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The Impact of Green Investor Entry on the High-Quality Development of Manufacturing Enterprises

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Abstract

Addressing climate change, pursuing green development, and achieving high-quality development are rapidly coalescing into a global strategic consensus. Against this backdrop, this paper empirically examines the impact of green investor entry on the high-quality development of manufacturing enterprises. Using a sample of A-share listed manufacturing companies from 2015 to 2023, it employs fixed-effects and mediation models. The findings reveal: (1) Green investor entry significantly promotes high-quality development in manufacturing enterprises, a conclusion that holds after endogeneity and robustness tests. (2) Mechanism effects indicate that green investors empower manufacturing enterprises to achieve high-quality development through the integration of digital and physical technologies. (3) Heterogeneity tests indicate that in eastern regions and non-heavily polluting industries, the entry of green investors exerts a more pronounced promotional effect on the high-quality development of manufacturing enterprises. (4) Green investor entry significantly promotes high-quality development of manufacturing enterprises under the negative moderation of financing constraints. These findings confirm the catalytic role of green investor entry in advancing high-quality development within manufacturing enterprises, clarify the mechanism of digital–physical integration linking the two, and provide empirical evidence and policy insights to support strategic decisions promoting high-quality development through green investor entry in China's manufacturing sector.

Keywords: green investor entry; digital–real economy integration; high-quality development

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Academic Editor: Grigorios L. Kyriakopoulos

Received: 18 August 2025
Revised: 29 September 2025
Accepted: 21 October 2025
Published: 23 October 2025

Citation: Jia, X.; Zhang, R. The Impact of Green Investor Entry on the High-Quality Development of Manufacturing Enterprises. *Sustainability* **2025**, *17*, 9422. https://doi.org/10.3390/su17219422

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1. Introduction

As stated explicitly in the report of the 20th CPC National Congress, "the promotion of green and low-carbon economic and social development is a key element in achieving high-quality development". As the primary economic foundation of the nation, the adoption of environmentally sustainable practices, such as the "greening" of manufacturing processes and the "decarbonization" of production, directly impact the achievement of the nation's ambitious development objectives. Concurrently, the People's Bank of China has proposed a policy framework for green finance development centred on "three major functions" and "five pillars." The core objective of the initiative is to leverage the financial system's resource allocation capabilities to guide and promote the flow of financial resources towards green investment sectors. Consequently, the question of whether investors genuinely focus on and participate in the green development of the real economy has become a crucial entry point for studying high-quality development in manufacturing.

In the context of escalating global geopolitical tensions and intricate economic circumstances, the People's Republic of China has proactively advocated for the advancement

of enterprises towards a state of superior quality. This advocacy has been manifested through the implementation of a series of policy measures, encompassing the reduction in taxes and fees, as well as the introduction of incentives to encourage innovation [1]. Green investment is a pivotal driving force that directs capital towards green technologies and low-carbon industries. Furthermore, it provides enterprises with the necessary support to increase investment in the research, development and application of energy-saving and carbon-reduction technologies. The hallmark of high-quality development in manufacturing enterprises is the leveraging of green investment as an engine [2,3]. Through technological innovation, it reconfigures the production function [4,5], achieving synergistic advancement across three dimensions: resource intensification [6], environmental sustainability [7], and innovation-led growth [8]. This has resulted in the emergence of a novel development paradigm, characterised by economic resilience, ecological responsibility, and balanced technological advancement [9]. To a certain extent, this may be interpreted as indicative of the fact that the expansion of the notion of high-quality development for manufacturing enterprises is representative of a shift towards green production methods and the activation of corporate innovation systems.

The role of digital technologies in enabling corporate green transformation has gained widespread recognition [10–12]. Its core lies in activating innovation systems, with digitally driven green innovation and energy efficiency improvements becoming common research approaches [13,14]. However, under financing constraints, enterprises may face conflicts between capital allocation for green production transitions and innovation system activation, as environmental compliance investments may crowd out innovation funding. To meet minimum environmental requirements, firms allocate substantial capital expenditures to pollution control equipment, diverting resources from green technology R&D and trapping them in an innovation dilemma.

Consequently, research into the impact of green investors' entry on the high-quality development of manufacturing enterprises, coupled with an in-depth analysis of their interaction mechanisms, is imperative. Such research should focus on exploring ways to optimise capital allocation structures and balance the tension between environmental compliance and innovation investment. This is undoubtedly of significant strategic importance for advancing the green transformation of manufacturing. It is becoming increasingly evident that the digital and real economies are converging at an accelerated rate. In order to explore how this integration can be leveraged to facilitate synergies between green transformation and innovation during corporate green production transitions and innovation system activation, further research is required. It is anticipated that this approach will augment green investment and facilitate the realisation of high-quality development goals.

In summary, this paper proposes to utilize sample data from A-share manufacturing listed companies between 2015 and 2023. The number of green investors will serve as an indicator of green investor entry. Drawing upon the evaluation framework established by Sun Hao et al. [15], which is grounded in the new development philosophy of innovation, coordination, green development, openness, and sharing, Employing the Entropy-TOPSIS method to measure high-quality development levels, the study defines digital–real integration (DREI) as whether a firm's non-digital technology patent applications cite at least one digital technology patent (indicating digital technology integration). It further analyzes the underlying mechanisms and effects of this integration.

The potential contributions of this paper are as follows: Firstly, the impact of green investor entry on the high-quality development of manufacturing enterprises is examined, thereby enriching the research on the economic consequences of such entry. The present study provides a theoretical foundation for the utilisation of green investor entry as a catalyst for the advancement of manufacturing enterprises of a high calibre. Furthermore,

it offers a point of reference for the subsequent design of related studies. Secondly, in the context of the profound integration of digital and physical technologies, it is imperative to elucidate the impact mechanism of digital–physical integration (DREI) on the entry of green investors and the development of manufacturing enterprises. Thirdly, this study employs empirical research methods—including observation, experimentation, and data collection—to examine green investor entry. The study sheds light on the repercussions of such entry on the advancement of manufacturing enterprises of a high calibre, thus enabling the transition from a state of imbalance in resources to a state of synergistic development in green production methods and innovation systems.

2. Literature Review

In the initial phase of this study, we first define the concept of "green investor entry." Green investors constitute a distinct category within institutional investors [16], collectively forming the broader institutional investor base alongside non-green investors [17]. Unlike traditional investors who focus solely on corporate performance [18], green investors prioritize environmental performance—such as environmental standards, pollution control effectiveness, and ecological conservation—in their investment decisions, explicitly incorporating green, low-carbon, and sustainable objectives into their investment scope [19]. Specifically, green investor entry refers to the targeted allocation of capital toward projects aligned with green and sustainable objectives [20]. Through this differentiated investment preference, green investors emerge as a significant force empowering enterprises to transition toward green production methods and drive technological innovation.

Based on the economic consequences and development practices resulting from green investor entry, existing research primarily explores two dimensions. On one hand, the literature examines the economic consequences green investors bring to enterprises. Green investors participate in corporate green governance, providing professional oversight of the company's environmental performance and green projects. This oversight significantly impacts pollution levels and reforms corporate capital costs [21], effectively curbing opportunistic "greenwashing" [22]. It prevents reputational damage from superficial green initiatives, achieving a win-win for both economic and environmental benefits. Simultaneously, green investor entry can generate positive reputational effects for firms [23], signaling corporate responsibility to the market and reducing information asymmetry. According to stakeholder theory, institutional investors typically favor companies with strong credibility and high social responsibility fulfillment [24]. This further elevates corporate accountability, builds a positive corporate image [25], and attracts top talent and technological resources to corporate innovation projects. This creates a virtuous cycle, drawing more green investors to purchase company stocks and securing greater financial support for the enterprise [26,27]. However, some scholars further point out that certain companies, in order to cater to investor demands and obtain short-term financial support, create a false green corporate image through "greenwashing" tactics [28]. On the other hand, focusing on the development practices of green investors, numerous scholars have employed empirical research methods to explore the motivations behind green investor entry and its underlying mechanisms. Representative studies indicate that government incentives and corporate reputation are two primary pathways for attracting green investors. This green capital exerts powerful governance capabilities by improving environmental performance [29–31], enhancing environmental information transparency [32,33], optimizing resource allocation, and driving corporate green transformation [34].

The report of the 19th CPC National Congress states: "China's economy has shifted from a phase of high-speed growth to a stage of high-quality development." The essence of economic growth lies in achieving high-quality development for enterprises [35]. As global

competition intensifies, scholars recognize that the driving mechanisms for high-quality enterprise development exhibit multidimensional and cross-domain integration. For instance, some researchers have found that digital mergers and acquisitions can promote digital transformation and technological innovation, effectively advancing high-quality enterprise development [36]. Other research indicates that the synergy between human capital and data elements ("human-data synergy") can provide sustained endogenous momentum for high-quality development by enhancing enterprises' innovation, production, and marketing capabilities [37]. At its core, on the technological upgrading level, an innovative technological environment facilitates the adoption of sustainable circular technologies by reducing information asymmetry and curbing greenwashing [38]. On the operational efficiency level, while asset structure mismatches may constrain production efficiency, digital transformation processes can mitigate these negative impacts [39]. At the production organization level, entrepreneurial and artisan spirits foster collaborative production atmospheres and strengthen psychological contracts [40], while technical standards intelligence services—as an external support system—continuously empower enterprises through a multi-tiered "resource-platform-application" model [41]. Overall, high-quality enterprise development constitutes a systemic endeavor whose driving mechanisms integrate multiple factors including digital empowerment, factor synergy, institutional incentives, asset optimization, spiritual leadership, and service innovation.

Undoubtedly, the real economy serves as the core pillar and solid foundation of China's national economy, with its essence lying in the continuous upgrading and high-quality development of manufacturing. Given that green investors can enhance corporate ESG performance and reputation through signaling mechanisms and are more inclined to invest in real enterprises with greater innovative momentum, what kind of driving force does this exert on asset allocation, production organization, and technological upgrading for high-quality manufacturing development? In other words, high-quality development in manufacturing emphasizes a shift in economic growth patterns, placing greater emphasis on the quality and efficiency of development. Its core encompasses the new development philosophy of innovation, coordination, green development, openness, and sharing [15]. This comprehensive, multidimensional approach to measurement will be introduced into this paper's assessment of the high-quality development level of manufacturing enterprises, aiming to scientifically measure the relationship between green investor entry and the high-quality development of manufacturing enterprises.

3. Research Hypothesis

3.1. Impact of Green Investors on the High-Quality Development of Manufacturing Enterprises

Green investors drive high-quality development in manufacturing enterprises primarily through two channels. On one hand, by entering the market through targeted support mechanisms, they sign subscription agreements with listed companies and acquire new shares via private placements, thereby providing enterprises with dedicated funds for green technology R&D. This alleviates financing constraints faced by enterprises during their transition to green production methods [42]. Among them, environmental performance commitments stipulated in the agreements compel enterprises to fulfill emission reduction pledges [43], thereby accelerating the transformation toward green production practices. From an environmental perspective, this transition reduces pollution emissions and resource consumption, yielding ecological benefits for enterprises and ultimately driving high-quality development in the manufacturing sector.

On the other hand, green investors participate in corporate financing through capital increases and share issuance, purchasing newly issued shares to provide enterprises with incremental equity capital. This capital is contractually restricted for green tech-

nology R&D and process innovation—such as product design and smart manufacturing upgrades—ensuring the continuity and exclusivity of innovation investments. This drives high-quality, innovative development in manufacturing enterprises. At the corporate efficiency level, enterprise innovation systems enhance technological progress and operational efficiency, strengthen economic competitiveness, and promote high-quality development in manufacturing enterprises.

Based on the above analysis, this paper proposes the following hypothesis:

H1. *Green Investors Enter to Promote High-Quality Development of Manufacturing Enterprises.*

3.2. Green Investors Entering the Market to Empower High-Quality Development of Manufacturing Enterprises Through Digital–Physical Integration (DREI)

With the vigorous development of digital technology and the real economy, the deep integration of digital technology and the real economy has become an indispensable force in national economic development. This integration manifests not only in the fusion of digital technology but also in the process of systemic, ecosystem-driven transformation. Its core lies in resource restructuring through the permeation and empowerment of data elements. According to endogenous growth theory based on energy characteristics, innovation serves as the endogenous driving force of economic growth, emphasizing "creative destruction" activities that promote technological progress. Leveraging the pervasiveness of digital–physical integration (DREI) to drive the digitalization and intelligent transformation of production factors, optimizing production processes, and enhancing resource allocation efficiency can reduce the economic activity costs of manufacturing enterprises. This shifts the scope of economic development, enabling businesses to utilize green investor capital more efficiently and precisely, thereby breaking the cycle where funding constraints deter companies from pursuing innovation.

Specifically, the emergence of digital technology has profoundly impacted three key areas. First, it has transformed traditional industrial innovation models and resource allocation structures. Through data-driven operations and digital platformization, digital technology has enabled the restructuring and optimized allocation of production factors, propelling manufacturing enterprises to transition from traditional factor-dependent approaches to data-driven development. Second, amid dual pressures from green transformation and technological change, the entry of green investors has accelerated the substitution of data elements for resource consumption in corporate production. Finally, while alleviating financing constraints for manufacturing enterprises, digital technologies—leveraging cloud computing, big data, the internet, and other advanced tools—empower businesses to build flexible production systems and intelligent decision-making mechanisms. This enables precise control over production processes and dynamic resource optimization, accelerating the penetration of digital–real integration (DREI). Consequently, it provides robust support for manufacturing enterprises to pursue greener, more efficient, and energy-saving development.

Overall, the integration of digital and physical technologies primarily drives high-quality development in manufacturing enterprises through the following approaches: First, leveraging digital empowerment pathways—utilizing digital technologies such as smart sensors and the Internet of Things to collect and analyze data at the equipment, workshop, and enterprise levels, thereby enhancing transparency and controllability in production processes. Second, leveraging networked collaboration pathways—relying on industrial internet platforms to break down organizational boundaries within manufacturing enterprises, enabling resource coordination and value sharing among upstream and downstream companies in the industrial chain. Third, through intelligent decision-making pathways,

technologies like artificial intelligence and digital twins are employed to build virtual simulation environments, supporting scientific decision-making in product R&D, process optimization, and management.

Moreover, under traditional models, environmental regulations compel enterprises to prioritize funding for end-of-pipe treatment equipment, thereby crowding out R&D budgets [44]. However, the entry of green investors mandates targeted capital allocation, providing focused support for digitally empowered enterprises to develop green productivity [45] and consequently reducing capital tied up in end-of-pipe treatment. For instance, leveraging digital twin technology to optimize pollution parameters through a hybrid R&D system that integrates virtual and physical environments can reduce trial-and-error costs for enterprises. This frees up capital for green technology R&D and innovation, enabling synergistic development across environmental optimization, technological advancement, and innovative research. Regarding R&D processes, intelligent equipment can refine production techniques, enable real-time data monitoring, collect and analyze diverse datasets, streamline manufacturing workflows, and enhance resource allocation efficiency. Consequently, this approach minimizes resource wastage and further propels enterprises toward high-quality development [46].

Based on the above analysis, the following hypothesis is proposed:

H2. *Green investors can promote high-quality development of manufacturing enterprises through the integration of digital and physical economies.*

4. Research Design

4.1. Data Source and Sample Selection

This study examines A-share manufacturing companies listed on the stock exchange from 2015 to 2023. Data measuring the high-quality development of manufacturing enterprises is sourced from company annual reports and the CNRDS database. Green investor entry data and other variables are sourced from the Guotai An database (CSMAR). Information on invention patents related to the integration of digital and physical technologies is sourced from the China Patent Database of the National Intellectual Property Administration. To ensure the robustness of empirical results, the sample underwent the following treatments: (1) Only manufacturing enterprise observations were retained; (2) Observations with missing key variable data were excluded; (3) To control the impact of extreme values, continuous variables underwent trimming at the 1% and 99% tail levels. (4) Observations from ST and PT-listed companies were excluded; (5) Observations from listed companies with a debt-to-asset ratio greater than 1 or less than 0 were excluded.

4.2. Variable Measurement

4.2.1. Dependent Variable

High-Quality Development of Manufacturing Enterprises. Drawing upon methodologies from scholars such as Sun Hao [15] and Li Linmu [47], this study establishes an evaluation index system based on the new development concepts of innovation, coordination, green development, openness, and sharing. The entropy-TOPSIS method was employed to measure the level of high-quality development in manufacturing enterprises. As shown in Table 1.

Raw Data Normalization

Positive indicator

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}$$

negative indicator

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)}$$

x_{ij} Original data for the i-th sample on the j-th indicator
x'_{ij} Standardized data
Calculate the weight of indicators

$$p_{ij} = \frac{x'_{ij} + \varepsilon}{\sum_{i=1}^{n}\left(x'_{ij} + \varepsilon\right)}$$

Table 1. Indicator System for High-Quality Development of Manufacturing Enterprises.

Primary Indicator	Secondary Indicators	Basic Indicators	Attribute
Innovative Development	Innovation Investment	Percentage of R&D personnel	+
		R&D expenditure as a percentage of operating revenue	+
	Innovative Achievements	Number of patents obtained that year	+
Coordinated Development	Corporate Governance Standards	Accounts Receivable Turnover Ratio	+
		Accounts Payable Turnover Ratio	-
		Management Expense Ratio	-
		Financial Expense Ratio	-
Green Development	Sustainable Development Capacity	Growth rate of net cash flow from operating activities per share	+
		Operating Revenue Growth Rate	+
		Huazheng ESG Rating System Environmental Score	+
Shared Development	corporate employees	Volunteer Activities	+
	Social Contribution	Total amount of social donations	+
Open Development	Open Outcomes	Overseas Revenue Share	+

P_{ij} Weighting factor for each indicator
ε Minimal displacement = 0.00000001
Calculate entropy values

$$e_j = -\frac{1}{ln(rn)}\sum_{i=1}^{n} p_{ij} ln(p_{ij})$$

where

rn is the total sample size (number of years × number of observations).
ln(rn) is used to standardize the entropy value range, ensuring $e_j \in [0, 1]$.
To calculate the coefficient of variation, the following equation can be used:

$$g_j = 1 - e_j$$

To calculate weights, the following equation can be used:

$$w_i = \frac{g_i}{\sum_{j=1}^{m} g_i}$$

4.2.2. Explanatory Variable

Green investors enter. Drawing on the definition methodology for green investor entry proposed by scholars such as Wang Hui [20], this study combines two datasets—"Fund Entity Information Form" and "Stock Investment Details Form"—to match fund data with investment data. It focuses on the types of funds investing in listed companies, identifying those whose "investment objectives" and "investment scope" include specific keywords such as "environmental protection," "green," or "new energy" as "green investors." Conversely, those lacking such keywords are classified as "non-green investors."

4.2.3. Control Variables

Drawing on the research findings of Wenke et al. [48], we selected a series of control variables including the proportion of fixed assets, Tobin's Q ratio, return on net assets, debt-to-equity ratio, proportion of independent directors, board size, cash flow ratio, proportion of inventory, and asset turnover rate. The definitions of each variable are listed in Table 2.

Table 2. Variable Definition Table.

Variable Code	Variable Name	Variable Definition
FAR	Fixed Assets Ratio	Net Fixed Assets/Total Assets
Tobin Q	Tobin's Q	[Total Liabilities + (Number of Tradable Shares × Year-end Closing Price) + (Number of Non-tradable Shares × (Owners' Equity/Total Shares))]/Total Liabilities
ROE	Return on Equity (ROE)	Net Profit/Average Shareholders' Equity
DAR	Debt-to-Asset Ratio	Total Liabilities/Total Assets
Ind DirRatio	Proportion of Independent Directors	Number of Independent Directors/Total Board Members (in the current year)
Board size	Board Size	Number of Board Members (in the current year)
ATO	Asset Turnover Ratio	Operating Revenue/Average Total Assets
CFR	Cash Flow Ratio	Net Cash Flow from Operating Activities/Total Assets
INV	Inventory Ratio	Net Inventory/Total Assets

4.3. Model Design

To examine the impact of green investors' entry on the high-quality development of manufacturing enterprises, a benchmark regression model (1) is constructed:

$$Hqd_{i,t} = \alpha_0 + \alpha_1 NGI_{i,t} + \sum \alpha_k \, Control_{i,t} + Year + City + Ind + \varepsilon_{i,t} \quad (1)$$

Variable definitions in Equation (1):

Hqd denotes high-quality development of manufacturing enterprises; NGI denotes green investor entry; Control denotes a set of control variables; i and t represent firm and year, respectively; Year indicates the year fixed effect, controlling for influences common to all samples within a given year; City denotes the city fixed effect, controlling for spatial factors that do not vary over time; Ind represents the industry fixed effect, controlling for unobservable factors that vary over time at both the industry and firm levels; ε denotes the random error term.

5. Empirical Results Analysis

5.1. Descriptive Statistics

This study examines the impact of green investor entry on the high-quality development (HQD) of manufacturing enterprises, using A-share listed manufacturing companies from 2015 to 2023 as the research sample. Descriptive statistics reveal (see Table 3) that the mean value for green investors (NGI) is 0.542 with a standard deviation of 0.765. This indicates that over half of the enterprises have yet to attract green investors, and there are significant disparities in green investment levels across different companies. The mean HQD score for manufacturing enterprises is 0.046 with a median of 0.016, exhibiting a right-skewed distribution. This indicates that most manufacturing enterprises have low HQD levels, while a minority demonstrate outstanding performance. Regarding control variables, the debt-to-asset ratio (DAR) had a mean of 40.7%, reflecting a generally sound financial structure across the sample. However, the range of the inventory ratio (INV) reached 0.642, indicating substantial variations in operational efficiency among enterprises.

Table 3. Descriptive Statistics.

VarName	Obs	Mean	Median	SD	Min	Max
HQD	6247	0.046	0.016	0.066	0.003	0.470
NGI	6247	0.542	0.000	0.765	0.000	2.944
NGI_SOC	6247	2.773	0.000	8.384	−51.969	98.269
SOC	6247	4.374	0.000	7.329	−23.652	41.371
NGI_FC	6247	0.170	0.000	0.292	0.000	1.913
FC	6247	0.470	0.487	0.277	0.000	0.988
NGI	6247	0.542	0.000	0.765	0.000	2.944
FAR	6247	0.224	0.204	0.123	0.002	0.733
TobinQ	6247	2.086	1.693	1.348	0.692	21.296
ROE	6247	0.077	0.080	0.132	−1.724	1.319
DAR	6247	0.407	0.409	0.173	0.014	0.976
IndDirRatio	6247	37.930	36.360	5.732	20.000	80.000
Boardsize	6247	2.109	2.197	0.191	1.386	2.833
ATO	6247	0.669	0.604	0.359	0.050	7.788
CFR	6247	0.059	0.055	0.064	−0.319	0.488
INV	6247	0.138	0.123	0.076	0.008	0.650

5.2. Baseline Regression

Table 4 presents the regression results between green investor entry (hereafter denoted as "NGI") and the high-quality development (HQD) of manufacturing enterprises. Column (1), without controlling variables and fixed effects, shows that the regression coefficient of NGI on HQD is significantly positive at the 1% level, preliminarily supporting that green investor entry promotes the high-quality development of manufacturing enterprises. Columns (2) to (5), which progressively incorporate control variables and fixed effects, maintain the positive relationship between NGI and HQD at the 1% level of significance. This indicates that increased NGI positively promotes high-quality development in manufacturing enterprises and remains robust after controlling for annual trends, regional differences, and industry variations. The possible reasons for these results are: the entry of green investors, on the one hand, optimizes corporate resource allocation by strengthening external oversight; on the other hand, it enhances enterprises' green technology levels by introducing green resources, thereby strengthening their ability to withstand environmental risks and driving high-quality development in manufacturing enterprises.

Table 4. Baseline Regression Results for the Dependent Variable.

	(1) HQD	(2) HQD	(3) HQD	(4) HQD	(5) HQD
NGI	0.019 ***	0.017 ***	0.016 ***	0.014 ***	0.014 ***
	(17.62)	(14.26)	(13.50)	(11.81)	(11.92)
FAR		−0.011	−0.008	0.001	−0.015 *
		(−1.52)	(−1.22)	(0.07)	(−1.95)
TobinQ		−0.004 ***	−0.004 ***	−0.004 ***	−0.005 ***
		(−5.41)	(−5.27)	(−6.25)	(−6.54)
ROE		0.022 ***	0.025 ***	0.028 ***	0.028 ***
		(3.07)	(3.49)	(3.99)	(4.07)
DAR		0.030 ***	0.024 ***	0.031 ***	0.034 ***
		(5.61)	(4.53)	(5.59)	(6.06)
IndDirRatio		0.001 ***	0.001 ***	0.001 ***	0.001 ***
		(6.75)	(6.83)	(7.26)	(6.21)
Boardsize		0.051 ***	0.055 ***	0.057 ***	0.053 ***
		(10.07)	(10.95)	(10.51)	(9.78)
ATO		0.005 **	0.006 **	0.006 **	0.003
		(2.21)	(2.34)	(2.26)	(1.14)
CFR		0.064 ***	0.056 ***	0.052 ***	0.053 ***
		(4.43)	(3.80)	(3.63)	(3.66)
INV		0.020 *	0.012	0.008	0.013
		(1.74)	(1.09)	(0.73)	(1.05)
_cons	0.036 ***	−0.128 ***	−0.132 ***	−0.143 ***	−0.125 ***
	(36.15)	(−8.39)	(−8.76)	(−8.77)	(−7.60)
Year	No	No	Yes	Yes	Yes
City	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes
Adjusted R^2	0.0472	0.0867	0.1155	0.2215	0.2367
Observations	6247	6247	6247	6247	6247

Note: t-values in parentheses; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3. Endogeneity Test

To address potential endogeneity issues arising from reverse causality in benchmark regression analysis, this study adopts an instrumental variable approach for endogeneity testing, drawing on research by Huang Qunhui et al. [49]. The NGI index is included in the regression model with first-, second-, and third-order lags, employing two-stage least squares (2SLS) for regression testing. The regression results are presented in Table 5. Columns (1) to (3) demonstrate that after lagging the NGI index by one, two, and three periods, respectively, the regression coefficients for manufacturing enterprises' high-quality development remain significantly positive, thereby ruling out the possibility of reverse causality. Columns (4) to (6), which utilize the lagged terms as instrumental variables, show that the NGI coefficients remain significantly positive. This further confirms that the NGI effectively promotes the high-quality development of manufacturing enterprises, providing empirical evidence for the formulation of relevant policies and corporate strategic development.

Table 5. 2SLS Regression Results (Including Endogeneity Test).

	(1) Lagged_1	(2) Lagged_2	(3) Lagged_3	(4) 2SLS_L1	(5) 2SLS_L2	(6) 2SLS_L3
L1_NGI	0.014 ***					
	(8.79)					
L2_NGI		0.016 ***				
		(8.57)				
L3_NGI			0.018 ***			
			(8.56)			
NGI				0.024 ***	0.034 ***	0.044 ***
				(8.72)	(8.43)	(8.32)
FAR	−0.019 *	−0.021 *	−0.031 **	−0.020 *	−0.024 *	−0.030 **
	(−1.74)	(−1.74)	(−2.10)	(−1.90)	(−1.93)	(−2.01)
TobinQ	−0.005 ***	−0.004 ***	−0.003 **	−0.007 ***	−0.009 ***	−0.011 ***
	(−5.11)	(−3.88)	(−2.29)	(−6.88)	(−6.74)	(−6.08)
ROE	0.046 ***	0.051 ***	0.062 ***	0.026 ***	0.016 *	0.013
	(4.50)	(5.68)	(5.80)	(2.64)	(1.69)	(1.20)
DAR	0.041 ***	0.035 ***	0.038 ***	0.028 ***	0.011	0.004
	(5.60)	(4.07)	(3.64)	(3.60)	(1.14)	(0.35)
IndDirRatio	0.001 ***	0.001 ***	0.001 ***	0.001 ***	0.001 ***	0.001 ***
	(5.10)	(4.23)	(3.97)	(4.65)	(3.33)	(2.72)
Boardsize	0.055 ***	0.058 ***	0.063 ***	0.052 ***	0.049 ***	0.050 ***
	(7.61)	(7.14)	(6.71)	(7.10)	(5.89)	(5.03)
ATO	0.004	0.007	0.003	0.004	0.007	0.002
	(1.00)	(1.52)	(0.50)	(0.96)	(1.48)	(0.29)
CFR	0.041 **	0.036 *	0.036	0.034 *	0.017	0.017
	(2.17)	(1.70)	(1.39)	(1.78)	(0.81)	(0.63)
INV	0.012	0.013	0.012	0.018	0.020	0.020
	(0.78)	(0.69)	(0.59)	(1.14)	(1.08)	(0.94)
Year	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
ACCLM				0.000	0.000	0.000
CDW				1795.69	721.49	448.12
DWHTS				20.84	29.11	35.09
DWHT				0.000	0.000	0.000
Adjusted R^2	0.248	0.256	0.255	0.016	−0.016	−0.058
Observations	4410	3535	2732	4410	3535	2732

Note: *, **, and *** are statistically significant at 10%, 5%, and 1%, respectively. The content in parentheses is t-value.

5.4. Robustness Tests

5.4.1. Replacement Indicators for Measuring High-Quality Development in Manufacturing Enterprises

Following the methodology outlined in [50,51], this study replaces HQD with TFP_GMM (the TFP_GMM estimation method) for benchmark regression tests to validate the robustness of the conclusions. The test results are presented in Table 6. The TFP_GMM regression coefficient for NGI is significantly positive, indicating that NGI continues to significantly promote the high-quality development of manufacturing enterprises.

Table 6. Robustness Test Results: Replacing the Dependent Variable Method.

	(1) TFP_GMM	(2) TFP_GMM	(3) TFP_GMM	(4) TFP_GMM	(5) TFP_GMM
NGI	0.287 ***	0.204 ***	0.199 ***	0.184 ***	0.183 ***
	(26.94)	(25.85)	(25.68)	(24.90)	(26.19)
FAR		−1.575 ***	−1.534 ***	−1.587 ***	−1.983 ***
		(−33.75)	(−33.66)	(−33.59)	(−41.70)
TobinQ		−0.069 ***	−0.067 ***	−0.062 ***	−0.060 ***
		(−15.27)	(−14.53)	(−13.96)	(−13.93)
ROE		0.447 ***	0.462 ***	0.438 ***	0.413 ***
		(9.19)	(9.74)	(9.93)	(9.95)
DAR		1.128 ***	1.070 ***	1.091 ***	1.130 ***
		(30.77)	(29.79)	(30.74)	(33.36)
IndDirRatio		0.012 ***	0.012 ***	0.009 ***	0.008 ***
		(10.28)	(10.67)	(8.35)	(7.07)
Boardsize		0.518 ***	0.558 ***	0.460 ***	0.378 ***
		(15.03)	(16.63)	(13.29)	(11.48)
ATO		0.982 ***	0.984 ***	0.960 ***	0.864 ***
		(60.16)	(61.90)	(59.48)	(51.72)
CFR		0.595 ***	0.472 ***	0.616 ***	0.712 ***
		(6.08)	(4.86)	(6.71)	(8.20)
INV		−0.639 ***	−0.707 ***	−0.731 ***	−0.543 ***
		(−8.41)	(−9.55)	(−9.84)	(−7.46)
_cons	5.470 ***	3.380 ***	3.320 ***	3.631 ***	3.974 ***
	(548.27)	(32.74)	(33.02)	(34.82)	(40.01)
Year	No	No	Yes	Yes	Yes
City	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes
Adjusted R^2	0.1040	0.6059	0.6284	0.6980	0.7357
Observations	6247	6247	6247	6247	6247

Note: Values in parentheses are t-values. *** indicates significance at the 1% level. *** $p < 0.01$.

5.4.2. Excluding Special Year Data

Considering other factors influencing the high-quality development of manufacturing enterprises—such as potential differences in time-varying effects between green investor entry and non-entry scenarios—may also introduce interference to empirical findings. Additionally, business operations during the COVID-19 pandemic may have been disrupted, leading to more defensive investment decisions that could impact the high-quality development of manufacturing enterprises. Therefore, to eliminate these confounding factors, the study excluded data from years affected by the COVID-19 pandemic, retaining only sample data from 2015 to 2020. To ensure the robustness of the conclusions, data from 2021 to 2023—the pandemic years—were also excluded. The test results are shown in Table 7 below. The validation results indicate that even after excluding years during the COVID-19 pandemic, NGI still significantly promotes the high-quality development of manufacturing enterprises.

Table 7. Robustness Test Results: Changing the Time Period.

	(1) HQD	(2) HQD	(3) HQD	(4) HQD	(5) HQD
NGI	0.018 ***	0.015 ***	0.016 ***	0.013 ***	0.013 ***
	(14.58)	(11.72)	(11.98)	(10.18)	(10.20)
FAR		−0.002	0.001	0.010	0.001
		(−0.26)	(0.07)	(1.23)	(0.11)
TobinQ		−0.002 ***	−0.002 **	−0.002 ***	−0.003 ***
		(−2.65)	(−2.56)	(−2.99)	(−3.45)
ROE		0.017 **	0.017 **	0.015 *	0.015 *
		(2.13)	(2.17)	(1.96)	(1.91)
DAR		0.029 ***	0.027 ***	0.030 ***	0.031 ***
		(4.97)	(4.55)	(5.02)	(5.04)
IndDirRatio		0.001 ***	0.001 ***	0.001 ***	0.001 ***
		(4.28)	(4.34)	(5.20)	(4.29)
Boardsize		0.044 ***	0.044 ***	0.049 ***	0.047 ***
		(7.85)	(8.00)	(8.16)	(7.79)
ATO		0.004 *	0.005 *	0.006 **	0.006 **
		(1.70)	(1.89)	(2.29)	(2.11)
CFR		0.049 ***	0.036 **	0.035 **	0.035 **
		(3.18)	(2.26)	(2.20)	(2.18)
INV		0.019	0.019	0.023 *	0.025 *
		(1.58)	(1.55)	(1.73)	(1.87)
_cons	0.029 ***	−0.108 ***	−0.110 ***	−0.131 ***	−0.118 ***
	(27.37)	(−6.52)	(−6.60)	(−7.21)	(−6.46)
Year	No	No	Yes	Yes	Yes
City	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes
Adjusted R^2	0.0478	0.0807	0.0835	0.1934	0.2082
Observations	4212	4212	4212	4212	4212

Note: t-values in parentheses; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.5. Moderation Effect Model Design

5.5.1. Model Design

Construct the moderating effect model as shown in Equation (2):

$$Hqd_{i,t} = \alpha_0 + \alpha_1 NGI_{i,t} + \alpha_2 (NGI_{i,t} * MV_{i,t}) + \alpha_3 MV_{i,t} + \sum \alpha_k \, Control_{i,t} + Year + City + Ind + \varepsilon_{i,t} \quad (2)$$

Variable definitions in Equation (2): MV denotes the manipulated variable, while the meanings of other variables remain consistent with those in Equation (1).

5.5.2. Moderating Role of Ownership Concentration

Based on Model 2, the following tests were conducted to examine the moderating effect of green investor entry on the high-quality development of manufacturing enterprises. The test results are presented in Table 8: Column (2) of the regression results in Table 8 indicates that equity concentration exerts a positive effect on the high-quality development of manufacturing enterprises. When major shareholders hold concentrated stakes, corporate decision-making efficiency improves and resistance to NGI implementation decreases, thereby facilitating the high-quality development of manufacturing enterprises.

Table 8. Moderating Effect Test Results.

	(1) Baseline Model	(2) Ownership Concentration	(3) Financing Constraints
NGI	0.014 ***	0.013 ***	0.016 ***
	(11.92)	(9.96)	(9.18)
NGI_SOC		0.000	
		(0.61)	
SOC		0.000 **	
		(2.16)	
NGI_FC			−0.032 ***
			(−7.96)
FC			−0.050 ***
			(−10.84)
FAR	−0.015 *	−0.016 **	−0.014 *
	(−1.95)	(−2.03)	(−1.81)
TobinQ	−0.005 ***	−0.005 ***	−0.004 ***
	(−6.54)	(−6.52)	(−5.26)
ROE	0.028 ***	0.028 ***	0.031 ***
	(4.07)	(4.02)	(4.55)
DAR	0.034 ***	0.033 ***	−0.021 ***
	(6.06)	(5.86)	(−3.18)
IndDirRatio	0.001 ***	0.001 ***	0.001 ***
	(6.21)	(6.45)	(5.15)
Boardsize	0.053 ***	0.053 ***	0.040 ***
	(9.78)	(9.81)	(7.51)
ATO	0.003	0.003	0.003
	(1.14)	(1.05)	(1.28)
CFR	0.053 ***	0.052 ***	0.036 **
	(3.66)	(3.59)	(2.57)
INV	0.013	0.015	0.044 ***
	(1.05)	(1.23)	(3.67)
_cons	−0.125 ***	−0.128 ***	−0.046 ***
	(−7.60)	(−7.76)	(−2.71)
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Adjusted R^2	0.2367	0.2378	0.2741
Observations	6247	6247	6247

Note: t-values in parentheses; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.5.3. The Moderating Role of Financing Constraints

Following the methodology of scholar Zeng Fuquan [52], this study selects financing constraints as the moderating variable. Results indicate that the coefficient of the interaction term NGI_FC in Column (3) is −0.032, significantly negative at the 1% level. This suggests that financing constraints significantly inhibit the impact of NGI on the high-quality development of manufacturing enterprises. This implies that manufacturing enterprises may face relatively severe financing constraints, making it difficult for the "policy dividends" intended to promote their high-quality development to translate into substantive "development momentum."

6. Further Analysis and Discussion

6.1. Discussion on Mechanistic Effects

The preceding theoretical analysis suggests that the entry of green investors can promote high-quality development in manufacturing enterprises through the integration of digital and physical dimensions. To examine the mediating role of this integration, this study adopts a stepwise approach inspired by Wen et al.'s [53] methodology for testing mediating effects, constructing the following mediation model:

$$Hqd_{i,t} = \alpha_0 + \alpha_1 NGI_{i,t} + \sum \alpha_k \, Control_{i,t} + Year + City + Ind + \varepsilon_{i,t} \quad (3)$$

$$DREI_{i,t} = \alpha_0 + \alpha_1 NGI_{i,t} + \sum \alpha_k \, Control_{i,t} + Year + City + Ind + \varepsilon_{i,t} \quad (4)$$

$$Hqd_{i,t} = \alpha_0 + \alpha_1 NGI_{i,t} + \alpha_2 DREI_{i,t} + \sum \alpha_k \, Control_{i,t} + Year + City + Ind + \varepsilon_{i,t} \quad (5)$$

Equation (3) examines the impact of green investor entry (NGI) on the high-quality development of manufacturing enterprises, while Equation (4) assesses the effect of NGI on the digital–real integration (DREI). Equation (5) incorporates a mediating variable into the benchmark regression for testing. Variables in Equations (3)–(5) share the same definitions as those in Equation (1) above, with DERI serving as the mediating variable in this study.

To overcome potential limitations of stepwise testing, this study adopts the Bootstrap sampling method to test the significance of indirect effects, following the approach of Preacher et al. [54], and calculates their 95% confidence intervals. If the confidence interval does not include zero, it indicates a significant mediating effect. The mediating effect was tested using the bias-corrected nonparametric percentile Bootstrap method, with results presented in Table 9. The indirect effect value of green investors entering the market through the integration of digital and physical economies on the high-quality development of manufacturing enterprises is 0.000703, with a Bootstrap standard error of 0.000193, significant at the 1% level. The 95% confidence interval based on the percentile method is [0.000363, 0.001114], while the 95% confidence interval based on the normal distribution is [0.000325, 0.001081]. Both intervals exclude zero, further validating the robustness of the indirect effect. Meanwhile, the direct effect of green investor entry on the high-quality development of manufacturing enterprises was 0.016003, significant at the 1% level, with a 95% percentile confidence interval of [0.013333, 0.018698]. The results indicate that the integration of digital and physical technologies plays a significant partial mediating role in the process by which green investor entry promotes the high-quality development of manufacturing enterprises, accounting for 4.21% of the total effect.

Table 9. Results of Mediating Effect Tests Using the Bootstrap Method.

	Observed Coefficient	Bootstrap Std. Err	Z	*P*	[95% Conf. Interval] (Normal-Based)	[95% Conf. Interval] (Percentile)
indirect	0.000703	0.000193	3.64	0.000	[0.000325, 0.001081]	[0.000363, 0.001114]
direct	0.016003	0.001375	11.64	0.000	[0.013307, 0.018698]	[0.013333, 0.018698]
overall	0.016706	-	-	-	-	-
Proportion	4.21%	-	-	-	-	-

Table 10 reports the regression results for Model (2). In Column (1), the regression coefficient for green investor entry (NGI) on the log-real convergence is significantly positive at the 1% level, indicating that green investor entry promotes log-real convergence. After progressively incorporating control variables and fixed effects for year, city, and industry in columns (2) to (5), the coefficient for green investor entry (NGI) remains significantly

positive, indicating strong robustness in the promotional effect of green investor entry on the logarithm of digital–real integration.

Table 10. Baseline Regression Results for the Mediating Variable.

	(1) NumDREI	(2) NumDREI	(3) NumDREI	(4) NumDREI	(5) NumDREI
NGI	0.093 ***	0.086 ***	0.083 ***	0.069 ***	0.065 ***
	(9.55)	(8.00)	(7.96)	(6.45)	(6.12)
FAR		0.030	−0.092	0.050	0.042
		(0.47)	(−1.50)	(0.74)	(0.58)
TobinQ		−0.016 ***	−0.027 ***	−0.026 ***	−0.020 ***
		(−2.62)	(−4.34)	(−3.95)	(−3.02)
ROE		0.142 **	0.123 *	0.132 **	0.145 **
		(2.15)	(1.93)	(2.07)	(2.31)
DAR		0.279 ***	0.371 ***	0.375 ***	0.299 ***
		(5.59)	(7.72)	(7.30)	(5.82)
IndDirRatio		0.007 ***	0.006 ***	0.008 ***	0.007 ***
		(4.29)	(4.14)	(4.73)	(4.24)
Boardsize		0.351 ***	0.281 ***	0.376 ***	0.330 ***
		(7.48)	(6.24)	(7.50)	(6.61)
ATO		0.058 ***	0.052 **	0.048 **	0.025
		(2.62)	(2.46)	(2.07)	(1.00)
CFR		−0.591 ***	−0.150	−0.053	0.031
		(−4.43)	(−1.15)	(−0.40)	(0.23)
INV		−0.620 ***	−0.521 ***	−0.395 ***	−0.360 ***
		(−5.99)	(−5.25)	(−3.67)	(−3.27)
_cons	0.184 ***	−0.820 ***	−0.672 ***	−0.982 ***	−0.827 ***
	(20.09)	(−5.84)	(−4.99)	(−6.51)	(−5.49)
Year	No	No	Yes	Yes	Yes
City	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes
Adjusted R^2	0.0143	0.0436	0.1276	0.1720	0.2047
Observations	6247	6247	6247	6247	6247

Note: t-values in parentheses; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 11 reports the regression results for Model (3). After controlling for the digital–real integration index (DREI), the direct effect of green investor entry (NGI) on the high-quality development (HQD) of manufacturing enterprises remains significant. The regression coefficient for the digital–real integration index (DREI) on the high-quality development (HQD) of manufacturing enterprises is also significantly positive at the 1% level.

The stepwise regression results in Tables 10 and 11 corroborate the conclusions of the Bootstrap test, jointly supporting the mediating role of digital–real integration.

Digital–physical integration refers to the deep convergence of digital technologies with the real economy [48]. Empirical findings reveal that the entry of green investors (NGI) promotes high-quality development in manufacturing enterprises through digital–physical integration (DREI). This occurs because data elements, by closely integrating with corporate R&D, market operations, and production organization, permeate various operational models within traditional industry supply chains, achieving deep convergence with the physical sector.

Table 11. Regression Results with Mediating Variable in the Dependent Variable Model.

	(1) HQD	(2) HQD	(3) HQD	(4) HQD	(5) HQD
NumDREI	0.011 ***	0.008 ***	0.014 ***	0.011 ***	0.010 ***
	(7.72)	(5.94)	(9.57)	(8.04)	(7.38)
NGI	0.018 ***	0.016 ***	0.015 ***	0.013 ***	0.013 ***
	(16.65)	(13.62)	(12.57)	(11.16)	(11.35)
FAR		−0.011	−0.007	−0.000	−0.016 **
		(−1.56)	(−1.04)	(−0.01)	(−2.02)
TobinQ		−0.004 ***	−0.003 ***	−0.004 ***	−0.004 ***
		(−5.23)	(−4.77)	(−5.87)	(−6.27)
ROE		0.021 ***	0.023 ***	0.026 ***	0.026 ***
		(2.92)	(3.27)	(3.80)	(3.87)
DAR		0.028 ***	0.019 ***	0.027 ***	0.031 ***
		(5.19)	(3.60)	(4.84)	(5.52)
IndDirRatio		0.001 ***	0.001 ***	0.001 ***	0.001 ***
		(6.44)	(6.37)	(6.79)	(5.82)
Boardsize		0.049 ***	0.051 ***	0.053 ***	0.050 ***
		(9.49)	(10.24)	(9.74)	(9.16)
ATO		0.005 **	0.005 **	0.005 **	0.003
		(2.02)	(2.06)	(2.06)	(1.04)
CFR		0.069 ***	0.058 ***	0.053 ***	0.052 ***
		(4.77)	(3.97)	(3.69)	(3.66)
INV		0.025 **	0.019 *	0.013	0.016
		(2.19)	(1.73)	(1.11)	(1.36)
_cons	0.034 ***	−0.122 ***	−0.123 ***	−0.132 ***	−0.116 ***
	(33.30)	(−7.95)	(−8.20)	(−8.11)	(−7.09)
Year	No	No	Yes	Yes	Yes
City	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes
Adjusted R^2	0.0561	0.0917	0.1282	0.2297	0.2435
Observations	6247	6247	6247	6247	6247

Note: t-values in parentheses; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The entry of green investors further strengthens this process. By incorporating environmental and social responsibility factors into investment decisions, they guide the digital–physical integration toward green intelligent transformation, driving enterprises to balance efficiency gains with sustainable development during digital transformation. Simultaneously, green capital investment provides stable funding for long-term projects, effectively alleviating financing pressures during the initial stages of transformation. Moreover, leveraging their intelligent networks and green technology resources, green investors introduce advanced technologies and market channels to enterprises, significantly enhancing their capacity for deep integration.

Given that digital technology's pervasive nature reduces search, replication, transmission, tracking, and verification costs in economic activities [50], it inherently possesses the advantage of driving flexible production and organizational model innovation in manufacturing through deep application and data element integration. This not only elevates production complexity and added value while comprehensively improving operational and management efficiency but also fully empowers the transformation of production factors and relations within manufacturing enterprises, unlocking the driving force for high-quality development.

Specifically, from a process dynamics perspective, the integration of digital and physical realms drives enterprises toward full-process intelligent transformation by embed-

ding advanced digital technologies—such as artificial intelligence, cloud computing, and blockchain—into traditional industrial workflows, laying a solid foundation for high-quality development. On the production side, this integration leverages intelligent assistance and real-time interaction mechanisms to reconstruct economic segments including R&D, manufacturing, distribution, and consumption, substantially reducing transaction costs and resource misallocation while significantly boosting production efficiency. On the innovation front, digitalization substantially lowers barriers to knowledge spillovers, enabling enterprises to swiftly identify and absorb external innovations. This facilitates access to global resource networks, enhances cross-border collaboration capabilities, and deepens participation in international division of labor. Consequently, it continuously drives innovation in product processes, services, and business models, solidifying the foundation for high-quality enterprise development.

From a technological perspective, digital–physical integration treats data as a new key factor of production. By fully leveraging and efficiently circulating data, it facilitates precise matching of information between supply and demand sides, providing robust support for corporate strategic decision-making, resource integration, and innovation activities. This drives industrial upgrading at the micro-mechanism level. On the supply side, the digital industrialization of traditional sectors continuously cultivates digital technology service models—such as data analytics and intelligent search—injecting innovative tools and methodologies into the transformation and upgrading of traditional enterprises. simultaneously, industrial digitalization permeates critical stages like R&D, production, and sales, catalyzing new business models such as platform and sharing economies while continuously modernizing industrial systems. On the demand side, this convergence establishes high-bandwidth, low-latency real-time information channels. Enterprises can leverage internet platforms and big data technologies to efficiently capture consumer preferences, feeding demand signals back to product design and manufacturing in real time—driving flexible manufacturing and personalized customization. This bidirectional empowerment mechanism not only significantly improves supply-demand matching efficiency but also establishes a virtuous cycle where demand drives production and research fuels sales. This cycle forms the core driving force for enterprises to lead the market, pursue continuous innovation, and achieve high-quality development.

6.2. Discussion on Heterogeneity Analysis

To further analyze the impact of green investor entry on the high-quality development of manufacturing enterprises and arrive at more robust conclusions, this paper conducts a heterogeneity analysis based on the preceding research, examining the regional location, industry attributes, and corporate governance structures of enterprises. It investigates the heterogeneous effects of green investor entry on the high-quality development of manufacturing enterprises.

6.2.1. Analysis of Regional Heterogeneity

This paper references [55], defining the eastern region based on the province where enterprises are registered as: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Zhejiang, Fujian, Jiangsu, Shandong, Guangdong, and Hainan. The central and western regions comprise: Neimenggu, Chongqing, Sichuan, Guangxi, Guizhou, Yunnan, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, Xizang, Shanxi, Jilin, Heilongjiang, Henan, Hubei, Hunan, Anhui, and Jiangxi. Grouped regression tests were conducted.

Table 12 reports the results of the regional heterogeneity test. Findings indicate that the estimated coefficients for green investor entry (NGI) in eastern and non-eastern enterprises are 0.017 and 0.011, respectively, both significant at the 1% level. This outcome

may be attributed to the saturation of enterprise development quality. Eastern regions possess stronger research capabilities, abundant higher education and high-quality talent resources, and more pronounced agglomeration effects. Consequently, eastern regions have established solid foundations in infrastructure, talent resources, and policy support, making them more attractive to green investors. Enterprises in these areas face fewer financing constraints, leading to more pronounced promotional effects and higher enterprise development quality compared to central and western regions. Constrained by complex geographical conditions, lower levels of marketization, and lagging institutional environments, the manufacturing sectors in central and western regions lag relatively behind. Numerous factors limit high-quality enterprise development in these areas, ultimately resulting in a relatively weaker promotional effect of green investor entry on the high-quality development of manufacturing enterprises.

Table 12. Heterogeneity Test Results.

	(1) HPI	(2) NHPI	(3) EC	(4) CWC	(5) High Div	(6) Low Div
NGI	0.013 ***	0.016 ***	0.017 ***	0.011 ***	0.014 ***	0.020 ***
	(5.45)	(13.37)	(14.53)	(4.01)	(12.47)	(6.36)
_cons	0.045 ***	0.035 ***	0.036 ***	0.046 ***	0.036 ***	0.050 ***
	(24.48)	(32.34)	(34.20)	(20.86)	(35.99)	(18.54)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	Yes	Yes	Yes	Yes	Yes	Yes
Observations	Yes	Yes	Yes	Yes	Yes	Yes
Industry	0.3106	0.1846	0.1866	0.2650	0.1995	0.2532
Adjusted R^2	1696	4551	4863	1384	5212	1035

Note: Values in parentheses are t-values. *** indicates significance at the 1% level. *** $p < 0.01$.

6.2.2. Analysis Based on Industry Heterogeneity

To examine the impact of green investor entry across different industries on the high-quality development of manufacturing enterprises, this study further categorizes enterprises into heavily polluting and non-heavily polluting groups based on Reference [56] for grouped regression analysis. Enterprises classified under the following sectors are included: coal mining and washing, petroleum and natural gas extraction, ferrous metal mining and beneficiation, non-ferrous metal mining and beneficiation, textiles, leather, fur, feather products, and footwear manufacturing, paper and paper products manufacturing, petroleum processing, coking, and nuclear fuel processing; chemical raw materials and chemical products manufacturing; chemical fiber manufacturing; rubber and plastic products manufacturing; non-metallic mineral products manufacturing; ferrous metal smelting and rolling; non-ferrous metal smelting and rolling; or electricity, heat production, and supply, it is classified as a heavily polluting enterprise. All others are non-heavily polluting enterprises.

Table 12 reports the regression results for the industry heterogeneity test. The findings indicate that the estimated coefficients for green investor entry (NGI) in heavily polluting industries and non-heavily polluting industries are 0.013 and 0.016, respectively, both significant at the 1% level. The coefficient for non-heavily polluting industries is higher than that for heavily polluting industries. This suggests that, compared to heavily polluting industries, green investor entry can more effectively promote high-quality development among enterprises in non-heavily polluting industries. Under the new development philosophy, heavily polluting industries face stricter environmental regulations. Pressured by institutional constraints, they place greater emphasis on environmental governance, further enhancing their green management capabilities and actively signaling their green

transformation to the market. The relative weakening of environmental risks naturally attracts more green investors to enter these industries.

6.2.3. Analysis of Heterogeneity Based on Corporate Governance Structures Based on Corporate Governance Structure

Analysis based on corporate governance heterogeneity reveals that while separation of ownership and control typically exacerbates agency conflicts, potentially leading management to avoid green transition risks and uncertainties due to short-term performance pressures, results show that the coefficients for green investor entry (NGI) in high- and low-separation firms are 0.014 and 0.020, respectively, both statistically significant at the 1% level. Moreover, the difference between the two groups is not statistically significant. This finding suggests that ownership-control separation does not significantly inhibit green investor entry. This effect may stem from green investors mitigating agency problems through explicit environmental performance requirements and a focus on long-term corporate value. Their involvement strengthens oversight mechanisms, fosters consensus with management on green strategies, and thereby reduces short-termism in principal-agent relationships. This provides support for enterprises to achieve long-term sustainable development.

6.3. Discussion

Interpretation of Findings: Empirical results from this study indicate that the entry of green investors significantly promotes high-quality development in manufacturing enterprises. Further analysis reveals that this entry facilitates high-quality development through synergistic digital–physical integration.

Literature Comparison: Our findings align with those of Jebbor et al. [57], further validating the pivotal role of deep integration between "green capital" and "advanced technology" in corporate sustainability. Compared to traditional investors, green investors primarily distinguish themselves through a greater emphasis on environmental benefits and long-term sustainable value. Traditional investors, however, often prioritize short-term financial returns and typically rely on external regulatory forces to drive corporate green transformation. Consequently, green investors possess inherent advantages in promoting green transformation, upgrading, and innovative development through proactive engagement in corporate strategy and oversight governance.

Practical Significance: Feasibility: This model demonstrates high implementation feasibility under the current policy and market environment. On one hand, the state is vigorously promoting the digital economy and green development, creating a favorable policy climate. On the other hand, the environmental benefits and long-term economic gains driven by green investment-led innovation and transformation often offset the corresponding governance and innovation costs, ensuring economic sustainability.

Future Research: This study is limited to A-share listed manufacturing companies. Expanding the sample to include non-listed manufacturing firms and small-to-medium enterprises, while further categorizing green investor types, would undoubtedly paint a more comprehensive picture of the relationship between green investor entry and corporate high-quality development.

7. Conclusions and Policy Implications

This study examines the high-quality development of manufacturing enterprises in China using a sample of A-share listed manufacturing companies from 2015 to 2023. It measures green investor entry through the number of green investors and establishes an evaluation framework based on the new development philosophy of innovation, coordination, green development, openness, and sharing. The entropy-TOPSIS method is employed to measure the high-quality development level of manufacturing enterprises. Digital–Real

Economy Integration (DREI) is assessed through mutual citation behavior between digital technology and real economy patents within patent citation networks. Empirical analysis examines the impact of green investor entry on manufacturing enterprises' high-quality development and its underlying mechanisms. This research on how green investor entry promotes high-quality development in manufacturing holds significant implications for corporate strategies and government policy formulation.

Research findings reveal: First, the entry of green investors significantly promotes the high-quality development of manufacturing enterprises. This conclusion remains valid after undergoing a series of robustness tests, including benchmark regression analysis, endogeneity tests, and substitution of the dependent variable. From a micro-enterprise perspective, this study scientifically measures the relationship between green investor entry and the high-quality development of manufacturing enterprises. It not only enriches the research on the economic effects of green investor entry in the technological domain but also points the way toward exploring the driving factors for the high-quality development of manufacturing enterprises.

Second, the mechanism test indicates that the digital–real integration (DREI) plays an intermediary role in the process of green investors participating in the high-quality development of manufacturing enterprises. By analyzing the mechanism linking green investor entry to the high-quality development of manufacturing enterprises, this study further enriches the exploration of pathways through which green investor entry impacts the economic performance of manufacturing enterprises.

Third, the heterogeneity analysis reveals that the promotional effect of green investor entry is more pronounced among enterprises located in eastern regions and those operating in non-heavily polluting industries. This study clarifies the boundaries of green investor entry and its promotional effects on manufacturing enterprises by conducting heterogeneity tests across regions, industries, and corporate governance structures.

Fourth, moderation effect tests reveal that green investor entry significantly promotes the high-quality development of manufacturing enterprises under the negative moderation of financing constraints. This finding further delineates the operational boundaries of green investors across different scenarios, providing practical policy implications for government authorities.

This study focuses solely on A-share listed manufacturing companies as its sample. Future research could expand the sample to include non-listed manufacturing firms and small and medium-sized enterprises, while also refining the classification of green investors to explore their impact on the high-quality development of manufacturing enterprises in greater depth.

Based on the findings of this study, the following policy implications can be drawn:

First, as the backbone of socially responsible investment, green investors should fully leverage their positive effects to guide and oversee enterprises in practicing green governance. This will help realize the social benefits and environmental value derived from green governance, accelerate the realization of its economic value, and ultimately achieve sustainable corporate development.

Second, enterprises should fully leverage the enabling role of green investors by actively signaling their commitment to green governance to attract green investors. Granting these investors commensurate governance influence fosters a virtuous cycle, enhances sustainable competitiveness, and attracts greater support from long-term value investors.

Finally, as the core policy formulators, governments should proactively advance the establishment of green finance standards, implement diverse measures such as fiscal and tax incentives, and foster a stable and predictable policy environment. This will guide

capital market funds toward precise allocation in green and low-carbon sectors, thereby powerfully propelling enterprises toward high-quality development.

Author Contributions: Conceptualization, R.Z. and X.J.; methodology, R.Z.; software, R.Z.; validation, R.Z. and X.J.; formal analysis, R.Z.; resources, R.Z.; data curation, R.Z.; writing—original draft preparation, R.Z.; writing—review and editing, X.J.; project administration, X.J.; funding acquisition, X.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Foundation of China (No. 22BJY199).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: All the authors declare no conflicts of interest.

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