ESG, Corporate R&D Investment, and Financial Performance: Evidence from China's Typical Heavy Pollution Industries

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Abstract. Given the critical function corporations serve in economic progression, a burgeoning body of evidence underscores the necessity for the amalgamation of Environmental, Social, and Governance (ESG) performance with research and development (R&D) expenditures to bolster corporate proficiency and value. Consequently, strategizing the harmonious application of R&D expenditure and ESG performance emerges as a topic of significant import. This research delves into the isolated repercussions of R&D investments and ESG, in addition to their cumulative impact on financial performance, utilizing data amassed from representative industries with high pollution output, traded in Shenzhen and Shanghai's stock markets. The findings reveal an inconsequential direct correlation between ESG and short-term financial performance. Nevertheless, both R&D investment and ESG possess the capacity to directly shape a corporation's prospective market value. This study enriches existing literature regarding the influence of R&D investment and ESG on future corporate market value. The symbiotic influence of R&D investment and ESG offers insights germane to decision-making processes within the ambit of sustainable development, thereby facilitating the balanced evolution of China's economic, societal, and environmental spheres.

Keywords: R&D investment; ESG; financial performance; typical industries List.

1. Introduction

As the maturation of innovative and responsible ideologies continues, an intensified focus has been directed towards Research & Development (R&D) investment and Environmental, Social, and Governance (ESG) progression. In 2022, China's R&D expenditure elevated to 3.087 trillion yuan, exceeding the 3 trillion yuan threshold for the first time, marking an annual growth rate of 10.4% and signifying the seventh consecutive year of double-digit growth since the inception of the "Thirteenth Five-Year Plan" period. Despite the manifest upward trajectory of China's R&D funding, impediments such as a deficiency in innovation capacity remain. Li et al. (2020) conducted a study on the effects of R&D capability, environmental management capability, and social responsibility capability on corporate performance, with the findings indicating a significant positive impact of all three capabilities on corporate performance. Fang (2023) accentuated the necessity of "green technology innovation" for the sustainable development of corporations and identified the need for companies to introduce corresponding innovations in technological, organizational, and market domains. Zhao et al. (2018) discerned a substantial positive correlation between a firm's ESG performance and its financial performance, particularly when the company exhibits robust environmental stewardship and social responsibility. In conclusion, enhancing R&D investment, augmenting technological innovation competencies, devising new products and services to satisfy societal demands, and fortifying social responsibility management can all contribute positively to a company's sustainable development. However, traditional research tends to concentrate primarily on the direct analysis of the correlation between R&D investment and financial performance, but singular focus on either R&D investment or ESG may not fully address the requirements of corporations. To better cater to the need of stakeholders, this study probes their combined effect on a company's financial performance.

This study is based on the research findings regarding the relationship between R&D investment, ESG, and financial performance in domestic and international studies. From an investor's perspective, this research aims to examine how R&D investment in typical industries of listed companies in China affects their short-term and long-term financial performance, based on theories such as corporate

innovation theory and resource-based theory. Second, it explores how the social responsibilities undertaken by listed companies in typical industries in China affect their short-term and long-term financial performance. Third, it focuses on whether R&D investment and social responsibility have a moderating effect on a company's financial performance. This study contributes to the literature in two ways. First, it comprehensively examines the interactions between R&D investment and ESG from an investor's perspective regarding their impact on financial performance. If the research perspective is taken differently, the model mechanism can be different. Second, financial performance is not only a measure of a company's current financial situation but also includes an evaluation of the company's future growth value. Based on the two-stage model, this study measures financial performance in two stages: short-term financial performance based on accounting profits and long-term financial performance based on a company's market value. Furthermore, it investigates the impacts of R&D investment and ESG on financial performance in heavy pollution industries. This research is helpful for companies to integrate R&D investment and ESG from a management perspective, formulate effective strategic decisions, and implement targeted policy measures. It encourages companies to establish the correct concepts of innovation and social responsibility management, raise awareness of environmental protection, and leverage the positive impact of both on a company's financial performance.

2. Literature Review

2.1 Innovation Theory

Over the past decade, scholars have engaged in comprehensive research and discourse on innovation theory, primarily focusing on the origins of innovation, influencing factors, traits of innovative organizations, and innovation management. Schumpeter's innovation theory underscores various forms of innovation, encapsulating market innovation, raw material innovation, product innovation, process innovation, and management model innovation. The present study specifically involves technological innovation, comprising both product and process innovation associated with Research & Development (R&D) activities. As research advances, novel concepts of innovation persistently emerge. Lv et al. (2018) conceptualized 'innovation resilience,' positing it as a pivotal factor for enterprises to attain innovation and sustained development. This concept refers to the adaptability and responsiveness of enterprises amidst the innovation process. Benner and Tushman (2003) introduced the notion of 'ambidextrous innovation,' which involves the exploitation and exploration of innovation. The technological innovation discussed in this study largely engages in exploiting innovation through active participation in technology communities and the sharing of resources and technology with other enterprises. Innovation activities can be used as a proxy for firm performance, assisting companies in gaining a competitive advantage (Hughes et al., 2010; Dixit et al., 2022).

2.2 Resource-Based Theory

This study adopts the Resource-Based View (RBV) as the theoretical underpinning for the model. The RBV has emerged as a widely accepted theory for explaining organizational competitive advantage within strategic management research. The enterprise is a collection of various resources and takes the characteristics of resources as the development of the enterprise in the enterprise strategy decision As these competitive resources are challenging to accumulate, replicate, develop, acquire, or be wholly imitated by competitors, they can subsequently lead to superior performance (Surroca et al., 2010; Barney, 2011).

Investors (Eccles et al., 2011) and financial analysts (Ioannou & Serafeim, 2015) are increasingly acknowledging the importance of intangible assets. Although information pertaining to corporate social responsibility is not directly manifested in financial statements, investors may perceive an increase in social responsibility as a signal to mitigate negative ESG activities, seize revenue

opportunities, reduce higher risk-adjusted costs, and enhance the company's appeal to investors (Wong & Zhang, 2022).

3. Research Hypotheses

3.1 The Influence of R&D Investment on Financial Performance

Duque-Grisales et al. (2020) examined the moderating effects of environmental management systems (ISO 14001) and R&D investment on the relationship between green innovation and financial performance. They found that the implementation of ISO 14001 in Latin American firms did not influence their adoption of green innovation, and thus did not augment their financial performance. However, as the degree of R&D investment in companies escalated, it exerted a positive moderating effect. R&D investment assumes a pivotal role in a company's green innovation activities (Ketata et al., 2015). R&D investment endeavours to engender innovation, thereby augmenting a company's sales, and is considered one of the most influential factors in promoting economic growth (Ghisetti & Pontoni, 2015).

Zhang et al. (2020) discovered that the impact of R&D investment on financial performance might exhibit a temporal lag effect. They determined that considerable improvements in financial performance transpired three years post R&D investment. Consequently, R&D expenditure in the early stages may not effectively enhance a company's sales revenue and profit. From these perspectives, it is reasonably anticipated that the success of utilizing green innovation to improve financial performance is dependent on the level of R&D investment. By optimizing internal resource allocation and ameliorating levels of technological innovation, companies can manufacture high-quality products, offer efficient services, enhance their financial standing, and elevate long-term enterprise value (Bianchi et al., 2019). Therefore, we propose:

H1a: There exists a positive correlation between R&D investment and short-term financial performance. H1b: There exists a positive correlation between R&D investment and long-term financial performance.

3.2 The Impact of ESG on Financial Performance

Eccles and Serafeim (2013) posited a strong relationship between ESG and corporate financial performance. Numerous studies have suggested that high-quality ESG performance can bolster a company's brand reputation and market value, thereby catalyzing improved financial performance. Flammer (2015) discovered that companies with high ESG performance possess superior risk management and long-term planning capabilities, resulting in enhanced financial performance during economic downturns in comparison to other companies. Ioannou and Serafeim (2018) demonstrated that companies with high ESG performance showcase better long-term financial performance, even outstripping other companies in terms of stock price performance.

In essence, recent studies have unveiled a robust link between ESG and corporate financial performance. High-quality ESG performance can reinforce a company's brand reputation and market value, subsequently fostering improved financial performance (Bătae et al., 2020; Zhou et al., 2022). In contemporary corporate governance, ESG is not merely a requisite responsibility for companies but is progressively becoming a pathway for strategic development. Meeting ESG responsibilities offers benefits such as an enhanced corporate reputation and stronger employee cohesion. When investors recognize the latent value of a company, they formulate positive expectations, which can sway their investment behavior and augment the company's market value. In light of these insights, we propose:

H2a: There exists a positive correlation between a company's ESG and short-term financial performance. H2b: There exists a positive correlation between a company's ESG and long-term financial performance.

3.3 The Joint Effect of R&D Investment and ESG on Financial Performance

The analysis so far suggests a relationship between R&D investment and ESG. R&D investment is a facet of technological innovation, and such innovation is a component of a company's ESG responsibilities. Therefore, it makes sense to consider ESG and financial performance as interconnected aspects of a company's overarching strategic decisions. Different kinds of ESG investments can foster innovation in products or services, and a firm's engagement with ESG activities can influence the effect of intangible assets such as R&D expenses on company performance (McWilliams & Siegel, 2000).

When attempting to meet ESG responsibilities, many companies amplify their R&D investment in new products or services to enhance their effectiveness. However, if a company primarily promotes the commercial benefits of ESG adherence without making substantial improvements to its products, its ESG investment may not produce the expected outcomes and could even have negative effects (Bhattacharya & Luo, 2006). Therefore, fulfilling ESG responsibilities depends on the support of R&D investment, and the improvement of R&D investment capacity also requires a commitment to ESG adherence. Based on these observations, this study proposes:

H3a: R&D investment and the mutual regulation of ESG can reinforce their individual impacts on short-term financial performance. H3b: R&D investment and the mutual regulation of ESG can reinforce their individual impacts on long-term financial performance.

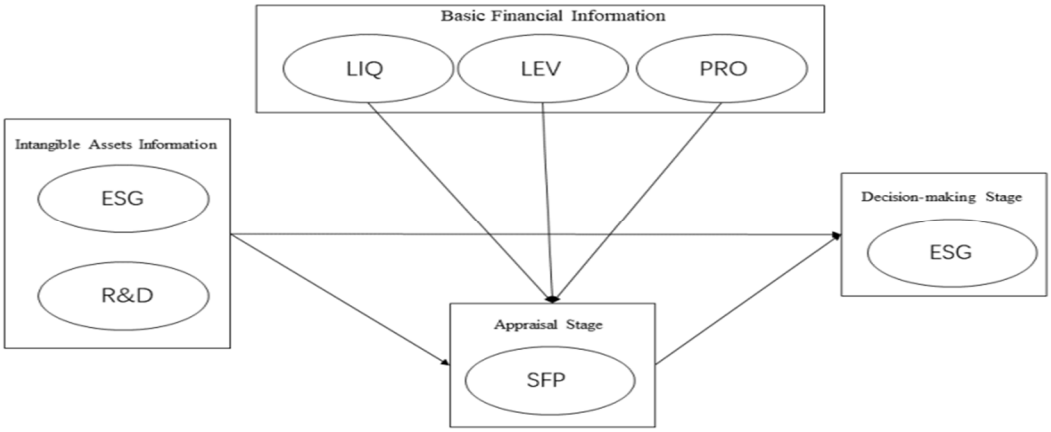

Fig. 1 Relationship between ESG,
Corporate R&D Investment, and Financial Performance

4. Research Design

4.1 Sample Selection and Data Source

In recent years, certain industries such as mining, petrochemicals, paper manufacturing, and pharmaceuticals have come under considerable scrutiny. Key areas of interest include their commitment to ESG responsibilities and their engagement in R&D investment to enhance performance. Accordingly, this study examines listed firms in typical high-pollution industries within the Shanghai and Shenzhen stock markets from 2017 to 2021. The sample is determined based on the classification of high-pollution industries as delineated in the "Guidelines for Environmental Disclosure of Listed Companies" published by the Ministry of Environmental Protection in 2017.

The sample encompasses four primary sectors and eight sub-industries, namely mining, petroleum, the chemical industry, chemical fibers, plastics, pharmaceuticals and biotechnology, papermaking, and printing. To ensure the reliability of the research outcomes, the sample selection adheres to certain exclusion criteria: (1) excluding ST and *ST firms and companies listed post-2009; (2) excluding firms with inaccessible or abnormal financial data; (3) excluding firms with a zero score on selected social responsibility evaluation indicators utilized in this study. Adhering to these criteria resulted in

a final sample of 299 continuously listed companies over a 5-year period, providing a total of 1395 research observations. Data for this study are sourced from the CCER China Economic and Financial Database, the Wind Financial Database, and the CSMAR Database. Raw data is processed in Excel, and empirical analyses are performed utilizing SPSS software.

4.2 response variables

In this research, the company's current financial condition is depicted through Altman's Z-score. Empirical examinations have indicated that this scoring methodology is apt for investigating listed companies in China. Altman's Z-Score model is a multifaceted financial equation employed to evaluate a firm's financial health, encompassing aspects such as asset size, liquidity, and financial structure. It serves as a comparably comprehensive indicator for assessing a company's short-term financial performance and elucidates the company's financial distress circumstances. The Z-Score data utilized in this research is procured from the Wind database, and the calculation formula is as follows:

Z-Score=1.2X1+1.4X2+3.3X3+0.6X4+0.99X5

X1 = Working Capital/Total Assets = (Current Assets - Current Liabilities) / Total Assets

X2 = Retained Earnings/Total Assets = (Net Profit - Dividends) / Total Assets

X3 = Earnings Before Interest and Taxes (EBIT)/Total Assets = (Profit Before Tax + Financial Expenses) / Total Assets

X4 = Market Value of Preferred Stock and Common Stock/Total Liabilities = (Stock Market Value * Total Number of Shares) / Total Liabilities

X5 = Sales/Total Assets

The long-term financial performance of a company is chiefly signified through the appraisal of the company's future value and denotes the firm's capability for sustained development. Tobin's Q ratio, postulated by the American economist James Tobin, quantifies the ratio of a company's market value to its replacement cost and can be utilized as a benchmark for deciding whether to embark on new investments. Market value comprises the total market price of a company's stocks, equating to the product of the per-share stock price and the total number of shares. Tobin's Q ratio is frequently employed as a significant indicator to gauge company performance or growth potential. Consequently, this study utilizes Tobin's Q ratio as the measurement indicator for long-term financial performance.

4.3 Explanatory variables

The explanatory variable in this study captures the various efforts made by a firm to fulfill its ESG responsibilities. Measuring ESG indicators poses a complex issue, hence this study opts to use the relative indicator of R&D investment, specifically the ratio of R&D expenditure to operating income, as a measurement indicator. The data is predominantly sourced from the CCER database. A company's basic financial information chiefly encompasses factors like asset liquidity, solvency, operational capacity, profitability, and developmental capacity. This study draws predominantly from the financial basic information indicators proposed in studies on the relationship between ESG and financial performance, mainly including asset liquidity, profitability, and solvency. To reflect asset liquidity, the cash ratio is selected. Profitability symbolizes capital appreciation ability and represents the firm's level of profitability. The asset-liability ratio, an essential determinant of financial risk, serves as a comprehensive indicator for evaluating a company's debt level. As such, this study chooses the asset-liability ratio to measure the firm's solvency. Additionally, control variables like firm size (SIZE), nature of ownership (SOE), and industry attributes (IND) are also considered in this study.

In summary, all variables in this study are defined as shown in the table below:

Table 1. Variable Representations and Explanations in the Model

Variable Representations	Variables	Symbols	efinition
Response variables	Short-Term Financial Performance	Z	Altman's Z-score, a measure of the company's current financial health and crisis status.
	Long-Term Financial Performance	Q	Tobin's Q, the ratio of the market value of the company to its replacement cost, used as a measure of company performance and growth potential
	ESG	ESG	Composite value calculated based on the designed indicator system and relevant weightings.
Explanatory variable	R&D Investment	R&D	R&D investment, calculated as the ratio of R&D expenditure to operating income
	Operating Capacity	LIQ	Cash ratio, calculated as (cash and cash equivalents + trading financial assets) divided by current liabilities
	Profitability	PRO	Earnings per share, calculated as net profit divided by total number of shares multiplied by 100%
	Solvency	LEV	Leverage, calculated as total liabilities divided by total assets.
Control Variables	Firm Size	SIZE	Natural logarithm of total assets
	Ownership Nature	SOE	Ownership nature, with a value of 1 for state-owned enterprises and 0 for non-state-owned enterprises.
	Industry	IND	Industry dummy variable based on the China Securities Regulatory Commission industry classification, with a value of 1 if the company belongs to the specific industry and 0 otherwise.

4.4 Construction of the model

Based on the theoretical analysis and the proposed hypotheses in the previous paper, combined with the variable design, the model design will be carried out in two steps in this paper. In the first step, the impact of corporate R&D investment and ESG on corporate short-term financial performance is tested, respectively.

In order to test hypothesis 1a and hypothesis 2a, model 1 and model 2 are built, and the models are as follows:

Model 1:

If the coefficient in model 1 is significantly positive, then it indicates that the higher the level of corporate R&D investment, the better its short-term financial performance, proving the hypothesis la,i.e., corporate R&D investment positively affects short-term financial performance.

Model 2:

$$Z = \alpha + \beta_0 ESG + \beta_1 LIQ + \beta_2 PRO + \beta_3 LEV + \beta_4 SIZE + \beta_5 SOE + IND + \varepsilon$$

Model 2 tests the relationship between ESG and short-term financial performance, and if is positive, then it indicates that the current financial performance and ESG level are positively proportional, which can prove hypothesis 2a.

Model 3:

$$Z = \alpha + \beta_0 R\,\&\,\mathrm{D} + \beta_1 ESG + \beta_2 LIQ + \beta_3 PRO + \beta_4 LEV + \beta_5 SIZE + \beta_6 SOE + IND + \varepsilon$$

Model 4:

$$Z = \alpha + \beta_0 R\,\&\,\mathrm{D} + \beta_1 ESG + \beta_2 R\,\&\,\mathrm{D} * \mathrm{ESG} + \beta_3 LIQ + \beta_4 PRO + \beta_5 LEV + \beta_6 SIZE + \beta_7 SOE + IND + \varepsilon$$

Model 3 and Model 4 are built to compare and analyze with Model 1 and Model 2. Model 3 indicates how effective the effect of ESG or R&D investment on short-term financial performance is analyzed by controlling for R&D investment or ESG, respectively. Model 4 adds the interaction term of R&D input and ESG to model 3, which is to test the effect on short-term financial performance in hypothesis 3.

In the second step, the effects of corporate R&D investment and ESG on long-term financial performance are tested separately. Each model from model 5 to model 6 has the same test role as model 1 to model 4, so it is not described in detail below.

Model 5:

$$Q = \alpha + \beta_0 Z + \beta_1 \mathrm{R\ \&\ D} + \beta_2 SIZE + \beta_3 SOE + IND + \varepsilon$$

Model 6:

$$Q = \alpha + \beta_0 Z + \beta_1 \mathrm{E}SG + \beta_2 SIZE + \beta_3 SOE + IND + \varepsilon$$

Model 7:

$$Q = \alpha + \beta_0 Z + \beta_1 \mathrm{R\ \&\ D} + \beta_2 ESG + \beta_2 SIZE + \beta_3 SOE + IND + \varepsilon$$

Model 8:

$$Q = \alpha + \beta_0 Z + \beta_1 R\ \&\ \mathrm{D} + \beta_2 ESG + \beta_3 R\ \&\ \mathrm{D} * \mathrm{ESG} + \beta_2 SIZE + \beta_3 SOE + IND + \varepsilon$$

5. Descriptive Statistics and Correlation Analysis

5.1 Descriptive Statistics

Table 2. Descriptive statistics

Variable	Minimal value	Maximal value	Mean value	Standard deviation
Z	0.1349	29.5786	4.9757	4.9827
Q	0.9496	9.2670	2.3562	1.3135
R&D	0.1174	0.9186	0.3688	0.1630
ESG	1.3470	27.2430	8.6618	6.8019
PRO	-7.2851	0.4586	0.0332	0.4026
LEV	0.0645	29.6976	0.6037	1.6519
LIQ	0.0275	70.2512	1.4378	2.6506
SIZE	2.2461	25.1214	18.6815	7.4804
SOE	0.0000	1.0000	0.4700	0.4990
Effective N	1395	1395	1395	1395

Table 2 provides the variables of the research sample from 2017 to 2021, followed by descriptive analysis. The descriptive results of the financial performance variables indicate the mean and standard deviation of Z and Q values as follows: Z mean = 4.9757, standard deviation = 4.9827; Q mean =2.3562, standard deviation = 1.3135. There is a discernible difference in the mean and standard deviation of short-term and long-term financial performance, underscoring the necessity of utilizing both indicators in the research. While extreme values show a significant divergence between the two indicators, no replacement of extreme values has been conducted, given the limited size of the research sample and the preservation of data authenticity. The mean of R&D expenditure as a proportion of operating income is 0.3688. Although the R&D investment level of each company is not yet high, there has been a noticeable increase relative to the past, aligning with the continuous upward trend of R&D investment in the country. The mean ESG score for these companies is 8.6618, with a standard deviation of 6.8019. This indicates a variation in the ESG performance level among different companies, which is closely linked to the nature and scale of the companies in the country. It also reflects the current state of ESG management in the country, which is still at a rudimentary level with a weak sense of responsibility, necessitating further improvement. Regarding basic financial information, the sample indicators do not differ significantly from the standard deviation, indicating that the overall financial health of the selected research sample is satisfactory.

5.2 Correlation Analysis

Table 3 presents the correlation coefficient matrix between variables and Z-values from 2017 to 2021. In the short term, the correlation between ESG and Z-values is positive, but it is not statistically significant, suggesting that hypothesis 2a is not supported. On the other hand, R&D expenditure shows a significant positive correlation with Z-values at a 5% level, which aligns with the expected

direction. Among the three basic financial information indicators, except for LEV (leverage), PRO (profitability), and LIQ (liquidity) are positively correlated with other variables. The correlation coefficients are -0.019, 0.032, and 0.246, respectively, indicating a negative impact of solvency on corporate financial conditions and positive correlations with profitability and asset liquidity. The variables SIZE (firm size) and SOE (ownership nature) are negatively correlated with the response variable, indicating that larger firms and state-owned enterprises tend to have lower Z-values.

Table 4 displays the correlation coefficient matrix between variables and Q-values from 2017 to 2021. While the correlation between ESG and Z-values is not significant, ESG and Q-values exhibit a significant positive correlation at a 1% level. This suggests a positive relationship between ESG and long-term financial performance, providing support for hypothesis 2b. R&D expenditure also shows a significant positive correlation with Q-values at a 5% level, confirming the expected relationship. Additionally, ESG and R&D expenditure display a certain level of correlation, indicating that these two factors are not entirely independent. The basic financial information indicators, SIZE, and SOE variables exhibit correlations with the response variable consistent with the findings in the short-term financial performance analysis, but further elaboration is beyond the scope of this discussion.

Table 3. presents the correlation analysis between variables and short-term financial performance of companies.

	Z	R&D	ESG	PRO	LEV	LIQ	SIZE	SOE
Z	1	0.109** (0.000)	0.028 (0.252)	0.325** (0.000)	-.368** (0.000)	0.256** (0.000)	-0.306** (0.000)	-0.185** (0.000)
R&D	0.055* (0.023)	1	0.012* (0.010)	0.103** (0.000)	0.110** (0.000)	-0.098** (0.000)	-0.024 (0.323)	0.009 (0.713)
ESG	0.021 (0.388)	0.024 (0.443)	1	0.074** (0.002)	-0.060* (0.012)	0.074** (0.002)	-0.049* (0.041)	-0.049* (0.042)
PRO	0.031* (0.022)	0.062** (0.010)	0.014* (0.047)	1	-0.486** (0.000)	0.457** (0.000)	0.162** (0.000)	-0.039 (0.107)
LEV	-0.017* (0.030)	-0.048* (0.046)	-0.040 (0.093)	-0.108** (0.000)	1	-0.711** (0.000)	0.210** (0.000)	0.126** (0.000)
LIQ	0.247** (0.000)	-0.017** (0.070)	0.069** (0.004)	0.068** (0.005)	-0.102** (0.000)	1	-0.030 (0.204)	-0.079** (0.001)
SIZE	-0.280** (0.000)	-0.023 (0.347)	-0.030** (0.014)	0.071** (0.003)	0.023 (0.332)	-0.088** (0.000)	1	0.329** (0.000)
SOE	-0.217** (0.000)	0.022* (0.063)	-0.049* (0.047)	0.048* (0.046)	-0.038 (0.116)	-0.178** (0.000)	0.216** (0.000)	1

Table 4. Correlation Analysis between Variables and Long-term Financial Performance

	Q	R&D	ESG	PRO	LEV	LIQ	SIZE	SOE
Q	1	0.044* (0.069)	0.074** 0.002)	0.102** (0.000)	-0.222** (0.000)	0.128** (0.000)	-0.438** (0.000)	-0.235** (0.000)
R&D	0.042* (0.061)	1	0.013** (0.010)	-0.104** (0.000)	0.109** (0.000)	-0.097** (0.000)	-0.024 (0.326)	0.009 (0.713)
ESG	0.025** (0.021)	0.027* (0.058)	1	0.074** (0.002)	-0.060* (0.012)	0.074** (0.002)	-0.049* (0.041)	-0.050* (0.041)
PRO	0.067** (0.005)	-0.062* (0.010)	-0.014 (0.567)	1	-0.476** (0.000)	0.457** (0.000)	0.162** (0.000)	-0.040 (0.105)
LEV	-0.098** (0.000)	0.048* (0.046)	-0.039 (0.091)	-0.110** (0.000)	1	-0.711** (0.000)	0.210** (0.000)	0.128** (0.000)
LIQ	0.146** (0.000)	-0.017 (0.470)	0.069** (0.004)	0.066** (0.005)	-0.102** (0.000)	1	-0.030 (0.204)	-0.080** (0.001)
SIZE	-0.199** (0.000)	-0.021 (0.347)	-0.030 (0.214)	0.072** (0.003)	0.023 (0.332)	-0.088** (0.000)	1	0.330** (0.000)
SOE	-0.176** (0.000)	0.023 (0.366)	-0.048* (0.047)	0.051* (0.046)	-0.038 (0.116)	-0.179** (0.000)	0.214** (0.000)	1

5.3 Regression Results and Analysis of the Relationship between ESG, R&D Investment, and Financial Performance

Table 5. Regression Analysis of R&D Investment and ESG on Short-term Financial Performance

	Z			
	Model1	Model2	Model3	Model4
Con_s	10.489*** (21.245)	9.375*** (22.042)	9.894*** (19.237)	9.583*** (17.868)
R&D	0.029*** (3.938)		0.033*** (3.948)	0.033** (3.950)
ESG		0.017 (0.021)	0.061 (0.095)	0.521 (0.629)
R&D*ESG				0.021** (2.163)
PRO	2.684*** (2.846)	2.724*** (2.906)	2.722*** (2.898)	2.756*** (2.933)
LIQ	0.197*** (8.420)	0.193*** (8.094)	0.193*** (8.088)	0.191*** (8.053)
LEV	-0.606*** (-2.653)	-0.602*** (-2.633)	-0.600*** (-2.626)	-0.608*** (-2.651)
SIZE	-0.137*** (-8.980)	-0.148*** (-9.554)	-0.148*** (-9.552)	-0.149*** (-9.611)
SOE	-1.149*** (-4.972)	-1.241*** (-5.358)	-1.239*** (-5.345)	-1.260*** (-5.417)
IND	Control			
F	34.041***	37.410***	33.792***	31.490***
Adjusted R^2	0.192	0.197	0.198	0.196
DW	1.204	1.219	1.219	1.2230

Table 5 presents the results of the regression analysis investigating the impact of R&D investment and ESG on short-term financial performance, while controlling for industry variables. Model 1 examines the direct effect of R&D investment on financial performance. The results show a significant and positive coefficient for R&D investment ($P = 0.029$, $p < 0.01$), providing support for hypothesis 1a. In Model 2, the direct impact of ESG on short-term financial performance is examined, but no significant correlation is found between ESG and the Z-value ($P = 0.016$, $p > 0.1$). It indicates that there is no significant direct causal relationship between corporate ESG and short-term financial performance, so hypothesis 2a is not supported.

Model 3 analyzes the combined effects of both variables, controlling for one while examining changes in the other. From the model, it can be found that the effect of ESG on Z value remains insignificant when controlling for the R&D investment variable, so hypothesis 3a is not supported due to the insignificance of ESG and short-term financial performance; however, the effect is enhanced when controlling for the ESG variable (0.032>0.029). This indicates that the inclusion of ESG makes R&D investment has an enhanced effect on short-term financial performance, but the effect of ESG is not significant on short-term financial performance. In Model 4, an interaction term (R&D*ESG) is introduced, and the coefficient of the interaction term is significant at the 5% level ($P = 0.021$, $p < 0.05$). Although the coefficient of ESG remains nonsignificant ($P = 0.033$, $p < 0.1$), the inclusion of the interaction term further enhances the positive effect of ESG on short-term financial performance ($0.033 > 0.032 > 0.029$). Therefore, including ESG in the short-term analysis strengthens the role of R&D investment on financial performance, while the inclusion of R&D investment does not render the impact of ESG on financial performance significant.

In these models, the variable SIZE is found to have a significant negative correlation with the Z-value at a significance level of 1%. Furthermore, the ownership property SOE (state-owned enterprise) is negatively related to short-term financial performance. This implies that state-owned enterprises may experience lower economic benefits in relation to ESG, possibly due to policy-related reasons

compared to private enterprises. Among the financial basic information variables, PRO (profitability) and LIQ (liquidity) are positively correlated with financial performance, while LEV (asset-liability ratio) exhibits a negative correlation. This implies that higher profitability and liquidity are favorable for improving financial performance, while a higher debt ratio may have an adverse impact.

Table 6 presents the regression analysis results for the impact of R&D investment and ESG on long-term financial performance. In this stage of the two-stage research model, the focus is on examining the impact on firm value. Model 5 demonstrates that R&D investment has a significant and positive correlation with the Q-value at a significance level of 5% ($P = 0.547$, $p < 0.05$). Additionally, the Z-value is also significantly and positively correlated with the Q-value ($P = 0.079$, $p < 0.01$). These findings indicate a direct positive relationship between R&D investment and long-term financial performance, supporting hypothesis 1b. Model 6 investigates the impact of ESG on long-term financial performance and reveals a significant positive correlation between ESG and the Q-value ($P = 0.025$, $p < 0.05$).

The fulfillment of ESG contributes to the enhancement of firm value, aligning with expectations and supporting hypothesis 2b. Moreover, the coefficient of the Z-value is positive, indicating that short-term performance has a promotive effect on long-term development. This suggests that a better short-term financial condition of the company is more favorable for investors when assessing the company's future growth value.

Table 6. Regression Analysis of R&D Investment and ESG on Long-term Financial Performance

	Q			
	Model5	Model6	Mode7	Model8
Con_s	3.269*** (24.671)	2.985*** (26.019)	3.282*** (24.050)	2.910*** (20.628)
Z	0.079*** (12.877)	0.079*** (12.849)	0.079*** (12.846)	0.079*** (12.842)
R&D	0.546** (3.427)		0.549** (3.435)	0.554* (3.458)
ESG		0.025** (3.239)	0.033** (3.831)	0.035*** (3.913)
R&D*ESG				0.187* (2.539)
SIZE	-0.033*** (-7.887)	-0.029*** (-7.662)	-0.029*** (-7.667)	-0.029*** (-7.692)
SOE	-1.211** (-3.004)	-1.213** (-3.030)	-1.211** (-3.014)	-1.202* (-2.871)
IND	Control			
F	59.616***	59.501***	54.191***	46.649***
Adjusted R^2	0.253	0.252	0.252	0.252
DW	1.228	1.289	1.289	1.289

In Model 7, both R&D (R&D) investment and ESG are introduced as explanatory variables. Comparing Model 7 to Model 5, the inclusion of ESG in Model 7 strengthens the impact of R&D investment on the Q-value, as evidenced by a higher coefficient value ($0.549 > 0.546$). This indicates that ESG enhances the relationship between R&D investment and financial performance. Model 8 extends the analysis by including an interaction term. Although the significance does not increase, the coefficient of R&D investment becomes larger ($0.554 > 0.549 > 0.546$) in Model 8. This suggests that when R&D investment and ESG jointly influence long-term financial performance, the impact of R&D investment on financial performance is further enhanced in the presence of ESG. These findings support hypothesis 3b.

Next, based on Model 6, the impact of including R&D investment is analyzed. From Model 7, it is observed that the inclusion of R&D investment strengthens the impact of ESG on the Q-value ($0.031 > 0.026$). In Model 8, where the interaction term between ESG and R&D investment is included, the correlation coefficient between ESG and the Q-value remains significant ($P = 0.036$, p

< 0.01), and its significance is further strengthened. Additionally, the coefficient of the interaction term is also significant (P = 0.187, p < 0.1). The validation through Models 7 and 8 indicates that when R&D investment and ESG jointly influence long-term financial performance, R&D investment strengthens the positive impact of ESG on long-term financial performance.

Based on the comparative analysis of the models, hypothesis 3b is supported. The influence of other variables on financial performance is found to be similar to that of short-term financial performance.

It is important to note that the mechanisms through which R&D investment and ESG affect financial performance differ. While ESG does not have a significant direct impact on short-term financial performance, R&D investment has significant effects on both short-term and long-term financial performance. The empirical analysis above leads to the following results:

Table 7. Summary of Empirical Results

Research Hypothesis	Result
H1a: Positive correlation between R&D investment and short-term financial performance	Supported
H1b: Positive correlation between R&D investment and long-term financial performance Supported	Supported
H2a: Positive correlation between ESG and short-term financial performance	Not supported
H2b: Positive correlation between ESG and long-term financial performance	Supported
H3a: Interaction between R&D investment and ESG enhances their respective effects on short-term financial performance	Not supported
H3b: Interaction between R&D investment and ESG enhances their respective effects on long-term financial performance	Supported

5.4 Robustness Tests

In the previous study, the selected response variables were the Z-value and Tobin's Q-value. To comprehensively examine the impact of R&D investment and ESG factors on financial performance, additional variables such as Return on Assets (ROA), Return on Equity (ROE), Asset Turnover Ratio (ATA), and Sales Growth Rate (ASALES) were chosen as alternative response variables. These alternatives were included to ensure the reliability and robustness of the selected response variables. These results suggest that the influence of ESG on financial performance may vary depending on the specific financial indicators and contextual factors under consideration. Importantly, the overall test results were consistent with the previous findings, indicating the validity and stability of the research conclusions. The specific results are presented in Tables 8:

Table 8. Results of robustness test

	ROA	**ROE**	**ATA**	**ASALES**
Con_s	10.836***	11.147***	14.533***	28.268***
	(16.826)	(11.881)	(9.189)	(13.536)
R&D	0.025**	0.033**	0.035***	0.024**
	(3.239)	(3.831)	(3.913)	(3.239)
ESG	6.013***	7.254***	7.672**	6.596
	(5.859)	(4.848)	(3.045)	(1.679)
R&D*ESG	0.172***	0.240***	0.195***	0.172***
	(7.602)	(7.304)	(3.470)	(2.331)
SIZE	-0.058***	-0.117***	-0.209***	-0.021***
	(-3.085)	(-4.260)	(-4.467)	(-0.727)
SOE	-1.537***	-2.088***	-2.467***	-4.963***
	(-5.365)	(-4.994)	(-3.500)	(-5.333)
IND	Control			
F	34.975***	32.379***	9.835***	24.196***
Adjusted R^2	0.176	0.165	0.107	0.128
DW	1.179	1.052	1.363	1.182

6. Research Conclusions and Recommendations

6.1 Research Conclusions

Investment in R&D (R&D) has a notable influence on a firm's financial performance, impacting both their immediate financial status and future growth value. Despite earlier literature demonstrating either negative or non-existent correlation between R&D investment and short-term financial performance owing to time lag effects, this study reveals a significant positive relationship between R&D investment and current financial performance. This relationship can influence long-term financial performance via the immediate financial condition. A plausible reason for this divergence is that previous studies primarily targeted high-tech industries characterized by prolonged R&D cycles and high costs. Conversely, in heavy-polluting industries, R&D investments are typically more application-oriented, focusing on real-world social challenges such as developing pollution gas filters and tail gas treatment devices. The R&D cycle in these industries is relatively shorter, and success rates are higher, enabling firms to yield specific economic benefits in the short term. Moreover, R&D investment is a long-term strategic commitment for companies, and the impacts of various R&D investment activities slowly manifest and accumulate over time. R&D pursuits trigger technological advancements and augmentations in product and service quality. In the long run, accumulated technological progress enhances a company's core competitive advantage and propels its market value.

6.2 Research Recommendations

Firms should adopt "social innovation" as a guiding principle, integrating R&D investment and ESG into their innovation activities.

Firstly, there necessitates a shift in ESG consciousness, underlining the significance of strategic ESG management. Conventional ESG concentrates on corporate responsibility towards social welfare, such as philanthropic contributions. However, an ESG strategy solely centered on social donations may not sufficiently cater to the varied needs of stakeholders. It is vital to balance the requirements of multiple stakeholders and address their genuine concerns. Establishing a long-term vision for ESG development and identifying a responsible blueprint for sustainable corporate growth are of paramount importance.

Secondly, firms should prioritize enhancing service value through effective R&D investments. Further improvements in the policy environment are required to stimulate greater R&D expenditure and boost the efficiency of fund utilization in the marketplace. Concurrently, deepening reforms that minimize administrative intervention and bolster market-driven mechanisms are needed to create conducive conditions for optimal allocation of R&D resources via market mechanisms. This will ensure the relevance, timeliness, and effectiveness of R&D investments, thereby fully harnessing their supportive and leading role in economic revitalization and upgrading.

Lastly, the establishment of a robust technological innovation framework is indispensable. Our findings reveal a lack of significant correlation between R&D investment and short-term financial performance in firms, suggesting that R&D investments have not produced the anticipated benefits. This discrepancy stems from the absence of a sound mechanism for technological innovation within these firms. On one hand, it is essential for firms to concentrate on both nurturing and retaining innovative talent. On the other hand, limited R&D capabilities within firms and a lack of inter-organizational collaboration and communication culminate in low R&D output efficiency. Enhancing collaborative efforts with other firms and entities is therefore pivotal. Furthermore, refining the R&D mechanism to align better with a firm's R&D strategies and fostering innovative models are crucial steps towards improving corporate performance.

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