantly allocating to EFA (76.7%), with a smaller investment in SPY (23.2%), and an almost negligible position in TAN (0.0823%). This risk-averse approach yields a lower portfolio return of 7.66%, but also reduces risk to 20.8%, offering a Sharpe Ratio of 0.368. These contrasting strategies highlight the trade-off between pursuing maximum risk-adjusted returns and minimizing portfolio volatility.

In both portfolio strategies, TAN plays a minimal role, with its allocation being substantially lower compared to the other ETFs. In the Maximum Sharpe Ratio Allocation, TAN constitutes just 0.814% of the portfolio, reflecting its relatively smaller contribution to optimizing the risk-adjusted return of the portfolio. Despite its minor presence, it is included, suggesting that it still provides a marginal benefit to the portfolio's Sharpe Ratio. On the other hand, in the Minimum Variance Allocation, TAN's weight is almost negligible at 0.0823%, indicating that its role in reducing portfolio variance is limited. The extremely low allocation to TAN in both portfolios implies that its standalone risk-return profile may not be as favorable as EFA's or SPY's within the context of these optimization objectives. Therefore, TAN appears to have a limited impact on both the pursuit of maximum efficiency in terms of risk-adjusted returns and the minimization of risk.

Conclusions

This paper has examined the integration of solar equity investments, specifically through solar ETFs like TAN, into investment portfolios post-pandemic, focusing on their role in sustainable diversification. The analysis suggests that while TAN presented a higher risk profile and volatility, indicative of the growth dynamics and sector-specific sensitivities within the solar industry, its incorporation into diversified portfolios did not manage to enhance risk-adjusted returns when compared to portfolios composed only of EFA and SPY. Both the Maximum Sharpe Ratio and Minimum Variance Portfolios demonstrated a minimal allocation to TAN, highlighting a preference for more traditional equity investments that offer a more stable risk-return profile.

The study's results imply that while solar equity investments like TAN can be an element of diversification, their role is comparatively limited within the context of these portfolio strategies. This is particularly evident given their marginal contribution to the portfolios' Sharpe Ratios and the negligible impact on variance reduction. The findings align with the growing interest in sustainable investments post-pandemic, acknowledging the potential of solar investments but also recognizing the need for a cautious approach given their high volatility and the current market structures.

The implications for investors, portfolio managers, and policymakers are clear: solar equity investments can be a component of a diversified, sustainable portfolio, but their allocation should be calibrated against the backdrop of their risk profiles and market performance. As the push towards sustainable investment continues to evolve, the role of solar equity investments will likely become more pronounced, warranting further research and analysis. This paper has laid the groundwork for understanding their current impact and has opened the door for future studies to explore the long-term potential of solar equities in a rapidly changing investment landscape.

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