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| RESEARCH ARTICLE

Exploring Investment Optimization and "Greenwashing" from ESG Disclosure: A Dual Examination of Investor Perception

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| ABSTRACT
This study investigates the intricate correlation between environmental, social, and governance (ESG) information and the financial performance of companies, with a focus on the fundamental nature of ESG and its influence on the choices made by investors. This study examines available literature and data analysis to uncover how disclosing ESG information impacts investment optimization. Additionally, it clarifies the relationship between greenwashing and the advancement of green financial products. The study employs the XGBoost ensemble learning method, using non-financial features of ESG combined with financial features to construct a prediction model, achieving a prediction accuracy rate of 71.26%. Furthermore, applying this model aims to further utilize it in stock selection and constructing a stock pool. By analyzing the financial performance of companies predicted by the model, we will select potential high-performance stocks to build an investment portfolio. Then, we use the Markowitz portfolio theory to optimize the weight combination of stocks in the pool to maximize expected returns and minimize risk. After backtesting the investment portfolio using the closing prices in 2021, its annualized return was a positive 5.76%, significantly higher than the benchmark portfolio. Additionally, this study provides theoretical references and practical guidance for insight and addressing the potential large-scale greenwashing behavior under the trend of increasing ESG information disclosure in the future.

| KEYWORDS
ESG, financial performance, investor choices, ensemble learning, greenwashing, prediction model, stock selection, portfolio optimization, backtesting.

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1. Introduction

The prominent aspects of Environmental, Social, and Governance (ESG) criteria have increased significantly worldwide, becoming the crucial benchmark for evaluating corporate social performance and sustainability efforts. Scholars have extensively researched the disclosure of ESG information and its implications for investor decision-making, encompassing foundational theories, real-world contexts, and the possible effects on investment strategies. Such investigations furnish profound insights into the function of ESG within the contemporary economic and social milieu, serving as invaluable resources for investors and policymakers. However, existing research still lacks sufficient exploration of how ESG information disclosure can optimize investment decisions and interact with corporate "greenwashing" behavior. Existing research has not yet delivered conclusive findings, especially grasping the multifaceted nature and complexity of ESG information disclosure and detecting and averting the risk of greenwashing throughout this procedure. Therefore, this study aims to delve into these issues, hoping to fill the gaps in existing literature and guide enterprises and investors towards more sustainable and responsible development.

With the increasing global attention on sustainable development and social responsibility, listed companies are increasingly required to demonstrate a proactive attitude towards ecological governance, social responsibility, and corporate governance. They are expected to showcase their achievements in these areas to investors and the public through ESG reports. Concurrently, some enterprises have engaged in "greenwashing," which involves inflating their environmental and social performance in ESG reports to mislead investors and the public. Such actions damage a company's standing and pose risks to investment choices and market efficiency. It is imperative to gain a profound comprehension and conduct precise evaluations of the authenticity and quality of ESG information. This approach enables well-informed investment decisions and maintains the market's integrity.

ESG information disclosures are crucial in enhancing the investment optimization and fostering the growth of sustainable financial products. However, greenwashing behavior—exaggeration or false statements by enterprises in their environmental and social performance—poses a challenge to this process. Through analysis of relevant literature, this paper explores the role of ESG information disclosure in investment optimization and the impact of greenwashing behavior on the development of green financial products.

ESG disclosure is of significant importance for investor decision-making. Kotsantonis et al. (2016) indicate that integrating ESG factors can significantly enhance investment management effectiveness. Investors can leverage ESG disclosures to gauge a company's long-term value and associated risks more effectively, enabling them to make well-informed decisions in their investment strategies. On the other hand, Cesarone et al. (2022) also demonstrate that ESG impact indeed strengthens the profitability of investment portfolios. Providing high-quality ESG disclosures is vital for directing investors toward optimizing their investment portfolios. However, the prevalence of greenwashing threatens the credibility of green financial products. Research by Nyilasy et al. (2014) finds that consumers are sensitive to discrepancies between a company's green advertising claims and actual environmental practices (i.e., instances of greenwashing), which may lead to diminished trust and reduced consumer willingness to purchase green products. Furthermore, research by Pimonenko et al. (2020) suggests that greenwashing can irreparably harm a company's green brand image and impede its progress toward sustainability objectives.

Moreover, greenwashing may also impact investor trust and recognition of a company. Research by Dhar et al. (2022) indicates that disclosing corporate social responsibility (CSR) is crucial for driving green accounting and sustainable development. If a company engages in greenwashing in its CSR or ESG reports, it will undermine its integrity in the eyes of investors, impacting its ability to attract green investments. Lins et al. (2017) support this view, finding that practicing corporate social responsibility contributes to building social capital and trust, enhancing company performance, especially during financial crises. Therefore, understanding consumer sensitivity to environmental attributes and obtaining accurate consumer intelligence is crucial for achieving positive business outcomes. A company's environmental performance improvement may be a better investment than "green" marketing if the attributed risk is too high.

In summary, the disclosure of ESG factors plays a pivotal role in optimizing investment strategies. Accurate ESG information can assist investors in making better decisions, thereby enhancing the profitability and security of investment portfolios. However, greenwashing behavior may damage the reputation and green brand of companies, affecting investor trust and interest in green financial products. Sincere and transparent ESG disclosure is essential for companies. It not only fosters public trust but also propels the advancement of green financial products. Existing literature on ESG disclosure, investment optimization, and greenwashing has addressed core issues and provided explanations. However, as mentioned earlier, there are still some controversies and gaps. This study will delve deeper into these issues in the following sections.

While the studies by Kotsantonis et al. (2016) and Cesarone et al. (2022) underscore the importance of integrating ESG factors for enhancing the profitability of investment portfolios, these investigations have not adequately considered the impact of varying ESG disclosure standards across different industries and regions on investment decision-making. Furthermore, the current literature lacks details regarding the specific content and quality of ESG disclosures and how to effectively utilize this information across diverse market and regulatory environments.

Nyilasy et al. (2014) and Pimonenko et al. (2020) have demonstrated the detrimental effects of greenwashing on consumer confidence and corporate branding. However, the existing scholarly discourse is notably sparse regarding the drivers, operational frameworks, and efficacious methods for detecting and preventing instances of greenwashing. Moreover, the expressions and repercussions of greenwashing can differ significantly among firms of various sizes and types, an aspect that has received scant attention within the current body of research.

Although there have been studies exploring the impact of ESG information disclosure and greenwashing on investor decisions, how to integrate these factors into a more complex investment decision framework and their specific roles and impact in different investment strategies remains a worthy area for further research. Based on the current situation, this study aims to fill the research

gap in the related fields, including the association between ESG and investment optimization, "greenwashing," and green financial products, by using quantitative and qualitative methods, combining the latest theoretical frameworks and empirical analysis, and analyzing the various dimensions and qualities of ESG information disclosure, as well as its specific impact on investor decisions, to explore how to identify and prevent greenwashing effectively.

Judge on these grounds, from the perspective of investors' perception, this paper analyzes the impact of investment optimization and greenwashing behaviour on ESG factors. They are both different and interrelated.
These differences are:

The impact of ESG information on investment optimisatiom: ESG standards are regarded as important indicators to measure corporate social responsibility and sustainable development capabilities, and ESG has become a concept that investors are eager to pursue. In this regard, we need to investigate how publicly disclosed ESG information becomes a non-financial corporate characteristic, helps investors make more informed investment choices, and optimizes their investment returns.

Greenwashing and the Development of Green Financial Products: ESG has become highly sought-after, but it has also led to the emergence of greenwashing. In this aspect, we aim to interpret current policies targeting greenwashing while examining the relationship between the current state of greenwashing and the growth of green financial products, as well as its impact on investors' perception.

Specifically, the former studies the value of publicly disclosed ESG information from the perspective of investors' investment optimization, while the latter examines the current situation and potential impact of greenwashing from the perspective of policies and current status.

These interrelationships lie in these two aspects jointly stand out the importance of ESG information disclosure in investment decision-making and green financial development.

Common background: Both aspects are based on the trend and importance of ESG information disclosure.

Policy implications: Addressing the issue of greenwashing is crucial for promoting the development of green financial products and maintaining investors' trust in ESG information.

This study aims to verify the correlation between ESG factors and corporate financial performance and to build a model to predict corporate financial performance. We employ the XGBoost ensemble learning approach to develop a predictive model that integrates non-financial and financial indicators derived from ESG data. With the application of this model, we hope to predict the financial performance of companies accurately and further apply the constructed model to stock selection and portfolio construction. By analyzing the model's predictions regarding corporate financial performance, we will identify promising high-performing stocks to include in our investment portfolio. We will then optimize the weight combinations of stocks in the portfolio using the Markowitz portfolio theory to maximize expected returns and minimize risks. We will compare this with a selected standard investment portfolio to evaluate the effectiveness of our model and provide an in-depth interpretation and analysis of the current "greenwashing" policy and situation. These operations will provide a more comprehensive perspective for our research and help us identify whether companies have implemented substantive environmental protection measures.

2. Literature Review

2.1 Organization of the ESG Disclosure Literature Lineage

ESG disclosure has become an important issue of concern to many companies and investors, and it can reveal, to a certain extent, the performance of enterprises at the level of sustainable development and risk management ability. In this economic environment full of challenges and opportunities, promoting and landing ESG disclosure will bring a more stable and reliable foundation for sustainable development and long-term investment. The critical driving force leading to the increase in reporting disclosure with environmental factors as an essential element is the growing concern of stakeholders about the social and environmental performance of companies and its impact on the financial strength of companies. On the other hand, civil society requires companies to achieve environmental and social goals and increase shareholder wealth, leading to a growing tendency for corporate stakeholders to understand the impact of corporate operations on society and the environment. In addition, as corporate governance practices have evolved, it has been recognized that equal and full disclosure of environmental information is essential for assessing corporate performance and responsibility, which has led to an increase in the practice of environmental accounting globally.

Friede et al. (2015) showed that ESG disclosure positively affects corporate financial performance. Through a comprehensive analysis of more than 2,000 empirical studies, they found that companies with good ESG typically exhibit higher financial performance. This study reveals that firms can enhance their market competitiveness and financial performance while achieving sustainability goals. On the other hand, Amiraslani et al. (2023) analyzed the bond market benefits of ESG performance from the perspective of social capital and market trust. Their study finds that companies with high ESG performance can obtain lower financing costs in the bond market, which suggests that investors hold high levels of trust and social capital in these companies.

On the other hand, a study constructed by Pástor et al. (2021) focuses on the market equilibrium of sustainable investment. Through modeling analysis, they explore the impact of ESG investments on market dynamics, pointing out that ESG investments can generate long-term stable capital flows for firms. Starks et al. (2017) examine the relationship between firms' ESG characteristics and investors' investment horizons. They found that ESG-focused firms are more attractive to long-term investors who support the firm's long-term sustainability strategy. On the other hand, Doron et al. (2021) focused on the impact of ESG rating uncertainty on sustainable investments. Their study shows that even in the presence of ESG rating uncertainty, firms can still attract investors through a clear sustainability strategy.

These studies reveal the important role of ESG disclosure in shaping corporate policies, assessing risks, and publishing sustainability reports. They show that transparent and comprehensive ESG disclosure not only helps to enhance a firm's market credibility and investment attractiveness but is also crucial in guiding firms toward long-term sustainable growth.

2.2 Organization of the Investment Optimization Literature Lineage

In the current investment landscape, individuals responsible for making decisions encounter growing challenges due to the escalating intricacy of financial instruments and investment strategies. ESG are factors that need to be referred to, and compared when making investment decisions and influencing investment behavior, and thus, their impact on corporate financial performance has become an important research theme. We have compiled a comprehensive analysis of numerous studies investigating the correlation between ESG factors and the financial performance of corporations. These studies explore the correlation between investor preferences and ESG, and based on these findings, they investigate the long-term impact of ESG factors on investment returns and risk.

The study by Yang et al. (2023) points out that ESG disclosure positively correlates with corporate economic performance. By carefully analyzing the ESG performance of firms, they found that firms with high ESG scores usually have better financial performance, which suggests that good social responsibility and governance mechanisms can effectively enhance the market competitiveness of firms. Through their study, Gao et al. (2021) found that excellent ESG performance helps increase firms' capital utilization efficiency, thus improving investment effectiveness. The reason is mainly that these firms pay more attention to long-term interests and risk management in their decision-making process. Xie and Li (2023) found through their study of listed companies in China that improved ESG performance can reduce the financial risk of firms. The study by Zhang et al. (2013) explored the interactive cross-sectional effects of CSR behaviors on financial performance. The findings reveal that CSR has a significant impact on financial performance not only in the present but also in the future. The study further corroborates that the positive impact of ESG on corporate financial performance (CFP) is stable over time, with about 90% of the findings presenting a non-negative ESG-CFP relationship. The study by Wang et al. (2024) delves into the mechanism by which ESG performance affects firm value. They concluded that ESG performance, directly and indirectly, affects firm value by improving corporate governance structure and operational efficiency.

Based on the above research results, we can determine that ESG factors are essential in corporate financial performance, investor preferences, return on investment, and risk management. Excellent ESG performance helps firms improve their financial performance, attract more long-term investors, and play a significant role in risk control and enterprise value enhancement.

2.3 Greenwashing Literature

While more and more enterprises have begun to use environmental protection and sustainable development as a marketing tool to attract consumers by promoting their so-called green products and services, actual surveys have shown that many enterprises are not environmental leaders but rather mislead consumers by covering up their environmental problems through green propaganda, which is known as “greenwashing,” whereby companies exaggerate or misrepresent their environmental and social responsibility performance in their publicity, thereby confusing the public and investors. For a long time, there has been no universally accepted definition of greenwashing, and various scholars hold different views. However, greenwashing impacts market risk and investor decision-making, and further research is needed to fill the conceptual and empirical gaps in understanding greenwashing and its impact on stakeholders and corporate reputation.

Akturan (2018) explored how green brand equity and purchase intention are affected by greenwashing behavior. The study shows that consumers are susceptible to companies' greenwashing behaviors, which damage companies' brand image and reduce consumers' purchase intentions. On the other hand, Rahman and Nguyen-Viet (2023) analyze the role of green marketing strategies and consumer perceptions in inhibiting greenwashing from the perspective of market strategies. They argued that greenwashing behavior could only be effectively reduced if green marketing strategies match consumers' environmental awareness. On the other hand, Du's (2015) study focuses on how the market evaluates companies' greenwashing behavior. By analyzing the case of the Chinese market, it was found that the market reacts sensitively to firms' greenwashing behaviors, which negatively affects their share price and market performance. Marquis et al. (2016) examined greenwashing behaviors globally and found that public scrutiny and social norms significantly impact the selective disclosure of firms' environmental behaviors. They suggest that firms are more likely to be truthful about their environmental performance when faced with stringent social norms and public scrutiny. Parguel et al. (2011) examine how sustainability ratings can help curb 'greenwashing.' Companies are more likely to engage in genuine environmental practices if a trustworthy third-party rating agency exists. Torelli et al. (2020) explored the impact of greenwashing behaviors on stakeholder perceptions. They found that when firms engage in greenwashing, stakeholders have less trust in them, which may affect the firm's long-term sustainability. "Greenwashing" behavior can adversely affect the value of a company's securities listed on stock exchanges. Wu et al. (2020) differentiated between "good greenwashing" and "bad greenwashing" and argued that transparent disclosure could help to differentiate between actual environmental behavior and the greenwashing behavior of firms. Xu et al. (2020) investigated the impact of green finance on firms through a meta-analysis method to study the impact of green finance on corporate green performance. The study shows that green finance helps to improve firms' environmental performance and reduce the occurrence of greenwashing behavior. On the other hand, Yu et al. (2020) analyzed greenwashing behavior in the context of ESG disclosure. Their study reveals the existence of greenwashing behavior in firms' ESG disclosure and highlights the importance of strengthening regulation and improving transparency.

Many companies are using CSR as a marketing gimmick, but it is difficult for investors and consumers to identify whether the companies are hiding greenwashing behaviors. Greenwashing behaviors go against the core concept of ESG, which may not only damage the competitive environment of the whole industry but also impede the sustainable development of society and exacerbate the severity of environmental and social problems. This phenomenon has been verified in a number of cases. Although companies enhance their sustainability and social responsibility image through ESG and CSR reporting, greenwashing behaviors have a severe negative impact on corporate credibility and investor decision-making. Therefore, there is a high degree of urgency to improve transparency, regulation, and third-party assessment.

3. Methodology

3.1 Data Source and Sample Selection

Our study delves into the A-share market in Shanghai and Shenzhen, two of China's most significant financial hubs. The companies listed from 2011 to 2020, which serve as our research subjects, are crucial players in the Chinese economy. To ensure the accuracy and authority of the data, we rely on the CSMAR database and the Tonghuashun iFinD financial data terminal. The China Securities ESG evaluation system provides the rating results used to assess companies' ESG performance in this study.

The data organization process for this study was meticulous. We excluded companies under certain special circumstances, including those in the financial industry, those that have been delisted, and those that were marked for special treatment (ST) or special transfer (PT) in the given year. This rigorous screening process resulted in 23,825 valid sample observations, ensuring the robustness of our findings.

This study constructed investment portfolios to gain a comprehensive understanding of these companies' performance. We used the 2020 closing price data provided by the Tonghuashun iFinD financial data terminal to calculate the return and volatility of these companies. The closing price data of 2021 was then used for backtesting to verify the effectiveness of the optimized investment strategy, providing a robust basis for our investment recommendations.

3.2 Variable Selection

3.2.1 Dependent variable

Financial Performance y_ROA - Future One-Year Return on Total Assets: Return on total assets is an indicator that can objectively measure the financial performance of listed companies. It is widely used in accounting research to measure a company's profitability. This paper chooses to use the future one-year return on total assets (ROA) of listed companies to assess the future financial performance of enterprises. This indicator truly reflects the profitability and performance status of enterprises. Therefore, it is considered a universal measurement indicator.

3.2.2 Independent variable

ESG Score: We adopt the nine-point system of the Huazheng ESG scoring system to assess the company's information disclosure in three aspects: Environment (E), Social (S), and Governance (G). The higher a company scores in this scoring system, the better its performance in ESG aspects. For an annual period, this paper collects the company's ESG scores for each quarter and then calculates the average of these scores. Through this method, we can obtain a more comprehensive and accurate annual ESG performance assessment.

3.2.3 Control variables:

This paper, referencing previous research, uses the following financial characteristics as control variables:

Table 1. Control Variables

Variable Symbol	Variable Name	Description
ROA	Return on Total Assets	Net Income / Average Total Assets
Size	Company Size	Natural logarithm of annual total assets
Growth	Revenue Growth Rate	Current Year's Revenue / Last Year's Revenue - 1
Cashflow	Cash Flow Ratio	Cash generated from operations / the total value of assets
FIXED	Fixed Asset Ratio	Net fixed assets divided by total assets
Board	Number of Directors	Natural logarithm of the number of board members
ListAge	Listing Age	Natural logarithm of (Current Year - Listing Year + 1)
Top10	Concentration of Ownership	Percentage of shares held by the top ten shareholders
M share	Management Shareholding Ratio	Management's shareholding divided by total share capital

3.3 Predictive Modeling

Our analysis employs predictive modeling to anticipate the financial performance of companies in the upcoming year. The extreme gradient boosting (XGBoost) algorithm is commonly utilized in financial prediction(Qin, 2022)and offers distinct benefits in speed and accuracy (Rahman & Nguyen-Viet, 2023). We leverage the XGBoost learning algorithm to examine the listed companies using input features and pinpoint those poised to exhibit exceptional financial performance in the coming years.

XGBoost represents a robust machine-learning algorithm that solves various prediction and classification problems using gradient-boosting decision trees. As an ensemble learning technique, XGBoost creates a more robust and more accurate model by combining weaker learning models. The base learner of XGBoost is the CART decision tree. Assuming that T decision trees $(\mathrm{f}_1(x), \ldots, \mathrm{f}_\mathrm{T}(\mathrm{x}))$ have been trained, then the ensemble model can be represented as:

$$\hat{\mathrm{y}} = \sum_{\mathrm{t}=1}^{\mathrm{T}} \mathrm{f}_\mathrm{t}(\mathrm{x}) \,, \mathrm{f}_\mathrm{t} \in \mathrm{F}$$

Among them, f_t is the decision tree mapping, and F is the set of all possible decision trees.

The ensemble learning process of XGBoost involves the following steps:

1. Initialization: Create a single decision tree model from the training dataset. $\hat{\mathrm{y}}^{<0>} = \mathrm{f}_0(\mathrm{x})$
2. Iteration: For each subsequent iteration, train a new decision tree model to predict samples with larger errors in the previous model. $\hat{y}^{<t>} = \sum_{\mathrm{l}=1}^{\mathrm{t}} \mathrm{f}_\mathrm{l}(y) = \hat{y}_\mathrm{l}^{<t-1>} + \mathrm{f}_\mathrm{t}(\mathrm{y})$
3. Weighting: Add the new model's weighted prediction to the previous model, thereby creating a new ensemble model.
4. Repeat: Repeat the process above until reaching an acceptable minimum error range or the maximum number of iterations for this iterative process.

By combining multiple decision trees, XGBoost ensemble learning can:

Effectively reduce the model's overfitting on training data and significantly improve the model's adaptability and predictive ability for new data.

Capture complex relationships and interactions within the training data.

Utilize the parallelism of decision trees for efficient training.

The advantages of XGBoost ensemble learning include:

High accuracy: XGBoost often produces highly accurate predictions in classification and regression tasks.

Interpretability: Decision tree models are easy to interpret, and the output of feature importance makes XGBoost a valuable tool for understanding model predictions.

Efficiency: The parallel training capability of XGBoost enables it to process large datasets quickly.

3.4 Portfolio Modeling

Once the stock selection process is completed using predictive modeling, the next step is to assign weights to the chosen stock pool. To achieve this, we utilize the Markowitz model, which is a weighted allocation investment portfolio model.
The Markowitz Portfolio Model is a modern portfolio theory that provides investors with a method to maximize investment returns at a given level of risk. This model was proposed by Markowitz (2009) and has been the foundation of portfolio construction.

Steps to construct a Markowitz portfolio:

1. Determine investment objectives: Define the portfolio's expected return and risk tolerance.
2. Select assets: To build the investment pool, choose assets from various asset classes, such as stocks, bonds, commodities, etc.
3. Estimate returns and covariance: For the selected asset i, use historical data to calculate the daily return rate $P_{it} = \frac{x_{it} - x_{i,t-1}}{x_{i,t-1}}$, and estimate the annualized expected return rate $P_i = 252E_i(P_{it})$. At the same time, estimate the annualized volatility covariance matrix COV={cov}_ij, $COV = \{cov\}_{ij}, COV_{ij} = \sqrt{252}cov(p_i, p_j)$ for the selected asset pool.
4. Optimize the portfolio: Establish an optimization problem to solve for the weights w of the portfolio that meets the expected return while minimizing the target risk level:

$$\min_w w^T COV w = \sum w_i w_j cov_{ij}$$
$$s.t. \begin{cases} \sum w_i p_i \geq \mu \\ \sum w_i = 1 \\ \forall i, 0 \leq w_i \leq 1 \end{cases}$$

μ is the required investment return rate of 0.1 in this paper.

The advantages of the Markowitz model include:

Risk management: Through this model, investors can carefully design their investment portfolios according to their risk preferences.

Diversification: The model emphasizes diversifying investment choices within the asset pool to reduce the portfolio's overall risk.

Quantitative analysis: The model uses quantitative methods to optimize the portfolio, thus providing objective and repeatable results.

The Markowitz model has been widely applied in portfolio construction, especially for investors seeking to balance risk and return. However, it is important to note that the model relies on estimates of future returns and covariance, which may be unreliable.

3.5 Methodology Integration and Data Flow

To summarize, our dataset, predictive modeling, and portfolio modeling are interconnected in the following way.

1. Dataset and XGBoost Learning:

XGBoost learning is a robust machine learning algorithm that predicts the financial performance of stocks by analyzing ESG non-financial and financial features. So that, the trained XGBoost model identifies stocks with high potential for financial performance.

2. XGBoost Learning and Markowitz Theory:

Markowitz's theory is an effective portfolio optimization technique that allocates assets based on risk and return objectives.

Therefore, the pool of stocks identified by the XGBoost model is used as input for the Markowitz optimization model.

The process of moving from one step to another is as follows:

1. The dataset is divided into different periods for training, validating, testing the XGBoost model and backtesting the portfolio.
2. The XGBoost model identifies a pool of stocks with high financial performance potential.
3. The pool of stocks is then used as input for the Markowitz optimization model.
4. The Markowitz model outputs a portfolio that is optimized for minimum risk, with the stocks weighted appropriately.

By leveraging the power of XGBoost learning and Markowitz theory, we can utilize the ESG dataset to identify stocks with high financial performance potential while creating a portfolio that aligns with our sustainability goal in the investment optimization aspect.

4. Empirical Analysis

4.1 Analysis Design

Our empirical analysis explores how ESG factors influence investor cognition from two perspectives.

Firstly, we focus on the aspect of how ESG factors optimize investments. We verify the correlation between ESG factors and corporate financial performance through regression analysis, and then, combining financial and non-financial ESG characteristics, we have constructed a predictive model. This model aims to screen for companies with excellent financial performance in the coming year. Using this model, we select stocks based on historical data and apply a portfolio model to allocate the stock pool weights, thereby back-testing the portfolio's performance to assess its investment benefits. During this process, we will compare with a Baseline to demonstrate the accuracy of our prediction model and the superior performance of the selected investment portfolio.

From another aspect, given that ESG disclosure optimizes investment, we will focus on the phenomenon of "greenwashing." Greenwashing refers to some companies covering up their actual environmental damage through superficial environmental actions, which is an increasingly concerning issue. We conduct an in-depth discussion on this phenomenon by interpreting relevant policies, current situations, and literature analysis and propose a series of countermeasures and suggestions.
The specific process is as shown in Figure 1.

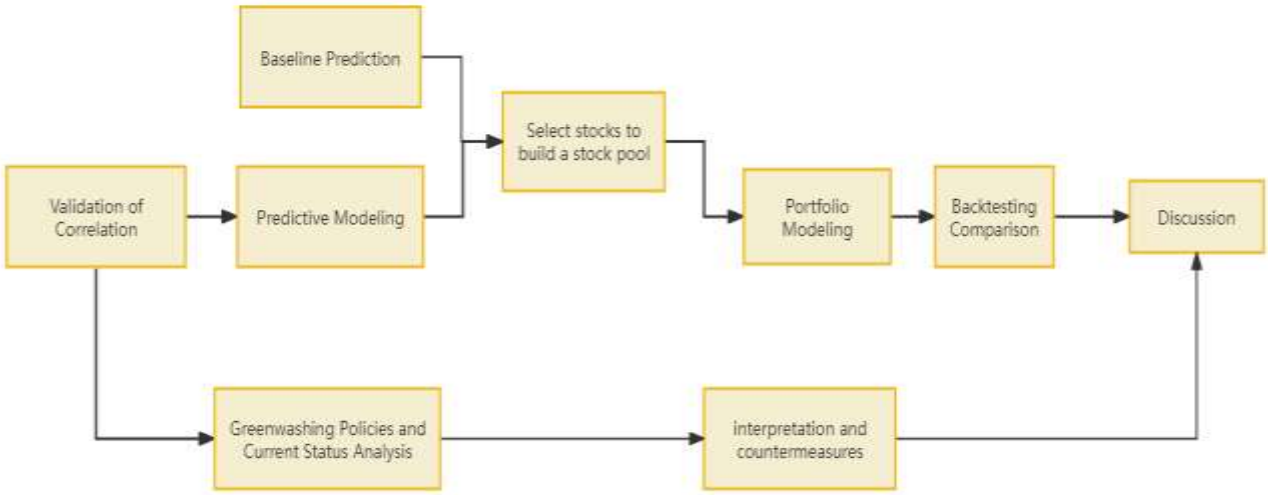

Figure 1. Analysis Design Flow

4.2 Descriptive Statistics

As can be seen from Table 2, the average ESG score is 4.1182. This finding reveals a critical insight: Despite the increasing global attention to ESG issues, many companies still need more room for improvement in fulfilling their related responsibilities. The median ESG score is 4, highlighting that in our sample, half of the companies have an annual average ESG performance score of no more than 4, which should capture the attention of all stakeholders. The standard deviation of the ESG scores is 1.0178, indicating a considerable variance among companies in their commitment to ESG responsibilities. Some companies may have made significant efforts in environmental protection, social responsibility, and good governance, while others may perform poorly in these areas. This variability points to an important issue: the fulfillment of corporate social responsibility varies significantly among different companies, which could impact their image in the eyes of investors, consumers, and other stakeholders.

Table 2. Descriptive Statistics of Main Variables

	count	mean	Std	median
Size	23825	22.2416	1.3054	22.0584
Growth	23825	0.3138	12.3945	0.0995
Cashflow	23825	0.0465	0.0735	0.0458
FIXED	23825	0.2139	0.1617	0.1815
Board	23825	2.1299	0.1999	2.1972
ListAge	23825	2.1861	0.7530	2.3026
Top10	23825	0.5788	0.1511	0.5869
M share	23825	0.1304	0.1954	0.0050
ROA	23825	0.0386	0.0730	0.0374
ESG	23825	4.1182	1.0178	4.0000

4.3 The Association between ESG Factors and Financial Performance

Through in-depth research on the correlation between Environmental, Social, and Governance (ESG) indicators and corporate financial performance, we have found that ESG has become one of the core issues for companies' future development, with its impact on corporate financial performance gradually attracting more attention. According to existing research summaries and our data analysis, the two have a significant positive correlation. Companies that excel in environmental, social, and governance (ESG) aspects also demonstrate superior financial performance.

The regression results of the correlation between ESG factors and corporate financial performance are as follows:

$$ROA_{i,t+1} = \beta_0 + \beta_1 ESG_{i,t} + \sum_j \beta_j control_{j,i,t} + \sum_l \beta_k Year_k + \sum_l \beta_l IND_l$$

$Year_k$ is a dummy variable for fixed year effects and IND_l is a dummy variable for fixed industry effects.

Table 3. Regression results on the association between ESG factors and financial performance

Variables	**y-ROA**
ESG	0.0098***
	(26.579)
Control	Yes
Year	Yes
Ind	Yes
N	23825
Adj. R-squared	0.338

Note: *p<0.10, **p<0.05, ***p<0.01; values in parentheses are t-values; control includes Size, Growth, Cashflow, FIXED, Board, ListAge, Top10, M share, ROA.

This study selects the ROA of the following year as the dependent variable and the ESG score as the independent variable while also considering multiple factors such as financial characteristics, year, and industry fixed effects as control variables. The regression results shown in Table 3 indicate that the coefficient of ESG factors on the following year's ROA is 0.0098, with a statistical significance level of p<0.01 and a t-value of 26.579, which means that the better a company performs in terms of environment, social, and governance, the more likely its financial performance is to improve. Therefore, valuing and improving a company's ESG performance benefits the company's sustainable development and helps enhance its financial performance.

4.4 Financial Performance Prediction Model Incorporating ESG Characteristics

Investors increasingly focus on a company's financial performance in today's business environment. Against this backdrop, in conjunction with the findings in Section 5.2 confirming the impact of ESG on the profitability return of financial performance, this study proposes an innovative predictive model aimed at forecasting a company's financial performance in the coming year, exceptionally whether the Return on Assets (ROA) will exceed the 15% threshold. This threshold is based on a simple fact: a ROA higher than 15% typically indicates a higher profitability return, thereby attracting widespread investor attention (Fiix Software, n.d.).

In this study, we employed two different forecasting methods. First, as a baseline prediction, we only considered whether a company's current year's ROA exceeded the 15% benchmark to predict whether its performance in the next fiscal year would

remain at the same level. Although this method is straightforward and intuitive, it overlooks other vital factors that may impact future financial performance.

Table 4. Data Set Split

	Year	Data Volume
Training Set	2011-2017	14611
Validation Set	2018	2975
Test Set	2019	3075
Backtesting Set	2020	3164

We utilized data from 2011 to 2017 as the training set to train the XGBoost prediction model. To optimize the hyperparameters, we chose the data from 2018 as the validation set and used the grid search method for parameter tuning. Furthermore, this paper uses the data from 2019 as the test set to evaluate the model's predictive performance. Finally, we also used the data from 2020 as the backtesting set for establishing the investment portfolio and backtesting section in the following section.

Table 5. The effectiveness of the prediction model

	Baseline	ESG-XGB
Predict the number of positive samples for the next year	119	87
Number of positive samples in the forecast sample that are actually positive in the following year	76	62
Precision	63.87%	71.26%

In the performance comparison analysis conducted on the test set, we initially noted the benchmark model's ability to predict the financial performance of companies in the following year with a certain level of accuracy. The model correctly predicted that 119 companies would exhibit excellent financial performance in the next fiscal year. Among these predictions, 76 companies actually achieved outstanding financial results, resulting in a precision rate of 63.87%. While this result indicates the benchmark model's predictive ability, it also highlights the potential for further enhancement.

The ESG-XGB model, in contrast, demonstrated a substantial improvement in precision. It predicted that 84 companies would exhibit excellent financial performance. Among these predictions, 61 companies achieved outstanding financial results, boosting the model's precision rate to 71.26%. Compared to the benchmark model, this significant leap in accuracy underscores the ESG-XGB model's superiority in predicting company financial performance.

It is important to consider that while a prediction model with higher precision may limit the number of selectable stocks, this approach can significantly enhance the quality of investment decisions. This trade-off, where a higher precision model may offer a narrower selection, can lead to a notable increase in the accuracy of predictions, potentially improving investment outcomes.

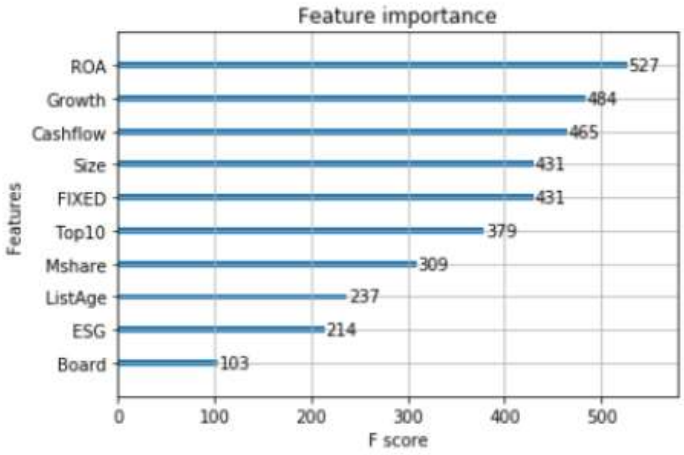

Figure 2. Feature Importance

As shown in Figure 2, from the perspective of feature importance, the ESG score, as a non-financial feature, contributes 5.98% to the feature importance, playing a significant and influential role in prediction.

4.5 Portfolio Construction and Optimization Evaluation

Based on the data from 2020, we can predict and analyze the financial performance for 2021.
Our primary goal is to identify companies with exceptional financial performance, that is, those expected to have a return on assets (ROA) exceeding 0.15 in the next year (2021) and include them in our quality stock pool. To more effectively evaluate the validity of our model's predictions, we compared the stock pool composed of companies with an ROA over 0.15 in 2020 and the stock pool predicted by our model.

This analysis goes beyond identifying quality companies and further explores how to construct the optimal investment portfolio within the selected stock pool. Based on the 2020 daily closing price data, we calculated the average daily return rate and volatility of the stocks. Then, we applied the Markowitz portfolio theory to determine the optimal proportion of each stock in the investment portfolio. This method considers not only expected returns but also fully considers risk control, aiming to provide investors with the best balance between risk and return.

Based on 2020 feature data, the stock pool obtained with the benchmark model consists of 132 companies, while the stock pool predicted with the ESG-XGB model consists of 92 companies.

We apply the Markowitz portfolio model to allocate weights to each company's stock in these two pools, respectively. The core goal is to minimize the portfolio's overall volatility by optimizing stock weight allocation, thus providing a balanced investment portfolio in terms of risk and return. Analyzing the daily closing prices of companies in 2020 and using a volatility minimization model, each stock was assigned a weight, reflecting its proportion in the investment portfolio.

In 2021, as a year to test the actual effect of the model, the CSI 300 Index experienced a decline of 5.2%, providing us with a benchmark for comparison. The portfolio constructed based on the stock pool and calculated weights had the following backtest results for 2021:

Table 6. Portfolio 2021 Backtest Results

	Annually Return	Maximum Drawdown
Baseline	-16.46%	30.90%
ESG-XGB Portfolio	5.76%	26.11%

The trend of the net value backtest in 2021 is shown as Figure 3.

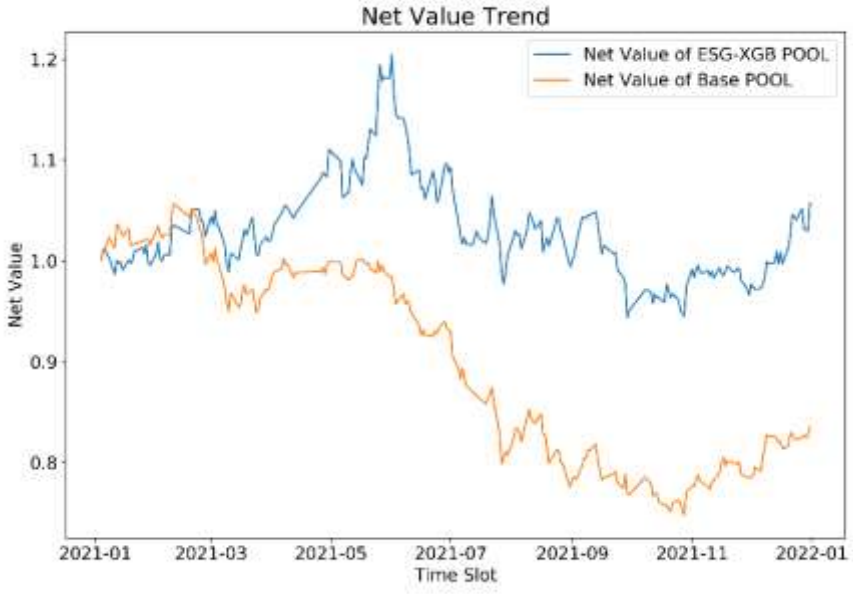

Figure 3. Portfolio Net Value Trend in 2021

As shown in Table 6 and Figure 3, the investment portfolios, meticulously constructed with stock pools and calculated weights, embarked on divergent paths in 2021. Despite careful selection and allocation, the baseline portfolio suffered a harsh blow with

an annualized return rate of -16.46% and a maximum drawdown of 30.90%. This sobering outcome underscores the significant market risks that even the most carefully constructed portfolios can face, leading to substantial wealth loss.

While the benchmark forecast portfolio struggled with an annualized return rate of-16.46% and a maximum drawdown of 30.90% in 2021, the ESG-XGB forecast portfolio stood out with a positive annualized return rate of 5.76% and a maximum drawdown of 26.11%. This stark contrast underscores the superiority of the ESG-XGB model, which effectively combines ESG factors and machine learning algorithms for stock selection and portfolio construction. The ESG-XGB model helped investors maintain asset appreciation in volatile markets and demonstrated superior risk control.

5. Interpretation of Policies Related to Greenwashing

According to the Mega Arithmetic Index, public interest in the issue of "greenwashing" continues to rise. Specifically, the overall attention index doubled in 2022 compared to last year's period, and the search index increased by 54.55 percent year-on-year. Overall, although many scholars have conducted research in the field of "greenwashing," the total amount of research is not large, and the research themes have not blossomed; the field is an emerging research area and is in a period of rapid development, the market's understanding of "greenwashing" and the government's understanding of "greenwashing" are not yet fully understood. The market's understanding of "greenwashing" and the government's guidance on business practices need more authoritative articles for reference.

In addition to academic papers, the theme of "greenwashing" is also gradually increasing in corporate reports and official policy documents. According to the statistics of social responsibility reports in 2022, the Bank of Jiangsu, China Construction Bank, Bank of China, and other banks have explicitly disclosed the risk of preventing "greenwash." In addition, the Shanghai Stock Exchange's Carbon Peak and Carbon Neutral Action Plan for the 14th Five-Year Plan Period also mentions the issue of preventing "greenwash" but does not specify the content. The PBOC R&D released an article entitled "Green Finance Helps Carbon Peak and Carbon Neutrality," stating that the relevant departments will step up efforts to improve the disclosure system, requiring financial institutions to disclose the issuance of green loans and their uses publicly and that third-party organizations should intervene in the investigation and verification process, to help the people's supervision. China's Supreme People's Court issued a regulatory document on dual-carbon in February 2023, explicitly requiring the regulation of corporate disclosure of environmental information and increasing market supervision to effectively curb the phenomenon of corporate "greenwashing" in the market.

Green bonds have the advantage of low interest rates, which can help enterprises reduce financing costs. Under the current situation of imperfect regulation in the field of green bonds in the financial market, there are a few cases of enterprises issuing products that pretend to be green bonds. In the economic context, the global demand for green bonds is increasing. At the same time, the review and supervision by governments and regulators are also being strengthened, and the challenge of circumventing and preventing "greenwash" behavior will increase as the base of green bonds becomes more considerable in the future. There is a need to increase the transparency of corporate information and to prove the authenticity and sustainability of green financing with verifiable data. Third-party institutions, such as regulators and non-governmental organizations, should play their part in exposing potential greenwash and providing the market with more information to guide the flow of funds to truly sustainable projects.

6. Discussion

The research findings in this article emphasize the importance of ESG factors in corporate financial performance and portfolio construction. By combining ESG scores and XGBoost ensemble learning algorithms, the ESG-XGB model has proven to be highly accurate in anticipating company financial performance and creating optimized portfolios.

Key insights from this research include:

Significant impact of ESG factors: The success of the ESG-XGB model indicates the positive impact of ESG factors on corporate financial performance. Excellent ESG performance is closely related to financial outcomes, highlighting the indispensability of sustainability and social responsibility in shaping long-term value.

Application of machine learning in ESG prediction: Machine learning algorithms, such as XGBoost ensemble learning, can handle large datasets and identify non-linear relationships, enabling them to capture complex patterns and insights that traditional financial forecasting models may overlook.

Optimization of portfolio construction: Integrating predicted financial outcomes with Markowitz's portfolio theory enables us to craft investment portfolios that strike a harmonious balance between managing risk and maximizing returns. The ESG-XGB model

provides a scientific approach to identifying stocks with high financial performance potential, helping investors maximize returns and control risks.

Challenges of "greenwashing": Despite the growing popularity of ESG investments, "greenwashing" remains a challenge. Companies and financial institutions must take measures to enhance transparency and ensure the authenticity of green financing. Regulatory agencies and third-party organizations are crucial in disclosing and preventing "greenwashing" practices.
This research offers in-depth insights for investors and decision-makers based on data and scientific methods. By integrating ESG factors and leveraging the advantages of machine learning technology, it is possible to improve corporate financial performance, build more sustainable investment portfolios, and address the challenges of "greenwashing."

7. Conclusion

Against the backdrop of the current global financial market, sustainability and social responsibility issues have taken an increasingly prominent role in policy making and public discussions. Consequently, ESG (Environmental, Social, and Governance) information disclosure has gradually evolved into a key metric for evaluating a company's commitment to social responsibility and sustainability achievements. Naturally, businesses, investors, and regulatory agencies are paying increasing attention to ESG information, viewing it as a crucial lens through which to assess a corporation's enduring value and potential risks. However, despite the widespread recognition of the importance of ESG information disclosure and the growing trend of ESG investing driving the development of green finance, numerous challenges remain in practice. Notably, the existence of "greenwashing" behavior not only damage the credibility and reputation of the enterprise but also undermines investors' confidence and the market's acceptability of environmentally friendly financial products. After an in-depth analysis of the current situation, this study comprehensively examines the interplay between ESG investment and corporate financial outcomes, considering investor cognition in optimizing investments and environmentally conscious behaviors. It proposes several key contributions to the field.

Providing Decision Support for Investors: The ESG-XGB model serves as a tool for investors to identify stocks with high financial performance potential, which can assist them in making prudent investment decisions and creating more sustainable portfolios.

Improving Corporate ESG Practices: The research results indicate that ESG performance aids in predicting financial outcomes, which can motivate companies to elevate their ESG practices and recognize the value of sustainability and social responsibility for long-term success.

Revealing the Sustainability of Green Finance: By highlighting the importance of ESG factors, this study contributes to promoting the sustainable development of green finance. It offers a framework for governments, regulators, and financial institutions to devise policies and practices ensuring the authenticity and effectiveness of green financing.

This study makes unique contributions but still has particular limitations:

Dependence on Historical Data: Predictive models and investment optimization are trained based on historical data. Hence, future events and market changes that are not captured in the data may affect their predictive capability.

Data Availability: The availability and quality of ESG data may vary by industry and company, potentially affecting the model's generalizability.

Sample Size: Despite drawing upon a significant dataset, the paper's sample size for specific industries or company profiles may be relatively modest, potentially introducing limitations that could compromise the model's resilience and reliability. Greenwashing Reports Often Involve Subjective Factors: It is challenging to characterize greenwashing using purely objective behavioral attributes.

In order to overcome these constraints and broaden the scope of inquiry discussed in this study, forthcoming efforts may concentrate on the subsequent domains:

Incorporating real-time ESG data: Investigating strategies to integrate up-to-the-minute environmental, social, and governance information into our analytical models, thereby improving the timeliness and precision of our forecasts and assessments. Cross-Industry Analysis: Comparing and contrasting the impact of ESG factors across different industries and regions to assess their universality and transferability.

Advancing greenwashing detection: Creating more sophisticated techniques to uncover and deter instances of greenwashing, equipping investors and regulatory authorities with tools to expose unsustainable practices.

Based on in-depth analysis, this article proposes several suggestions for future prospects, aiming to provide valuable references for further exploration and research in related fields.

Future research endeavors should aim to unravel the complex dynamics between Environmental, Social, and Governance (ESG) factors and the financial markets, especially during extreme circumstances such as financial crises or large-scale environmental disasters. It is imperative to understand the profound influence that ESG considerations exert on the decision-making processes of investors and their pivotal role in cushioning the volatility of financial markets.

Furthermore, it is crucial to remain vigilant against the potential repercussions of greenwashing, which can cast doubt on the integrity of ESG-related information disclosure. Ensuring that investors have access to high-quality, reliable, and transparent ESG information is essential for them to effectively assess risks and seize opportunities.

Consequently, upcoming scholarly investigations should concentrate on identifying and implementing strategies designed to counteract the negative effects of greenwashing on the precision and promptness of ESG information disclosure. This can be accomplished through the refinement of information disclosure frameworks, the enhancement of the quality of services provided by intermediaries, and the bolstering of regulatory oversight.

By pursuing these initiatives, we can foster an environment that encourages the efficient allocation of capital towards businesses that demonstrate a heightened sense of social responsibility and possess the potential for sustained competitive advantage in the long run.

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