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Article

ESG performance, biomechanical technologies on sustainable growth of sports firms

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Abstract: In today's complex and volatile world economic situation, extending the life cycle of sports enterprises and maintaining sustainable growth is a top priority for enterprise development. Under the background of advocating high-quality development, sports enterprises practicing ESG development concept can help realize sustainable growth. This paper empirically examines the impact of ESG performance on the sustainable growth rate of sports enterprises through the panel data of A-share sports listed companies in 2018–2022, and finds that good ESG performance can significantly enhance the sustainable growth rate of sports enterprises, and the enterprise's R&D investment in biomechanical technology has a certain promotion effect on the relationship between the impact of ESG performance and the sustainable growth rate of sports enterprises by grouping the enterprise group regression according to industry and property rights to further derive the results of heterogeneity analysis. The results found that ESG performance has a significant positive impact on the sustainable growth rate of both sporting goods enterprises and non-state-owned enterprises. Therefore, this paper concludes that sports enterprises should actively practice the ESG development concept to ensure sustainable growth, extend the enterprise life cycle, promote the high-quality development of the sports industry, and form a virtuous cycle of economic development.

Keywords: ESG performance; sports enterprises; sustainable growth; biomechanical technologies

1. Introduction

1.1. Research background

In today's society, corporate social responsibility and environmental impact are increasingly in the public eye. ESG, or Environmental, Social and Governance, is a three-dimensional approach to corporate performance that is closely linked to long-term sound development and sustainable prospects. Globally, as climate change intensifies and resources become more scarce, corporations are being given more social responsibilities, covering key areas such as environmental protection and maintaining social stability. At the same time, environmental, social, and corporate governance factors have a profound impact on corporate reputation, brand image, and investor trust, and are of great significance to a company's financial performance and long-term development.

Taking sports companies as an example, biomechanics plays a unique and critical role. For sports equipment design companies, a good ESG performance can encourage them to invest more in biomechanics research. With in-depth biomechanical research,

companies can accurately understand the human body's movement patterns and design equipment that performs better and better meets the needs of athletes. This not only helps to improve athletes' performance but also further enhances the competitiveness and brand value of enterprises in the market. For example, Schuhua Sports, as a sports equipment manufacturer, incorporates biomechanical performance indicators into its production standards, strictly controls product quality, and demonstrates good governance. In the production process, it adopts energy-saving and emission reduction technologies to reduce energy consumption and pollutant emissions and actively fulfills the ESG concept. These initiatives have enabled the company to stand out in the market, improve customer satisfaction, and gradually expand its market share.

From the perspective of sustainable development, ESG's philosophy is highly compatible with the long-term benefits of biomechanics in the field of sports and health. Optimizing sports training programs through biomechanical research can effectively reduce the risk of sports injuries and prolong athletes' sporting careers. This is not only in the long-term interest of the individual athlete, but from a corporate perspective, it also complements the company's goal of pursuing sustainable development. This will benefit the long-term development of the business. At the same time, corporate ESG development also helps to improve employee job satisfaction and loyalty, attract and retain excellent talents, and build a solid talent base for the long-term development of the enterprise [1]. For example, the development of biomechanical tools that can accurately assess the exercise load and help athletes rationally plan their training programs not only helps to improve the overall quality of athletes but also ensures that the long-term investment made by companies in athlete training and event operation will yield stable returns. This study not only provides operational guidance for the actual operation of sports enterprises but also provides practical guidance for future research on how to better integrate ESG concepts into the development strategy of sports enterprises, which will lead to subsequent research on the combination of theory and practice and promote the continuous innovation and development of sports enterprises on the road of ESG and biomechanics integration [2].

To sum up, enterprises have gradually realized the importance of ESG development for their sustainable development and have actively taken relevant measures to improve their ESG performance in order to achieve the organic unity of economic benefits, social benefits, and environmental benefits. At a time when all industries are accelerating towards a sustainable development model, it has become a realistic and inevitable trend for enterprises to engage in ESG construction in line with the trend of the times.

1.2. Academic review

While the research on the ESG indicator system in China started relatively late, this research has still provided many valuable findings and insights. The economic benefits generated by the promotion of ESG rating systems and the impact on enterprises. Most scholars support the positive impact of ESG performance on enterprises. Hu et al. [3] and other scholars believe that promoting the implementation of the ESG system concept by enterprises is not only beneficial for the green

transformation and development of the enterprises themselves, but also conducive to promoting green and sustainable development of the whole society. In terms of the impact of ESG on corporate value, most research results also support a significant positive correlation between ESG performance and corporate value. Sun [4] and other scholars conducted a heterogeneity analysis of ESG and corporate value, believing that there is a threshold effect in the impact mechanism of ESG under different company sizes and policy backgrounds. A review of existing literature reveals that the current research on how ESG performance enhances corporate value transmission is not yet sufficient. Based on the perspective of sports enterprises, research on the ESG indicator system is scarce. The research related to ESG performance and sports enterprises has only 10 documents in the China Knowledge Network literature database, and the research that combines ESG performance, biotechnology research, and sports enterprise development has not found the same research direction in the literature database. Therefore, this study fills the existing research gap. The study is highly innovative and necessary.

Therefore, the main research direction of this paper is the relationship between ESG performance of sports enterprises and the value of sports enterprises, as well as the role of innovation in ESG performance and the value of sports enterprises. Attempting to answer the following questions: (1) Can good ESG performance of sports enterprises significantly enhance the value of sports enterprises? (2) Can good ESG performance of sports enterprises enhance the company's innovation capabilities? (3) Is the good ESG performance of sports enterprises enhancing the value of sports enterprises by improving the company's innovation capabilities?

2. Theoretical analysis and research hypotheses

2.1. Theoretical analysis

Currently, ESG is highly compatible with the new development concept and is ushering in a major strategic opportunity. Promoting the construction of China's ESG system and enhancing the ESG practices and performance of Chinese enterprises is an important practice to fully implement the new development concept accurately and comprehensively, promote high-quality development, and help the construction of a Chinese-style modernization. The ESG concept and rating system is the first evaluation system that combines social responsibility [5], corporate governance, and environmental protection. It aims to help investors understand the impact of environmental, social, and governance factors on the development and investment value of companies.

Firstly, the environmental (E) dimension is intrinsically linked to the sustainable development of sports companies in the following ways: (1) Enterprise risk management perspective: sports enterprises (e.g., stadium operations, event organizations, etc.) often face environmental risks, such as energy consumption, carbon emissions, and waste management. By implementing environmentally friendly practices (e.g., using renewable energy, reducing plastic use, optimizing water management), companies can reduce the risk of environmental violations, potential fines and litigation costs, and thus improve financial performance; (2) brand building perspective: Through environmental responsibility practices (e.g., carbon-neutral

tournaments, green stadium construction), sports companies can create a green brand image and attract environmentally conscious consumers and sponsors, thus enhancing brand value and market competitiveness and gaining more attention; as consumers pay more attention to environmental protection, sports companies can enhance consumer loyalty by demonstrating their environmental responsibility (e.g., promoting environmentally friendly products, reducing the carbon footprint of tournaments). footprint), they can enhance consumer loyalty and expand market share; (3) resource acquisition perspective: Sports companies with excellent environmental performance are more likely to obtain financing tools such as green bonds and sustainable development loans, which reduces financing costs. The government usually provides policy support (e.g., tax incentives, subsidies) to companies with good environmental performance, which helps sports companies reduce operating costs and enhance financial performance; (4) long-term development perspective: Through environmental technology innovation (e.g., energy-saving equipment, intelligent venue management), sports companies can reduce long-term operating costs, improve resource utilization efficiency, and achieve sustainable development. Sports companies that lead in environmental responsibility can set industry benchmarks and drive the entire industry to green transformation, thus gaining a long-term competitive advantage.

Secondly, the intrinsic connection between the social (S) dimension and the sustainable development of sports enterprises includes the following aspects: (1) Enterprise risk management perspective: The social risks faced by sports enterprises include insufficient employee welfare, community conflicts, and consumer rights disputes. By fulfilling their social responsibilities (e.g., providing fair remuneration, protecting employee rights and interests, and participating in community building), companies can reduce social risks and avoid reputation loss and legal disputes. By promoting diversity management (e.g., gender equality, racial inclusion), sports enterprises can reduce internal conflicts, enhance team cohesion, and lower management costs; (2) branding perspective: By practicing social welfare (e.g., supporting disadvantaged groups and promoting physical education), sports enterprises can build a responsible corporate image and enhance the trust of consumers and investors. By supporting social welfare practices (e.g., charity events, community activities), sports enterprises can enhance consumers' emotional identity and brand loyalty; (3) resource acquisition perspective: By actively participating in community building and public welfare, sports enterprises can accumulate social capital, gain support from the government, community and the public, and reduce operational resistance. By fulfilling their social responsibility, sports enterprises are more likely to attract and retain excellent talents and reduce recruitment and training costs; (4) long-term development perspective: By fulfilling social responsibility in the long term, sports enterprises can enhance their social influence and gain more cooperation opportunities and policy support. By promoting sports culture and values, sports enterprises can promote the healthy development of society and realize long-term sustainable development.

Thirdly, the intrinsic connection between the governance (G) dimension and the sustainable development of sports enterprises includes the following aspects: (1) Enterprise risk management perspective: governance risks faced by sports enterprises

include corruption, management decision-making errors, and opaque information disclosure. By improving the governance structure (e.g., independent board of directors, transparent decision-making mechanism), enterprises can reduce governance risks and improve operational efficiency. Good governance practices (e.g., anti-corruption policies, compliance audits) can help companies comply with laws and regulations and reduce legal risks; (2) brand building perspective: Trust and Reputation: Transparent and efficient governance structure can enhance the trust of investors and consumers and improve corporate reputation. Sports enterprises with good governance performance are more likely to establish long-term and stable cooperative relationships with partners and reduce transaction costs; (3) resource acquisition perspective: Good governance practices can enhance investor confidence, reduce financing costs and attract more capital. Enterprises with excellent governance performance are more likely to gain government support and industry recognition and gain government support; (4) long-term development perspective: By improving the governance structure, sports enterprises can ensure the long-term stability of their strategies and avoid strategic fluctuations caused by management changes. A good governance structure can promote the enhancement of the enterprise's innovation ability and promote long-term sustainable development.

On 2 February 2021, China issued the "Guiding Opinions of the State Council on Accelerating the Establishment of a Sound Green, Low-Carbon, and Circular Development Economic System", which stated, "We must resolutely implement the new development concept, coordinate the promotion of high-quality development and high-level protection, establish a sound green, low-carbon, and circular development economic system, ensure the achievement of peak carbon emissions and carbon neutrality goals, and promote China's green development to a new level" [6]. In this dual-carbon context, the attention to ESG is further heightened. From a practical perspective, sports enterprises can use the results of ESG performance to explore problems and operational risks in their past development management, analyze the weak links in corporate management, and formulate targeted and effective measures based on this analysis to optimize and improve business operations, provide sustained power support for the company's development, and ensure sustainable growth. In conclusion, the ESG evaluation system is a specific practice of the sustainable development concept for sports enterprises. If sports enterprises can adjust their development strategies in a timely manner according to ESG performance and move towards the path of green environmental protection and sustainable development, these enterprises will be able to extend the company's lifecycle and promote the sustainable growth of sports enterprises.

2.2. Research hypotheses

With the continuous development of the economy and society, accompanied by the increasing uncertainty of the external economic environment and the intensifying market competition trend, the sustainable growth of enterprises has become the focus of enterprise management. The concept of enterprise sustainable growth rate was first proposed by Robert C. Higgins in 1977. He defined the sustainable growth rate (SGR) as "the maximum rate at which a company's sales can grow without depleting financial

resources." His research perspective starts from a static perspective, assuming that various financial indicators of the enterprise, such as capital structure, profitability [7], operational capabilities, shareholder equity, etc., remain unchanged, and the company can achieve the maximum growth rate under fixed operating efficiency and financial policies. Therefore, Higgins' sustainable growth model is established under the assumption that the enterprise's capital structure, net profit margin, asset turnover ratio, equity multiplier, etc., remain unchanged. The model is: SGR = Net profit margin × Asset turnover ratio × Equity multiplier × Retention rate [8]. This model addresses the main financial factors that constrain and influence enterprise growth, and it is simple and easy to understand, with a certain applicability to mature large enterprises in the market. However, the model has a significant flaw—the economic market and enterprise operations in reality are constantly changing, and the static model's overly idealized assumptions are not applicable to practical environments. Van Horne further improved and supplemented the Higgins model. He believed that the "maximum growth rate of enterprise sales revenue determined by target operating ratios, debt, and dividend payout ratios" is the sustainable growth rate of the enterprise [9]. To meet the calculation needs of various development situations of different enterprises, Van Horne divided the sustainable growth model into static and dynamic models. The dynamic model studies enterprise growth issues from a dynamic perspective, which is more in line with the actual operating environment and, under certain conditions, overcomes the limitations of the Higgins model.

Currently, domestic and foreign scholars have conducted relatively mature research on the sustainable growth rate of enterprises. Most scholars believe that the sustainable growth rate is crucial for a company's growth and is an important indicator to determine the stage of a company in its lifecycle [10]. Management should formulate reasonable financial management policies and corporate development strategies based on the calculation results of this indicator, combined with the current development situation and circumstances of the enterprise. Sustainable growth is the key to enabling companies to have long-term vitality [11]. Companies should consider sustainable growth as a business philosophy [12], and view the theory of sustainable growth as a theoretical support for strategic transformation analysis. The goal of strategic transformation is to achieve sustainable growth for the company, and the grasp of transformation time and the allocation of company resources determine whether the strategic transformation can be successful [13]. After reviewing and commenting on existing models of sustainable growth for enterprises, domestic scholars are exploring how to construct sustainable growth models applicable to Chinese enterprises [14]. Fan and Guo [15] specifically analyzed two sustainable growth models by Robert. Higgins and Van Horne, believing that these two models are the most representative research in the financial field, and subsequent research results are mostly extensions based on this foundation. Research on the ESG indicator system started relatively late in China. Most of the current research results indicate that ESG performance can have a positive impact on enterprises. Practicing the ESG system concept is not only beneficial for the company's own green transformation and green development but also conducive to promoting the overall green sustainable development of society [3]. Empirical research on ESG performance and corporate value shows that ESG has a significant promoting effect [16]. However, some studies

suggest that a company's ESG score is directly proportional to its enterprise value, but the results may be constrained by financing constraints [17]. In addition, some opinions believe that there is a threshold effect in the impact mechanism of ESG on companies, mainly due to differences in company size and policy backgrounds [4]. Further review of existing literature reveals that there are very few studies on the ESG indicator system from the perspective of sports enterprises. As for the research topic of how ESG performance affects the sustainable growth rate of enterprises, no academic research results have been found so far. In conclusion, this article believes that conducting research on the relationship between ESG performance and the sustainable growth rate of enterprises is somewhat innovative, and the research results have practical significance for the growth of sports enterprises and the development of the sports industry. Based on this, the article proposes the following research hypothesis: H1: Good ESG performance in sports enterprises can have a positive impact on the sustainable growth rate of sports enterprises.

Sports enterprises can be categorized into sports manufacturing and sports services according to industrial categories, and their production methods, products and service objects are different. The production methods of the sports service industry are generally characterized by low pollution and high-quality development. While the production method of the sports manufacturing industry is more traditional, the implementation of ESG concept will change more enterprise development modes. Therefore, the implementation of ESG concepts in sports manufacturing enterprises will better improve corporate reputation, obtain more government support, expand the market, enhance long-term competitiveness, and improve the sustainable growth rate of sports enterprises to produce more significant positive impacts. H2: The ESG performance of sports manufacturing firms has a more significant positive impact on the sustainable growth rate of sports firms than the ESG performance of sports service firms.

By dividing sports enterprises into state-owned and non-state-owned based on ownership, state-owned enterprises have characteristics of serving national policies. Compared to non-state-owned enterprises, they bear more social responsibilities and fulfill more responsibilities. Their positive image is more easily recognized by the public, thus establishing a good corporate image and more efficiently conveying the message of honest operation and responsibility. Therefore, state-owned enterprises are more likely to obtain financing in the capital market, and thus the impact of improving ESG performance on the sustainable growth rate of enterprises is slightly higher for state-owned enterprises than non-state-owned enterprises. Hence, the following hypothesis is proposed: H3: The ESG performance of state-owned sports firms has a more significant positive impact on the sustainable growth rate of sports firms than the ESG performance of non-state-owned sports firms.

3. Materials and methods

3.1. Sample

This paper analyzes the relevant data of A-share sports listed companies from 2018 to 2022 as the research sample, empirically investigates the impact of ESG performance of sports enterprises in these 5 years on the sustainable growth of the

enterprise. Before conducting empirical research, the following data preprocessing was carried out: (1) Screening research samples. The "Industry Classification Guidelines for Listed Companies" issued by the China Securities Regulatory Commission (revised in 2012) determines the industry classification principles of listed companies: When the proportion of operating income of a certain type of business of a listed company is greater than or equal to 50%, it will be classified into the industry corresponding to that business; when a listed company does not have a type of business with an operating income proportion greater than or equal to 50%, but a certain type of business has the highest income and profit among all businesses, and both account for 30% or more of the total income and total profit of the company (including this number), then the company belongs to the industry category corresponding to that business. According to this principle, this paper reviewed the main business of listed companies to determine whether they belong to the "Sports Industry Classification (2019)" (National Bureau of Statistics Order No. 26), and based on this, 124 sports listed companies were selected. (2) Excluding samples with missing variables. In 2018–2022 some companies delisted some companies did not participate in the evaluation of ESG, and companies that do not disclose ESG data will not be the object of research in this paper. For the above reasons, this paper selects 79 sports companies as the research sample. The data of listed companies involved in this paper are from the Wind Energy Information Financial Database, and the data processing uses Stata17 software.

In this paper, we will establish a regression model to analyze the problem, which has the advantages of strong interpretability, high predictive ability and flexibility, and can quantify the relationship between variables and provide reliable prediction results; its role is to explore the relationship between variables, predict future trends, optimize decision-making, and is widely used in the analysis of data and decision-making analysis in the fields of economy, medicine, engineering and so on.

3.2. Variable selection and definition

3.2.1. Explanation of variables

The formulation of ESG rating indicators in the Wind database conforms to the international ESG disclosure and management framework, aligns with the characteristics of Chinese enterprises, and the effectiveness and data availability of the indicators can reflect industry ESG characteristics. Referring to the research of Wang and Peng [18], this paper selects the ESG performance of sports enterprises (represented by ESG) as the explanatory variable. The ESG comprehensive score consists of the ESG core assessment model, the environmental risk assessment model, and the dispute event assessment model, starting from the three dimensions of social, environmental, and governance of enterprises and weighting the scores of the three dimensions to obtain the total score to comprehensively reflect the level of ESG management practices and significant sudden risk factors of enterprises.

3.2.2. Dependent variable

This paper takes sustainable growth of sports enterprises (represented by SGR) as the dependent variable. Referring to the research of Han and Gan [19], Ding and Lu [20], and other scholars, combined with the characteristics of financial indicators of

A-share listed companies, this paper uses the static model of the Van Horne sustainable growth model to calculate the sustainable growth rate (SGR) of sports enterprises.

3.2.3. Control variables

Referring to the studies of Zhou et al. [21–24] and others, this article selects the biomechanical performance R&D investment (BI) of the firm's products as the control variable. In this case, the R&D investment in biomechanical properties of enterprise products (BI) is the biomechanical R&D investment in biomechanics of sports products produced by the enterprise published in the annual report of the enterprise, which is used to measure the level of biomechanical applications of the enterprise. In addition, considering the impact of individual effects and time effects on the regression results of the model, this article further sets two indicators, ID and Year, to control for the individual and time effects of different years of enterprises. The definitions of the relevant variables are shown in **Table 1**.

Table 1. Description of main variables.

Variable type	Variable name	Variable symbol	Variable definition
Explanatory variables	ESG performance of sports enterprises	ESG	Environmental score × 0.4 + Social score × 0.4 + Corporate governance score × 0.2
Dependent Variable	Sustainable growth of sports enterprises	SGR	Net sales rate * Earnings retention rate * (1 + equity ratio)/[1/Total asset turnover − Net sales rate * Earnings retention rate * 1 + equity ratio]
Control variables	Research and development investment in biomechanical performance of enterprise products	BI	The sports products produced by the enterprise and the investment in biomechanical research and development disclosed in the annual report of the enterprise

3.2.4. Model setting

To verify whether the ESG performance of sports enterprises can promote the increase of the sustainable growth rate of sports enterprises, this paper sets the following benchmark regression model:

$$SGR_{it} = \alpha_0 + \alpha_1 \times ESG_{it} + \alpha_2 \times Control_{it} + \sum ID + \sum Year + \varepsilon_{it} \quad (1)$$

where the subscripts *i* and *t* represent the company and year, SGRit is the sustainable growth rate of company *i* in period *t*; ESGit represents the ESG performance of company *i* in period *t*; Controlit represents the set of 5 control variables; ∑ID and ∑Year represent individual fixed effects and time fixed effects, and ε represents the random error term.

4. Results

4.1. Descriptive statistics

Table 2 shows the descriptive statistics of the main variables. The average Sustainable Growth Rate (SGR) of sports enterprises is 0.0676, with a standard deviation of 0.12, a minimum value of −0.273, and a maximum value of 0.987. This indicates an uneven distribution of sustainable growth rates among sports enterprises in the sample, with some having very high rates while others have lower rates or even negative growth trends, highlighting significant disparities in the development of

different sports companies. The average Environmental, Social, and Governance (ESG) performance of sports enterprises is 5.71, with a standard deviation of 1.53, a minimum value of 0, and a maximum value of 8.27. This suggests a significant disparity in ESG practices among sample enterprises, with some companies possibly not giving enough attention to ESG performance or still being in the early stages of ESG indicator implementation, resulting in very low ESG scores. Therefore, further efforts are needed to strengthen the implementation and promotion of ESG principles in sports enterprises. The statistics, such as the minimum value of −1.346, the maximum value of 2.231, the mean value of 1.138, and the standard deviation of 0.630 of the research and development investment (BI) of the biomechanical properties of the enterprises' sports products, also reflect the uneven level of biomechanical applications of the enterprises.

Table 2. Descriptive statistics.

	(1)	(2)	(3)	(4)	(5)
variable	**sample number**	**average**	**standard deviation**	**minimum value**	**maximal value**
SGR	395	0.0676	0.120	−0.273	0.987
ESG	395	5.714	1.532	0	8.270
BI	395	1.138	0.630	−1.346	2.231

4.2. Correlation analysis

In this study, the Pearson correlation coefficient is used to analyze the correlation between variables, and the analysis results are shown in **Table 3**. The analysis results show that there is a strong correlation between the explanatory variable enterprise sustainable growth rate (SGR) and the explanatory variable ESG at the 5% level, and there is also a certain correlation between R&D investment in biomechanical properties of enterprise products (BI) and the performance of enterprise sustainable growth rate (SGR) and ESG, which preliminarily suggests that biomechanical factors may play a role in it. And there is no serious covariance problem among the control variables, and the model is less likely to be disturbed by covariance.

Table 3. Correlation analysis.

Variable	SGR	ESG	BI
SGR	1		
ESG	0.12**	1	
BI	0.24***	0.05*	1

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

4.3. Benchmark regression analysis

In order to test the impact of the ESG performance of sports enterprises on the sustainable growth of sports enterprises, this paper adopts a two-way fixed effects model and conducts empirical analysis on the basis of controlling individual effects and year effects. Due to the different scales of the explanatory variables, the explained variables, and the control variables, the data samples are standardized before the regression analysis in order to eliminate the differentiation problem caused by the

different scales of the sample data. In this paper, we first do the baseline regression analysis on the model data, and the regression results are shown in **Table 4**.

Table 4. Benchmark regression results.

Variable	(1)	(2)
	SGR	SGR
ESG	0.005**	0.005***
	(2.32)	(7.45)
BI		0.015***
		(5.62)
Constant	−0.059	0.062***
Individual fixation	YES	YES
Fixed year	YES	YES
N	395	395
R^2	0.118	0.012
F	9.784	55.443

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

According to the regression results, the regression coefficients of the explanatory variables ESG are significantly positively correlated at the 5% level, controlling for time effects and individual effects, which verifies Hypothesis H1, which states that the sustainable growth rate (SGR) of sports companies will increase when the ESG performance of sports companies improves. At the same time, the R&D investment in the biomechanics of enterprise products (BI) also has a significant effect on SGR, and then after adding the control variable BI, the explanatory variable ESG is significantly and positively correlated with the explanatory variable (SGR) at the 1% level, and the correlation between the two is improved, and the coefficient of BI is at the level of positivity, suggesting that the improvement of biomechanics application has favored or constrained the enterprise's sustainable growth to a certain degree, which further highlights the importance of biomechanics in sports business development.

4.4. Heterogeneity analysis

In this paper, based on the baseline regression analysis, a heterogeneity analysis is conducted on the study sample in order to further analyze the impact of ESG performance on the sustainable growth rate of sports firms. Heterogeneity analysis, as a research method, is mainly used to explore the difference or diversity among members within a group. The results of heterogeneity regression are mainly used for comparative analysis after grouping the samples and do not affect the regression results of the benchmark regression.

First of all, the 79 sports enterprises in the data sample of this paper are divided by enterprise industry category and enterprise property right category, respectively, i.e., two industry categories, 47 sports product enterprises and 32 sports service enterprises; two property right categories, 21 sports state-owned enterprises and 58 sports non-state-owned enterprises. Then, group regressions are conducted to analyze the differences in the impact of ESG performance on the sustainable growth rate of

sports enterprises with different industry attributes and different ownership categories and to test the hypotheses H2 and H3 of this paper, and the regression results are shown in **Tables 5** and **6**.

Table 5. Heterogeneity results of industrial classification.

Variable	(1) sporting goods	(2) Sports service
	SGR	SGR
ESG	0.005***	0.093
	(6.99)	(0.61)
Constant	0.061***	−0.093·
	(10.25)	(−0.34)
Industry	control	control
ID/YEAR	control	control
Control (BI)	control	control
N	235	160
R^2	0.01	0.00
F	48.866	0.377

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

Table 6. Heterogeneity results of property rights classification.

Variable	(1) state-owned enterprise	(2) Non-state-owned enterprises
	SGR	SGR
ESG	0.086	0.006***
	(0.87)	(8.07)
Constant	−0.113	0.073***
	(−0.65)	(10.92)
Industry	control	control
ID/YEAR	control	control
Control (BI)	control	control
N	105	290
R^2	0.009	0.023
F	0.764	65.123

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

The results of the heterogeneity analysis by industry classification show that ESG performance has a significant positive impact on the sustainable growth rate of sporting goods companies, while the impact is not significant for sports service companies, which verifies Hypothesis H2. In the heterogeneity analysis by ownership classification, the regression results comparing state-owned enterprises and non-state-owned enterprises further verify Hypothesis H3. It is worth noting that in the regressions of each subgroup, the ESG performance of the enterprises' products, biomechanical performance R&D inputs (BI), and the ESG performance of the enterprises' products and services have a significant impact on the growth rate of sports enterprises. It is worth noting that in the regressions of each group, the R&D investment in the biomechanical properties of enterprises' products (BI) also shows a

significant effect on the sustainable growth rate in some groups, and there are differences in the degree and direction of this effect in enterprises of different industrial and ownership categories, which further suggests that the relationship between biomechanical factors, ESG, and the sustainable growth of enterprises has complexity and uniqueness in different enterprise scenarios.

4.5. Endogeneity and robustness test

(1) Endogeneity: Considering the potential bidirectional causality between ESG scores and corporate sustainable development, the model may have endogeneity issues, leading to biases in the estimation of core explanatory variables in the model. Therefore, this study re-estimates the regression results of the impact of ESG on corporate sustainable development in sports enterprises using the two-stage least squares (2SLS) method. The endogeneity problem usually results from the fact that the explanatory variables are correlated with the error terms, which can bias the estimation results. The least squares method estimates the model parameters by minimizing the sum of squares of the residuals, which can effectively deal with and identify the endogeneity problem in the model. The results are shown in **Table 7**. The coefficient of the core explanatory variable ESG remains significantly positive, passing the significance test at the 1% confidence level. The signs of the coefficients of various control variables also remain consistent with the basic regression results, indicating that ESG scores in sports enterprises promote corporate sustainable development.

Table 7. Two-stage least squares method (2SLS) test result.

SGR	Coefficient of regression	Standard error	*T* value	*P* value	[95% Confidence interval]		Significance
ESG	0.005	0.002	3.15	0.002	0.002	0.008	***
BI	−0.016	0.004	−4.53	0	−0.023	−0.009	***
Constant	−0.039	0.064	−0.61	0.542	−0.163	0.086	
Mean dependent var		0.070	SD dependent var		0.129		
R-squared		0.134	Number of obs		316		
Chi-square		38.824	Prob > chi2		0.000		

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

(2) Robustness: This paper applies a 1% trimming process to the variables in the benchmark regression model to eliminate the impact of extreme observations on the empirical results. **Table 8** presents the regression results using this method. After applying the robustness test method mentioned above, the significance level of the explanatory variables changed from 5% to 1%, making the regression results more significant. The empirical results of other variables also remain consistent with the benchmark regression results, indicating the robustness of the empirical results in this paper.

Table 8. Inspection results of tailing treatment.

SGR	Coefficient of regression	Standard error	*T* value	*P* value	[95% Confidence interval]		Significance
ESG	0.005	0.001	5.350	0.000	0.003	0.007	***
BI	−0.017	0.003	−5.920	0.000	−0.023	−0.011	***
Constant	−0.080	0.055	−1.470	0.143	−0.187	0.027	
Mean dependent var		0.068	SD dependent var		0.111		
R-squared		0.161	Number of obs		395		
F-test		10.825	Prob > *F*		0.000		
Akaike crit. (AIC)		−674.845	Bayesian crit. (BIC)		−646.993		

Note: * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

5. Case study

Take the enterprise Pathfinder as an example, which is a sports enterprise focusing on the development of high-performance running shoes. In the field of biomechanics, the enterprise invests a lot of resources in research. Through biomechanical experiments, it collects various data from athletes in the process of exercise, such as foot landing angle, pressure distribution, joint movement trajectory, etc., and analyzes the human body's movement rules and needs in depth. On this basis, the design of sports shoes is optimized, such as the use of special shock-absorbing materials and sole structure design, which effectively reduces the impact of running on athletes' knees, ankles and other joints, reflecting the company's concern for athletes' health and fulfilling its social responsibility.

In terms of material selection, Pathfinder chooses environmentally friendly and biodegradable materials to reduce environmental pollution during the production process. Meanwhile, by improving the biomechanical properties of the products, Pathfinder prolongs the service life of the sports shoes and reduces the frequency of product replacement, thus practicing the concept of ESG at the environmental level. In terms of corporate governance, we continue to invest in scientific research and innovation, establish a professional biomechanics R&D team, and improve the internal management mechanism to ensure that the R&D work is carried out efficiently. These biomechanics-based practices not only enhance the market competitiveness of the products and increase sales and profits, but also win the recognition and trust of consumers, establish a good corporate image, attract more investment and cooperation opportunities, and strongly promote the sustainable growth of the enterprise.

Another example is Shuhua Sports, a sports equipment manufacturer, which, through biomechanical research, optimizes the design of sports equipment to make it more ergonomic and enhance the athletes' experience and sports efficiency. At the same time, the enterprise incorporates biomechanical performance indicators into production standards, strictly controls product quality, and demonstrates good governance. In the production process, it adopts energy-saving and emission reduction technologies to reduce energy consumption and pollutant emissions and actively fulfills its environmental responsibility. These initiatives have enabled the enterprise to stand out in the market, increase customer satisfaction, and gradually expand its market share.

6. Conclusion and discussion

6.1. Conclusion

(1) Positive correlation between ESG performance and sustainable growth rate: Good ESG performance of sports firms has a positive impact on the sustainable growth rate of sports firms. When sports companies improve their ESG performance, their sustainable growth rate will also increase. This suggests that companies' emphasis on ESG can be effectively transformed into a driving force for long-term development, and lay a solid foundation for sustainable development while improving their competitiveness.

(2) Influence of industry category on ESG enhancement: Compared with sports service companies, sports manufacturing companies' improved ESG performance has a more significant positive effect on the sustainable growth rate of sports companies. When the ESG performance of sports enterprises is optimized, the sustainable growth rate of sports manufacturing enterprises increases more, while the sustainable growth rate of sports service enterprises is relatively weak. This may be due to the fact that the sports manufacturing industry has more room for improvement in terms of resource utilization and production processes, and by practicing ESG concepts, it can reap more obvious results in cost control, product innovation and market image building.

(3) Differences in ESG enhancement by nature of ownership: Compared with state-owned enterprises, non-state-owned enterprises have a more significant positive impact on the sustainable growth rate of sports enterprises by improving ESG performance. In the case of improved ESG performance, the sustainable growth rate of non-state-owned enterprises increases more than that of state-owned enterprises. Due to their relatively flexible decision-making mechanisms, non-SOEs may be more efficient and faster in responding to ESG concepts and translating them into actual business growth.

6.2. Discussion

There are significant differences between sports manufacturing companies and sports service industry companies in the relationship between ESG performance and the sustainable growth of the companies, and these differences mainly stem from factors such as market structure, policy environment, industry characteristics, and corporate management mode. The sports manufacturing industry has a high degree of industry concentration. ESG performance directly affects brand reputation and consumer loyalty, which in turn affects market share and profitability. ESG practices in the manufacturing industry are easier to quantify, and investors and consumers are more sensitive to their ESG performance. In contrast, the market structure of the sports services industry is highly fragmented and competitive. ESG practices in the sports services industry are more often reflected in service quality and social responsibility, which are difficult to quantify. Policies are more binding on the manufacturing industry, where companies must comply through ESG practices or face possible fines or market access restrictions. Policies are less binding on the service industry, and companies' ESG practices are driven more by market competition and brand image

needs. As a result, the impact of ESG performance on sustainable growth rates is stronger for sports manufacturing firms than for sports service firms.

In terms of management mode: Non-state-owned sports enterprises have a flexible management mode, high decision-making efficiency, and more innovative and executive ESG practices. State-owned sports enterprises have rigid management modes, complex decision-making processes, and lower innovation and execution efficiency in ESG practices. In terms of policy dependence: The sustainable growth of non-state-owned sports enterprises relies more on the competitive advantage in the market brought by ESG performance. The sustainable growth of state-owned sports enterprises relies more on government support and policy dividends than on ESG performance. From the perspective of market competition: Market competition-driven: Non-state-owned sports enterprises face greater market competition pressure, and ESG practices are an important means to enhance market competitiveness and brand reputation. State-owned sports enterprises have less market competition pressure, and ESG practices are more driven by policy requirements than by market competition. Therefore, the impact of ESG performance on the sustainable growth rate of non-state-owned sports enterprises is stronger than that of state-owned sports enterprises.

7. Recommendations

7.1. Enterprise level

(1) Strengthen R&D investment and cooperation: It is recommended that sports enterprises further increase their investment in biomechanics R&D as a core driving force to improve ESG performance and sustainable growth rates. Encourage sports equipment enterprises to actively establish biomechanics laboratories and carry out in-depth independent research. At the same time, they should strengthen cooperation with universities and research institutions to jointly conduct biomechanics research projects. For example, jointly explore the mechanical characteristics of the human body in different sports states, and develop biomechanical technology products with independent intellectual property rights, such as intelligent sports shoes that can adaptively adjust the support strength according to the athletes' real-time sports data, or lightweight sports protectors that conform to the human body's joints' movement trajectory.

(2) Optimize sports training guidance: guide sports training enterprises to introduce advanced biomechanical monitoring equipment, such as high-precision motion capture systems, pressure sensors, etc., to collect athletes' real-time sports data. At the same time, professional biomechanics talents are hired to conduct in-depth analysis of these data to provide athletes with more scientific and accurate training guidance. Through the use of biomechanical principles to optimize sports technology, help athletes improve sports efficiency, reduce the risk of injuries caused by irrational sports practices, and extend the athletes' sports careers, thus enhancing the company's sense of social responsibility and brand image.

(3) Focus on cost-benefit analysis and resource integration strategies for sports enterprises. On the one hand, assess the financial return and social benefits of biomechanics R&D investment to ensure the efficient utilization of resources. Firstly, conduct a cost analysis to clarify the direct costs (R&D equipment, laboratory

construction, personnel remuneration, material costs, etc.) and indirect costs (management costs, training costs, etc.) of the enterprise. Second, conduct a benefit analysis to clarify the financial benefits (income from new product sales, brand premium, etc.) and social benefits (enhancement of athletes' performance, promotion of public health, enhancement of corporate social image, etc.). Calculate the enterprise's return on investment; conduct a project risk assessment and formulate countermeasures. On the other hand, optimize resource allocation and enhance R&D efficiency. The internal departments of the enterprise realize data sharing, and the R&D department works closely with the marketing, production, and sales departments to ensure that the R&D results meet the market demand. Cooperate with universities and research institutions outside the enterprise: reduce R&D costs with the help of external experts and technical resources. Optimize the supply chain and cooperate with material suppliers and equipment manufacturers to optimize the R&D process.

7.2. Market level

(1) Building evaluation standards and certification systems: All market parties are called upon to emphasize the key role of biomechanics in the evaluation of the quality of sports products and services, and to actively promote the establishment of a unified, scientific evaluation standard and certification system for biomechanical performance. The system should cover a wide range of evaluation indicators, from the comfort and function of sports equipment to the scientific and safety aspects of sports training services. (a) The development of biomechanical performance evaluation standards should firstly conduct a demand analysis, research market demand, and determine the core indicators of the evaluation standards (e.g., shock-absorbing performance of sports equipment, supportive performance of sports shoes). Then organize a team of experts to develop evaluation standards with reference to international standards (e.g., ISO) and industry best practices. Verify the scientificity and operability of the standards through laboratory testing and practical application. Finally, release the evaluation standards and promote them through industry conferences and media publicity; (b) the establishment of the certification system is to enhance the market trust of the products through the certification system. First of all, an authoritative third-party certification body should be selected to ensure the fairness and authority of the certification. Completion of the design of the certification process, including application, testing, auditing, licensing and other aspects of the long-term cooperation agreement with the certification body to ensure the stability and efficiency of the certification process. And design a unified certification logo to facilitate consumer identification. Finally, develop a marketing plan to highlight the unique advantages of certified products.

(2) Guiding consumer choice and enterprise competition: A perfect biomechanical performance evaluation standard and certification system helps consumers clearly identify and choose sports products and services with excellent biomechanical performance. When consumers are more inclined to choose products that meet biomechanical standards, market competition will prompt enterprises to pay more attention to biomechanical research and development, and continuously improve the quality of products and services. This will not only benefit the development of

individual enterprises, but also drive the ESG level of the whole sports industry to improve and enhance the industry's sustainable development.

7.3. Government level

(1) Policy support and fund establishment: It is recommended that the government include biomechanics research and application in the scope of key support when formulating sports industry-related policies. Set up a special research fund to encourage enterprises, universities and research institutions to carry out industry-university-research cooperation projects in the field of biomechanics. For example, subsidize enterprises and universities to jointly carry out research on the application of new biomechanical materials in sports equipment, accelerate the transformation of scientific research results into actual products, and promote the technological upgrading of the sports industry.

(2) In terms of policy support, R&D subsidies can be set up to reduce the cost of R&D for enterprises; tax incentives can be set up to provide tax breaks and encourage sports enterprises to invest in innovation; and special funds can be set up to support colleges and universities and scientific research institutes to cultivate talents for sports enterprises. Promote international technical cooperation and introduce advanced foreign technology and experience. The government should formulate detailed policy implementation rules, specifying the application conditions and processes for subsidies and tax incentives. Regularly assess the effects of the policy and make adjustments and optimizations based on feedback.

Ensure the efficient use of funds in the use of funds to promote the transformation of biomechanics R&D results. Reasonably allocate funds according to the priority and expected benefits of R&D projects. Establish a mechanism for monitoring the use of funds to ensure that the funds are used for the designated purposes. Establish a fund for the transformation of results to support the commercialization and application of R&D results. Improve the establishment of a system for evaluating the use of funds and audit the use of funds on a regular basis. Set up a specialized results transformation team to promote the market application of R&D results.

(3) Strengthening quality supervision and protection of rights and interests: The government should strengthen the supervision of the quality of biomechanical products and services provided by sports enterprises, and establish a strict supervision and inspection mechanism to ensure that the products and services provided by the enterprises are in line with the relevant biomechanical standards. For example, regular sampling of biomechanical performance of sports equipment on the market, and order rectification or off-shelf treatment of products that do not meet the standards. By protecting the legitimate rights and interests of consumers and creating a fair and healthy market environment, the sports industry will be promoted to develop steadily on the path of integrating biomechanics and ESG.

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