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Exploration of the Risk Return Equilibrium Mechanism for ESG Portfolio Optimization: Evidence from China's Carbon Financial Market

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Abstract: ***This study investigates the equilibrium mechanism between risk and return in ESG portfolio optimization under the development of China's carbon financial market. It finds that carbon finance reduces portfolio risks by incentivizing corporate ESG improvements while simultaneously offering new investment opportunities. By integrating ESG factors with carbon pricing signals, portfolios can achieve superior risk-adjusted performance. The analysis contributes to the literature by bridging carbon market mechanisms and ESG investment theory, providing new insights for investors, regulators, and policymakers.***

Keywords: ESG investment, Carbon financial market, Portfolio optimization, Risk-return equilibrium**.**

1. Introduction

Under the guidance of the "carbon peak and carbon neutrality" strategic goals, China is accelerating the construction of a national carbon emissions trading market and promoting the transformation of the economy towards green and low-carbon. The concept of ESG investing is booming in the international capital market, and investors are increasingly focusing on the environmental performance, social responsibility and corporate governance level of enterprises, viewing them as important indicators for measuring the long-term value and risk of enterprises [1]. The China Securities Regulatory Commission (CSRC) has mandated ESG-related disclosures in corporate reports, underscoring ESG's growing role in capital allocation.

Carbon finance and ESG investment are inherently interconnected. Carbon markets incentivize emission reductions, technological innovation, and corporate responsibility, all of which enhance ESG scores. Meanwhile, investors increasingly integrate ESG factors to manage risks and align with sustainable preferences. However, empirical evidence reveals a paradox: while ESG leaders often outperform in the short term, long-run returns sometimes converge or even lag behind low-ESG firms, reflecting mispricing or investor underreaction. This "ESG anomaly" highlights the need to examine the risk-return equilibrium mechanism under carbon market conditions.

This study aims to fill the gap in this research. Specifically, it explores the balance of risk and return in ESG portfolio optimization from the perspective of China's carbon finance market. This study addresses three questions:

1) How do carbon market mechanisms shape portfolio risk-return characteristics through ESG improvements?

2) How can investors dynamically balance risk, ESG preferences, and financial performance?

3) What institutional policies can optimize the risk-return equilibrium?

2. ESG Investment and Portfolio Performance

Extensive literature confirms that ESG factors affect portfolio returns through two primary channels:

1) Risk-adjustment channel: Firms with robust ESG practices experience fewer environmental accidents, governance failures, or social controversies, reducing volatility and downside risk.

2) Preference-driven channel: ESG-conscious investors may accept lower returns, paying a "green premium" that raises prices of high-ESG assets.

In China, empirical studies demonstrate a measurable ESG risk premium. High-ESG firms display stronger fundamentals (e.g., higher ROA), yet their long-term stock returns sometimes underperform due to delayed market recognition [2]. Small-cap ESG leaders are especially prone to mispricing. These findings suggest that ESG integration can reduce risk exposure and enhance stability, though excess returns are conditional on market maturity.

3. Integration of Carbon Financial Markets and ESG Factors

3.1 Role of Carbon Markets

Launched in 2021, China's national carbon emissions trading scheme (ETS) is now among the world's largest. By pricing carbon quotas, the ETS internalizes externalities, compelling firms to adopt low-carbon strategies. Evidence shows that participation in carbon markets significantly improves firms' ESG scores, particularly in environmental and governance dimensions, while also reducing financing costs.

3.2 Portfolio Implications

For investors, carbon risk represents a new systemic factor. High-carbon firms exhibit positive "carbon beta," suffering disproportionately during periods of climate policy

uncertainty. Ignoring carbon risk may expose portfolios to systemic shocks. Conversely, incorporating carbon assets, for example, emission allowances, carbon ETFs diversify risks and introduces new return sources.

3.3 Theoretical Extensions

Recent models, such as Pedersen et al. (2021), extend the mean-variance framework by incorporating ESG preferences and carbon constraints [3]. The resulting “ESG-efficient frontier” shows that higher ESG or lower carbon intensity often reduces attainable returns or increases volatility, but mitigates tail risks. In practice, portfolios constrained by ESG standards trade off short-term efficiency for long-term resilience.

4. Risk-Return Equilibrium Mechanism

Based on the above theoretical research, an analytical framework is proposed to explore the risk-return equilibrium mechanism for ESG portfolio optimization in the carbon financial market environment. The risk-return equilibrium model for ESG portfolio optimization presents the conceptual model of this framework: the development of the carbon financial market affects the risk and return of the portfolio by influencing the ESG performance of enterprises and market risk factors; Investors can make trade-offs and optimizations between risk and return by adjusting the weights of assets in their portfolios, including the allocation ratio of high/low ESG assets and the use of carbon finance tools. This section will focus on this framework and discuss it from three aspects: risk control mechanisms, return impact mechanisms, and equilibrium realization paths.

$$E(R_i) = R_f + \beta_i\left[E(R_m) - R_f\right] + \lambda_{ESG} \cdot ESG_i - \lambda_{carbon} \cdot Carbon_i$$

Where $E(R_i)$ represents the expected return level of asset i; R_f is the risk-free rate; β_i represents the market beta coefficient of asset i; $E(R_m)$ refers to the expected return of the market; The λ_{ESG} table represents the investor's preference coefficient for ESG; λ_{carbon} represents the impact coefficient of carbon cost; Carbon i represents the carbon emission intensity of asset i.

4.1 Risk Control Mechanism: Carbon Risk Transmission and ESG Mitigation

In a carbon financial market environment, a new source of risk for portfolios is carbon price

volatility and climate policy risk. When the government intensifies emission reduction policies, raises carbon prices or imposes strict environmental regulations, high carbon emission industry enterprises increase costs, lose profits and share prices fall, and such risks are sudden and systemic and difficult to be eliminated by traditional diversification. However, ESG portfolios, which tend to allocate to companies with good environmental performance can avoid such risks to some extent by nature. For example, companies with higher ESG ratings typically have relatively low carbon emission intensity or have clear emission reduction strategies, so they are less directly affected when carbon prices rise. On the contrary, companies with low ESG ratings tend to be in industries with high carbon emissions and more environmental risks, and suffer greater declines in performance and valuation adjustments when policies are tightened. As a result, an ESG-oriented portfolio holds fewer "carbon exposure" stocks compared to the market average, thereby reducing the tail risk of the portfolio on a global scale.

In addition to passive avoidance, investors can actively hedge carbon risk. Carbon financial instruments, such as carbon emission quotas and their derivatives, can hedge the carbon risk exposure of portfolios, such as buying carbon emission rights futures or carbon funds to hedge the carbon risk exposure of stock portfolios. Investors can build long positions in the carbon market to cover losses from falling stocks when they expect a significant increase in carbon prices. As trading activity in China's national carbon market increases, the feasibility of hedging operations grows. At present, large institutional investors are exploring the inclusion of carbon financial derivatives in portfolio management to enhance portfolio climate resilience. This cross-market hedging mechanism introduces a new dimension of risk management, enabling portfolios to achieve dynamic risk mitigation through financial engineering in addition to ESG factors.

More broadly, the social and governance dimensions of ESG factors also help to reduce tail risks. Good social responsibility practices can reduce the impact of security and mass incidents on stock prices, and improved corporate governance can reduce risks such as financial fraud and corruption, which though not directly within the scope of carbon finance, complement environmental risk control and jointly build the risk mitigation mechanism of ESG portfolios. From the perspective of the carbon finance market, ESG portfolios can withstand the impact of climate policies and bring stability through extensive risk management. A well-designed portfolio with low carbon emissions exposure and high ESG quality can reduce portfolio volatility and extreme loss risk, laying the foundation for risk-return balance.

4.2 Return Impact Mechanism: ESG Premium and Return Sources

While focusing on risks, investors are more concerned about whether they can maintain a reasonable level of returns or even achieve excess returns while adhering to the ESG concept and reducing carbon risks? This question involves ESG premiums (or discounts) and an analysis of the sources of returns for ESG portfolios. First, the level of returns on an ESG portfolio depends on whether the market is adequately priced in ESG factors. If high ESG assets are widely sought after and highly valued by the market, future returns may be lower than those of low ESG assets, resulting in an ESG discount; Conversely, if the market underestimates ESG value, high ESG assets may outperform the market and generate excess returns. The current Chinese market's understanding of ESG value is gradually deepening, but the opportunities brought by ESG mismatches have not yet been completely eliminated. For instance, the ESG vision of small-cap companies reflects underpricing by investors. As more investors incorporate ESG into their decisions, this anomalous return will tend to narrow. Therefore, from a dynamic perspective, the opportunities for excess returns in ESG portfolios are mostly in the early stages of transition, when the

marginal utility of ESG information rises but is not fully reflected. From a long-term equilibrium perspective, if the ESG risk premium is widely recognized, high ESG assets may yield more stable but slightly lower average returns in exchange for the high volatility and high return characteristics of low ESG assets. The key lies in the evolution of investor mindset and market competition.

Secondly, the carbon finance market provides a new source of income for ESG portfolios. On the one hand, direct participation in carbon asset investment can generate returns. For example, investors may realize capital gains by holding carbon quotas or buying related funds when expecting a long-term increase in carbon prices. On the other hand, holding stocks of companies that are leading the low-carbon transition may also yield excess returns. These companies, having made early investments in new energy and improved energy efficiency, are less affected when carbon prices rise, thanks to their technological and management advantages. Instead, they can expand their market share, increase profits, and outperform their peers in stock price performance, which is a strategic source of excess returns. Investors can capture alpha (excess return factor) in the transition to a low-carbon economy by identifying and heavily investing in these companies through ESG analysis. It needs to be emphasized that ESG portfolios are not incompatible with returns, but rather pursue the optimization of risk-adjusted returns after a comprehensive consideration of risks. Some empirical studies have shown that high ESG portfolios can yield higher Sharpe ratios in certain markets, that is, higher excess returns per unit of risk. For example, the MSCI China ESG Leading Index achieved an annualized return of 16.0% from 2013 to 2021, which is higher than the 11.0% of the MSCI China Index, while the volatility was comparable, indicating higher risk-adjusted returns for ESG indices [4]. Therefore, to measure the success of ESG investments, one should look not only at absolute returns but also at better yield efficiency after risk control. Theoretically speaking, the returns of an ESG portfolio are mainly derived from three parts: first, the basic returns brought by market beta; The second is the excess returns α from ESG stock selection; Third, additional gains from carbon asset allocation or low-carbon theme investments. A reasonable portfolio optimization should retain market beta gains, increase alpha contributions and introduce carbon theme gains, thereby boosting the yield curve at a given level of risk.

4.3 Implementation Path

With the above breakdown of risk and return mechanisms, it further explores the specific paths to achieving risk-return balance in ESG portfolio optimization. To address a multi-objective optimization problem where investors want to achieve the best risk-adjusted return while meeting ESG objectives such as reducing carbon footprint and improving ESG scores. The conventional mean-variance model has only two dimensions of risk and return, and now with the addition of the ESG dimension, a balance needs to be struck among the three.

1) Achieving equilibrium requires multi-objective optimization:

$$max_w \frac{E(R_w)-R_f}{\sigma_W} \; E_W \geq E_0$$

Where ω is the portfolio asset weight vector, E(R) represents the expected return of the portfolio, R_f is the risk-free rate, σ represents the standard deviation risk, and E_0 is the minimum portfolio ESG level (or maximum carbon intensity limit) required by the investor. This constraint ensures that the portfolio meets certain ESG standards. Solving this problem yields an efficient ESG constraint frontier, each of which corresponds to a trade-off between risk and return when a certain ESG level is met. As E_0 increases (demanding higher ESG), the σ_ω of the optimal combination increases or $E(R_\omega)$ decreases, as shown by a shift in the frontier curve. Investors can choose a satisfactory point through trade-offs, such as maintaining the Sharpe ratio at its maximum when ESG meets a certain standard. If the investor's utility to ESG itself is taken into account, the weight of ESG in the objective function can also be introduced to solve in the form of multi-objective optimization or utility maximization.

2) Equalization mechanism regulation: Under the above framework, the balance of risk and return is mainly regulated in two ways: one is adjusting the asset allocation weights, and the other is adjusting the ESG target level. On the one hand, investors need to allocate weights between high ESG assets (which typically have low risk but may have low expected returns) and low ESG assets (which have high risk but may have higher returns). When the market environment changes, such as an expected rise in carbon prices and stricter ESG policies, the risk of low ESG assets is magnified. Portfolios should reduce exposure to such assets and increase the proportion of high ESG assets to rebalance risk and return. Conversely, if high ESG assets are overvalued, future returns are limited, and short-term carbon policy risks are not significant, the allocation of medium ESG assets with

attractive valuations can be temporarily increased to enhance returns. In summary, through dynamic rebalancing, portfolios can strike a balance between risk and return. On the other hand, the determination of ESG target levels requires investors to weigh against their own responsible investment philosophy and performance assessment requirements. If investors view ESG as a constraint, they will seek the best ESG level to maximize the Sharpe ratio of the portfolio; If there is a strong preference for ESG (such as social responsibility funds), the target ESG level will be higher, willing to sacrifice some of the returns. Ultimately, the best solution varies among different investors, but it is a trade-off of risk, return, and ESG.

3) The equilibrium path in the Chinese context: For Chinese investors, achieving a risk-return equilibrium in ESG portfolios requires considering the characteristics of the domestic market and the institutional environment. In the current A-share market, many companies are not covered by international mainstream ESG ratings. If screened strictly, the investment scope may be narrowed and the degree of portfolio diversification may be reduced. Therefore, investors should combine the results of domestic ESG evaluation systems such as ESG indicators of the Shanghai and Shenzhen stock exchanges and international systems such as MSCI, etc. to flexibly set ESG targets and avoid over-concentration of holdings. In addition, China's carbon market started relatively

late and covers limited industries currently mainly the power industry, and the effectiveness and continuity of carbon price signals are still improving. When investors use carbon financial tools for risk management, they should pay attention to policy changes and market liquidity and gradually establish hedging strategies. Portfolio carbon risk management will be more comprehensive as carbon markets expand to more high-emission industries such as steel and cement. The realization of the ESG portfolio balance mechanism in the Chinese context is a gradual process: constantly calibrating the relationship between ESG targets and yield targets as policies and markets improve, and adjusting investment strategies in a timely manner based on carbon market signals. Only when the institutional environment and market pricing mechanism are mature can the balance of risk and return be more stable and efficient.

5. Policy Recommendations

Based on the above analysis, in order to promote the positive interaction between China's carbon finance market and ESG investment and facilitate the realization of a risk-return balance mechanism for investment portfolios, this study puts forward the recommendations.

5.1 Improving ESG Information Disclosure and Rating Systems

Policy regulators should accelerate the establishment of unified and authoritative ESG information disclosure standards, gradually shift ESG information disclosure from "encouraged" to "mandatory", and improve data quality and comparability. At the same time, support the development of domestic third-party rating agencies and draw on international methods such as MSCI and Refinitiv to form an ESG rating system suitable for China's national conditions. This will provide a reliable basis for investors to conduct ESG assessments and optimize their portfolios. Regulators can also build ESG data platforms that bring together key indicators such as environmental (like carbon emissions), social, and governance to reduce information asymmetry. Only when ESG information is fully transparent can the market reasonably price ESG risk premiums and avoid mispricing due to the lack of information.

5.2 Deepening and Expanding the National Carbon Market

The maturity of the carbon financial market itself plays a fundamental role in ESG investment. It is suggested that regulators steadily expand the coverage of the carbon market, incorporate more high-emission industries and enterprises into the national carbon trading system and gradually increase the proportion of quota auctions to enhance the price signal. At the same time, enhance the liquidity of the carbon market and foster active spot and derivatives trading to ensure that the carbon price fully reflects expectations of emission reduction policies. Studies suggest that increased trading activity in the carbon market will reinforce its impact on corporate behavior and ESG performance. In addition, explore the introduction of carbon financial derivatives (such as carbon options, carbon swaps) and support for the development of carbon funds, carbon ETFs, and other products to provide investors with convenient channels for carbon risk hedging and investment. When the carbon price signal is clear and the tools are in place, investors can effectively incorporate carbon factors into their portfolio decisions and achieve both risk hedging and profit acquisition.

5.3 Guiding Institutional Investors to Implement ESG Integration Strategies

Financial regulators and industry associations should provide ESG investment guidance and training for institutional investors and encourage banks, insurance companies, funds, etc.to incorporate ESG into their investment research processes. Positive incentives for ESG investment could be considered in terms of performance evaluation and custodian accountability, such as recognition or tax incentives for institutions that have consistently adhered to ESG investment over the long term and have stable performance. In investment practice, it is advocated that institutional investors adopt a strategic and tactical approach to ESG asset allocation: strategically set long-term ESG goals and low-carbon paths for the portfolio, and tactically make dynamic adjustments based on market conditions to balance short-term gains with long-term responsibility goals. In addition, it is advocated that investors use cutting-edge methods, such as scenario analysis and stress testing, to assess the impact of climate change on their portfolios in order to prepare for asset adjustment in advance. These measures will help increase the overall market's emphasis on ESG risk-return tradeoffs, allowing more funds to flow to high ESG quality assets and creating a positive cycle.

5.4 Exerting the Government's Supporting Role in Green Finance

The government can guide more capital to participate in ESG investment and the carbon market through fiscal and financial policy tools. For example, setting up green development funds and ESG themed guidance funds to support enterprises and projects in the low-carbon transition sector; Provide appropriate incentives for the issuance of financial products for environmental protection and carbon reduction, such as green bonds and sustainable development bonds, to enrich the asset options of ESG portfolios. Regulatory authorities may require large state-owned enterprises to take the lead in enhancing ESG information disclosure and performance, linking ESG performance to executive assessment and credit granting to set an example. Through policy signals, the government can also influence investor expectations - clarifying long-term emission reduction routes and carbon price expectations, enabling investors to better assess the risks of high-carbon assets and thereby proactively reduce their allocation to high-carbon assets. This actually lowers the overall carbon risk in the market and contributes to the stability of the financial system.

5.5 Continuing to Promote Investor Education and Research Support

For the majority of small and medium-sized investors, efforts should be made to enhance the promotion of ESG concepts and carbon risk awareness, and encourage long-term investment and responsible investment concepts. Stock

exchanges and investor education bases can hold special lectures and release popular reports to explain the significance and methods of ESG investment, share international success cases, and correct misunderstandings such as "ESG necessarily reduces returns". Academics and think tanks should further delve into topics such as the relationship between ESG and financial performance in the Chinese context and the impact of carbon markets on asset prices to provide localized evidence for policy-making and market practice. For example, interdisciplinary research could be carried out to introduce models of environmental economics into financial risk analysis and enrich the theoretical tools for ESG portfolio optimization. These efforts will lay a solid foundation for understanding ESG risk-return equilibrium among all market participants.

6. Conclusion

This study systematically explores the risk-return equilibrium mechanism in ESG portfolio optimization from the perspective of carbon financial markets. Research shows that in the context of the rapid development of China's carbon trading market, the impact of ESG factors on portfolio risk and return is increasingly prominent: on the one hand, the implementation of the carbon market reduces the investment risk of high-emission enterprises by improving corporate environmental performance and information transparency, making ESG-oriented portfolios more resilient to risks; on the other hand, the return characteristics of ESG portfolios depend on the extent to which the market prices sustainable development value. There may be some ESG excess returns or discounts in the short term, but the long-term equilibrium will be reflected in the optimization of risk-adjusted returns. Investors need to use a scientific portfolio optimization model to incorporate ESG objectives into investment decisions and find the best solution in multi-dimensional trade-offs. China's institutional environment and market characteristics determine that the realization of this balanced mechanism requires a gradual approach: through measures such as improving ESG disclosure, deepening the carbon market, and strengthening investor guidance, gradually eliminating information bottlenecks and inconsistent incentives that hinder the effectiveness of ESG investment.

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