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Optimizing Green Portfolios: Navigating the ESG-Risk Paradox in China's New Energy Investments

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Abstract. The volatility of the new energy industry in China, especially with the background of the global energy transition toward the so-called Dual Carbon strategy, has become a major challenge to the old approach to investing in China. This paper empirically examines how ESG constraints affect new energy investment portfolio optimization. The research samples, which are 10 major enterprises within the industry, such as CATL and BYD, will provide their weekly trading data and Huazheng ESG rating indicators in 2024-2026. Using the Markowitz mean-variance model and solver programming, it identifies risk-minimizing efficient portfolios. According to the empirical findings, the variance of the investment portfolio following the imposition of the ESG ≥ 85 constraint decreases by 36.61 percent as compared to the equal-weight benchmark portfolio. Nonetheless, the research also finds that there are important implementation issues, such as a green allocation paradox (high-ESG assets with high volatility are left out) and excessive concentration (the two largest holdings constitute 88.35%), which can negatively affect diversification returns. This paper suggests optimization strategies, such as the creation of a dynamic ESG monitoring system, the establishment of weight caps in subdivided industries, and improved active governance participation, in order to address these pain points. This paper adds a quantitative model of including ESG in portfolio development, providing not only a risk-management perspective to green investors but also practical suggestions toward the high-quality, capital-markets-appropriate development of the new energy sector in China.

Keywords: New Energy Investment, ESG Integration, Portfolio Optimization, Mean-Variance Analysis, Green Finance

1. Introduction

1.1. Research background

The new energy industry has become the center of the capital market in the global context of tackling the issue of climate change and the introduction of the strategy of the Dual Carbon in China. However, the new energy sector has high volatility, particularly as a result of the rapid technological turnover and changes in policies. To investors, the environmental risks and governance costs can scarcely be incorporated in the traditional financial evaluation models. The environmental, social, and governance (ESG) investment philosophy has increased at an alarming

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rate in the past few years across the world. Consequently, non-financial-based ESG criteria have become an important additional framework to evaluate and manage these multidimensional risks, particularly in those industries with significant environmental and social impact, like new energy. Escrig-Olmedo et al. pointed out that the consideration of ESG factors in the investment process is a moral aspect and a management instrument that helps to assess the deep-rooted uncertainties in companies and make financial strength more sustainable over the long run [1]. In China, as regulators increase the non-financial disclosure requirements, ESG performance has become the second report card to gauge the core competitiveness of new energy businesses over time [2].

1.2. Literature review

Scholars have engaged in multidimensional investigations of the quantification of the ESG value of investment portfolios. Wu discovered using comparative research that Markowitz's mean-variance model is more adaptable than the index model with regard to incorporating the ESG constraints, hence greatly enhancing the total score of the portfolio and minimizing the risk exposure to assets with high levels of carbon emissions [3]. The theory of the ESG efficient frontier by Pedersen et al. mathematically illustrates how rational ESG asset allocation helps investors to optimize the risk structure of a portfolio without compromising on the long-term expected returns [4].

Chen and Xie carried out an empirical study with the A-share data between 2009 and 2021 and discovered that great performance in the ESG area could substantially improve the financial performance by mitigating the corporate financing costs and improving the corporate image in the Chinese market [5]. Moreover, researchers like Eliwa et al. have also proposed that transparent ESG disclosure may substantially decrease the equity capital cost of enterprises, which offers a theoretical foundation for new energy enterprises to access cheap capital through the capital-intensive R&D phase [6].

1.3. Research gap

Despite the fact that the existing studies have proved the importance of ESG in a variety of aspects, the following gaps still exist. A majority of the literature is concerned with broad-based indices by industry or advanced European and American markets, and limited literature does quantitative empirical research on the new energy of China, a volatile, segmented track, in the particular time frame of 2024-2026. Moreover, the literature on the dynamic observation of the weights of the top companies in the field (including CATL and BYD) under the conditions of high-frequency data (weekly) with strict ESG thresholds is limited [3].

1.4. Research objectives and framework

The following research logic strives to fill the above gaps in this paper. The first one is to take the 10 major firms in the new energy business in China as the sample, and the weekly returns of the sample companies are acquired between 2024 and 2026. Secondly, a Markowitz model with a constraint of Huazheng ESG score is developed, and solver programming is employed to achieve the best allocation to minimize risks. Thirdly, the effect of ESG constraints on the distribution of portfolio weight and possible issues are examined on a detailed level. Lastly, the findings of the research are used to present decision-making references to green investors and policymakers.

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2. Research design and data

2.1. Sample selection: representatives and heterogeneity

To empirically test the effectiveness of the ESG constraints in the high-volatility setting described in the introduction, this paper will create a targeted portfolio of 10 top A-share firms in the new energy market of China. Being the pioneer in the world energy transition, the listed new energy companies in China are, of course, not only influential in the technological development of the world but also well-represented in the performance in the capital market. To guarantee the depth and breadth of the research, this paper will choose 10 target enterprises that will be the leaders in the industrial chain. The samples include various core segmented tracks, such as power batteries (CATL, EVE Energy), vehicle manufacturing (BYD), photovoltaic energy (LONGi Green Energy, Sungrow Power, TCL Central), lithium battery materials (Tianqi Lithium, Tianci Materials), and wind power and industrial automation (Goldwind Technology, Inovance Technology).

These targets are not only selected on the basis of dual considerations. The former is market representativeness: all the sample enterprises are of high market capitalization scale and liquidity in the A-share market. The second is heterogeneity of ESG indicators. The Chinese new energy companies analyzed by Liu et al. identified that despite the natural green gene of the industry, there are very big discrepancies in internal governance and social responsibility performance of enterprises, which is an ideal sample to test the reshaping effect of ESG constraints on the investment portfolio [2].

2.2. Data gathering and significant variables

The data of the research comprises two indicators. This empirical study is based on two pieces of data available in the financial market: returns and ESG ratings. The former is the market transaction data. This paper picks 104 weeks of closing stock prices between April 7, 2024, and March 29, 2026, which were obtained via Investing. com. Weekly data are used, as opposed to daily data, in order to cut down random interference due to short-term speculation, and still obtain a large enough sample size, thus better estimating the covariance matrix between assets [3].

The second section is ESG evaluation indicators. This paper takes Huazheng ESG rating scores as the main constraint variable. Based on the sample data, the scores of the 10 enterprises lie between 84.8 and 99.1, which are between BBB and AAA ratings. The study conducted by Chen and Xie was able to confirm that the Huazheng rating system can effectively reduce information asymmetry between Chinese listed companies using multidimensional and sub-indicator-based indicators and is a valid indicator of the sustainable development ability and financial stability of the enterprises [5]. Thus, the use of Huazheng ESG scores offers a plausible and uniform measure to form the binding constraint (ESG $\geq$ 85) in the optimization model to ensure that the constraint indicates a well-known evaluation of corporate sustainability performance in the Chinese setting.

2.3. Data processing and model implementation

The initial stock returns are calculated in logarithmic returns before model computation, to satisfy the basic stationarity conditions of the mean-variance model. Initial examination shows a strong connection and a clustering of sample assets with each other, which will form a strong empirical basis for subsequent solver programming to find the optimal risk-minimizing path and to further investigate the concept of the green premium and the allocation bias under the ESG constraint.

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In this study, the processed series of returns is used to compute the variance-covariance and expected returns. This, combined with the Huazheng ESG scores as constraints, is input into a Markowitz mean-variance optimization model, which is numerically solved to find the minimum-variance portfolio. The initial analysis ensures that there are strong inter-asset links and sectoral grouping in the sample, which proves the use of a portfolio optimization framework, preconditioning the exploration of the trade-offs and reallocation impacts of the ESG constraint.

3. Empirical results and analysis

3.1. Risk mitigation and capital allocation effects

Portfolio Risk Reduction. The essence of the current research is that it also measures non-financial indicators under rigid constraints to examine their test effect in hedging investment portfolio risk (variance). The Marko-witz optimization model developed in this paper has the following objective:

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

In the meantime, the lowest ESG access limit is established as a limitation:

$$\sum_{i=1}^{n} w_i S_i \geq 85, \sum w_i = 1, w_i \geq 0 \tag{2}$$

where w_i represents asset weight, σ_{ij} represents covariance, and S_i represents the Huazheng ESG score.

In order to confirm the effectiveness of the model, the basic equal-weight portfolio (Base Case, 10% weight of each asset) is employed as the control group. The empirical comparison of solver programming (see Table 1) shows that there are important positive impacts.

Table 1. Comparison of performance indicators of the portfolio before and after the optimization of ESG constraints

Performance Metrics	Basic Equal-weight Portfolio (Base Case)	ESG Constraint Optimized Portfolio (Optimized)	Change Range
Portfolio Variance (Portfolio Risk)	0.002065	0.001309	-36.61%
Expected Weekly Return	0.31%	0.56%	+80.64%
Portfolio Weighted ESG Score	92.31	89.21	-

The data indicate that the overall risk (variance) of the portfolio decreases by 36.61 after the ESG ≥ 85 constraint is imposed. This finding is a powerful affirmation of the empirical finding of Wu that the Markowitz model is effective in the elimination of high-volatility assets within ESG constraints, and as such, an effective tool in avoiding tail risks [3]. Mechanically, the ESG constraint serves as a screening filter, whereby assets that can potentially have high returns are systematically screened out or underweighted due to their disproportionate contribution to portfolio volatility, often due to implicit environmental or governance uncertainties. This confirms the role of the model as a risk-identification instrument, not just of pure financial measures. It also confirms the theory of Pedersen et al. of the ESG efficient frontier, i.e., the investors can optimize the risk structure without reducing the returns by removing low-quality assets with high environmental and governance risks [4].

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Focus on High-Resilience Leaders. The solution of the optimization model is not merely a mathematical solution, but also captures the risk aversion of the capital market in a very volatile cycle. With the limitation, capital demonstrates a high concentration tendency among absolute industry leaders (see Table 2).

Table 2. The best weight distribution in an investment portfolio and ESG rating

Stock Name	Stock Code	Final Weight	Huazheng ESG Score	Rating
BYD	002594	50.64%	84.8	BBB
CATL	300750	37.71%	93.4	AA
Inovance Technology	300121	11.65%	94.9	AA
The other 7 targets	-	Close to 0%	86.4 - 99.1	A - AAA

BYD and CATL make up 88.35 percent of the total weight. The study of the Chinese market by Chen and Xie indicated that a high ESG performance (particularly, good corporate governance G and resource efficiency E) may greatly reduce corporate financing disadvantages and give enterprises a high reputational premium [5]. With the backdrop of intense price competition in the new energy sector between 2024 and 2026, the model automatically selects and invests heavily in these most successful ventures with high compliance and high free cash flow. This implies that, to a certain degree, ESG indicators have been incorporated as a new leading proxy variable in quantifying corporate survival resilience [2]. This implies that in the constrained optimization, the ESG score, combined with financial strength, is a mixed indicator of quality and resilience in a turbulent market. Nonetheless, such a sharp concentration, which is mathematically optimal to minimize risks, creates new vulnerabilities as discussed below.

3.2. Unintended consequences and practical limitations

The Green Allocation Paradox. This study finds a major counterintuitive anomaly when comparing the weight results; that is, having an extremely high ESG score does not always gain capital favor. Using the example of Sun-grow Power (300274), the enterprise has the highest Huazheng score in the entire sample (99.1, AAA grade), but the final allocation weight is practically zero (3.07×10 -7). This shows a key paradox of restricted green investing: the most ESG-rated asset gets done away with in the portfolio. A close study of its covariance matrix reveals that, despite the high weekly returns SunGrow Power had obtained in the statistical period, the returns had extremely high volatility and were very highly correlated with other assets in the photovoltaic industry. This reveals a general covert threat of green investment. This paradox is due to the fact that a limit on the average portfolio ESG score is blind to the individual asset volatility of a high score. It points to a serious weakness of a first-moment (average) ESG constraint alone in the case of the second-moment (variance) minimization of the investment goal. When investors or institutions blindly chase the highest ESG scores and disregard the financial volatility characteristics of assets, they are most likely to get into the green trap [7]. This also proves the fact that the investors have to make a serious trade-off between the approach of adopting the best practices of social responsibility and the approach of minimizing the financial risks in pursuing sustainable investment strategies, as stated by Wu [3].

Too much Concentration and Diversification Failure. The model uses the extreme winner-takes-all allocation strategy (only 3 stocks are retained and 7 are eliminated) to seek the absolute minimum variance. This allocation is an ideal fit of the objective function in mathematical logic, but is a

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severe breach of the diversification principle of not keeping all the eggs in one basket in real-world financial engineering. The article by Wu was a clear warning that ESG restrictions will inevitably cause a severe decline in the investable pool of assets, thus undermining the mechanism of diversifying idiosyncratic risk in the portfolio [3]. Here, the portfolio is over-invested in one industrial chain, which is the power battery and vehicle manufacturing. Therefore, the maximization of minimum variance subject to ESG constraint is a counterproductive maximization to a portfolio that is highly sensitive to undiversified, idiosyncratic shocks in a certain technological sector, which is counterintuitive to the very concept of risk dispersal that is the goal of portfolio theory. Should some future policy constraint or technological sabotage (such as the wholesale replacement of current systems with solid-state batteries) of this segmented sector take place, the portfolio of investments will be devastatingly at risk of drawdown because they lack diversity in assets (i.e., hedging wind power and photovoltaic modules).

The Greenwashing Risk and Data Lag. In addition to problems in allocation, there is a basic problem of input data. The immutable character of third-party ESG ratings is incongruent with the dynamic reality of the market. Nevertheless, as third-party ESG ratings are usually based on past annual balances of enterprises, the indicators themselves lag in time by 0.5 to 1 year. The discrepancy between the fixed data and the dynamic markets undermines the ability of quantitative models to predict in real-time. As enterprises are under a survival crisis, they could secretly decrease environmental protection investments or decrease governance transparency, which might not be captured in the present scores. Moreover, under the conditions of tightening regulatory requirements, certain businesses can abuse the gaps in compliance to practice information whitewashing, that is, greenwashing [8]. Unless the quality of the underlying data is well measured by quantitative models, then investors will invest in high-risk assets when they are being misrepresented as being high quality. As a result, the predictive capability and strength of any quantitative optimization model, such as the one used in this paper, is limited by the timeliness and credibility of the ESG scores it obtains. This information hazard is a major boundary condition to the application of the findings in practice.

4. Towards a more robust ESG-integration framework

4.1. Moving out of static scores: dynamic ESG-finance screening model

To address the puzzle of the Green Allocation (Section 3.2.1), in which high-ESG assets cannot be included because they are volatile in financial terms, investors do not need to be limited to a simple filtering of ESG scores. The answer is to develop a multidimensional and dynamic evaluation system that will optimize both sustainability and financial stability. There needs to be a two-way dynamic screening model of "ESG-Finance. Real-time financial quality factors (including free cash flow stability and asset-liability ratio) other than Huazheng scores ought to be added before quantitative allocation. According to the study of Eliwa et al., pure disclosure of ESG without related financial transparency enhancement will raise the information-processing costs of investors [5]. Thus, it is suggested to introduce the term second-moment optimization in solver programming, i.e., not only to restrain the average of ESG, but also to restrict the contribution of ESG investment to financial volatility to the margins. By doing so, high-score and high-correlation assets can be found, e.g., Sungrow Power (300274), and their risk exposure ratio in the portfolio can be dynamically adjusted depending on market conditions in order to prevent a green trap.

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4.2. Application of diversification guardrails: caps on weights and limits on sectoral exposures

To address the weakness of too much asset concentration in BYD and CATL observed in 3.2.2, strict restrictions on the weight cap of the single stock and sub-industry coverage should be imposed in the Markowitz optimization model. In his study, Wu observed that applying ESG constraints should have sensible weight limits to ensure that the portfolio does not lose the benefits of diversification as a result of having a smaller sample pool [1]. It is recommended to set the weight cap of a single stock as w_i ≤ 20\%. This strict limitation will force the model to invest more capital into the areas that are specialized, like photovoltaics (LONGi Green Energy), wind power (Goldwind Technology), or automation (Inovance Technology). To some extent, this can add a bit of variance to a portfolio in the short run; however, looking at the systemic risk of the portfolio on a long-term basis, it can dramatically improve the portfolio's protection against variations in one line of technological advancement or particular barrier to trade, which ensures the soundness of asset allocation [9]. This kind of constrained optimization can assure that capital funds a more balanced and robust ecosystem of emerging energy technologies, and that portfolio construction is in line with the overarching strategic objective of diversified and secure energy transition.

4.3. Using alternative data to monitor ESG in real time

To mitigate the risks of ESG rating and greenwashing identified in 3.2. A big data and artificial intelligence-based, so-called ESG negative public opinion monitoring system should be created. The high-frequency and volatile market environment in 2026 will not support traditional annual report disclosures. Chen and Xie pointed out that a well-developed ESG rating system must possess greater real-time feedback ability [5]. Financial institutions and investors ought to incorporate unstructured information (including real-time penalty lists by environmental protection departments and real-time tracking of supply chain carbon footprints) to perform monthly fine-tuning of equity ESG ratings of enterprises. Meanwhile, substantive audits of the intensity of enterprises' investment in R&D and their rate of conversion of green projects should be reinforced to detect fake publicity to raise capital premiums [8]. Quantitative models using weekly returns (the model used in this study) can only provide more realistic early warning risk functions through shortening of the rating feedback cycle.

4.4. Passive screening to active ownership and stewardship

Finally, the deepest influence can be the shift to not identifying with the quantitative model as a passive filter. Due to their size and power, institutional investors ought to adopt a fiduciary obligation to become active shareholders and stewards, with a direct involvement in portfolio firms in terms of enhancing their ESG underpinnings. According to Liu et al., the Chinese new energy companies usually encounter tension as the opaque governance structure in the transition period [2]. To enhance human rights and environmental standards within the supply chain, institutional investors need to use their shareholdings to advance upstream material ventures, including Tianqi Lithium and Tianci Materials. By intervening deeply into the governance (G) dimension of enterprises, the source of compliance risks can be mitigated, and the inherent value of enterprises in the long term can be increased, achieving the deep coupling of the ESG performance and financial returns, and eventually advancing the new energy industry to the high-quality sustainable stage [10]. This may include voting on shareholder proposals concerning climate transition plans, negotiating with boards on executive compensation associated with sustainability KPIs, and working with portfolio companies to audit and enhance standards in their supply chains. This is a direct attack on

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the G (governance) and S (social) pillars, which tend to be the genesis of long-term ESG risks in the first place, and improving financial resilience and intrinsic value, inside-out.

5. Conclusion

5.1. Summary of empirical insights

The paper presents a fine-grained empirical analysis of the impact of binding ESG commitments on optimal portfolio-building in the high-volatility new energy industry in China. The two main findings in the analysis are two principles that are comparatively contrasting. The analysis indicates that once the strict requirement ESG ≥ 85 is applied, the risk (variance) of the portfolio is decreased by 36.61, which is remarkable evidence of the excellent potential of sustainable indicators to detect systemic risks. The work, however, also notes the so-called green allocation paradox: the model excludes certain assets with high scores (like Sungrow Power) because they are too volatile, and the concentration of the portfolio is too high in the top companies (BYD, CATL), which cover approximately 88 percent. To address these issues, this paper suggests optimization measures, such as the creation of a dynamic ESG monitoring system, capping the sub-industry weight, and reinforcement of active intervention by institutional investors. Such results underline the necessity to strike a balance between social value and financial strength in green investment.

5.2. Research significance

This study has significant practical and business implications. Within the global energy transition background, the present paper offers the quantitative decision-making foundation to new energy enterprises and green investors. To develop the industry, it shows the empirical usefulness of ESG indicators as a risk-hedging instrument, which can assist in attracting more high-quality capital into green enterprises with actual governance resilience and facilitate the transition of the new energy industry in China out of scale expansion and into high-quality development. In the case of enterprise management, it serves as a reminder that being limited to getting compliance scores is not enough, and that ESG investment needs to be turned into financial stability in order to acquire a competitive edge in the quantitative allocation models. To solve the problem, the paper is successful in tackling the delay in the traditional financial models of dealing with non-financial risks and offers a reproducible analytical framework in building more robust green investment portfolios.

5.3. Limitations and future research opportunities

Limited by objective circumstances, this research is mainly based on secondary data on rating agencies of third parties, which are slow to capture real-time operational variations of enterprises. Moreover, the quantitative modeling approach, predominantly used in this paper, and which relies on the past price information, does not adequately reflect the short-term effect of the sudden policy change or extreme market sentiment on ESG assets.

To explore the dynamic logic of internal ESG decision-making of enterprises, in further studies, it is possible to use primary data collected via questionnaires or expert interviews. In the meantime, additional unstructured data (satellite remote sensing to track carbon emissions, social media to analyze the opinion of the population, and so on) can be added to create a more proactive, real-time monitoring system, thus further enhancing the accuracy of investment portfolios in highly unpredictable environments.

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