Does Intelligent Manufacturing Enhance Enterprise Esg Performance? Empirical Evidence from China

Chen Xu[1,2]*, Batkhuyag Ganbaatar[1]

1 University of Finance and Economics, Ulaanbaatar, Mongolia

2 College of Economic and Management, Chifeng University, Chifeng, Inner Mongolia, China,

*Corresponding author: Chen Xu chenalicexu@gmail.com

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Abstract

This study investigates the impact of intelligent manufacturing on the Environmental, Social, and Governance (ESG) performance of Chinese A-share listed companies from 2015 to 2023. As China undergoes simultaneous industrial upgrading and ESG institutionalization, understanding this relationship is critical for sustainable corporate development. Adopting a mixed-methods approach, the research employs a two-way fixed-effects panel regression complemented by multiple case studies of industry leaders, including Haier and CATL. Intelligent manufacturing is measured at the firm level, while ESG performance is captured through comprehensive enterprise ratings. The empirical results demonstrate that intelligent manufacturing exerts a significantly positive and robust effect on ESG performance. These findings remain consistent across various robustness checks, including Propensity Score Matching with Difference-in-Differences (PSM-DID) and System GMM estimation to address potential endogeneity. Mechanism analysis reveals that the positive impact is primarily driven by three mediating channels: enhanced information transparency, strengthened green technological innovation capacity, and optimized synergistic governance. Conversely, financing constraints are found to exert a suppressing mediation effect, highlighting the role of financial frictions in shaping ESG outcomes. Heterogeneity analysis further indicates that the ESG-enhancing effects are more pronounced in high-tech enterprises and firms located in non-Western regions of China. By integrating econometric rigor with qualitative insights, this research provides a multidimensional framework for understanding how digital transformation serves as a catalyst for corporate sustainability. The findings offer practical implications for policymakers and corporate managers aiming to leverage intelligent transformation to meet evolving ESG standards in emerging markets.

Keywords: Intelligent manufacturing, ESG performance, Sustainable development, Information transparency, Green-innovation, Chinese listed companies.

I. Introduction

In the context of the digital economy and the ongoing transformation of global industrial systems, the manufacturing sector is undergoing a profound restructuring driven by digitalization, automation, interconnectivity, and intelligence (Liao et al., 2017; Xu et al., 2018). Intelligent manufacturing has emerged not merely as a technological upgrade, but as a strategic pathway for industrial transformation, organizational renewal, and sustainable development (Zhong et al., 2017). Increasingly, enterprise competitiveness is no longer determined solely by production efficiency or cost advantage; rather, it depends on the ability to integrate advanced technologies into production and management systems to enhance adaptability, efficiency, and long-term value creation (Porter & Heppelmann, 2014).

Globally, major economies have incorporated intelligent manufacturing into their national development strategies, such as Industry 4.0 in Germany, Society 5.0 in Japan, and advanced manufacturing initiatives in the United States (Kagermann et al., 2013; Fukuyama, 2018). These frameworks emphasize the integration of digital technologies into manufacturing processes to improve precision, flexibility, and sustainability. Within this global trend, China has developed a particularly distinctive pathway, positioning intelligent manufacturing as a central component of its industrial upgrading strategy through policies such as Made in China 2025 and the 14th Five-Year Plan for Intelligent Manufacturing Development (State Council of China, 2015). These policy initiatives highlight the role of intelligent manufacturing not only in enhancing industrial competitiveness but also in promoting green transformation and high-quality economic development.

At the same time, the increasing urgency of climate change, rising stakeholder expectations, and the institutionalization of sustainability governance have significantly elevated the importance of Environmental, Social, and Governance (ESG) performance (Friede et al., 2015; Gillan et al., 2021). ESG has evolved from a voluntary disclosure practice into a critical benchmark for evaluating corporate sustainability, legitimacy, and long-term value creation. In China, this transition is particularly evident as regulatory frameworks, capital markets, and public expectations increasingly emphasize environmental responsibility, social accountability, and governance transparency (Eccles et al., 2014). Consequently, ESG performance has shifted from a “soft” reputational indicator to a more binding constraint affecting firm valuation, financing conditions, and strategic decision-making.

Despite the parallel advancement of intelligent manufacturing and ESG governance, the relationship between these two domains remains insufficiently explored. Existing research on intelligent manufacturing has largely focused on outcomes such as productivity, innovation, and firm performance (Acemoglu & Restrepo, 2020), while ESG studies have primarily examined determinants related to governance structures, regulatory pressure, and financial conditions (Ioannou & Serafeim, 2015). As a result, there is a notable gap in understanding whether and how intelligent manufacturing contributes to enterprise ESG performance.

From a theoretical perspective, intelligent manufacturing represents more than the adoption of advanced technologies; it reflects a comprehensive transformation of production systems, information processing, and organizational coordination (Brynjolfsson & McAfee, 2014). This transformation may influence ESG performance through multiple channels. For instance, it can enhance environmental performance by improving resource efficiency and reducing emissions, strengthen social performance through improved product quality and operational reliability, and improve governance by increasing transparency and data-driven decision-making. However, these mechanisms have not yet been systematically examined within an integrated empirical framework.

Moreover, the effects of intelligent manufacturing are unlikely to be uniform across enterprises. Differences in firm size, industry characteristics, regional development levels, and technological capabilities may shape both the adoption of intelligent manufacturing and its impact on ESG outcomes (Chen et al., 2021). In the Chinese context, where significant heterogeneity exists across regions and industries, understanding these variations is particularly important for both theory and practice.

Against this background, this study aims to investigate whether intelligent manufacturing improves enterprise ESG performance, through what mechanisms this effect occurs, and under what conditions it varies across firms. Using panel data from Chinese A-share listed companies over the period 2015–2023, this study provides a systematic empirical analysis of the relationship between intelligent manufacturing and ESG performance.

This study contributes to the literature in three important ways. First, it extends the research on intelligent manufacturing by linking it to sustainability outcomes captured by the ESG framework. Second, it provides a mechanism-based explanation of how intelligent manufacturing influences ESG performance by examining channels such as information transparency, green innovation, financing constraints, and governance synergy. Third, it explores the heterogeneous effects of intelligent manufacturing across different firm characteristics and institutional contexts, thereby offering a more nuanced understanding of its role in sustainable corporate development.

Overall, this study seeks to bridge the gap between technological transformation and sustainability governance by providing a comprehensive analysis of how intelligent manufacturing contributes to enterprise ESG performance in the Chinese context.

II. Theoretical Background

2.1 Intelligent Manufacturing and ESG Performance

The relationship between intelligent manufacturing and enterprise ESG performance can be explained through the integration of Resource-Based View, Institutional Theory, and Stakeholder Theory. From the Resource-Based View, intelligent manufacturing represents a strategic capability that enhances firms' operational efficiency and sustainable competitiveness (Barney, 1991). Recent studies in the Chinese context demonstrate that the adoption of intelligent manufacturing technologies significantly improves energy efficiency and reduces pollutant emissions, thereby enhancing environmental performance (Liu et al., 2022; Zhang & Chen, 2023). By leveraging digital technologies such as industrial IoT and big data analytics, firms can optimize resource allocation and reduce production inefficiencies.

Institutional Theory suggests that firms face increasing regulatory and societal pressures to improve ESG performance. In China, government policies promoting digital transformation and green development further strengthen such pressures. Empirical evidence shows that intelligent manufacturing helps firms comply with environmental regulations and enhances their ESG ratings by improving monitoring and reporting systems (Wang et al., 2022; Li et al., 2023). From the perspective of Stakeholder Theory, intelligent manufacturing enhances firms' ability to meet stakeholder expectations by improving product quality, workplace safety, and corporate transparency. Studies have found that digital transformation in manufacturing firms improves labor conditions and strengthens corporate social responsibility performance (Xu et al., 2021; Zhou et al., 2023). In addition, intelligent manufacturing improves governance efficiency by enabling data-driven decision-making and reducing agency problems (Chen & Xie, 2022). Taken together, intelligent manufacturing enhances environmental performance, social responsibility, and governance quality, leading to improved ESG performance.

H1: *Intelligent manufacturing has a positive impact on enterprise ESG performance.*

2.2 Intelligent Manufacturing and Information Transparency

The impact of intelligent manufacturing on information transparency can be understood through Information Asymmetry Theory and digital transformation perspectives. Information Asymmetry Theory posits that unequal access to information between firms and stakeholders reduces market efficiency (Akerlof, 1970). Intelligent manufacturing reduces such asymmetries by enhancing firms' capabilities in data collection, integration, and real-time reporting. Recent Chinese studies show that digital transformation significantly improves the quality and timeliness of corporate information disclosure (Guo et al., 2022; Sun & Du, 2023).

Moreover, intelligent manufacturing promotes the construction of digital platforms and integrated information systems, which increase transparency across the value chain. Empirical evidence suggests that firms adopting intelligent manufacturing technologies exhibit higher levels of disclosure quality and reduced earnings management behavior (Liang et al., 2022; Huang et al., 2023).

Thus, intelligent manufacturing is expected to significantly enhance enterprise information transparency.

H2: *Intelligent manufacturing has a positive impact on information transparency.*

2.3 Information Transparency and ESG Performance

The relationship between information transparency and ESG performance can be explained through Signaling Theory and Agency Theory.

According to Signaling Theory, firms use information disclosure to signal their quality and credibility to external stakeholders (Spence, 1973). In the Chinese market, higher transparency has been shown to improve corporate reputation and investor confidence, thereby encouraging firms to enhance ESG performance (Zhang et al., 2022; Liu & Sun, 2023). Agency Theory suggests that increased transparency reduces information asymmetry and strengthens external monitoring, thereby mitigating agency problems (Jensen & Meckling, 1976). Empirical studies indicate that improved disclosure quality reduces opportunistic managerial behavior and promotes sustainable corporate practices (Healy & Palepu, 2001; Wang & Li, 2022). Furthermore, transparency strengthens stakeholder engagement and increases pressure on firms to improve environmental and social performance. Recent evidence shows that firms with higher transparency levels achieve better ESG ratings and sustainability outcomes (Chen et al., 2023; Zhao et al., 2024).

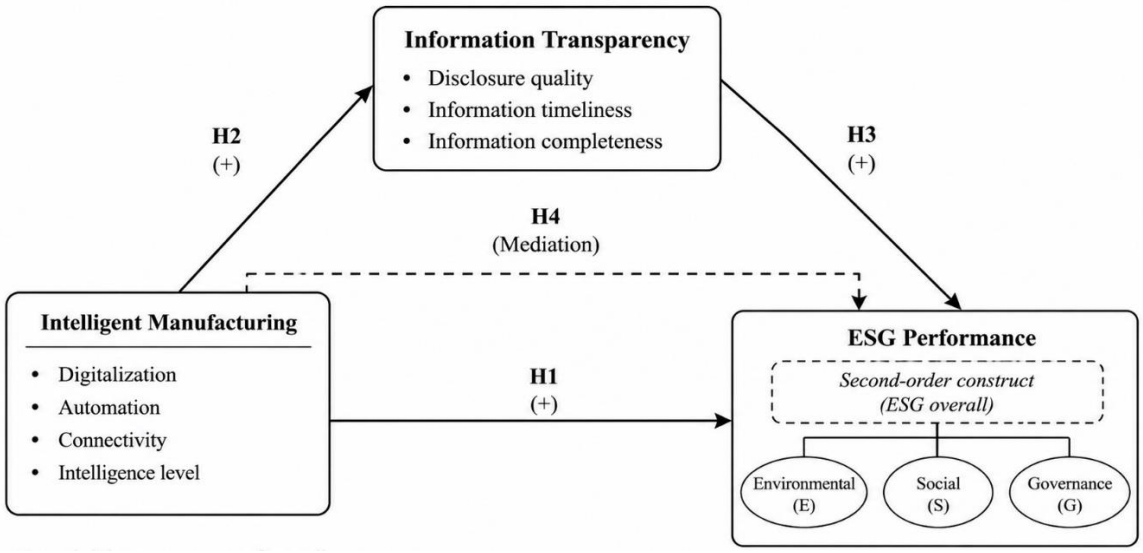
H3: *Information transparency has a positive impact on enterprise ESG performance.*

2.4 Mediating Role of Information Transparency

The mediating role of information transparency can be understood as a key mechanism linking intelligent manufacturing to ESG performance. Intelligent manufacturing enhances firms' digital infrastructure and information processing capabilities, which in turn improves transparency (Vial, 2019; Guo et al., 2022). Increased transparency strengthens governance, reduces agency costs, and enhances stakeholder trust, ultimately improving ESG performance (Wang et al., 2022; Chen et al., 2023). Recent empirical studies in China provide evidence for this indirect mechanism, showing that digital transformation influences ESG performance through improved information disclosure and transparency (Li et al., 2023; Zhao et al., 2024). This suggests that information transparency acts as an important transmission channel.

H4: *Information transparency mediates the relationship between intelligent manufacturing and enterprise ESG performance.*

Figure 1. Research model



Source: developed by the author

III. Empirical Analysis Method

3.1 Model Specification

The empirical analysis of this study is based on panel data of Chinese A-share listed companies covering the period from 2015 to 2023. To examine the impact of intelligent manufacturing on enterprise ESG performance, this study employs econometric regression techniques within a panel data framework.

Specifically, a two-way fixed effects model is adopted to control for unobserved firm-specific heterogeneity and time-specific effects. This approach helps mitigate potential omitted variable bias and enhances the robustness and credibility of the estimated results.

The baseline regression model is specified as follows:

$$ESG_{it} = \alpha_0 + \alpha_1 IM_{it} + \sum Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where ESG_{it}represents the ESG performance of firm $i$in year t, IM_{it}denotes the level of intelligent manufacturing, $Controls_{it}$refers to a set of control variables, $\mu_i$captures firm fixed effects, and $\lambda_t$represents time fixed effects.

3.2 Mediation Effect Model

To further investigate the underlying mechanism through which intelligent manufacturing affects ESG performance, this study constructs a mediation effect model based on the theoretical framework presented in Figure X.

In particular, this study examines whether information transparency serves as a transmission channel linking intelligent manufacturing to enterprise ESG performance.

Following standard mediation analysis procedures, the following equations are estimated:

Step 1: Direct effect

$$ESG_{it} = \beta_0 + \beta_1 IM_{it} + \sum Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Step 2: Effect on mediator

$$IT_{it} = \gamma_0 + \gamma_1 IM_{it} + \sum Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Step 3: Mediation effect

$$ESG_{it} = \delta_0 + \delta_1 IM_{it} + \delta_2 IT_{it} + \sum Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where IT_{it}represents information transparency.

A significant $\gamma_1$and δ_2, together with a reduction in $\delta_1$compared to β_1, indicates the presence of a mediating effect. To further ensure the robustness of mediation results, bootstrapping methods are applied to test the significance of the indirect effect.

3.3 Heterogeneity Analysis

To provide a more comprehensive understanding of the relationship between intelligent manufacturing and ESG performance, this study further conducts heterogeneity analyses across different firm characteristics. Prior literature suggests that the impact of digital transformation and intelligent manufacturing is not uniform across firms, but rather depends on institutional environments, ownership structures, and technological capabilities (Li et al., 2023; Zhang et al., 2025). First, this study examines regional heterogeneity by dividing firms into eastern, central, and western regions of China. Due to disparities in economic development, digital infrastructure, and regulatory environments, firms located in more developed regions are likely to benefit more from intelligent manufacturing in

terms of ESG performance (Wang et al., 2022). The eastern region, characterized by higher levels of marketization and technological readiness, may exhibit a stronger positive relationship compared to less-developed regions. Second, this study investigates heterogeneity based on firm ownership structure, distinguishing between state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs). According to Institutional Theory, SOEs are subject to stronger government intervention and social responsibility expectations, which may amplify the ESG effects of intelligent manufacturing (Liu et al., 2025). In contrast, non-SOEs may exhibit more market-driven behavior, leading to differences in how intelligent manufacturing translates into ESG outcomes. Third, heterogeneity is analyzed based on technological intensity, by classifying firms into high-tech and traditional industries. Firms in high-tech industries generally possess stronger absorptive capacity and innovation capabilities, enabling them to more effectively leverage intelligent manufacturing technologies to improve ESG performance (Cohen & Levinthal, 1990; Huang et al., 2024). Therefore, the ESG-enhancing effects of intelligent manufacturing are expected to be more pronounced in high-tech sectors. Through these sub-sample analyses, this study provides a nuanced understanding of how contextual factors shape the effectiveness of intelligent manufacturing in promoting ESG performance.

3.4 Robustness Tests

To ensure the reliability and validity of the empirical findings, this study conducts a series of robustness checks. Robustness testing is essential in empirical research to verify that results are not sensitive to model specifications, variable definitions, or estimation methods (Wooldridge, 2010). First, this study employs alternative measures of ESG performance to verify the consistency of the results. Given that ESG indicators can vary across data sources and measurement approaches, replacing the dependent variable with alternative ESG proxies helps confirm the stability of the findings (Eccles et al., 2014; Zhao et al., 2024). Second, to address potential endogeneity issues, this study introduces lagged independent variables. Specifically, the lagged value of intelligent manufacturing is used to mitigate reverse causality and simultaneity bias, as current ESG performance may also influence firms' digital transformation decisions (Li et al., 2023). Third, this study applies alternative estimation methods, including random effects models and regressions with clustered standard errors, to ensure that the results are not driven by specific econometric techniques. These approaches help account for potential heteroskedasticity and serial correlation in panel data (Wooldridge, 2010). In addition, further robustness checks may include excluding extreme values to reduce the influence of outliers, which is a common practice in corporate finance and ESG-related studies (Chen et al., 2023).

IV. Results

4.1 Descriptive Statistics

Table 3.1 reports the descriptive statistics of the main variables used in this study, based on a sample of 30,730 firm-year observations of Chinese A-share listed companies from 2015 to 2023. The mean ESG score is 4.238, with a standard deviation of 0.959, indicating substantial variation in ESG performance across firms. The average value of intelligent manufacturing (IM) is 0.0176, suggesting that while some firms have adopted advanced intelligent manufacturing practices, many firms remain at relatively early stages. Information transparency (TRANS) also exhibits considerable variation, indicating differences in firms' disclosure practices. Overall, the variation in key variables provides a suitable basis for empirical analysis.

Table 1. Descriptive statistics

Variable	Observations	Mean	SD	Min	Max
ESG	30,730	4.238	0.959	1	8
IM	30,730	0.0176	0.0250	0.000868	0.402
SIZE	30,730	22.28	1.322	17.64	28.70
LEV	30,730	0.406	0.201	0.00836	0.998
ROA	30,730	0.0344	0.0787	-1.856	0.786
Top1	30,730	0.332	0.148	0.00286	0.900
Age	30,730	3.011	0.306	1.386	4.304
SOE	30,730	0.295	0.456	0	1
TRANS	30,730	0.148	0.163	0	3.07
ESG2	30,730	1.620	2.516	0	9
IM2	30,730	7.064	27.63	0	856

4.2 Correlation Analysis and Multicollinearity Test

Table 2 presents the Pearson correlation matrix. Intelligent manufacturing is positively correlated with ESG performance, providing preliminary support for the hypothesized relationship. To assess multicollinearity, variance inflation factor (VIF) tests are conducted (Table 3.3). The results show that all VIF values are well below the threshold of 10, with a mean VIF of 1.260, indicating that multicollinearity is not a concern.

Table 2. Correlation Matrix

Variable	ESG	IM	SIZE	LEV	ROA	Top1	Age	SOE
ESG	1							
IM	0.057***	1						
SIZE	0.199***	-0.062***	1					
LEV	-0.100***	-0.041***	0.499***	1				
ROA	0.187***	-0.084***	0.032***	-0.304***	1			
Top1	0.095***	-0.112***	0.168***	0.019***	0.155***	1		
Age	-0.035***	-0.051***	0.191***	0.190***	-0.074***	-0.048***	1	
SOE	0.046***	-0.058***	0.374***	0.267***	-0.049***	0.229***	0.232***	1

4.3 Baseline Regression Results

Table 3 reports the baseline regression results examining the impact of intelligent manufacturing on enterprise ESG performance. The Hausman test strongly rejects the null hypothesis ($\chi^2 = 367.54$, $p < 0.001$), indicating that the fixed effects model is more appropriate than the random effects model. Therefore, all regressions are estimated using a two-way fixed effects model. The results show that intelligent manufacturing has a positive and statistically significant effect on ESG performance across all model specifications. In the fully specified model, the coefficient of IM is 0.8032 ($p < 0.05$), indicating that a higher level of intelligent manufacturing is associated with improved ESG performance. This finding provides strong empirical support for H1, suggesting that intelligent manufacturing plays a significant role in enhancing corporate sustainability outcomes.

Table 3. Baseline Regression Results

Variables	(1) ESG	(2) ESG	(3) ESG
IM	3.0132***	0.8003**	0.8032**
SIZE		0.2224***	0.2301***
LEV		-0.9966***	-0.9527***
ROA		1.3562***	-0.0519
Top1		0.2440***	0.0170
Age		-0.1244***	-0.1335
SOE		-0.0058	0.0043
Year FE	No	Yes	Yes
Firm FE	No	Yes	Yes
N	30,730	30,347	30,347
Adj. R^2	0.112	0.479	0.489

4.4 Mediating Effect of Information Transparency

To examine the underlying mechanism, this study tests the mediating role of information transparency. As shown in Table 4, intelligent manufacturing significantly improves information transparency ($\beta = 0.1905$, $p < 0.01$), supporting H2. Furthermore, information transparency has a positive and significant effect on ESG performance ($\beta = 0.0889$, $p < 0.05$), supporting H3. When both intelligent manufacturing and information transparency are included in the regression, the coefficient of intelligent manufacturing remains significant, while the coefficient of information transparency is also significant. This indicates a partial mediation effect. The Sobel and Goodman tests further confirm that the indirect effect is statistically significant ($p < 0.001$), supporting H4. Overall, these results suggest that intelligent manufacturing enhances ESG performance not only directly but also indirectly through improving information transparency.

Table 4. Mediation analysis

Variables	(1) ESG	(2) TRANS	(3) ESG
IM	0.9933***	0.1905***	1.0103***
TRANS			0.0889**
SIZE	0.2426***	0.0324***	0.2455***
LEV	-0.8741***	0.1240***	-0.8631***
ROA	-0.0727	-0.0068	-0.0733
Top1	-0.0927	-0.1594***	-0.1069
Age	-0.0082	0.4570***	0.0325
SOE	0.0084	0.0027	0.0086
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
N	30,347	30,347	30,347

V. Discussion

This study provides robust empirical evidence that intelligent manufacturing significantly enhances enterprise ESG performance in the context of Chinese A-share listed companies. The findings contribute to the growing literature on digital transformation and sustainability by demonstrating that intelligent manufacturing is not only a technological upgrade but also a governance-enhancing mechanism that promotes sustainable corporate development (Li et al., 2023; Zhang et al., 2025). First, the baseline regression results confirm that intelligent manufacturing has a positive and statistically significant impact on ESG performance. This finding is consistent with the Resource-Based View, which suggests that firms can achieve sustainable competitive advantage through the development of strategic capabilities such as digitalization and intelligent production systems (Barney, 1991). By integrating advanced technologies into production processes, firms are able to improve resource efficiency, reduce environmental impact, and enhance operational transparency (Porter & Heppelmann, 2014). Second, the mediation analysis reveals that information transparency serves as an important transmission mechanism linking intelligent manufacturing to ESG performance. This finding supports Information Asymmetry Theory and Signaling Theory, which emphasize the role of information disclosure in reducing uncertainty and enhancing stakeholder trust (Akerlof, 1970; Spence, 1973). Intelligent manufacturing improves firms' data processing capabilities and disclosure quality, thereby strengthening external monitoring and governance effectiveness (Guo et al., 2022; Zhao et al., 2024). As a result, firms are more likely to engage in substantive ESG practices rather than symbolic compliance (Eccles et al., 2014). Third, the heterogeneity analysis highlights that the ESG-enhancing effects of intelligent manufacturing are not uniform across firms. The results indicate that the positive impact is more pronounced in non-Western regions and high-tech enterprises. This finding is consistent with Institutional Theory and Resource-Based View, suggesting that institutional environments and firm-level capabilities jointly shape sustainability outcomes (Wang et al., 2022; Huang et al., 2024). In regions with stronger market institutions and regulatory enforcement, firms face greater pressure to convert technological upgrading into sustainability performance (DiMaggio & Powell, 1983). Similarly, high-tech firms, with stronger innovation capabilities and absorptive capacity, are better positioned to leverage intelligent manufacturing for ESG improvement (Cohen & Levinthal, 1990). Overall, the findings underscore that intelligent manufacturing operates through both direct efficiency-enhancing effects and indirect governance-related mechanisms. This dual role expands the understanding of digital transformation from a purely productivity-oriented perspective to a broader sustainability and governance framework (Vial, 2019).

VI. Conclusion

This study investigates the relationship between intelligent manufacturing and enterprise ESG performance using panel data from Chinese A-share listed companies over the period 2015–2023. The empirical results provide strong and consistent evidence that intelligent manufacturing significantly improves ESG performance (Li et al., 2023; Liu et al., 2025). More importantly, this study identifies information transparency as a key mediating mechanism through which intelligent manufacturing influences ESG outcomes. By enhancing data integration, disclosure quality, and transparency, intelligent manufacturing strengthens corporate governance and stakeholder trust, thereby facilitating sustainable business practices (Healy & Palepu, 2001; Zhao et al., 2024). The heterogeneity analysis further reveals that the ESG benefits of intelligent manufacturing are contingent upon regional institutional environments and firm-level technological capabilities. Specifically, the positive effects are stronger in non-Western regions and high-tech enterprises, highlighting the importance of contextual factors in shaping the effectiveness of digital transformation (Wang et al., 2022; Huang et al., 2024). This study makes several important contributions. First, it extends the literature on intelligent manufacturing by linking it to ESG performance, thereby bridging the gap between technological transformation and sustainability research (Zhang et al., 2025). Second, it provides a mechanism-based explanation by identifying information transparency as a key transmission channel. Third, it offers new insights into the heterogeneous effects of intelligent manufacturing, contributing to a more nuanced understanding of its role in sustainable corporate development. From a practical perspective, the findings suggest that policymakers should promote intelligent manufacturing not only as a tool for industrial upgrading but also as a means of enhancing ESG performance. Firms should actively invest in digital technologies and information systems to improve transparency and governance quality (Guo et al., 2022). In addition, targeted policies may be needed to support firms in less-developed regions and traditional industries to fully realize the ESG benefits of intelligent

transformation. Despite its contributions, this study has several limitations. First, the measurement of intelligent manufacturing relies on proxy indicators, which may not fully capture its complexity. Second, the analysis focuses on Chinese listed firms, which may limit the generalizability of the findings to other institutional contexts. Future research could explore cross-country comparisons and examine additional mechanisms, such as organizational capabilities or digital governance practices (Vial, 2019). In conclusion, this study demonstrates that intelligent manufacturing plays a critical role in promoting enterprise ESG performance, both directly and indirectly through improved information transparency. As digital transformation continues to reshape the global economy, understanding its implications for sustainability will remain an important direction for future research.

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