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Game Simulation and Capital Structure Co-optimization of Corporate Green Investment and Financing Decisions under ESG Rating Constraints

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Abstract With society's emphasis on environmental, social and governance (ESG) factors, how enterprises make effective financing decisions and optimize their capital structure under ESG rating constraints has become a key factor affecting their sustainable development. This paper explores the synergistic optimization of enterprises' green investment and financing decisions and capital structure under ESG rating constraints through game simulation model and empirical analysis. First, the study constructs a game model to analyze the decision-making behaviors and interactions among the three parties: enterprises, ESG rating agencies and investors, and simulates the strategic choices under different scenarios and their impacts on corporate decisions. Secondly, by empirically analyzing 217 enterprises with the ESG ratings of Shangdao Ronggreen from 2018 to 2023, it is found that the ESG ratings show a significant correlation with the adjustment of capital structure. The results show that for every 1-unit improvement in corporate ESG performance, the speed of capital structure adjustment significantly increases by 0.312 units. In addition, financing constraints and agency costs play a mediating role in the impact of ESG performance on capital structure adjustment. Finally, a capital structure optimization path based on ESG rating constraints is proposed, including innovative financing methods and improving the quality of information disclosure, which aims to help enterprises achieve capital structure optimization and sustainable development in the context of green finance.

Index Terms ESG rating, green investment and financing, capital structure, game simulation, financing constraint, agency cost

I. Introduction

Enterprise green investment and financing includes both green investment process and financing process, which is the unification of green investment and green financing [1]. Green investment refers to investing in projects, enterprises or assets that contribute to environmental protection, resource conservation and sustainable development [2]. It covers a wide range of fields, including renewable energy, clean energy, energy conservation, environmental protection, green transportation, and resource recycling [3]. Green financing refers to the financing behavior of providing financial services in order to promote green development [4]. Green financing has a clear environmental focus and the principle of sustainable development, implements the concept of resource conservation and environmental protection, realizes the construction of ecological civilization, and then creates a good social environment [5], [6]. And with the rapid development of the global economy, environmental problems are becoming more and more serious, climate change, resource depletion, loss of biodiversity and other issues have become the focus of global attention [7], [8]. In this context, the concept of corporate social responsibility (CSR) has gradually been emphasized, in which the concept of environmental, social and governance (ESG), as a new type of CSR concept, is gradually becoming an important reference basis for corporate investment decisions [9]-[12].

ESG is a kind of assessment framework to consider the sustainable development ability of enterprises, which emphasizes that enterprises should pay attention to environmental protection, social responsibility and corporate governance while pursuing economic benefits in order to achieve sustainable development, and the ESG rating system is based on these three dimensions to score and rate enterprises, and the higher the rating is, the better the performance of the enterprise in sustainable development [13]-[16]. For enterprises, a good ESG rating can bring many benefits. First, it helps to enhance corporate image [17]. In today's world where consumers are increasingly concerned about corporate social responsibility, a company that actively fulfills its ESG responsibilities is more likely to win consumers' trust and favor [18], [19]. Secondly, it reduces the risk of business operations and attracts investment [20].

This study analyzes the interactive relationship among enterprises, ESG rating agencies and investors through a game simulation model, explores the constraining role of ESG ratings on enterprises' green investment and financing decisions, and combines empirical data to study the adjustment mechanism of enterprises' capital structure under ESG constraints. It is found that the ESG performance of enterprises has a significant impact on their capital structure adjustment, while mediating variables such as financing constraints and agency costs play a role in it. Through an in-depth analysis of enterprises' green investment and financing decisions, this study proposes two capital structure optimization paths: one is to provide enterprises with diversified sources of funds through innovative financing methods; the other is to enhance the quality of information disclosure to improve market transparency and investor trust. These optimization paths are of great theoretical and practical significance to promote the capital structure optimization of enterprises under ESG constraints and the development of green economy.

II. Game Simulation of Financing Decision and Co-Optimization of Capital Structure

II. A. Constructing the game simulation model

II. A. 1) ESG rating agencies

The model considers only pure strategies, and the rating criteria of the ESG rating agencies are divided according to the ESG performance of the firm, which is positively correlated with the ESG rating: if the firm possesses a high ESG performance, it receives an ESG rating $R = r_H$. If the company has low ESG performance, it receives an ESG rating $R = r_L$ [21], [22]. It is assumed that ESG ratings conducted by ESG rating agencies are influenced by the company's decision to invest in new projects and the investors' buying strategy, resulting in three ESG ratings: if the company defaults at an early stage, the ESG rating is 0. If it invests in PT, the ESG rating is $R = r_L$. If investing in ST, the ESG rating is $R = r_H$. The reputational income that ESG rating agencies can earn from ESG ratings of companies can be considered as floating income $I_F(R)$, along with the operating income earned from ESG advisory services, and the operating income earned from the sale of ratings data can be considered as fixed income $I_D(R)$, which together make up the ratings of ESG rating agencies. Profit $I(R) = I_D(R) + I_F(R)$, while the ESG rating agency also needs to invest capital $C_1(R)$ to bear the potential risk of rating $C_2(R)$, which constitutes the cost of ESG ratings $C(R) = C_1(R) + C_2(R)$, and obtains the rating revenue $I(R) - E(C(R))$.

II. A. 2) Enterprises

Suppose the firm issues a zero-coupon bond with a fixed par value of $N > 1$ and maturity at date2, the marginal cost of a bank loan is M ($M > N$ and $M < (r_H S - r_L P)/(r_H - r_L)$), the liquidity of the bond market is γ, $\gamma \in (L,1)$, and B denotes the number of investors willing to buy the bond. If the firm defaults neither endogenously on date1 nor exogenously on date2, it will pay off all cash flows in full at the end of the date2 period. The firm can choose one or both sources of financing, $\gamma \in (L,1)$ ensures that the firm cannot pay off its current liabilities in full even if investors are inclined to buy bonds, and $M < (r_H S - r_L P)/(r_H - r_L)$ it can be ensure that the firm may also have the ability to continue to invest in new projects when it can only obtain loans from the bank.
Therefore, the firm's financing cost is:

$$BN + (1 - B)M \tag{1}$$

Companies investing and disclosing ESG need to bear effective ESG costs $f(\alpha)$, the better their ESG performance α, the higher the effective ESG costs, but when the company's ESG performance α tends to be positively infinite, the increase in ESG costs will become more and more flat. Influenced by the pro-ESG attitudes of investors and the market environment, companies with low ESG performance will, out of interest, use ESG as a marketing tool to influence investors' preconceptions of the company's future financial performance, incurring greenwashing costs $h(\alpha)$, and the better the company's ESG behavior α the less greenwashing it will do. Investors, on the other hand, judge the default rate of new projects and predict future financial performance based on the firm's ESG performance α, so the number of investors buying corporate bonds B can be viewed as an equilibrium ESG rating function endogenously determined with respect to α, written as $B(\alpha)$. The total cost of the firm can be expressed:

$$T = B(\alpha)N + (1 - B(\alpha))M + g(\alpha) + f(\alpha) + h(\alpha) \tag{2}$$

Suppose that U denotes the firm's return: if the firm defaults, whether endogenously or exogenously, its return is 0. If the firm does not default, its return will be affected by the new project. Denote:

$$U = 0 \ Default \tag{3}$$

$$U = r_H \left\{ S - [B(\alpha)N + (1 - B(\alpha))M + g(\alpha) + f(\alpha) + h(\alpha)] \right\} \quad Invest \ in \ ST \tag{4}$$

$$U = r_L \left\{ P - [B(\alpha)N + (1 - B(\alpha))M + g(\alpha) + f(\alpha) + h(\alpha)] \right\} \quad Investment \ PT \tag{5}$$

Assuming that the firm invests in PT, it earns a total economic return of $r_L P$. Where the investor's expected return is $r_L BN + (1 - B)$, the bank's expected return is denoted as $(1 - B) r_L M - (1 - B)$, the firm's expected return is denoted as $r_L \left\{ P - \left[BN + (1 - B)M + g(\alpha) + f(\alpha) + h(\alpha) \right] \right\}$, and the employee's expected return is $r_L [g(\alpha) + f(\alpha) + h(\alpha)]$. Similarly, if the firm invests in ST, the total economic efficiency is $r_H S$. If the firm defaults on date1, the total economic efficiency is L, i.e., the firm liquidates the total assets and all of them belong to the firm.

II. A. 3) Investors

The development of green finance and reasonable environmental responsibility is an important means to support the quality improvement of future economic growth and an important direction for the development of financial institutions in China, so we can reasonably assume that investors are socially conscious and rational investors, who pay attention to the firm's economic profitability as well as its environmental performance, social performance, and internal governance, and decide whether to purchase corporate bonds based on their private ESG signals. The private signal p_i of investor i is influenced by the private perceptions formed by their observation of corporate ESG behavior in addition to the ESG rating results R published by ESG rating agencies, i.e., $p_i = \alpha + \delta_i$, $\delta_i \sim N(0, \beta^{-1})$ and is independent of the private ESG signals of α and the private ESG signals of the investors as a whole. Suppose that $e_i \in \{0,1\}$ denotes that investor i's decision to purchase corporate bonds is influenced by his or her prediction of the company's project decision. If investor i predicts that the firm invests in ST, he purchases the corporate bond, i.e., $e_i = 1$. If the prediction is that the firm invests in PT or defaults, it does not purchase, i.e., $e_i = 0$.

In the monotonic equilibrium global game model, investor i decides whether to buy corporate bonds or not based on the private signal $p_i = \alpha + \delta_i$ by adopting a truncated strategy with p^* as the cut-off value: since there exists a time-lagged facilitating effect of the firm's ESG performance on the firm's financial performance, when the private signal p_i is very positive $\left(p_i > p^* \right)$, investor i will believe that the firm will invest in ST and thus firmly purchase corporate bonds, i.e., the positive investment region. If investor i receives a very negative private signal $p_i \left(p_i < p^* \right)$, he will believe that the company will default on DATE1 and firmly refrain from purchasing corporate bonds, i.e., the negative investment region. When $p_i = p^*$, investor i will not receive additional returns from corporate bonds, has no incentive to have to buy corporate bonds, and is called a marginal investor.

II. A. 4) Subject Decision Objective Function

From the previous model description, the decision-making behavior and objectives of each subject are as follows:

The company's investment decision, based on the investment in new projects to bring the company's total cost T and revenue U to make a judgment. Assuming that the company succeeds in financing and continues to invest in new projects, the investor's investment strategy is clear, at which time the company defaults if its total cost $T > P > S$. If the firm's expected return from investing in ST is greater than PT, i.e., $T(\alpha) \le (r_H S - r_L P) / (r_H - r_L)$ holds, then the firm invests in ST. Otherwise, the firm invests in PT. whose decision-making objective is to maximize the firm's return U. That is:

$$U=\begin{cases}0 & Default\\ r_L\{P-[B(\alpha)N+(1-B(\alpha))M & \\ +g(\alpha)+f(\alpha)+h(\alpha)]\} & Investment\ PT\\ r_H\{S-[B(\alpha)N+(1-B(\alpha))M & \\ +g(\alpha)+f(\alpha)+h(\alpha)]\} & Invest\ in\ ST\end{cases} \tag{6}$$

ESG Rating Agency Decision-making Based on the company's ESG performance α, ESG rating agencies will fully consider the best response strategy for investors and companies in the face of the "masking effect" of the company's ESG rating bias: if the ESG rating agency predicts that the company will default on date 1, it will give it a rating of $R=0$. If an ESG rating agency predicts that a company will invest in PT, it will give it a rating of $R=r_L$. If an ESG rating agency predicts that a company will invest in ST, it will give it a rating of $R=r_H$. The goal of the decision is to maximize the rating returns $I(R)-E(C(R))$ of ESG rating agencies. Namely:

$$R=\begin{cases}0 & Default\\ r_L & Investment\ PT\\ r_H & Invest\ in\ ST\end{cases} \tag{7}$$

For investor decision making, investor i decides whether or not to purchase a corporate bond based on the private signal $p_i=\alpha+\delta_i$, and purchases the corporate bond when the private signal $p_i>p^*$. Otherwise, no purchase is made. The decision objective is to maximize the investor's expected return $r_L BN+(1-B)$ (or $r_H BN+(1-B)$).

Given the firm's α and the creditor's p^*, the investor's criterion for purchasing corporate bonds can be expressed as:

$$B(\alpha)=(1-\gamma)\Pr(p\geq p^*\mid\alpha)=(1-\gamma)\left\{1-\phi\left[\sqrt{\beta}(p^*-\alpha)\right]\right\} \tag{8}$$

Investors will follow Bayes' rule to update the prior beliefs in time to form the posterior ESG beliefs, i.e., $\alpha\mid p_i\sim N(p_i,\beta^{-1})$, and thus the expected return of investor i on purchasing the corporate bond is:

$$\begin{aligned}&\left[\phi(\sqrt{\beta}(\alpha_H-p_i))-\phi(\sqrt{\beta}(\alpha_L-p_i))\right]r_L N\\ &+[1-\phi(\sqrt{\beta}(\alpha_H-p_i))]r_H N\end{aligned} \tag{9}$$

In the above model based on the company's ESG performance α for decision making, the probability of the company defaulting at date0 can be predicted, the ESG rating agency is the key to delivering the company's ESG information, in order to ensure the effectiveness of the ESG rating agency's ratings, it is necessary to set a very large public expectations of the cost of $C(D)(>I(R))$ constraints on the behavior of the ESG rating agency to effectively prevent the ESG rating agencies to assign a rating of $R>0$ to firms that default in date0.

II. B.Capital Structure Exploration under ESG Evaluation Constraints

II. B. 1) ESG performance

Regarding the measurement of ESG performance, this paper adopts the assignment method, in which companies with the lowest level of ESG rating of Business Gateway Unigreen, D, are credited with 1 point, and one point is added for each level up, and the highest rating, A, is credited with 10 points. Based on the three core dimensions of Environment (E), Society (S) and Corporate Governance (G), Business Gateway Unigreen has further expanded the ESG rating, and finally established 14 topics, including environmental policy, energy consumption, pollutant emissions, employee development, supply chain management, data security, community, governance structure, business ethics, compliance management, etc., and more than 200 ESG indicators derived from them, which are used as the basis indicators for constructing the ESG system. ESG system. The underlying data includes more than 700 ESG data points derived from six sources: disclosure data, regulatory data, media data, macro data, geographic data and satellite data.

II. B. 2) Capital structure

Regarding capital structure, scholars currently use two indicators to measure it, one indicator is the ratio of total liabilities to total assets, which is the gearing ratio [23], [24]. Another indicator is the ratio of interest-bearing liabilities to total assets, which is the interest-bearing debt ratio. The latter mainly measures the active liabilities resulting from the increase of interest-bearing debt, therefore, this paper adopts the gearing ratio to measure the capital structure of enterprises.

II. B. 3) Intermediate variables

(1) Financing constraints

There are more ways to measure financing constraint variables, which can be specifically categorized into univariate and multivariate methods based on the degree of comprehensiveness of the indicators. The univariate calculation method usually uses indicators such as Z-score and bond rating to represent the degree of financing constraint. The multivariate calculation method, on the other hand, uses comprehensive indicators such as KZ index, WW index and SA index. Due to the lack of comprehensiveness of the univariate method, this paper chooses the multivariate calculation method, and the three indices in the multivariate calculation method are not the same, among which the SA index has the advantages of simplicity and robustness of results. Therefore, this paper finally chooses the SA index to measure the degree of financing constraints of enterprises, and the larger the value of the SA index, the more serious the financing constraints of enterprises. The calculation method is shown below:

$$SA = -0.737 * size + 0.043 * size^2 - 0.040 * age \tag{10}$$

where size denotes the natural logarithm of firm size (in millions of dollars). age denotes the time of firm establishment.

(2) Agency Costs

Regarding the measurement of agency cost, it is mainly measured by the management expense ratio or the ratio of the year-end balance of other receivables to total assets. The latter is mainly used to measure the second type of agency cost, and the agency cost in this paper is mainly the first type of agency cost, therefore, the management expense ratio is selected to represent the agency cost variable. A higher management expense ratio indicates a greater agency cost, which suggests a more serious agency problem for the firm.Table 1 reports a description of the main variables of the baseline model of this paper and the firm characteristic variables that are used as control variables.

Table 1: Variable Names and Definitions

Variable name	Variable symbol	Variable definition
Capital structure	Lev	Total liabilities/Total assets
Target capital structure	$Lev_{i,t}^{*}$	It is obtained through fitting based on financial indicators
Degree of target deviation	TdLev	$Lev_{i,t}^{*} - Lev_{i,t-1}$
Actual degree of deviation	dLev	$Lev_{i,t} - Lev_{i,t-1}$
ESG performance	ESG	The ESG rating of Shangdao Ronglv has been converted to 1 to 10 points
Financing constraint	SA	It is obtained according to the formula of the SA index
Agency cost	AC	Administrative expenses/Total assets
Enterprise scale	Size	The natural logarithm of total assets.
Profitability	Profit	Ebit/Total assets
Growth ability	Growth	(Total assets of the current period - Total assets of the previous period)/ Total assets of the previous period
Non-debt tax shield	Dep	Depreciation of fixed assets/total assets
Mortgage capacity	Mortgage	Fixed assets/Total assets
Industry capital structure	IndLev	The median of the asset-liability ratio of the industry in which the enterprise is located

II. B. 4) Mathematical modeling

According to the dynamic trade-off theory, when the enterprise obtains the benefit (such as the tax shield benefit) and the cost that needs to be paid by raising debt are equal, the capital structure at this time is optimal. However, the reality of the capital market can not reach the ideal state in the theory, there are many unavoidable factors, such

as information asymmetry, transaction costs, etc., which will lead to the enterprise is difficult to perfectly make their own capital structure to achieve the desired value, and can only be partially realized to adjust the magnitude of the target, that is, only partially adjusted. Therefore, this paper refers to the best practices recognized by existing research to portray the speed of adjustment, the model is as follows:

$$Lev_{i,t} - Lev_{i,t-1} = \theta(Lev_{i,t}^{*} - Lev_{i,t-1}) + \varepsilon_{i,t} \tag{11}$$

In Equation (11), i and t denote the enterprise and the year respectively, $Lev_{i,t}$ denotes the actual capital structure of the enterprise i in the year t, $Lev_{i,t}^{*}$ denotes the target capital structure of the enterprise i in the year t, and θ denotes the speed of capital structure adjustment. If $\theta > 0$, it means that the firm's capital structure is converging to the target, and the larger the value of θ, the faster the capital structure adjustment. Usually θ will not be greater than 1, when $\theta = 1$, it means that the capital structure has reached the target optimal capital structure.

The target capital structure $Lev_{i,t}^{*}$ in Equation (11), as an unobservable variable of the enterprise, has an important significance in the academic research on the dynamic adjustment of capital structure. Many scholars have found that the target capital structure of an enterprise is related to a series of financial indicators of the enterprise, and this paper follows the practice of mainstream scholars and uses a series of financial data of the enterprise to fit its model as follows:

$$Lev_{i,t}^{*} = \alpha X_{i,t-1} \tag{12}$$

The $X_{i,t-1}$ in Equation (12) are the characteristic variables of the firms in the lagged period, specifically including six variables: industry median capital structure, firm size, profitability, collateralization ability, non-debt tax shield, and growth ability, and the specific descriptions of the six variables are shown in the variable descriptions below.

Substitute model (12) into model (11) to get model (13), regress model (13) to get the estimated values of $1-\theta$ and $\alpha\theta$, and then get the estimated value of α, and substitute the estimated value of α into model (12) to get the target capital structure $Lev_{i,t}^{*}$. Common estimation methods include fixed-effects model, GMM model, least squares dummy variable method, etc. In this paper, we will choose the fixed-effects model to regress the model (13), so as to obtain the theoretical value of the target capital structure. Namely:

$$Lev_{i,t} = \alpha\theta X_{i,t-1} + (1-\theta)Lev_{i,t-1} + \varepsilon_{i,t} \tag{13}$$

In order to explore the relationship between ESG performance and the speed of corporate recapitalization, this paper refers to the relevant research methods to carry out research, in the coefficients of model (11) and the right side of the coefficients can be added to $ESG_{i,t}$ can be obtained to the model of the impact of ESG performance on the speed of recapitalization, that is, model (14). That is:

$$Lev_{i,t} - Lev_{i,t-1} = (\theta + \beta_1 ESG_{i,t}) \times (Lev_{i,t}^{*} - Lev_{i,t-1}) + \beta_2 ESG_{i,t} + \varepsilon_{i,t} \tag{14}$$

Model (14) can be simplified into model (15), and this paper uses model (15) as the baseline model, where $dLev_{i,t} = Lev_{i,t} - Lev_{i,t-1}$, and $dLev_{i,t}$ denotes the difference between the capital structure in period t and that in period $t-1$, i.e., the actual change in the firm's capital structure. $TdLev_{i,t} = Lev_{i,t}^{*} - Lev_{i,t-1}$, $TdLev_{i,t}$ denotes the difference between the target capital structure in period t and that in period $t-1$, i.e., the target change in capital structure. At this point, the regression coefficient β_1 of the interaction term between $ESG_{i,t}$ and the deviation magnitude $TdLev_{i,t}$ measures the effect of ESG performance on the speed of capital structure adjustment. If β_1 is significantly positive, it indicates that the better the firm's ESG performance, the faster the speed of capital structure adjustment. Conversely, if β_1 is significantly negative, it indicates that the better the firm's ESG performance, the slower the speed of capital structure adjustment. For:

$$dLev_{i,t} = (\theta + \beta_1 ESG_{i,t}) \times TdLev_{i,t} + \beta_2 ESG_{i,t} + \varepsilon_{i,t} \tag{15}$$

Based on the mediation effect test model of causal analysis, this paper tests whether the two mediating variables, financing constraints and agency costs, play a partial mediating role by constructing models (15) (16) and (17).

Model (15) (16) (17) serves as a portfolio composition mechanism identification test using SA index and total asset turnover to measure financing constraints and agency costs. For:

$$Mediator_{i,t} = c_1 ESG_{i,t} + c_2 X_{i,t} + \varepsilon_{i,t} \tag{16}$$

$$dLev = \left(\theta + \beta_1 ESG_{i,t}\right) \times TdLev + \beta_2 ESG_{i,t} + \beta_3 Mediator_{i,t} + \varepsilon_{i,t} \tag{17}$$

In (16) and (17), c_1 and β_1 are the key coefficients. When c_1 is significantly negative and β_1 in (17) declines relative to β_1 in (15), it suggests that financing constraints and agency costs partially mediate the effect of ESG performance on the dynamic adjustment of capital structure.

III. Model numerical simulation and empirical analysis

III. A. Numerical simulation analysis of game models

III. A. 1) Description of parameters

The two sides of the game are enterprises and ESG rating agencies, and they are both limited rational subjects, in which enterprises are the party that carries out green technology innovation and ESG rating agencies are the party that provides financing subsidies. For enterprises, assuming that their normal income without green investment and financing decisions is s, the new income brought by green investment and financing decisions to enterprises is μs, the corresponding investment cost is c_0, and the subsidy from ESG rating agencies is m, and in the case of green investment and financing decisions, the cost of financing for enterprises without subsidies from ESG rating agencies is c_1, When the subsidy is provided by an ESG rating agency, the cost of financing for a company is c_2. In the case where enterprises do not make green investment and financing decisions, the cost of obtaining financing is c_3 when ESG rating agencies provide subsidies, and c_4 when there are no subsidies from ESG agencies, in which, since subsidies provided by ESG rating agencies can provide enterprises with "implicit guarantee", therefore, $c_1 > c_2, c_4 > c_3$. For ESG rating agencies, it is assumed that in the case of a company making a green investment and financing decision, the social gains of ESG rating agencies with and without subsidies are R_1 and R_3, respectively. And when firms do not make green investment and financing decisions, their social returns are R_2 regardless of whether ESG rating agencies apply subsidies or not. In addition, ESG rating agencies subsidize enterprises will incur corresponding regulatory costs, this paper assumes that in the case of ESG rating agency subsidies, the regulatory cost of ESG rating agencies is d_1 when enterprises make green investment and financing decisions, and the regulatory cost of ESG rating agencies is d_2 when enterprises do not make green investment and financing decisions. Among them, there are $R_1 > R_2$ as companies making green investment and financing decisions can indirectly generate positive social gains for ESG rating agencies. And with the addition of ESG rating agency subsidies, the likelihood that more companies will participate in the ranks of green investment and financing decisions increases, which leads to $R_3 > R_1$. When firms make green investment and financing decisions, ESG rating agencies pay somewhat greater regulatory costs, which is caused by the fact that regulation of green investment and financing decisions is additionally increased, thus $d_1 > d_2$.

III. A. 2) Numerical simulation analysis

Based on the above analysis, it can be seen that the behaviors of whether enterprises make green investment and financing decisions and whether ESG rating agencies provide subsidies are closely related to the variables affecting the return matrices of both. In this section, MATLAB R2020a software is mainly used to carry out numerical simulation experiments to verify the results of the game model, and on the other hand, to study the impact of different changes in the values of the variables on the evolution of the results, so as to put forward targeted recommendations for the effective promotion of green investment and financing decisions.

(1) Strategy selection of enterprises and ESG rating agencies under different circumstances

When the parameters $(\mu s - c_0) > 0$, $c_4 - c_1 > 0$, $c_3 - c_2 > 0$, $R_3 - d_1 - R_1 > 0$ (Case 1), set the variable values to $s = 20$, $\mu = 1.0$, $m = 10$, $c_0 = 6$, $c_1 = 4$, $c_2 = 2$, $c_3 = 4$, $c_4 = 6$, $R_1 = 8$, $R_2 = 6$, $R_3 = 16$, $d_1 = 4$, $d_2 = 2$, and the numerical simulation results of the whole system are shown in Figure 1. At this time, the probability of the occurrence of the enterprise to carry out green investment and financing decisions x, the final stable take the value of 1, the probability of the ESG rating agency to provide subsidies for the enterprise y the final stable take the value of 1, i.e., the stable strategy of the enterprise and the ESG rating agency for the (investment, subsidies), and the results of the evolutionary game of the case 1 are consistent with the results of the case 1.

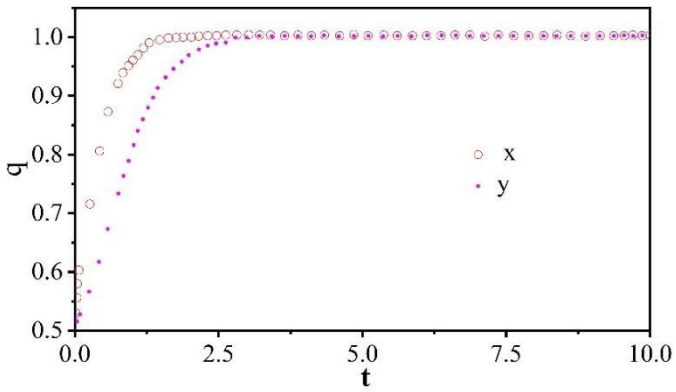

Figure 1: The numerical simulation results of Situation 1

When the parameters $(\mu s - c_0) < 0$, $c_4 - c_1 < 0$, $c_3 - c_2 < 0$, $R_3 - d_1 - R_1 < 0$ (Case 2), set the variable values to $s = 20$, $\mu = 0.6$, $m = 10$, $c_0 = 8$, $c_1 = 6$, $c_2 = 4$, $c_3 = 2$, $c_4 = 4$, $R_1 = 12$, $R_2 = 8$, $R_3 = 14$, $d_1 = 4$, $d_2 = 2$, and the numerical simulation results of the whole system are shown in Figure 2. At this time, the occurrence probability x of the enterprise to carry out green investment and financing decisions is finally stable to take the value of 0, and the probability y of the ESG rating agency to provide subsidies for the enterprise is also finally stable to take the value of 0, i.e., the stable strategy of the enterprise and the ESG rating agency is (no investment, no subsidies), which is consistent with the results of the scenario two evolutionary game.

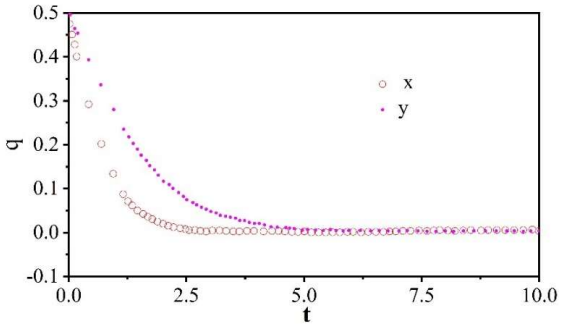

Figure 2: The numerical simulation results of Situation 2

When the parameters $(\mu s - c_0) > 0$, $c_4 - c_1 > 0$, $c_3 - c_2 > 0$, $R_3 - d_1 - R_1 < 0$ (case 3) In this case, the variable values are set as $s = 20$, $\mu = 1$, $m = 10$, $c_0 = 6$, $c_1 = 4$, $c_2 = 2$, $c_3 = 4$, $c_4 = 6$, $R_1 = 12$, $R_2 = 8$, $R_3 = 14$, $d_1 = 4$, $d_2 = 2$, and the numerical simulation results of the whole system are shown in Figure 3. At this time, the probability of the occurrence of the enterprise to carry out the green investment and financing decision-making behavior x final stable value is 1, the probability of the ESG rating agency to provide subsidies for the enterprise y final stable value is also 0, that is, the stable strategy of the enterprise and the ESG rating agency for the (no investment, no subsidies), and the results of the scenario 3 evolutionary game is consistent.

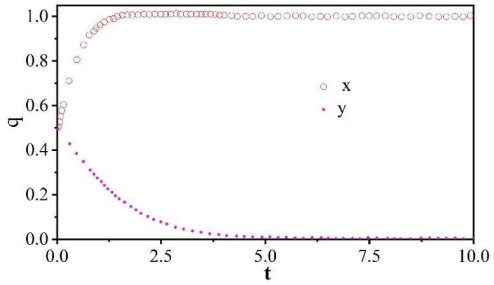

Figure 3: The numerical simulation results of Situation 3

When the parameters $(\mu s - c_0) < 0$, $c_4 - c_1 < 0$, $c_3 - c_2 < 0$, $R_3 - d_1 - R_1 > 0$ (Case 4), set the variable values to $s = 20$, $\mu = 0.6$, $m = 10$, $c_0 = 8$, $c_1 = 6$, $c_2 = 4$, $c_3 = 2$, $c_4 = 4$, $R_1 = 8$, $R_2 = 6$, $R_3 = 16$, $d_1 = 4$, $d_2 = 2$, and the numerical simulation results of the whole system are shown in Fig. 4. At this time, the probability of occurrence x of the enterprise to carry out green investment and financing decision-making behavior is finally stable to take the value of 0, and the probability y of the ESG rating agency to provide subsidies for the enterprise is also finally stable to take the value of 0, i.e., the stable strategy of the enterprise and the ESG rating agency is (no investment, no subsidies), which is the same as the result of the scenario 4 evolutionary game. Among them, the trend of curve y has an upward trend at the beginning and then returns to the downside, the reason for this situation is that the parameters related to ESG rating agencies meet the conditions that drive ESG rating agencies to choose to subsidize, that is, y evolves to 1, but because the strategy adopted by the enterprise is "no investment", according to the principle of maximizing their own interests, the final strategy of ESG rating agencies is "no subsidy".

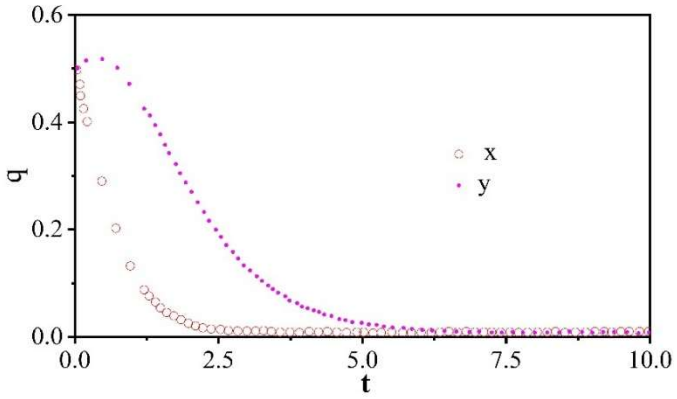

Figure 4: The numerical simulation results of Situation 4

(2) Strategy selection of enterprises and ESG rating agencies under different parameter values

Generally speaking, the smaller the investment cost c_0 of an enterprise's behavior in making green investment and financing decisions, the greater the probability that it tends to carry out green investment and financing decisions. Therefore, under the condition that the parameters satisfy the inequality of Case 1, the two cases of $c_0 = 2$ and $c_0 = 8$ are compared and analyzed, and the simulation results are shown in Fig. 5. In Fig. 5, x represents the probability that the enterprise carries out the green investment and financing decision-making behavior, and y represents the probability that the ESG rating agency provides subsidies, and it can be clearly seen from the figure that the curve of c_0=2 converges to 1 at a faster rate than the curve of c_0=8, that is to say, the lower enterprise green investment and financing cost can promote the enterprise and the ESG rating agency to evolve to the point (1, 1). Among them, there are many input costs of corporate green investment and financing decision-making behavior, including human cost, material cost, etc.

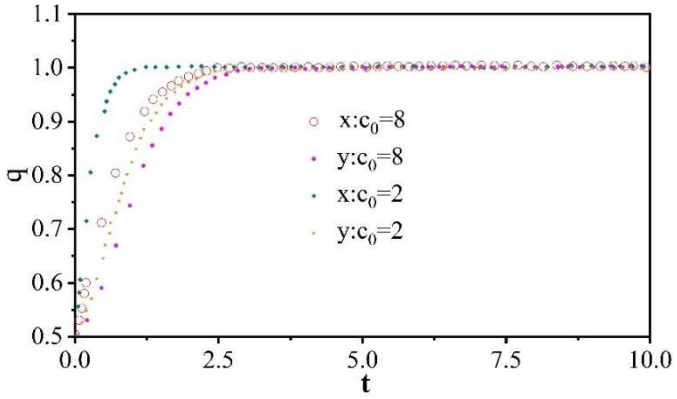

Figure 5: The influence of c_0 on the final evolutionary result

The smaller the cost paid by enterprises to make green investment and financing decisions to obtain the required financing, the stronger the willingness of enterprises to carry out green investment and financing decisions.

Therefore, under the condition that the parameters satisfy the inequality of case 1, the two cases of c_2=0.2 and c_2=2 are compared and analyzed, and the simulation results are shown in Figure 6. When enterprises make green investment and financing decisions while having innovation subsidies provided by ESG rating agencies, the curve represented by the smaller enterprise financing cost c_2 tends to 1 faster, i.e., it is favorable for the final strategies of enterprises and ESG rating agencies to evolve toward the point (1, 1).

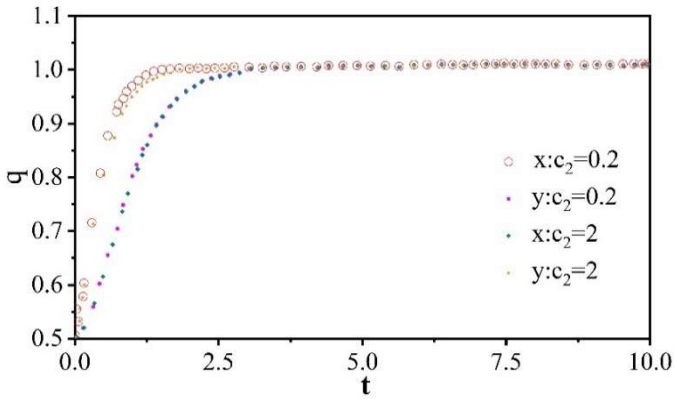

Figure 6: The influence of c_2 on the final evolutionary result

III. B. Empirical analysis of capital structure

III. B. 1) Sample Selection

First, this paper selects the enterprises with the ESG ratings of the Business Way Unity Green from 2018 to 2023 as the initial sample (the paper also uses the financial data of the enterprises in 2017 because the financial data of the lagged period needs to be used in the empirical process). Second, the final sample of this paper is screened according to the following guidelines:(1) Excluding financial enterprises. (2) Excluding enterprises with abnormal gearing ratios, such as gearing ratios greater than 1 or less than 0. (3) Excluding samples of enterprises with ST or ST* situations in the reporting period. (4) Samples with serious missing core data are excluded. After screening, a sample of 217 enterprises for the six-year period 2018-2023 is finally selected as the observation sample, with a sample capacity of 1,352. In addition, we fill in the very few missing values of certain variables with the arithmetic mean of the same enterprise at different times, and we replace all continuous variables with 5 percent of the top and bottom of the shrinking tail to ensure that the empirical results are more accurate.

III. B. 2) Data sources

The data on the ESG ratings of companies' business paths rung green and the average capital structure of the industry were obtained from the wind financial database, and all other data such as gearing ratio and total assets were obtained from the csmar database.

III. B. 3) Descriptive statistical analysis

With the help of statistical analysis software, the data of the research variables were analyzed with descriptive statistics, and the results of the descriptive statistical analysis are shown in Table 2. As can be seen in Table 2, first, the mean value of the ESG score of the sample is 3.63, which indicates that the ESG ratings of the sample are basically distributed around 3. Moreover, the minimum and maximum values are 0.5 and 5, respectively, which indicates that the lowest ESG rating of the sample is poor and the highest is good. Second, the mean values of Lev and $Lev_{i,t}^{*}$ are both greater than 0, and their values are 4.4851 and 4.2279, respectively, indicating that the magnitude of capital structure is high in relation to the target capital structure, and that there is a large discrepancy between the maximum and the minimum of the two values. Thirdly, the mean values of the degree of deviation from target and the actual degree of deviation are 1.6411 and 2.0513, which indicate that the sample as a whole has a low value of the degree of deviation from target and the actual degree of deviation, but there is a large gap between the minimum value of 0.5 and the maximum value of 5.

III. B. 4) Correlation analysis

With the help of Pearson's correlation coefficient, the correlation test of the research variables set above is conducted, and the results of the correlation test are shown in Table 3, where the N, PC, and Sig values denote the sample size, Pearson's correlation coefficient, and significance values, respectively. Based on the data performance in the table, it can be seen that the explanatory variables, mediator variables and explained variables have

significant correlation (P<0.05), which indicates that the research variables set up in this paper meet the requirements of the study, and can be further carried out in the subsequent study.

Table 2: Descriptive statistical analysis results

Variable	N	Mean	Std.Dev.	Min	Max
Lev	1352	4.4851	0.4655	0.5	5
$Lev_{i,t}^{*}$	1352	4.2279	0.1184	0.5	5
TdLev	1352	1.6411	0.3506	0.5	5
dLev	1352	2.0513	0.3799	0.5	5
ESG	1352	3.6395	0.4154	0.5	5
SA	1352	3.2377	0.1604	0.5	5
AC	1352	0.9502	0.4668	0.5	5
Size	1352	2.8293	0.1661	0.5	5
Profit	1352	3.8906	0.1405	0.5	5
Growth	1352	1.5597	0.4147	0.5	5
Dep	1352	1.5881	0.3463	0.5	5
Mortgage	1352	2.3519	0.4995	0.5	5
IndLev	1352	3.045	0.4436	0.5	5

III. B. 5) Regression analysis

After passing the correlation test of the research variables, the regression analysis of capital structure under ESG rating constraints was conducted using the model above and the results of the regression analysis are shown in Table 4. The regression coefficients of the research variables are all significantly positively correlated at the 0.05 level, for example, for every 1 unit increase in the ESG rating constraint of the enterprise, the overall capital structure increases by 0.312 units, demonstrating the changing law of capital structure under ESG rating constraints.

IV. Capital Structure Optimization Path

Based on the results of empirical analysis of capital structure under ESG evaluation constraints, this chapter will propose the optimization path of capital structure under ESG evaluation constraints from the two aspects of innovative financing methods and improving the quality of information disclosure. The details are shown as follows:

IV. A. Innovative financing

Financing innovation is a key way for modern enterprises to enhance the efficiency of capital operation and solve the problem of capital shortage. Enterprises can broaden their financing channels by virtue of direct financing methods centered on equity financing and bond financing. Equity financing can directly enhance the capital strength of enterprises, but may dilute the shares of existing shareholders. Bond financing, on the other hand, is a non-dilutive financing method that raises funds without affecting shareholders' rights and interests, and is therefore favored by many enterprises. The implementation of supply chain finance provides an effective way of financing for enterprises. By revitalizing current assets such as accounts receivable and inventory, enterprises are able to optimize the asset structure and enhance capital liquidity. Using this approach, enterprises can convert part of their current assets into capital, further reducing short-term capital pressure. Asset securitization, as an innovative financing method, enables enterprises to package high-quality operating assets or stable cash flow income rights into securities and launch financing in the capital market, which can provide enterprises with a long-term and stable source of funds and reduce the pressure of capital turnover. Financial leasing, especially the sale-and-leaseback model, is also an important means to revitalize fixed assets. Enterprises can sell and lease back existing fixed assets to release funds for other investments or business expansion. Internet financial platforms and crowdfunding financing have broadened financing channels for enterprises, and through online platforms, enterprises can raise funds directly for a wide range of investors. Strategic partnerships with venture capital organizations and industrial funds can also bring more financial support to enterprises and further promote their strategic development. Therefore, enterprises need to build a diversified and three-dimensional financing system to ensure that they can meet the financial needs of different stages of development and provide a strong guarantee for the long-term development of enterprises.

Table 3: Correlation analysis

Variable		Lev	$Lev^*_{i,t}$	TdLev	dLev	ESG	SA	AC	Size	Profit	Growth	Dep	Mortgage	IndLev
Lev	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	1	0.242	0.169	0.326	0.395	0.269	0.292	0.132	0.271	0.265	0.275	0.35	0.312
	Sig		0.018	0.024	0.035	0.031	0.024	0.022	0.018	0.001	0.029	0.028	0.019	0.038
$Lev^*_{i,t}$	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.242	1	0.44	0.154	0.225	0.305	0.465	0.443	0.33	0.422	0.493	0.141	0.248
	Sig	0.018		0.036	0.04	0.035	0.03	0.006	0.015	0.032	0.038	0.011	0.018	0.03
TdLev	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.169	0.44	1	0.423	0.491	0.451	0.257	0.185	0.385	0.456	0.244	0.337	0.298
	Sig	0.024	0.036		0.014	0.027	0.039	0.03	0.017	0.035	0.02	0.005	0.022	0.022
dLev	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.326	0.154	0.423	1	0.1	0.388	0.171	0.387	0.493	0.394	0.18	0.446	0.373
	Sig	0.035	0.04	0.014		0.016	0.033	0.033	0.031	0.001	0.014	0.039	0.002	0.019
ESG	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.395	0.225	0.491	0.1	1	0.366	0.104	0.232	0.323	0.28	0.105	0.155	0.254
	Sig	0.031	0.035	0.027	0.016		0.018	0.007	0.014	0.029	0.037	0.037	0.038	0.035
SA	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.269	0.305	0.451	0.388	0.366	1	0.231	0.365	0.378	0.459	0.486	0.339	0.479
	Sig	0.024	0.03	0.039	0.033	0.018		0.027	0.033	0.016	0.004	0.006	0.006	0.023
AC	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.292	0.465	0.257	0.171	0.104	0.231	1	0.359	0.273	0.445	0.351	0.388	0.315
	Sig	0.022	0.006	0.03	0.033	0.007	0.027		0.018	0.029	0.027	0.002	0.025	0.012
Size	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.132	0.443	0.185	0.387	0.232	0.365	0.359	1	0.242	0.37	0.461	0.286	0.204
	Sig	0.018	0.015	0.017	0.031	0.014	0.033	0.018		0.024	0.031	0.012	0.002	0.015
Profit	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.271	0.33	0.385	0.493	0.323	0.378	0.273	0.242	1	0.252	0.23	0.439	0.274
	Sig	0.001	0.032	0.035	0.001	0.029	0.016	0.029	0.024		0.031	0.029	0.001	0.006
Growth	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.265	0.422	0.456	0.394	0.28	0.459	0.445	0.37	0.252	1	0.394	0.31	0.128
	Sig	0.029	0.038	0.02	0.014	0.037	0.004	0.027	0.031	0.031		0.02	0.036	0.017
Dep	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.275	0.493	0.244	0.18	0.105	0.486	0.351	0.461	0.23	0.394	1	0.387	0.467
	Sig	0.028	0.011	0.005	0.039	0.037	0.006	0.002	0.012	0.029	0.02		0.003	0.039
Mortgage	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.35	0.141	0.337	0.446	0.155	0.339	0.388	0.286	0.439	0.31	0.387	1	0.27
	Sig	0.019	0.018	0.022	0.002	0.038	0.006	0.025	0.002	0.001	0.036	0.003		0.03
IndLev	N	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352	1352
	PC	0.312	0.248	0.298	0.373	0.254	0.479	0.315	0.204	0.274	0.128	0.213	0.27	1
	Sig	0.038	0.03	0.022	0.019	0.035	0.023	0.012	0.015	0.006	0.017	0.039	0.03	

Table 4: Regression analysis results

Variable	N	Coefficient	Standard deviation	T-Value	P-Value
Constant term	1352	0.125	0.019	1.074	0.004
Lev	1352	0.432	0.019	1.467	0.014
$Lev^*_{i,t}$	1352	0.421	0.025	1.06	0.025
TdLev	1352	0.318	0.013	2.156	0.041
dLev	1352	0.483	0.023	2.094	0.024
ESG	1352	0.312	0.016	1.499	0.036
SA	1352	0.153	0.029	2.411	0.038

AC	1352	0.203	0.023	2.176	0.02
Size	1352	0.302	0.023	2.479	0.012
Profit	1352	0.309	0.024	2.83	0.013
Growth	1352	0.115	0.023	1.993	0.013
Dep	1352	0.451	0.026	1.483	0.024
Mortgage	1352	0.402	0.019	1.966	0.024
IndLev	1352	0.297	0.028	2.706	0.023

IV. B. Improving the quality of information disclosure

Enhancing the quality of information disclosure is critical to improving corporate transparency and market trust. Enterprises should adopt standardized templates for disclosure standards to ensure the completeness, accuracy and comparability of financial information. Information asymmetry may lead the market to misunderstand enterprises, thus affecting investors' decisions. Establish a regularized quarterly information disclosure mechanism to release the financial and operational status of enterprises on a regular basis, and increase the frequency of information disclosure to ensure that external stakeholders can keep abreast of the latest developments of enterprises. For the occurrence of major events, enterprises should disclose relevant information in a timely and accurate manner, make clear its impact on the operation of the enterprise and its countermeasures, help investors make reasonable decisions and enhance investor confidence. By applying big data technology, enterprises can build an advanced information disclosure platform, realize automatic collection, intelligent processing and systematic release of information, and thus enhance the timeliness and accuracy of information. Enterprises can link the quality of information disclosure with the performance appraisal of management, prompting management to pay more attention to the standardization and transparency of information disclosure. Regularly organizing professional training related to information disclosure and enhancing the business level of relevant personnel are also effective means to improve the quality of information disclosure. Enterprises should take the initiative to accept social supervision and introduce third-party professional organizations to conduct independent assessment to ensure the authenticity and accuracy of disclosure information, enhance investors' trust in the enterprise, and create a good external financing environment.

V. Conclusion

The results of the study show that corporate ESG performance has a significant impact on the adjustment of capital structure, especially in the framework of green investment and financing decision-making, the speed of capital structure adjustment significantly increases by 0.312 units for every 1 unit increase in corporate ESG performance. In addition, financing constraints and agency costs play a mediating role in the impact of ESG performance on capital structure adjustment, further revealing the complex relationship between green finance and corporate capital structure.

Specifically, financing constraints are measured by the SA index, and the greater the financing constraints of a firm, the less flexible its capital structure adjustment, while agency costs are measured by the management expense ratio, and the higher the management expense ratio, the greater the agency costs, which adversely affects the optimization of the firm's capital structure. Through empirical analysis, this paper also finds that under lower green investment and financing costs, firms are more inclined to take green investment and financing decisions to achieve better ESG ratings and capital structure adjustment.

Based on these findings, this paper suggests that enterprises should focus on the improvement of ESG performance when optimizing their capital structure and adopt two paths, namely, innovative financing methods and improving the quality of information disclosure, in order to promote the optimization of capital structure and the development of green economy. These initiatives will provide enterprises with stronger capital support and help them gain an advantage in the competition of green investment and financing.

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