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Research on the Impact of Technological Innovation Investment on the ESG Performance of Manufacturing Enterprises

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Abstract: With the deepening of the concept of sustainable development and the continuous advancement of the "dual-carbon" goals, environmental, social, and governance (ESG) factors have become important indicators for measuring corporate value. As industries with significant resource consumption and environmental impact, technological innovation in manufacturing enterprises is crucial to both the environment and corporate value. This study uses panel data from A-share listed manufacturing companies in China between 2019 and 2023 and constructs a moderated mediation model to explore the impact of technological innovation investment on the ESG performance of manufacturing enterprises. The research finds that technological innovation investment significantly promotes corporate ESG performance; technological innovation investment positively affects ESG performance through enhancing technological innovation capability; the higher the level of government policy support, the stronger the effect of technological innovation investment on technological innovation capability. The conclusions of this study are of great guiding value for manufacturing enterprises in the rational allocation of innovation resources, enhancing technological innovation competitive advantages, and promoting improvements in environmental, social, and governance performance.

Keywords: manufacturing enterprises, technological innovation investment, technological innovation capability, government policy support, corporate ESG performance

1. Introduction

The report of the 20th National Congress of the Communist Party of China points out that Chinese-style modernization is a modernization that achieves harmonious coexistence between humans and nature. It emphasizes the need to adhere to sustainable development and ensure the long-term development of the Chinese nation. ESG performance provides a comprehensive evaluation of corporate sustainable development from the three dimensions of environment (E), society (S), and governance (G), reflecting the unified concept of social value and economic value in green development. This is highly consistent with the concepts of high-quality economic development and sustainable development [1]. Since the formulation of "Made in China 2025" by the State Council in 2015, China has been committed to achieving the three major transformations: from "Made in China" to "Created in China," from "Chinese speed" to "Chinese quality," and from "Chinese products" to "Chinese brands." The goal is to push China to basically achieve industrialization by 2025 and enter

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the ranks of manufacturing powerhouses. General Secretary Xi Jinping emphasized: “Innovation is the most important quality for business operations and is essential for overcoming obstacles in the future. It is essential to firmly grasp key core technologies, and the manufacturing industry must be under domestic control [2]. The evaluation of corporate ESG performance not only helps manufacturing enterprises reduce risks, enhance competitive advantages, and improve brand value, but also facilitates the establishment of good stakeholder relationships, promoting manufacturing enterprises to actively assume social responsibilities and achieve sustainable development.

In recent years, global ecological degradation has led to worsening health conditions, a decrease in foreign direct investment (FDI), and a decline in technological innovation. However, health, FDI, and technological innovation are crucial to sustaining global economic growth [3]. The development environment of the manufacturing industry and technological innovation play important roles in transforming the development model of manufacturing and optimizing the construction of the technological innovation system [4]. Therefore, manufacturing enterprises are currently in an unfavorable stage of environmental degradation and intense competition, with rapid changes in technology, processes, and equipment demands [5]. The operational costs of manufacturing enterprises and industry barriers continue to rise. In the transformation of the global industrial economic landscape, the overlap of new and old international political cycles and the impact on the global division of labor order have led to deepening cracks in industrial chains [6]. China’s manufacturing industry faces issues such as the substitution of low-end manufacturing supply and the return of high-end manufacturing to developed countries. Domestically, China’s manufacturing industry is undergoing industrial structural adjustments, with rapid digital transformation of enterprises. Traditional manufacturing industries are facing technological innovation and transformation and upgrading [7]. Additionally, there is an upgrade in consumer demand structure, and society’s demand for corporate innovation capability has increased. Internally, manufacturing enterprises face issues such as a lack of innovative spirit, low levels of R&D investment, and difficulties in managing efficiency and controlling operational costs. In fierce market competition, maintaining a management advantage has become difficult [8].

The theory of externalities emphasizes that the behavior of one economic entity can bring additional benefits (positive externalities) or additional losses (negative externalities) to other economic entities, while having no impact on the entity exerting the externality [9][10]. According to this theory, the production activities of manufacturing enterprises not only generate negative externalities, including air and water pollution, noise pollution, and land degradation, but also have a profound impact on the ESG performance of the enterprises. Currently, China’s manufacturing industry faces the challenges of “low-end lock-in” and “high-end barriers” [11]. Therefore, technological innovation investment to enhance corporate ESG performance is crucial. As China’s labor costs and land costs gradually rise, the low-cost advantage that once attracted foreign-funded enterprises has diminished, and the competitiveness of high-end manufacturing has yet to be fully formed. At the same time, changes in the population structure have led to a shortage of highly skilled labor, causing shifts in the labor force structure, which presents new challenges for corporate human resource management and social responsibility practices. Against this backdrop, manufacturing enterprises can not only improve production efficiency through digital upgrades and technological innovation, but also strengthen employee training and education to enhance labor quality and corporate social image. In terms of management, some manufacturing enterprises do not pay enough attention to R&D innovation and excessively rely on scale expansion or cost reduction to improve profits, leading to slow technological progress. This bottleneck limits the improvement of corporate ESG performance and the future sustainable development path of the enterprise. Therefore, enterprises should not only increase investment in technological innovation and optimize the R&D management system, but also strengthen internal governance, enhance the scientific and transparent

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nature of decision-making, and ensure the effective implementation of sustainable development strategies under the coordination and guidance of the government.

To explore the impact of technological innovation investment on the ESG performance of manufacturing enterprises, this paper uses panel data from A-share listed manufacturing companies in China from 2019 to 2023 and constructs a moderated mediation model for research. The article combines the perspectives of enterprises, governments, and the public. Based on the impact of technological innovation investment on corporate ESG performance, the mediating role of technological innovation capability, and the moderating role of government policy support, the paper discusses how technological innovation investment affects corporate ESG performance through technological innovation capability under the moderation of policy support. This study lays a solid foundation for enterprises to develop efficient technologies, promote energy saving and emissions reduction, and establish an environmentally friendly system that aligns with government policies and protects public interests. The relationship between innovation input and corporate ESG performance can provide ideas for the direction of technological innovation in enterprises and produce high-quality green products to guide public consumption habits and promote the spread of environmentally friendly concepts. In addition, the exploration of the moderating role in the mediation effect can improve employees' work efficiency, reduce work pressure, and enhance job satisfaction; or improve the transparency and efficiency of the supply chain, ensuring that every link complies with social responsibilities. Few studies have combined the three major entities—enterprises, society, and government—together. This paper, by constructing a moderated mediation model involving technological innovation investment, technological innovation capability, government policy support, and corporate ESG performance, discusses the interaction between the three major entities from the perspective of technological innovation. Furthermore, the paper explores the moderating role of government policy support in the impact of technological innovation investment on technological innovation capability and finds that there is a mismatch between the technological innovation investment of manufacturing enterprises and government policy support, providing direction for enterprises to rectify and improve their technological innovation capabilities.

The arrangement of future chapters in this paper is as follows: the first section is the literature review and research hypotheses; the second section is the research design; the third section is the research results; the fourth section is the discussion; the fifth section is the conclusion and outlook.

2. Literature Review and Research Hypotheses

2.1. Innovation Investment

Innovation is the driving force behind economic development and has attracted widespread attention from scholars. Innovation investment, human resource management (especially employee welfare), and government support have significant positive effects on the innovation performance of military-industrial enterprises and regions across China. Among these, innovation investment and employee welfare exhibit a complementary effect [12], and policy support can positively moderate the relationship between regional innovation investment and innovation performance [13]. In specific macroeconomic environments, state-owned enterprise shareholders can significantly enhance the innovation investment and output of private enterprises, thereby improving their performance [14]. At the same time, innovation can improve a company's market competitiveness. Investment and production in highly innovative products can enhance consumers' perception of brand innovation, forming a virtuous cycle [15]. Innovation investment and corporate performance influence each other, with management capabilities playing a positive moderating role between them [16]. Innovation is an investment in future growth and development, and the factors affecting it are crucial to enterprises. Factors such as customer stability, excessive confidence of managers, pressure from capacity

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reduction, and financing constraints affect innovation investment [17][18]. Different factors have varying impacts on the willingness to invest in innovation. Market competition pressure can reduce the willingness of upstream manufacturers to invest in innovation [19], while a favorable business environment promotes investment in innovation by enterprises [20]. Additionally, the supplier concentration of heavily polluting manufacturing enterprises in China is inversely U-shaped with low-carbon innovation investment and is moderated by cash holdings [21].

Enterprises not only differ in their investment in innovation input, but also in their innovation capabilities. Innovation capability can enhance the innovation process by improving the conversion of innovation input into innovation output [22], and it changes as the share of foreign enterprises in a cluster changes [23]. The input-output relationship of innovation is generally classified as research on innovation efficiency. There are significant differences in the innovation input, output, and efficiency of NGI companies [24], and digital transformation along with a higher level of education among founder-CEOs can enhance innovation efficiency [25][26].

2.2. Corporate ESG Performance

Digital transformation has improved companies' efficiency and perceptual capabilities, exerting a profound impact on corporate ESG performance. The digital strategies, internal controls, green innovation, reduction of agency costs, and enhancement of corporate reputation within digital transformation can all improve the ESG responsibility performance of manufacturing enterprises [27][28][29]. After industrial development entered the 5.0 era, it was found that the basic values of Industry 5.0 align with ESG values and can support ESG functions [30]. In terms of finance, ESG performance impacts risk [31], and ESG uncertainty affects risk-return trade-offs [32]. ESG performance is positively correlated with corporate performance, and the positive impact of ESG ratings on corporate financial performance is more significant in high-risk situations than in low-risk ones [33]. During the financial crisis triggered by the COVID-19 pandemic, ESG performance mitigated financial risk [34]. When a company's financial performance falls below expectations, the performance gap significantly positively affects the company's ESG performance [35]. Furthermore, government environmental awareness and institutional investors' ESG actions can promote corporate ESG and green innovation, with media reporting playing a moderating role in this process [36][37].

2.3. Literature Review

In summary, in the field of technological innovation investment, research perspectives have gradually diversified. Existing studies not only explore the mutual influence between innovation investment and corporate performance but also focus on the factors affecting innovation investment within enterprises. The conversion efficiency of innovation investment has also received widespread attention. In the field of ESG performance, existing studies mainly focus on stakeholder decision-making, investigating the impact of corporate ESG performance on corporate value, green innovation, financial risk, and other aspects. Some scholars have also researched the impact of digital transformation on corporate ESG performance. However, there is a lack of in-depth exploration, such as insufficient research on the effects of innovation investment, output, and efficiency. Future research should focus on the relationship between corporate technological innovation and ESG after digital transformation, as well as how ESG practices can enhance corporate sustainability and competitiveness.

Therefore, this paper combines innovation investment with corporate ESG performance to deepen the understanding of the interaction mechanism between the two. It provides new analytical tools and perspectives for investors, helping them better assess the long-term value and potential risks of enterprises when making investment decisions. At the same time, it helps enterprises more effectively

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allocate innovation resources, ensuring that resource investment not only promotes technological progress. Exploring corporate ESG performance from the perspective of innovation investment not only aligns with the current industry structure upgrade driven by digital transformation but also adds a dimension to the thinking on ESG information. Since both innovation investment and ESG performance are important reference indicators of corporate competitive advantage and long-term value, exploring the interaction between them is of great significance for improving industry competitiveness and corporate competitiveness. From the perspective of social responsibility, this study addresses environmental, social, and governance issues through innovative activities and uses innovation to guide enterprises in the right operational direction, thereby enhancing the overall sustainability of society.

2.4. Research Hypotheses

2.4.1. Technological Innovation Investment and Corporate ESG Performance

From the perspective of corporate social responsibility, in addition to pursuing economic benefits, enterprises should also bear social responsibilities, including responsibilities related to the environment, society, and governance (ESG). Therefore, when enterprises make technological innovation investments, they are influenced by considerations of social responsibility and exhibit different performances in terms of environmental, social, and governance aspects.

In terms of environmental performance, contemporary technological innovation must have an environmental value orientation. In the pursuit of technological activities, goals of protecting and constructing nature should be included [38]. Technological innovation helps reduce carbon emissions and can favorably mitigate the adverse effects of economic growth and trade liberalization on carbon emissions [39]. At the same time, innovation-driven policies can promote the synergy and efficiency of urban pollution reduction and carbon emission reduction through technological effects, structural effects, and industrial agglomeration effects [40].

In terms of social performance, the technological use of natural resources, research and development, recycling processes, and resource-rich human resources provide innovative products and services through the innovation process [41]. Product innovation and process innovation are two important pathways for the development of green products, which not only improve environmental performance but also enhance economic performance [42]. Good economic performance enables enterprises to invest in research and development and innovation, thereby bringing social benefits, such as more environmentally friendly products or solutions. The combination of green innovation and corporate social responsibility helps promote the sustainable development of enterprises, enhance their social image and competitiveness, and have a positive impact on the upgrading and transformation of the entire industry [43].

In terms of governance performance, innovation increasingly relies on the various knowledge held by multiple partners, who work together in inter-organizational projects [44]. In practice, to promote industrial upgrading, the green economy system in cloud-based agglomeration requires innovation-driven forces and strong digital platform governance capabilities [45]. Among them, management innovation capabilities have a significant positive moderating effect on the relationship between technological innovation capabilities and corporate performance [46].

Based on this, this paper proposes:

H1: Under other conditions unchanged, technological innovation investment and ESG performance are positively correlated.

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2.4.2. Mediating Role of Technological Innovation Capability

According to the resource-based theory, a firm's unique resources and capabilities are the sources of its sustained competitive advantage. Technological innovation investment increases a company's technical resources and capabilities, forming technological innovation capabilities that are difficult to replicate and irreplaceable as competitive advantages, thereby improving the company's performance in environmental, social, and governance aspects. Regions with a good innovation atmosphere can enhance the innovation capabilities of technology-driven enterprises by increasing investment in digital infrastructure, incentivizing innovation between enterprises, benchmarking enterprises, and promoting the application and integration of blockchain and other digital technologies in various life scenarios. This can be achieved through a "technology + talent" configuration-driven path [47]. Based on studies on the impact of digitalization on the market performance and ESG of small and medium-sized enterprises, digital resources, organization, adoption, management, and corporate competitiveness positively influence corporate ESG performance through their impact on corporate market performance [48]. In research on high-tech listed companies in China, technological innovation capability also has a significant positive impact on corporate performance [46]. Based on this, the paper proposes:

H2: Technological innovation investment positively influences corporate ESG performance by enhancing technological innovation capability.

2.4.3. Moderating Role of Government Policy Support

Stakeholder theory suggests that businesses need to consider and balance the expectations and demands of multiple stakeholders in their operations. Investments in facilities and infrastructure by companies may sometimes fail to meet technological barrier requirements, but effective public policies can provide rewards, subsidies, and managerial support, which are crucial for businesses to adopt sustainable practices and industry-wide standards [49]. For example, green credit policies have a significant incentivizing effect on corporate green innovation, and government R&D subsidies and debt financing scales play a mediating role in the impact of green credit policies on corporate green innovation and the moderating effect of corporate economic influence [50]. In the increasingly competitive international environment, technological sovereignty will become an additional, horizontal rationale for innovation policy through the construction of capabilities (competences) and capacities, supported by trade, investment, and competition policies when necessary [51]. Based on this, the paper proposes:

H3: Government policy support moderates the relationship between technological innovation investment and technological innovation capability, that is, the higher the level of government policy support, the stronger the promoting effect of technological innovation investment on technological innovation capability.

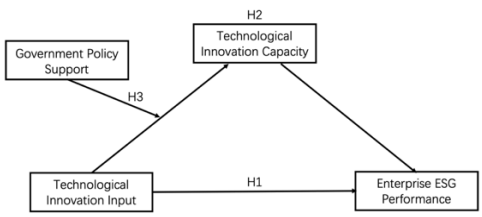

Figure 1: Moderated Mediation Model

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3. Research Design

3.1. Data Sources (2019-2023)

This study selects listed manufacturing companies in A-shares from 2019 to 2023, excluding the medical manufacturing industry, as the sample for analysis. Data on technological innovation investment, government policy support, and control variables of enterprises are obtained from the CSMAR database. Corporate ESG performance and technological innovation capability data are sourced from the Wind database and the CNRDS database, respectively. Finally, 9,725 listed manufacturing companies with ESG score data are selected as the research sample.

3.2. Variable Selection

3.2.1. Dependent Variable

Corporate ESG Performance. There are currently many established ESG assessment systems and channels for corporate ESG information disclosure. Many scholars obtain corporate ESG-related information through institutions, such as the Shandao Ronglü ESG rating [8], Bloomberg's ESG disclosure score [52][53], and the ASSET4 database [54]. Some scholars assign different scores to various ESG ratings, making measurement more convenient [55]. This paper uses the ESG rating score from the Wind database to measure corporate ESG performance.

3.2.2. Independent Variable

Technological Innovation Investment. Many studies categorize innovation input into different types based on the atmosphere of innovation investment. Cheng Huifang et al. divide innovation investment into three types: government research funding (GOV), corporate research funding (ENT), and technology R&D personnel investment (HTP) [56]. Zhao Zhihua and Chen Zitao categorize technological innovation input into internal R&D investment, external R&D investment, new product development investment, technology introduction and absorption investment, and technology purchase and transformation investment, measuring it by the proportion of R&D expenditure to main business revenue [57]. Considering the characteristics of research enterprises, some studies use the ratio of R&D investment to operating income to measure technological innovation investment [58][59][60]. Since many companies in the manufacturing sector are capital-intensive, this paper uses the ratio of R&D investment to operating income to measure technological innovation investment in manufacturing enterprises.

3.2.3. Mediating Variable

Technological Innovation Capability. Quintana-García and Benavides-Velasco establish innovation capability through the number of patents granted by a company within a year [61]. Guo Yanqing and Wang Huiling adopt this research outcome when exploring corporate technological innovation capabilities [62]. Xin Yan believes that regional innovation entities have the ability to transform knowledge into new products and processes, and refers to the research by Shen Yanan et al., measuring technological innovation capability in various provinces through the "number of patent applications granted" from an output quantity perspective [63][64]. Therefore, this paper uses the number of patents to measure a company's technological innovation capability.

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3.2.4. Moderating Variable

Government Policy Support. Huang Yan et al. suggest that fiscal incentive policies primarily involve direct subsidies issued by the government to enterprises. Therefore, government subsidies in the company's annual report are used as the measurement indicator [65]. Se-Kyoung Choi et al. measure government support policies using the annual level of government funding [66]. Kyunghwan and Seoyong use government environmental responsibilities and environmental expenditures as variables when exploring environmental policy support [67]. Chen Ling and Yang Wenhui regard government R&D subsidies as policy tools that incentivize corporate innovation [68]. Howell found that innovation subsidies received by new enterprises significantly positively affect their subsequent patent application numbers [69]. Guangshun Cheng et al. discovered through mediation effect testing that government subsidies promote substantial and strategic green innovation in family-owned enterprises by increasing R&D investment in these firms [70]. Therefore, this paper integrates the above content and selects government funding support for enterprises, i.e., government subsidies, to measure government policy support.

3.2.5. Control Variables (No Regional Consideration)

This paper selects the following indicators as control variables: profitability, company age, ownership concentration, return on total assets, debt-to-asset ratio, company size, intangible asset ratio, Tobin's Q ratio, company growth, board size, independent director ratio, and total cash recovery rate [8][52][55].

Table 1: Definition of Variables

Type	Variable	Symbol	Definition
Dependent variable	Technological innovation input	TI	R&D expenses/operating income
Independent variable	ESG performance	ESG	ESG disclosure score in Wind
Mediator variable	Technological innovation capacity	IC	Natural logarithm of patent authorization in that year
Moderator variable	Government policy support	GS	The current amount of the detailed items of government subsidies.
Control variable	Firm size	Size	Natural logarithm of total assets
	Total debt ratio	Lev	Total liabilities/total assets
	Return on total assets ratio	ROA	Return/total assets
	Total cash return on assets ratio	CF	Net cash flow from operating activities/total assets
	Tobin Q	TobQ	Market value/total assets
	Firm growth	g	Operating income growth rate
	Age of the firm	Age	Natural logarithm of the year minus listing year
	Number of directors	BS	The number of board directors
	Ratio of independent directors	Indep	The ratio of the number of independent directors to the total number of directors
	Intangible assets ratio	Intang	Net intangible assets/total assets
	Whether loss	Loss	If the annual net profit is less than 0, use 1; otherwise, use 0
	Ownership concentration	Share1	Shareholding ratio of the company's largest shareholder

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3.3. Model Specification

Data analysis is mainly conducted using SPSS 26.0 and Process v 4.2 software for descriptive analysis, regression analysis, and others. 1) Descriptive analysis is used to standardize the valid data. 2) Regression analysis is employed to examine the impact of technological innovation input on corporate ESG performance, as well as the mediating effect of technological innovation capability and the moderating effect of government policy support on the mediating effect.

This study constructs the following regression model to test the relationship between the intensity of technological innovation input and corporate ESG performance.

Model 1: $$ESG_{i,t} = \alpha_0 + \alpha_1 TI_{i,t} + \rho_a Controls + \varepsilon_{i,t}$$

Where, α_0 is the intercept, α_1 is the regression coefficient, i represents the individual firm, t represents the year, and ρ_a represents the regression coefficient for the control variables. ε is the error term; ESG represents corporate ESG performance, TI represents technological innovation input, and Controls represents control variables.

This study constructs the following mediation effect model to test whether technological innovation input enhances ESG performance through improving technological innovation capability.

Model 2: $$LNP_{i,t} = \beta_0 + \beta_1 TI_{i,t} + \rho_b Controls + \varepsilon_{i,t}$$

$$ESG_{i,t} = \gamma_0 + \gamma_1 TI_{i,t} + \gamma_2 LNP_{i,t} + \rho_c Controls + \varepsilon_{i,t}$$

Where, β_0 and γ_0 are the intercept terms, β_1、γ_1、γ_2 are the regression coefficients, i represents the individual firm, and t represents the year. ρ_b、ρ_c represent the regression coefficients of the control variables, and ε is the error term. ESG refers to the firm's ESG performance, TI refers to technological innovation input, LNP refers to technological innovation capability, and Controls represent the control variables.

This study constructs the following moderated mediation model to test whether technological innovation input enhances ESG performance through technological innovation capability, with the moderating effect of government policy support.

Model 3: $$LNP_{i,t} = \lambda_0 + \lambda_1 TI_{i,t} + \lambda_2 GI_{i,t} + \lambda_3 LNP_{i,t} \times GI_{i,t} + \rho_d Controls + \varepsilon_{i,t}$$

$$ESG_{i,t} = \varphi_0 + \varphi_1 TI_{i,t} + \varphi_2 LNP_{i,t} + \varphi_3 GI_{i,t} + \varphi_4 LNP_{i,t} \times GI_{i,t} + \rho_e Controls + \varepsilon_{i,t}$$

Where, λ_0 and φ_0 are the intercept terms, λ_1、λ_2、λ_3、φ_1、φ_2、φ_3、φ_4 are the regression coefficients, i denotes the individual firm, t denotes the year, and ρ_d and ρ_e are the regression coefficients for the control variables, with ε as the error term. ESG represents the firm's ESG performance, TI represents technological innovation input, LNP represents technological innovation capability, GI represents government policy support, and Controls refer to the control variables.

4. Research Results

This study first conducts a descriptive statistical analysis of the data, with the results shown in Table 2.

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Table 2: Descriptive Statistics

Variable	N	Min	Max	Mean	Std
Age	9725	1.386	4.205	2.985	0.307
Sh1	9725	1.844	86.913	31.395	14.115
Size	9725	17.880	27.640	22.098	1.207
Loss	9725	0.000	1.000	0.159	0.366
TobQ	9725	0.670	28.641	2.161	1.574
g	9725	-1.445	168.498	0.185	2.079
CF	9725	-0.704	0.874	0.052	0.073
ROA	9725	-7.700	0.786	0.029	0.141
Intang	9725	0.000	0.656	0.039	0.035
Lev	9725	0.008	11.386	0.402	0.246
BS	9725	4.000	17.000	8.099	1.533
IND	9725	16.670	80.000	38.106	5.750
GI	9725	-44.12	62.67	0.65	2.35
TI	9725	0.000	551.750	6.155	9.023
ESG	9725	2.470	9.620	6.085	0.778
LNP	9725	0.693	9.156	3.605	1.294

Before exploring the effects, all variables were standardized to eliminate multicollinearity. As shown in Table 4, from Model 1, the regression coefficient for the impact of technological innovation input on corporate ESG performance is 0.1245, which is positive and passes the significance test. This suggests that technological innovation input positively influences corporate ESG performance, supporting Hypothesis H1.

As shown in Table 3, from Model 2, the regression coefficient for the impact of technological innovation input on technological innovation capability is 0.1042, which is positive and passes the significance test, indicating that technological innovation input positively influences technological innovation capability. Model 3 introduces technological innovation capability based on Model 1, and the result shows that the regression coefficient for technological innovation capability is 0.1687, which is positive and passes the significance test. Compared to Model 1, the regression coefficient for the impact of technological innovation input on corporate ESG performance decreases from 0.1245 to 0.1096. Therefore, Hypothesis H2 is supported, and the mediating variable plays a partial mediating role. As shown in Table 4, the results of the indirect effects show that the regression coefficient for the impact of technological innovation input on corporate ESG performance via technological innovation capability is 0.0176, and "0" is not included in the confidence interval. The direct effect accounts for 86% of the total effect, while the mediating effect accounts for 14%. The mediating effect is significant, supporting Hypothesis H2.

Table 3: Regression Analysis Results

Variable	ZESG Model 1	ZLNP Model 2	ZESG Model 3	ZLNP Model 4
ZTI	0.1245***	0.1042***	0.1096***	0.108***
ZLNP			0.1687***	
ZGI				0.1231***
Int_1				0.0448***
ZAge	-0.0524***	-0.0107	-0.0506***	-0.0082
ZSh1	0.0571***	-0.0165**	0.0599***	-0.0176**

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Table 3: (continued).

ZSize	0.2573***	0.6120***	0.1541***	0.5489***
ZLoss	-0.0622***	-0.0266***	-0.0577***	-0.0257***
ZTobQ	0.0333***	0.0062	0.0323***	0.0001
Zg	-0.0107	-0.0123	-0.0087	-0.0123
ZCF	0.0230**	-0.0052	0.0239	-0.0035
ZROA	0.0260**	0.0316***	0.0206	0.0342***
ZIntang	-0.0378***	-0.0314***	-0.0325***	-0.0288***
ZLev	-0.1185***	0.0654***	-0.1295***	0.0710***
ZBS	0.0635***	0.0020	0.0632***	0.0036
ZIND	0.0373***	0.0134	0.0351***	0.0096
R2	0.1056	0.3975	0.1227	0.4095
F	88.1513***	492.8172***	97.0002***	448.8975***

Table 4: Mediation Effect Test

	Effect	BootSE	BootLLCI	BootULCI	Proportion/%
Indirect effect(s) of X on Y:	0.0176***	0.0080	0.0087	0.0379	14
Direct effect of X on Y	0.1069***	0.0101	0.0871	0.1268	86
Total effect of X on Y	0.1245***	0.0101	0.1047	0.1444	

As shown in Table 3, from Model 4, the regression coefficient for the interaction term on technological innovation capability is 0.1231, which is positive and passes the significance test, supporting Hypothesis H3. This indicates that the level of government policy support positively influences the effect of technological innovation input on technological innovation capability.

5. Discussion

This chapter discusses the significance of technological innovation input on corporate ESG performance, as well as the mediating role of technological innovation capability and the moderating effect of government policy support on its impact. Through regression analysis, it is concluded that technological innovation input has a positive effect on corporate ESG performance, and that technological innovation input can improve corporate ESG performance by enhancing technological innovation capability. Under the influence of government policy support, the promotion effect of technological innovation input on technological innovation capability is enhanced, thereby strengthening the impact of technological innovation input on corporate ESG performance through technological innovation capability. According to the mediation effect test, the direct effect of technological innovation input on corporate ESG performance accounts for 86%, while the indirect effect of technological innovation input on corporate ESG performance through innovation capability accounts for 14%. This indicates that the indirect effect makes up a smaller proportion of the total effect, with the direct effect of technological innovation input dominating the impact on corporate ESG performance.

In terms of the direct effect, technological innovation input can improve corporate ESG performance by enhancing internal management systems, optimizing governance structures, and increasing management transparency and decision-making efficiency. It can also boost technological support to achieve goals such as energy conservation, emission reduction, and increasing employee benefits, thereby improving environmental, social, and governance performance. In terms of the indirect effect, technological innovation input positively promotes technological innovation

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capability. A higher investment in R&D is more likely to lead to the development of new products and the acquisition of new patents by companies. However, on the one hand, the formation of technological innovation capability is challenging. Technological breakthroughs require time accumulation and exhibit a lag, so technological innovation input does not fully translate into technological innovation capability. On the other hand, technological innovation capability may not fully convert into improved ESG performance. In addition to innovation capability, other factors, such as management ability, financing capability, and market share, are also required. Therefore, the impact of the indirect effect is smaller than that of the direct effect.

Regarding the interaction between technological innovation input and government policy support on technological innovation capability, it appears that government policy support may be insufficient, or that after receiving government policy support, the distribution of resources, measures taken, and the direction of innovation input by companies do not align, leading to resource waste. For some companies with ample technological innovation input and strong innovation capabilities, the effect of government policy support on innovation input is relatively weak. For companies with weaker market competitiveness, government policy support cannot fully resolve the difficulties they face. Furthermore, some policies that support the industry may lead to lower industry barriers, more competitors, and increased competitive pressure. Companies often focus on market demand, neglecting the effect of government policy support on technological innovation input. By examining the regression analysis of control variables, it is found that the correlation with company growth rate is not significant, indicating that company growth rate does not directly affect technological innovation capability or corporate ESG performance. The total operating growth rate defined by financial indicators in this study shows that high-growth companies may focus more on strategies for expanding market share rather than improving technological innovation capability and corporate ESG performance.

This study integrates the three main stakeholders—enterprises, government, and society—to explore the manufacturing industry and examine the impact of technological innovation input on corporate ESG performance. Current literature on the manufacturing industry mainly focuses on transformation and upgrading [71][72][73]. Technological innovation input, as one of the driving forces for industry development, has a significant impact on the manufacturing sector. At the same time, some scholars indicate that there is a significant relationship between technological innovation input and technological innovation capability [74][75], with technological innovation capability being equally crucial. In terms of corporate ESG performance, both domestic and international literature mainly focuses on improving the ESG system, enhancing ESG information disclosure, guiding investments based on ESG, the impact of ESG on corporate value, and the influence of ESG on corporate risk. This study connects corporate ESG performance with financial performance by defining variables, expanding research on the impact of financial indicators on ESG performance, and exploring the role of technological innovation in corporate ESG performance. This provides new momentum for improving corporate ESG performance and offers insights into the specific impact of technological innovation on ESG performance in the three dimensions of environment, society, and corporate governance. Furthermore, this paper explores the moderating role of government policy support in the relationship between technological innovation input and technological innovation capability, making the analysis more comprehensive and enriching research on the role of government in helping enterprises fulfill social responsibilities, enhance ESG performance, and guide sustainable development.

This paper constructs a moderated mediation model to explore the interactions between specific factors of enterprises, government, and society, providing solutions for companies to address environmental changes, social development, and governance challenges. First, due to the significant promoting effect of technological innovation input on corporate ESG performance, manufacturing

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companies can improve their ESG performance by appropriately increasing R&D investment. This can include improving product manufacturing technologies to reduce pollution or upgrading pollution treatment technologies, helping R&D personnel improve their technical skills and work satisfaction, creating innovation incentives, and establishing a comprehensive corporate management system and product manufacturing processes to improve yield and quality. Secondly, since the indirect effect of technological innovation input on corporate ESG performance is much smaller than the direct effect, manufacturing companies can control the promotion effect of technological innovation input on technological innovation capability by appropriately reducing R&D investment in patent acquisition. Manufacturing companies focused on patent acquisition can adjust the direction and extent of their technological innovation input in combination with government policy support, allocating resources efficiently to enhance technological innovation capability. Finally, for manufacturing companies aiming to improve ESG performance, part of the resources allocated for company growth can be redirected towards technological innovation, such as developing clean energy, achieving resource recycling, and digital governance.

6. Conclusion and Outlook

This paper constructs a moderated mediation model and utilizes panel data from A-share listed manufacturing companies in China from 2019 to 2023 to deeply examine the impact of technological innovation input on corporate ESG performance. The study finds that: technological innovation input significantly promotes corporate ESG performance; technological innovation input positively affects corporate ESG performance by enhancing technological innovation capability; the higher the level of government policy support, the stronger the promoting effect of technological innovation input on technological innovation capability.

Based on these findings, this paper offers the following recommendations: First, manufacturing companies need to continuously increase the intensity of technological innovation input, focusing on areas related to ESG goals, and optimizing the allocation of innovation resources. Companies can incorporate ESG goals into their innovation strategies, prioritizing investments in areas such as clean energy technologies, green manufacturing processes, and intelligent governance tools. Second, manufacturing companies need to improve the efficiency of transforming technological innovation input into technological innovation capability. Companies can collaborate with universities to direct the delivery of talent that combines technical expertise and awareness of sustainable development, building a cross-disciplinary talent system. Additionally, they can apply agile methods by breaking down the R&D cycles of innovation technologies aimed at improving ESG performance to enhance technological innovation capability. Third, from a policy perspective, manufacturing companies should actively respond to government support policies, closely monitor policies such as tax incentives and green finance, and prioritize the deployment of green innovation pilot projects in regions with intensive government policies. In sectors where government policy support is relatively weak, companies should seek external innovation collaborations and share R&D resources. Moreover, the government could establish a dynamic, gradient-based subsidy mechanism, providing targeted subsidies based on the intensity of R&D input and the degree of results conversion, while guiding the construction of talent compensation systems.

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