The mediating effect of technology innovation among export performance, firms' heterogeneity and ESG performance

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Abstract

This study aimed to explore the mechanisms and pathways through which firm heterogeneity, environment, society, and governance (ESG) performance, and technological innovation influenced firm exports. Based on panel data from China's A-share main board listed companies between 2015 and 2022, the research empirically analyzed the impact of firm heterogeneity, ESG performance, and technological innovation on exports, while also examining the mediating role of technological innovation. The findings revealed that firm heterogeneity significantly affected exports, with ESG performance and technological innovation both having a positive influence on export performance. Furthermore, technological innovation partially mediated the relationship between ESG performance and exports. Additionally, group regression results on firm heterogeneity showed that the number of employees had a greater impact on exports than the total assets of the firm, suggesting that "human capital" played a more critical role in export performance than "total assets." As a result, enhancing ESG performance, increasing both assets and employee numbers, improving labor productivity, and advancing technological innovation were identified as key factors for boosting exports. Through the discussion of these findings, this study aims to offer insights for promoting sustainable economic development, informing government policies on low-carbon trade, and optimizing corporate production and operational strategies. It also seeks to enrich the existing theoretical framework, enhance the international competitiveness of companies in developing or emerging economies such as China, and provide new perspectives, ideas, and theoretical support for fostering the sustainable growth of the global economy.

Keywords: ESG performance, firm exports, firm heterogeneity, technological innovation.

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Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

1. Introduction

Corporate environmental protection and sustainable development have become central concerns for both governments and firms, consistently forming a focal point of academic research. The core principles of Environment, Society, and Governance (ESG) emphasize that firms' activities and financial investments need to account for their impact on sustainable development, social responsibility, and corporate governance [1]. ESG principles essentially guide companies to maximize overall economic and social benefits while pursuing their own growth [2]. Numerous studies have demonstrated that quantifying the impact of firms' ESG practices on the environment and society can effectively evaluate corporate sustainability and international competitiveness [3]. Companies with robust ESG performance generally exhibit better operational conditions, higher governance standards, and clearer long-term developmental visions and goals [4].

However, earlier discussions on ESG have predominantly focused on developed nations [5-7], making their conclusions potentially inapplicable to developing countries like China. Furthermore, variations in firm size, age, organizational structure, and productivity lead to differences in business objectives and management philosophies, affecting core factors such as cost, quality, and comprehensive competitiveness. Companies in developing nations generally exhibit higher degrees of heterogeneity [8].

Technological innovation, a critical factor in cultivating competitive advantage, is influenced by both ESG performance and firms' heterogeneity. Defined as the introduction of new technologies or the enhancement of existing ones [9], technological innovation aims to improve the efficiency, quality, functionality, or performance of products, services, or production processes.

To assess how these factors influence export competitiveness, this study analyzes firm exports from the perspective of export value. For firms, particularly those oriented toward export, export value is an essential indicator of international competitiveness and sustainable development capability [10].

2. Statement of the Problem

Although firms' heterogeneity, ESG performance, and technological innovation have garnered considerable attention, prior research has primarily concentrated on financial indicators of firm performance, paying less attention to the export aspect. Most studies have analyzed these factors in isolation or through pairwise relationships, without examining the interaction of multiple factors or their specific impact mechanisms. Additionally, the existing literature has focused primarily on developed countries, with limited studies addressing developing nations like China.

The interactions between firms' heterogeneity, ESG performance, technological innovation, and export performance remain insufficiently explored, particularly in the context of developing economies. The mechanisms through which these factors collectively influence export performance, and the mediating role of technological innovation in these relationships, require further investigation to provide a more comprehensive understanding of export dynamics in emerging markets such as China.

Consequently, this study seeks to explore the following questions from multiple dimensions:
1. How do firms' heterogeneity, ESG performance, and technological innovation affect export performance?
2. In what ways do firms' heterogeneity and ESG performance influence technological innovation?
3. Does technological innovation have a mediating effect on firms' heterogeneity and ESG performance through export performance?

The exploration of these questions aims to provide valuable insights for promoting sustainable economic development, informing governmental low-carbon trade policies, and optimizing corporate production and operational strategies. Additionally, it seeks to enrich relevant theories, enhance the international competitiveness of companies in developing or emerging economies like China, and offer new perspectives, ideas, and theoretical foundations for advancing global sustainable development.

3. Objectives

The primary objectives of this study are:
1. To examine the impact of firms' heterogeneity (firm age, size, productivity, and wages) on export performance of Chinese A-share listed companies.
2. To investigate the relationship between Environmental, Social, and Governance (ESG) performance and export value among Chinese firms.
3. To analyze the influence of technological innovation on export performance in the context of Chinese listed companies.
4. To explore the mediating role of technological innovation in the relationship between firms' heterogeneity and export performance.
5. To assess the mediating effect of technological innovation in the relationship between ESG performance and export value.
6. To provide empirical evidence and practical implications for enhancing export performance through ESG initiatives and technological innovation in developing economies.

4. Literature Review

4.1. Theoretical Framework of Firms' Heterogeneity and Export Performance

The theoretical foundation for understanding firms' heterogeneity and its impact on export performance can be traced to the seminal work of Melitz [11]. Building upon Krugman [12] trade model and Hopenhayn [13] dynamic industry model, Melitz [11] introduced a framework that incorporates differences in firm productivity to explain variations in international trade and export decisions. This model has been instrumental in identifying key factors that contribute to gaining competitive advantages in international markets [14].

In the Melitz [11] model, firms' heterogeneity is primarily attributed to differences in production efficiency. Subsequent studies have expanded this perspective by examining various dimensions of heterogeneity. Bernard et al. [15] posited that firms' heterogeneity is endogenous, with characteristics such as productivity, firm size, number of employees, and wage levels positively influencing export decisions. Conversely, Bustos [16] argued that firms' heterogeneity is exogenous, suggesting that factors such as firm size, market integration, and trade costs impact export decisions.

Empirical research on the relationship between firms' heterogeneity and export performance has generally found that firm size, factor intensity, and firm age are positively correlated with export performance [17-21]. However, findings regarding the effects of productivity and wage levels have been less consistent. This inconsistency may be attributed to differences in sample selection, varying stages of economic development, and the specific metrics used to measure these factors.

4.2. ESG Performance and Export Performance

Environmental, Social, and Governance (ESG) principles have emerged as a comprehensive framework for corporate social responsibility (CSR) [22]. ESG encompasses environmental responsibility, social governance, and corporate governance, providing a holistic approach to evaluating non-financial outcomes [23, 24]. Companies with robust ESG performance generally exhibit better operational conditions, higher governance standards, and clearer long-term developmental visions and goals [4].

Despite growing interest in ESG performance, most research has focused on its impact on financial performance and firm value [25], with limited studies directly addressing the relationship between ESG performance and export activities. The existing literature presents divergent views on this relationship. Some scholars argue that ESG performance is positively correlated with export outcomes [26, 27] while others suggest that improvements in ESG performance increase firm costs, thereby exerting a negative impact on exports [28].

Notably, prior research has predominantly concentrated on developed nations [5-7], raising questions about the applicability of these findings to developing economies like China. This gap underscores the need for more comprehensive investigations into the relationship between ESG performance and export outcomes in emerging markets.

4.3. Technological Innovation and Export Performance

Based on Schumpeter and Swedberg's [29] theory of technological innovation, research has confirmed that firms' innovation activities significantly impact export performance. Technological innovation, defined as the introduction of new technologies or the enhancement of existing ones [9], has been found to influence firms' export decisions [30] and increase their likelihood of participating in export markets [31].

Empirical studies have demonstrated that innovation positively affects the survival of both direct and indirect exporters Dai et al. [32]. Sandu and Ciocanel [33] noted that total R&D expenditure positively affects the export levels of high-tech products, with private R&D expenditures having a stronger impact than public R&D expenditures. Similarly, Shin [34] in their analysis of Korean export firms of different sizes, showed that innovation promotes exports.

Technological innovation serves as a core component of firms' competitiveness by reducing production costs, improving production efficiency, and enabling product differentiation. These benefits allow firms to offer export products at lower prices and capture larger shares in overseas markets. Continuous technological innovation also signals to the market that a company has strong growth prospects, thereby enhancing its international competitiveness.

4.4. The Mediating Role of Technological Innovation

$$c = c' + ab$$

Figure 1.
Schematic diagram of the mediation variables [35].

While the literature has explored the relationships between firms' heterogeneity, ESG performance, technological innovation, and exports, few studies have examined the mediating role of technological innovation in these relationships. Theoretically, technological innovation can serve as a mechanism through which firms' heterogeneity and ESG performance influence export outcomes.

Firms' heterogeneity factors, such as size and productivity, can affect their capacity for technological innovation. The relationship between firm size and innovation has been found to follow either an inverted U-shaped or a positive U-shaped pattern Aghion et al. [36]. Schumpeter and Swedberg [29] argued that firm size is positively correlated with innovation, while others suggest that large firms might inhibit innovation due to organizational rigidity [37, 38].

Similarly, ESG performance can influence technological innovation, with most researchers concluding that strong ESG performance enhances corporate innovation capabilities [39, 40]. This improved innovation capacity, in turn, can bolster international competitiveness and promote exports.

Some studies have begun to explore the mediating and moderating role of technological innovation in related contexts [41, 42]. However, there remains a need for more comprehensive analyses of the specific mechanisms and effects of this mediation on export performance, particularly in developing nations like China. Such investigations would provide valuable insights for fostering economic growth, optimizing trade policies, and informing firms' strategy development.

4.5. Hypotheses Development

Based on the theoretical framework and literature review, the following hypotheses are proposed:

Hypothesis 1: Firms' heterogeneity, ESG performance, and technological innovation have an impact on export value.

H1a: Firms' age has a significant positive impact on export value.

Justification: Older firms often benefit from accumulated experience, established networks, and brand recognition, which can facilitate export activities. However, this relationship may be moderated by factors such as organizational inertia and reduced innovation drive in older firms.

H1b: Firms' size has a significant positive impact on export value.

Justification: Larger firms typically possess greater resources, economies of scale, and market expansion capabilities, which can enhance their export performance. Both asset size and number of employees are considered measures of firm size in this study.

H1c: Firms' productivity has a significant positive impact on export value.

Justification: Higher labor productivity helps firms exceed export market entry thresholds, increasing the likelihood of exporting and improving export performance.

H1d: Firms' wages have a significant positive impact on export value.

Justification: Higher wages are expected to increase employee motivation and improve overall firm performance, which can positively affect export outcomes.

H1e: Firms' ESG score has a significant positive impact on export value.

Justification: Enhanced sustainability practices reduce environmental risks, improve product quality, and decrease production costs, while responsible corporate governance increases company visibility, employee loyalty, and customer satisfaction, collectively improving export performance.

H1f: Firms' technological innovation has a significant positive impact on export value.

Justification: Technological innovation reduces production costs, improves efficiency, enables product differentiation, and enhances a firm's reputation, thereby boosting export performance.

Hypothesis 2: Firms' heterogeneity and ESG performance have an impact on technological innovation.

H2a: Firms' age has a significant negative impact on technological innovation.

Justification: Younger firms tend to be more agile, less constrained by established routines, and more motivated to adopt innovative practices compared to older firms.

H2b: Firms' size has a significant positive impact on technological innovation.

Justification: Larger firms often have more resources to invest in R&D activities and greater capacity to absorb and implement new technologies.

H2c: Firms' productivity has a significant impact on technological innovation.

Justification: Productivity influences firms' technological innovation, though the direction of this effect may vary depending on whether resources are primarily directed toward capital assets or human resources.

H2d: Firms' wages have a significant positive impact on technological innovation.

Justification: Higher wages can attract and retain skilled employees, who are essential for successful innovation initiatives.

H2e: Firms' ESG score has a significant positive impact on technological innovation.

Justification: Strong ESG performance creates an environment conducive to innovation, with sustainable practices often requiring and driving technological advancements.

Hypothesis 3: Technological innovation has a mediating effect on firms' heterogeneity, ESG performance through export performance.

Justification: Technological innovation enhances firms' ability to absorb advanced technologies from international markets, facilitates continuous improvements in product quality, and meets the demands of international markets. It enables firms to transition to more sustainable production models, improve productivity, and reduce production costs, thereby mediating the relationship between firms' heterogeneity, ESG performance, and export value.

These hypotheses collectively aim to provide a comprehensive understanding of the direct and indirect relationships between firms' heterogeneity, ESG performance, technological innovation, and export performance in the context of Chinese listed companies.
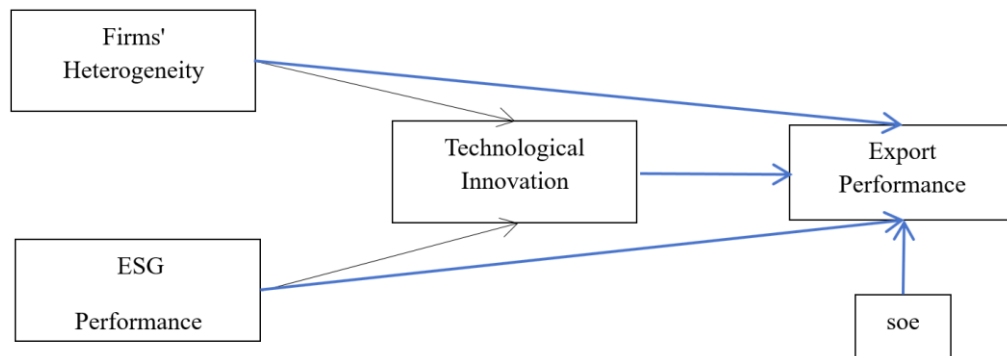

Figure 2.
The Proposed Hypothesized Structural Model.

4. Methods

4.1. Research Methodology

4.1.1. Population and Sample Selection

This study targeted listed companies with export activities in China's A-shares market from 2015 to 2022 as the initial population. To refine this population into an appropriate sample, a systematic selection process was implemented. First, listed companies in the financial and insurance sectors were excluded due to their distinctive operational characteristics and regulatory frameworks. Second, companies with potential financial anomalies or missing data were removed to ensure data integrity and analytical validity. Third, to mitigate the impact of outliers, the core variables were winsorized at the 1% and 99% quantiles.

The sample was further refined based on the financial support required for technological innovation. Specifically, from the initial population, 431 companies in the top 75% by export value were selected, resulting in a final sample of 3,448 observations over the eight-year period (2015-2022). This sampling approach ensured that the dataset contained companies with substantial export operations and adequate financial resources to support technological innovation activities.

4.2. Data Collection

This study utilized panel data from the selected 431 Chinese A-share listed companies. Data were collected from multiple reliable sources:

1. Annual reports of listed firms: Primary source for financial data, employee information, and operational metrics
2. CSMAR database: Source for firms' heterogeneity indicators (age, assets, employees, productivity, wages) and technological innovation metrics (R&D expenditure, R&D personnel)
3. CSI ESG index (https://www.chindices.com/): Source for ESG performance scores ranging from 0-100
4. Wind database: Source for export performance data, specifically overseas operating revenue

4.3. Variable Definition

This study included four main variables: firms' heterogeneity, ESG performance, technological innovation, and firm export. The technological innovation capability was represented by a comprehensive indicator, TI, composed of four individual indicators, while the firm's export performance was primarily assessed using the export value. Specific definitions of each variable were detailed in Table 1.

Table 1.

Variables, proxies and sources of data

Variables	Factor	Mnemonic	Definition	Source of Data
Independent variables				
Firms' Heterogeneity	Age	*age*	From firm listing time to current time	Annual reports of listed firms; CSMAR database
	Size (Total assets)	*lnsass*	The natural logarithm of the firm's total assets	Annual reports of listed firms; CSMAR database
	Size (Employees)	*lnsemp*	The natural logarithm of number of employees	Annual reports of listed firms; CSMAR database
	Productivity	*lnp*	The natural logarithm of labor productivity (Labor productivity = Operating revenue / Total number of employees)	Annual reports of listed firms; CSMAR database
	Wage	*wage*	Total wage expenditures	Annual reports of listed firms; CSMAR database
Independent variables				
Firm ESG Performance	Environment, Social Governance	*esg*	1. Use CSI ESG Index 2. The composite score of listed firms using CSI ESG is between 0 and 100, 0 is the lowest and 100 is the highest	CSI ESG index https://www.chindices.com/
Mediation variables				
Technical Innovation	Technical Innovation	*TI*	The factor analysis of R&D personnel, R&D spend sum, R&D person ratio, R&D spend sum ratio	Annual reports of listed firms; CSMAR database

Table 1.

Variables, proxies and sources of data (Cont.').

Variables	Factor	Mnemonic	Definition	Source of Data
Dependent variable				
Export Performance	Export Value	*lnev*	The natural logarithm of overseas operating revenue	Annual reports of listed firms; Wind database
Control variable				
Ownership	State-owned firms	*soe*	Dummy variable of the firm equity; 1=state owner and 0=the others.	Annual reports of listed firms; CSMAR database

4.3. Independent Variables

Firms' Heterogeneity was measured through several dimensions:
- Age (*age*): From firm listing time to current time
- Size (Total assets) (*lnsass*): The natural logarithm of the firm's total assets
- Size (Employees) (*lnsemp*): The natural logarithm of the number of employees
- Productivity (*lnp*): The natural logarithm of labor productivity (Operating revenue / Total number of employees)
- Wage (*wage*): Total wage expenditures

Firm ESG Performance (*esg*):
- Used CSI ESG Index

- The composite score of listed firms using CSI ESG is between 0 and 100, with 0 being the lowest and 100 the highest

Mediation Variable

Technical Innovation (*TI*):

- Factor analysis of R&D Person, R&D spend sum, R&D person ratio, and R&D spend sum ratio

Dependent Variable

Export Performance (*lnev*):

- The natural logarithm of overseas operating revenue

Control Variable

Ownership (*soe*):

- Dummy variable of the firm equity; 1=state owner and 0=the others

4.4. Statistics Analysis and Specification Models

This study first conducted descriptive statistics, Pearson correlation analysis, variance inflation factor (VIF) tests, and other relevant diagnostics on the data to establish a solid foundation for further analysis. Descriptive statistics summarize and describe the fundamental characteristics of the dataset, typically revealing measures of central tendency, distribution patterns, and the degree of data dispersion. These metrics serve as the basis for subsequent regression analyses.

The Pearson Correlation Coefficient measures the degree of linear correlation between two variables. Its criteria for multicollinearity are 0.8. The magnitude of the Variance Inflation Factor (VIF) values served as an indicator of the presence of significant correlations among the explanatory variables. According to Marquardt (1970), if $0 < VIF < 10$, it indicates the absence of substantial multicollinearity issues among the explanatory variables.

Multiple regression was used to evaluate the impact of multiple independent variables on a dependent variable. This method allowed for the analysis of how independent variables collectively influenced the dependent variable, helping to explain or predict changes in the dependent variable.

Because the correlation between the firm's total assets and the firm's employees was higher than 0.8, they were separately employed in multiple regression. Thus, the following specification models were constructed:

1. Responding for hypothesis 1:
   - $lnev_{it} = \beta_0 + \beta_1 age_{it} + \beta_2 lnsass_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (1a)
   - $lnev_{it} = \beta_0 + \beta_1 age_{it} + \beta_3 lnsemp_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (1b)
   - $lnev_{it} = \beta_0 + \beta_1 esg_{it} + \beta_2 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (1c)
   - $lnev_{it} = \beta_0 + \beta_1 TI_{it} + \beta_2 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (1d)
2. Responding for hypothesis 2:
   - $TI_{it} = \beta_0 + \beta_1 age_{it} + \beta_2 lnsass_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (2a)
   - $TI_{it} = \beta_0 + \beta_1 age_{it} + \beta_3 lnsemp_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (2b)
   - $TI_{it} = \beta_0 + \beta_1 esg_{it} + \beta_2 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (2c)
3. Responding for hypothesis 3:
   - $lnev_{it} = \beta_0 + \beta_1 age_{it} + \beta_2 lnsass_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 esg_{it} + \beta_7 TI_{it} + \beta_8 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (3a)
   - $lnev_{it} = \beta_0 + \beta_1 age_{it} + \beta_3 lnsemp_{it} + \beta_4 lnp_{it} + \beta_5 wage_{it} + \beta_6 esg_{it} + \beta_7 TI_{it} + \beta_8 soe_{it} + \sum Industry_t + \sum Year_i + \epsilon_{it}$ (3b)

Additionally, industry dummy variables (Industry) and time dummy variables (Year) were included to control for industry effects and time effects, respectively.

For investigating the mediating effect of technological innovation, this study employed a mediation effect analysis that combines the causal step analysis method with bootstrap testing. According to Baron and Kenny [35], if the coefficients c, a, and b are all significant, a mediating effect exists. If the coefficient c′ is not significant, it is referred to as a complete mediation effect. If the regression coefficient c′ is significant and c′ < c, this mediation effect is considered partial mediation. However, if c′ > c, this is referred to as the suppression effect [43], indicating that the mediating variable amplifies the impact of the independent variable X on the dependent variable Y.

To enhance the reliability of the regression results, this study conducted a robustness test by replacing the explanatory variable data. Specifically, export value was replaced with export intensity (*exp*), defined as the proportion of overseas operating income to total operating income, as a proxy variable for exports.

5. Research Results

5.1. Descriptive Statistics and Correlation Analysis

To reduce the result bias caused by extreme values, all data were first winsorized. Table 2 presents the descriptive statistics, reflecting the characteristics of the main variables.

Table 2.
Descriptive statistics of variables.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
lnev	3448	20.969	1.415	18.648	24.885
age	3448	14.653	6.808	2.000	29.000
lnsass	3448	23.000	1.312	20.633	27.269
lnsemp	3448	8.534	1.123	6.415	12.021
lnp	3448	13.970	.729	12.403	15.912
wage	3448	2.792	7.254	.009	52.475
esg	3448	74.126	5.211	58.48	85.19
TI	3448	4.337	.472	3.240	6.117
soe	3448	.407	.491	0	1

Note: lnev=natural logarithm of export value, age=firms' listing years, lnsass=natural logarithm of total firm asset, lnsemp=natural logarithm of number of total employees, lnp=natural logarithm of labor productivity, wage= total wage expenditures, esg= the score of environmental, social and firm governance, TI=technological innovation, soe= dummy variable of the firm equity; 1=state owner and 0=the others.

Table 2 shows the descriptive statistics of each variable. This indicated that the standard deviation of export value was 1.415, suggesting that the export scale of the sample enterprises was relatively small. Regarding firm heterogeneity, firm size was represented by two factors: the number of employees and total assets. The natural logarithm of the number of employees ranged from 6.415 to 12.021, with a mean of 8.534, indicating that the size of the sample enterprises varied widely and exhibited significant differences. The natural logarithm of total assets ranged from 20.633 to 27.269, with a mean of 23 and a standard deviation of 1.312, suggesting that the total assets of the sample firms were relatively small. The average number of years listed was 14.653 years, ranging from 2 to 29 years, reflecting the presence of newly listed companies in the sample, though the overall listing duration was relatively short. The natural logarithm of productivity had a mean of 13.970, with a range from 12.403 million to 159.12 million and a standard deviation of 0.729, indicating that the variation in labor productivity levels among the sample firms was relatively small. The standard deviation of enterprise wage expenditure was 7.254, showing substantial differences across firms. The mean ESG performance was 74.126, with a standard deviation of 5.211, suggesting that the overall ESG levels of the sample firms were relatively low and exhibited significant variation. The range of technological innovation was between 3.240 and 6.117, with a mean of 4.337 and a standard deviation of 0.472, indicating that the overall level of R&D innovation was still low but did not vary widely. In terms of ownership structure, the number of state-owned and non-state-owned enterprises in the sample was nearly equal, with a slightly higher number of non-state-owned firms.

Then the relationship between each variable and the variance inflation factor (VIF) test were shown in Table 3.

Table 3.
Pairwise correlations and variance inflation factor.

VIF	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(1) *lnev*	1.000								
1.40	(2) *age*	0.225***	1.000							
9.56	(3) *lnsass*	0.762***	0.325***	1.000						
7.55	(4) *lnsemp*	0.749***	0.287***	0.849***	1.000					
2.72	(5) *lnp*	0.432***	0.226***	0.521***	0.132***	1.000				
1.79	(6) *wage*	0.543***	0.072***	0.628***	0.600***	0.295***	1.000			
1.11	(7) *esg*	0.199***	0.028*	0.283***	0.247***	0.170***	0.220***	1.000		
2.29	(8) *TI*	0.498***	0.240***	0.724***	0.711***	0.296***	0.505***	0.263***	1.000	
1.33	(9) *soe*	0.180***	0.451***	0.294***	0.255***	0.238***	0.188***	0.130***	0.211***	1.000

Note: *** p<0.01, ** p<0.05, * p<0.1.

Table 3 shows the VIF was lower than 10. Concurrently, the correlation coefficient matrix demonstrated all significant correlations. However, the correlation coefficient for the variables *lnsass* and *lnsemp* was 0.849, indicating a high degree of

correlation. To ensure the accuracy of the regression results and enable a comparative analysis, these two indicators were grouped and subjected to separate regression analyses. Finally, there are no multicollinearity among the variables.

5.2. Empirical Findings

The multiple regression analyses were conducted on the specified models. The results of the Hausman [44] test indicated that a fixed-effect model should be employed; therefore, the industry and time fixed effects model was used to test the hypotheses. To verify the impacts of firms' heterogeneity and ESG performance on export value, the specification models 1a and 1b were regressed individually. The regression results are shown in Table 4.

Table 4.
Specification regression results for the responding hypothesis 1.

VARIABLES	(1a) *lnev*	(1b) *lnev*	(1c) *lnev*	(1d) *lnev*
age	-0.001	-0.010***		
	(-0.36)	(-3.99)		
lnsass	0.727***			
	(40.89)			
lnsemp		0.893***		
		(55.01)		
lnp	0.112***	0.679***		
	(4.33)	(31.45)		
wage	0.019***	0.003		
	(6.79)	(1.23)		
esg			0.041***	
			(9.30)	
TI				1.445***
				(30.10)
soe	-0.139***	-0.196***	0.316***	0.070
	(-3.71)	(-5.90)	(6.67)	(1.60)
Constant	2.016***	3.737***	16.003***	13.939***
	(4.42)	(10.00)	(34.99)	(40.93)
industry FE	YES	YES	YES	YES
year FE	YES	YES	YES	YES
N	3,448	3,448	3,448	3,448
Adj.R^2	0.607	0.690	0.161	0.320
F	206.15***	295.99***	29.76***	71.47***

Note: t-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4 shows the regression results of firms' heterogeneity on export value in columns (1a) and (1b). As previously mentioned, firms' heterogeneity was divided into two groups for the purpose of group regression. The first group included firm age, total assets, labor productivity, and wages (column (1a)), while the second group comprised firm age, number of employees, labor productivity, and wages (column (1b)). The regression results indicated that total assets and the number of employees were significantly positively correlated with firm export value; however, the coefficient for the number of employees was greater than that for total assets. This finding suggested that, while both factors played significant roles in promoting the firm's export value, the impact of "employees" was greater than that of "assets." As a result, hypothesis 1b was supported.

Additionally, improvements in labor productivity were found to significantly enhance the export value of firms. As a result, hypothesis 1c was supported.

In the asset group, wages had a positive impact on export value, while in the manpower group, the effect of wages on firms' export value was not significant. This discrepancy may be attributed to companies with a large number of employees incurring relatively high wage expenditures, leading to collinearity and endogeneity issues. As a result, hypothesis 1d was supported.

Notably, the firm's listing years were not significant in the asset group but exhibited a significant negative correlation with export value in the human resources group. Thus, hypothesis 1a was not supported. This might be because the companies with shorter listing years have greater motivation and awareness to increase their performance under intense competition. As companies aged, they tended to develop some inertia and entrenched thinking, which reduced their willingness to innovate.

For the ESG performance, the regression result was displayed in column (1c) of Table 4. The coefficient for ESG performance was significantly positive at the 1% confidence level, indicating that enhanced ESG performance significantly promoted improvements in export value. By improving ESG performance, companies were able to gain recognition in the international market, resulting in stable growth in overseas operating income and enhanced export value. Moreover, improving ESG performance reduced export costs and risks, thereby increasing firms' efficiency and exports. As a result, hypothesis 1e was supported.

For the technology innovation, the regression result in column (1d) further evident that technological innovation had a significant positive correlation with firm export value at the 1% level. This finding indicated that technological innovation promoted export value, and improvements in the level of technological innovation were associated with enhanced export value for firms. Therefore, Hypothesis 1f was supported.

To sum up, most of the results of specification regression models supported hypothesis 1, except for the firms' age. This verified that the newly established companies were able to adapt to stimulate export revenue better than long-established companies.

Thereafter, the specification models 2a and 2b were regressed individually. The regression results are shown in Table 5.

Table 5.
Specification regression results for the responding hypothesis 2.

Variables	(2a) TI	(2b) TI	(2c) TI
age	-0.001	-0.002**	
	(-0.63)	(-2.13)	
lnsass	0.261***		
	(46.20)		
lnsemp		0.278***	
		(49.03)	
lnp	-0.089***	0.107***	
	(-10.72)	(14.20)	
wage	0.004***	0.003***	
	(4.97)	(2.93)	
esg			0.021***
			(15.94)
soe	0.063***	0.045***	0.178***
	(5.32)	(3.88)	(12.16)
Constant	-0.955***	0.064***	1.906***
	(-6.57)	(0.49)	(13.48)
industry FE	YES	YES	YES
year FE	YES	YES	YES
N	3,448	3,448	3,448
$Adj.R^2$	0.643	0.659	0.280
F	239.65***	257.68***	59.36***

Note: t-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5 shows the regression results of firms' heterogeneity and ESG performance on technological innovation. The findings indicated that the relationship between firms' age and technological innovation was significant negative impact on technological innovation. Therefore, hypothesis 2a was supported. This might be because the newly established companies are enthusiastic about innovating modern technology to stimulate export value.

Firms' size in terms of total assets and the number of employees exhibited significant positive correlations with technological innovation; however, the coefficient for the number of employees was greater than that for total assets. This suggested that in the realm of technological innovation, the role of "employees" outweighed that of "assets.". Thus, hypothesis 2b was supported.

Additionally, wages demonstrated a significant positive motivating effect on firms' technological innovation, which the regression results reaffirmed. Thus, hypothesis 2d was supported.

Notably, the findings showed the significant impact of labor productivity on technological innovation. Thus, hypothesis 2c was supported. However, the impacts varied across different groups. When firms' size was reflected by total assets, labor productivity had a significant negative impact on technology innovation. This might be because firms prefer to invest in capital assets, leading to reduced labor productivity. In contrast, when firms' size was reflected by total employees, labor productivity had a significant positive impact on technology innovation because firms prefer to reduce costs.

The ESG performance had a positive and significant impact on technological innovation at the 1% level. This evidenced that most firms have to innovate new technology to save the environment, social and stakeholders for sustainable operations. Thus, hypothesis 2e was supported.

In conclusion, all results of specification regression models supported hypothesis 2.

Next, Then Baron and Kenny model was applied for analysis the mediation effect of technology innovation. However, the specification model 3a and 3b were separately analysis. The investigating the mediating effect were shown in Table 6 and Table 7 respectively.

Table 6.
Investigating the mediating effect from model 3a.

Variables	Step1: (1e) *lnev*	Step2: (2d) *TI*	Step3: (1d) *lnev*	Step4: (3a) *lnev*	Interpretation	Total effect	Direct Effect	Indirect effect
age	-0.009	0.002		-0.009	No mediator			
lnsass	0.682***	0.706***		0.790***	Partial mediator (suppression effect)	0.682	0.790	-0.107
lnp	0.058***	-0.138***		0.037***	Partial mediator	0.058	0.037	0.021
wage	0.099***	0.063***		0.108***	Partial mediator (suppression effect	0.099	0.108	-0.009
esg	-0.033***	0.078***		-0.021*	Partial mediator	-0.033	-0.021	-0.012
TI			1.445***	-0.152***				
soe	-0.045***	0.058***	0.070	-0.036***				
Constant	2.465***	-1.316***	13.939***	1.864***				
	(5.11)	(-8.63)	(40.93)	(3.86)				
industry FE	YES	YES	YES	YES				
year FE	YES	YES	YES	YES				
N	3,448	3,448	3,448	3,448				
Adj.R^2	0.608	0.648	0.320	0.616				
F	199.22***	236.19***	71.47***	198.75***				

Note: t-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6 reports that technology innovation provided a mediating effect on firms' heterogeneity except firms' age.
Next, Table 7 shows the results of the Baron and Kenny model for the specification model 3b below.

Table 7:
Investigating the mediating effect from model 3b.

Variables	Step1: (1f) *lnev*	Step2: (2e) *TI*	Step3: (1d) *lnev*	Step4: (3b) *lnev*	Interpretation	Total effect	Direct Effect	Indirect effect
age	-0.056***	-0.017		-0.061***	Partial mediator （Bootstrap test）			
lnsemp	0.718***	0.645***		0.915***	Partial mediator (suppression effect)	0.718	0.915	-0.197
lnp	0.355***	0.156***		0.403***	Partial mediator (suppression effect)	0.355	0.403	-0.048
wage	0.018	0.035***		0.029**	No mediator			
esg	-0.044***	0.080***		-0.019***	Partial mediator	-0.044	-0.019	-0.024
TI			1.445***	-0.305***				
soe	-0.064***	0.039***	0.070	-0.052***				
Constant	4.396***	-0.338**	13.939***	4.086***				
industry FE	YES	YES	(40.93)	YES				
year FE	YES	YES	YES	YES				
N	3,448	3,448	YES	3,448				
Adj.R^2	0.692	0.665	0.320	0.723				
F	287.17***	254.31***	71.47***	321.78***				

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

It can be observed from Tables 6 and 7 that there were differences in the mediating effects of technological innovation across various variables of firms' heterogeneity. In the asset group, all variables, except for firm age, were significant and demonstrated a partial mediating effect on exports. In the human resources group, firm age, the number of employees, and labor productivity were all significant, with technological innovation exhibiting a partial mediating effect on these variables

and export value. However, there was no mediating effect of wages on export performance. Regardless of the group, technological innovation consistently showed a partial mediating effect between ESG performance and export performance.

5.3. Robustness Test

   To enhance the reliability of the regression results, this study conducted a robustness test by replacing the explanatory variable data, following the methods of previous research. The results are presented in the table below. Specifically, export value was replaced with export intensity (*exp*), defined as the proportion of overseas operating income to total operating income, as a proxy variable for exports. This variable not only reflected improvements in the export business but also changes in the export structure. Both aspects could measure the impact of firms' heterogeneity and ESG performance on export performance. The results of the alternative regression analysis were shown in Table 8.

Table 8.
Robustness Tests for Replacing Dependent Variables.

Variables	(1) exp	(2) exp	(3) TI	(4) TI	(5) exp	(6) exp
age	-0.004***	-0.004***	0.000	-0.001	-0.004***	-0.005***
	(-6.20)	(-6.67)	(0.16)	(-1.30)	(-6.59)	(-7.22)
lnsass	-0.017***		0.254***		0.006	
	(-4.08)		(44.56)		(1.27)	
lnsemp		-0.009**		0.271***		0.016***
		(-2.11)		(47.49)		(3.47)
lnp	-0.050***	-0.061***	-0.089***	0.101***	-0.057***	-0.051***
	(-8.49)	(-10.92)	(-10.89)	(13.41)	(-9.86)	(-9.21)
wage	0.001*	0.001	0.004***	0.002***	0.002***	0.001
	(1.84)	(0.80)	(4.67)	(2.60)	(2.66)	(1.55)
esg	-0.002***	-0.003***	0.007***	0.007***	-0.002**	-0.002**
	(-3.48)	(-3.84)	(7.24)	(7.55)	(-2.16)	(-2.35)
TI					-0.090***	-0.097***
					(-11.07)	(-12.08)
soe	-0.047***	-0.046***	0.055***	0.038***	-0.041***	-0.041***
	(-5.55)	(-5.44)	(4.67)	(3.25)	(-4.84)	(-4.87)
Constant	1.523***	1.391***	-1.316***	-0.338**	0.983***	0.907***
	(13.91)	(13.48)	(-8.63)	(-2.41)	(8.33)	(8.34)
industry FE	Yes	Yes	Yes	Yes	Yes	Yes
year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	3,448	3,448	3,448	3,448	3,448	3,448
Adj.R^2	0.136	0.133	0.648	0.665	0.166	0.168
F	21.08***	20.56***	236.19***	254.31***	25.43***	25.88***

Note: t-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

   In Table 8, the regression coefficients of firms' heterogeneity indicators and ESG performance variables, aside from a few variables, were significant at the 1% to 10% level, with their directions largely consistent with the results of previous research. The significance and direction of these key variables confirmed the robustness of the earlier analyses. In columns (3) to (6), the regression coefficients of technological innovation on firms' export intensity were consistent with the conclusions drawn from the main regression, thereby demonstrating the overall robustness of the regression results.

6. Conclusion, Discussion, and Contribution
6.1. Discussion and Conclusion
   This study utilized panel data from 431 Chinese A-share listed companies engaged in the export business from 2015 to 2022 to empirically analyze the relationships between firms' heterogeneity, ESG performance, technological innovation, and export performance. The findings reveal several important insights that contribute to both academic literature and business practice.

   First, firms' heterogeneity significantly influences export performance, with the impact of "people" exceeding that of "assets." Specifically, our analysis demonstrates that while both total assets and employee numbers positively affect export value, the coefficient for the number of employees is substantially higher, suggesting human capital plays a more critical role in driving export performance than physical assets. This finding aligns with resource-based views of competitive advantage, emphasizing the importance of human resources in international business success. Additionally, labor productivity consistently shows a significant positive impact on exports, reinforcing the importance of operational efficiency. Our results regarding firm age reveal an interesting negative relationship with exports in the human resources group, contradicting traditional assumptions that longer-established firms export more. This suggests newer firms may possess

greater adaptability and innovation drive that benefits export activities, while older firms might face organizational inertia that hinders international expansion.

Second, ESG performance significantly and positively impacts export value, supporting the growing consensus that sustainability practices enhance international competitiveness. By improving ESG performance, companies can gain recognition in global markets, reduce operational risks, and enhance stakeholder trust, all contributing to export growth. However, our analysis also reveals that when accounting for firms' heterogeneity factors, ESG performance shows some negative correlations with export intensity, likely reflecting the short-term costs associated with ESG investments. This nuanced relationship demonstrates the complex trade-offs firms face when implementing sustainability practices while pursuing international expansion.

Third, technological innovation serves as a crucial partial mediator between firms' heterogeneity, ESG performance, and export outcomes. Our mediation analysis confirms that technological innovation amplifies the positive impacts of firm size, labor productivity, and ESG performance on exports. This finding highlights technological innovation's role as a "bridge" that transforms firm capabilities and sustainability practices into enhanced export performance. By investing in R&D and developing innovative capabilities, firms can translate their heterogeneity advantages and ESG commitments into stronger international competitiveness and export success.

Fourth, the robustness tests using export intensity as an alternative dependent variable generally support our main findings, confirming the stability of the relationships identified. The consistency of these results across different metrics of export performance strengthens the validity of our conclusions and indicates their broader applicability across diverse measures of international business success.

In conclusion, this study demonstrates that export performance is shaped by a complex interplay of firm characteristics, sustainability practices, and innovation capabilities. Firms seeking to enhance their export performance should focus on three key strategies: (1) strengthening human capital through talent acquisition and development, (2) improving ESG performance across environmental, social, and governance dimensions, and (3) investing in technological innovation to create competitive advantages in international markets. Policymakers in developing economies like China should consider these insights when formulating policies to support export growth, particularly emphasizing programs that enhance innovation capabilities and incentivize sustainable business practices.

6.2. Theoretical and Practical Contributions
6.2.1. Theoretical Contributions
This study makes several important theoretical contributions to the international business and sustainable development literature:

1. Integration of Multiple Theoretical Perspectives: We advance theoretical understanding by integrating insights from firm heterogeneity theory, ESG research, and innovation literature within a single analytical framework. This holistic approach offers a more comprehensive understanding of the complex determinants of export performance than previous studies that examined these factors in isolation.
2. Mediating Role of Technological Innovation: By empirically validating technological innovation as a mediating mechanism between firm characteristics, ESG performance, and export outcomes, we provide a more nuanced understanding of the causal pathways through which these factors influence international competitiveness. This extends existing theoretical models that have primarily focused on direct relationships.
3. Contextual Understanding of Developing Economies: Much of the existing literature on firm exports and ESG has focused on developed economies. Our research provides valuable theoretical insights specific to the context of developing economies like China, where firm heterogeneity is often more pronounced and ESG practices are still evolving.
4. Refinement of Firm Heterogeneity Theory: Our findings challenge traditional assumptions about the linear relationship between firm age and export performance, suggesting a more complex relationship wherein newer firms may possess advantages in export markets. This contributes to a more nuanced understanding of how different dimensions of firm heterogeneity affect international business outcomes.

6.2.2. Practical Contributions
This research offers several practical implications for business managers, policymakers, and other stakeholders:

1. Strategic Focus on Human Capital: Our finding that employee numbers have a greater impact on export performance than total assets suggests that firms should prioritize human resource development when seeking to enhance international competitiveness. Companies may benefit from investing in talent acquisition, training programs, and employee retention strategies as means to improve export capabilities.
2. ESG Implementation for Export Growth: The positive relationship between ESG performance and export value provides empirical support for sustainability investments as a strategy for international market expansion. Companies can leverage improved ESG performance to gain access to overseas markets, particularly in regions with strict environmental and social standards.
3. Innovation as a Catalyst for Export Success: The significant mediating role of technological innovation highlights the importance of R&D investments for export-oriented firms. Companies should view innovation not just as a standalone capability but as a crucial mechanism for translating their organizational strengths and sustainability practices into export advantages.

4. Policy Design for Sustainable Export Growth: For policymakers in developing economies, our research suggests that export promotion policies should incorporate elements focusing on technological innovation capabilities, ESG performance enhancement, and human capital development. Integrated policy approaches that address these multiple dimensions simultaneously may be more effective than isolated interventions.

5. Balanced Approach to ESG Implementation: The mixed findings regarding ESG performance's effect on different export metrics highlight the importance of strategic implementation that balances short-term costs with long-term benefits. Companies should adopt phased approaches to ESG investments that align with their export growth strategies.

By offering these theoretical and practical contributions, this study not only advances academic understanding of the determinants of export performance but also provides actionable insights for stakeholders seeking to enhance the international competitiveness of firms in developing economies through sustainable and innovative business practices.

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