The Influence of Smart Supply Chain Policies on Corporate Green Transformation: Empirical Evidence and Implications

Ziqi Zhai[1,2,#], Yanfei Su[1,2,#,*]
[1]*UTS Business School, University of Technology Sydney, Sydney, Australia*
[2]*SILC Business School, Shanghai University, 20 Chengzhong Road, Jiading District, Shanghai, China*
**Corresponding Author*
[#]Ziqi Zhai and Yanfei Su contributed equally to this work

Abstract: As the global movement toward carbon neutrality accelerates and China continues to advance its 'dual-carbon' goals, smart supply chain initiatives have become crucial tools for combining digital innovation with sustainable practices and fostering high-quality corporate growth. Drawing on panel data from Chinese A-share listed companies between 2010 and 2023, this study uses a difference-in-differences (DID) method to assess the impact of smart supply chain models on corporate green transformation. The findings show that these models significantly improve firms' environmental performance, with especially strong effects seen in non-state-owned companies, enterprises in eastern China, firms outside the high-tech sector, pollution-intensive industries, and those in the growth or decline phases of their life cycles. Additionally, the study finds that contextual elements play an important role: stronger environmental regulation boosts the positive effects, while higher industry concentration weakens them. Mediation analysis highlights that green innovation, green investment, and financing constraints are key channels through which smart supply chain upgrades drive sustainability outcomes. These insights help improve the institutional framework for intelligent supply chain systems and provide valuable evidence to support the green transition of businesses.

Keywords: Smart Supply Chain; Corporate Green Transformation; Environmental Regulation Intensity; Industry Concentration; Difference-in-Differences Model

1. Introduction

Corporate green transformation has become a critical pathway to reconciling the tension between environmental constraints and economic growth under the 'dual-carbon' goals. At its core, green transformation aims to boost resource efficiency and ecological benefits through supply chain restructuring and technological innovation. China's national strategy has emphasized 'fostering environmentally sustainable growth and ensuring a balanced relationship between human activities and the natural ecosystem' as a key priority, highlighting the need to align carbon reduction, pollution control, ecological protection, and economic growth while championing an ecological-first, resource-efficient, and low-carbon development model. In 2024, the release of the Opinions on Accelerating the Comprehensive Green Transformation of Economic and Social Development outlined clear top-level guidance for green transformation.

Despite these strategic directions, Chinese enterprises face significant hurdles, including an industrial structure reliant on traditional sectors, high emission reduction costs, and persistent technological bottlenecks, with energy-intensive industries in particular facing a long journey toward decarbonization. Against this backdrop, smart supply chains, driven by the extensive incorporation and utilization of digital technologies, have emerged as a key driver of China's high-quality economic development. Recognizing their importance, the national government has implemented a detailed and forward-looking strategic blueprint to support smart supply chain development, reflecting a strong commitment to sustainable growth. In 2018, the Ministry of Commerce, in collaboration with seven other governmental bodies, rolled out a pilot initiative on supply chain innovation and application. This program was designed to assist enterprises in identifying new engines of economic growth, revitalizing the manufacturing sector, advancing supply-side structural reforms, and consolidating the foundation for a modernized economic framework.

This initiative promotes the digital transformation of supply chains, providing strong backing for corporate green transformation. The integration of advanced technologies—such as big data analytics, the Internet of Things (IoT), and blockchain—throughout various stages of the supply chain, including procurement, production, logistics, and sales, enables firms to enhance process transparency. This digital transformation allows for the precise identification of energy-intensive and high-emission nodes, facilitates inventory and transportation optimization, minimizes resource inefficiencies, and ultimately contributes to source-level carbon reduction.

Building on this foundation, this study takes smart supply chain policies as its focus to systematically explore the mechanisms and boundaries through which they drive corporate green transformation. It addresses several key research questions: How do smart supply chain policies reshape firms' low-carbon production capabilities through digitalization? Are policy effects different across various types of firms and industries? Can green innovation and investment serve as twin pillars for effective policy implementation? How do environmental regulation intensity and industry concentration moderate these effects through regulatory and competitive pressures? To answer these questions, the paper applies a difference-in-differences (DID) model to assess the impact of smart supply chain policies on corporate green transformation, examining firms across various dimensions such as ownership type, location, sector classification, pollution intensity, and life cycle stage. It also investigates environmental regulation intensity and industry concentration as moderating factors and investigates how green innovation, green investment, and financing constraints function as mediating mechanisms. Furthermore, the study analyzes the different pathways through which smart supply chain policies influence green transformation, providing a broader base of empirical evidence.

2. Literature Review

Corporate green transformation generally refers to the shift of firms from traditional development models characterized by high energy consumption and emissions to more sustainable and environmentally friendly production and operational practices. This transformation involves systemic changes at both strategic and operational levels, as companies aim to reduce their environmental footprint through technological innovation and resource optimization, seeking a balanced coordination between economic growth and environmental protection. Existing research identifies four main approaches to measuring corporate green transformation: carbon emissions and energy efficiency indicators, ESG performance and ratings, green technological innovation metrics, and textual analysis. This study adopts a textual analysis approach to evaluate corporate green transformation.

Furthermore, previous studies have systematically explored the factors influencing corporate green transformation across four dimensions: managerial, resource and capability, institutional and policy, and supply chain and stakeholder perspectives. From a managerial viewpoint [1] argue that executives' environmental awareness and strategic focus significantly enhance firms’ green innovation outputs, particularly when supported by policy incentives and green investment environments [2] emphasize that managers’ green visions foster internal green organizational cultures, integrating environmental considerations across strategic planning, resource distribution, and performance evaluations [3] highlight that environmental leadership not only affects green technology adoption but also encourages employee participation in green initiatives, serving as a soft driver for corporate green transformation.

From the resource and capability perspective [4] find that technological innovation and dynamic capabilities are critical in building green competitive advantages, enabling firms to respond flexibly to external environmental changes [5] propose that a synergy between digitalization and green R&D investment results in clearer and more efficient green transition paths [6], based on the resource-based view, argue that green human capital, organizational slack, and internal governance capabilities jointly drive corporate green transformation, especially within the tech and manufacturing sectors.

From the institutional and policy angle [7] show that environmental disclosure and ESG reporting requirements enhance corporate environmental transparency, reinforcing external monitoring [8] suggest that China's 'dual-carbon' strategy, through tools like green taxes, green credit, and carbon trading, has established a structured green policy framework that directly influences firms’ green investment and innovation behaviors [9] further point out that mandatory regulations and fiscal incentives create a 'pressure–response' mechanism, encouraging firms to shift from passive compliance to proactive green innovation.

From the supply chain and stakeholder perspective, [10] argue that green information sharing, green standards, and performance coordination among supply chain partners drive green transformation, especially with the rise of digital supply chain platforms. [11] using stakeholder theory, find that investor, consumer, and NGO pressures compel firms to embed environmental responsibility into long-term strategies. [12] emphasize that green supply chain ecosystems promote green knowledge sharing and collaborative innovation, boosting the sustainability of firms' value chains.

Existing studies on the economic implications of smart supply chains have predominantly approached the topic from four main angles: regional coordination and resource reallocation, industry ecosystem restructuring and value chain upgrading, policy instrument design and technology diffusion, and corporate green innovation and carbon reduction. For regional coordination and resource reallocation, [13] studying the Yangtze River Economic Belt, demonstrate that smart supply chains reduce intercity logistics costs by 18%–25% and stimulate inland growth of high-value industries like the Wuhan Optics Valley electronics hub. [14] developed a blockchain-based data-sharing platform for the automotive supply chain, achieving over 90 transactions per second and reducing decision-making times to 26 milliseconds.

From an industry ecosystem and value chain upgrade perspective, [15] suggest that carbon account systems based on supply chain big data drive green compliance, resulting in a 22% reduction in carbon intensity in a chemical industrial park. [16] designed a blockchain-based access control system that enables SMEs to join R&D activities, increasing value-added rates by 12%. [17] note that hybrid supply chains improve reverse logistics recovery rates by 20%, emphasizing the need for balanced economic and environmental policies.

From a policy and technology diffusion angle, [18] proposes the concept of a 'blockchain holographic ecosystem' and stresses the distinction between tech-driven policies and institutionally constrained policies for synergistic outcomes. [19] caution that centralized supply chain finance platforms may marginalize SMEs, advocating for decentralized technologies like AntChain. [20] analyzing the EU's Deforestation Regulation, argue that 'smart hybrid regulation' must balance public and corporate interests to avoid marginalizing countries in the Global South.

From the perspective of corporate green innovation and emissions reduction, [21] provide evidence that smart supply chains boost green patents by 32%, while AIoT monitoring reduces steel industry emissions by 12%, and blockchain traceability improves recycled plastics use by 40%. [22] show that differential pricing and repurchase policies within electricity supply chains promote distributed energy adoption, increasing centralized supply chain profits by 15%. [23] warn that SMEs, facing high tech investment costs, may encounter a 'green innovation paradox,' calling for tiered subsidy policies.

Despite notable progress, important gaps remain in the literature. The relationship between smart supply chain policies and corporate green transformation is underexplored, and while some studies address regional and sectoral heterogeneity, firm-level life cycle differences and mediation mechanisms remain inadequately studied. Moreover, empirical analysis on how mediators like green innovation, green investment, and financing constraints influence policy outcomes is lacking. As a result, research remains weak in offering multi-dimensional, multi-pathway, and multi-level analyses. This paper addresses these gaps by systematically examining the effect of smart supply chain policies on corporate green transformation using a difference-in-differences (DID) model, analyzing firm heterogeneity, moderating factors like environmental regulation and industry concentration, and mediating mechanisms such as green innovation and investment, thereby clarifying policy transmission pathways and offering theoretical and empirical support for advancing green corporate practices.

3. Theoretical Analysis and Research Hypotheses

Smart supply chain policies improve resource utilization efficiency by optimizing supply chain management and scheduling, thereby reducing energy use and waste emissions during production. By integrating digital technologies and intelligent systems, firms can better forecast demand, manage inventories, and design transportation routes, effectively avoiding overproduction and unnecessary resource waste [24]. These efforts not only boost production efficiency and reduce raw material waste but also significantly lower carbon emissions, supporting a more sustainable production model [25]. In addition, intelligent data analytics and real-time monitoring enable firms to track energy consumption and emissions throughout various stages of the supply chain, helping them further optimize processes and promote eco-friendly operations as part of their green transformation efforts [26].

Simultaneously, smart supply chain policies encourage the adoption of green technologies and sustainability standards across supply chains, helping firms select more eco-friendly materials and production methods. Such initiatives foster partnerships with environmentally responsible suppliers, helping to uphold sustainability standards throughout the supply chain and driving more profound advancements in green innovation. [27]. Smart green supply chain management also enables firms to identify and adopt sustainable products and technologies, minimizing resource consumption and environmental pollution during production [28]. Technologies like smart packaging and green logistics systems further reduce material usage and transportation-related emissions, supporting green practices across the entire product lifecycle [29]. These initiatives not only strengthen firms' green production capabilities but also enhance their market competitiveness, adaptability, and reputation in an increasingly stringent global regulatory environment, ultimately facilitating successful green transformations [30].

Building on these insights, this study proposes the first hypothesis:

H1: Corporate green transformation can be significantly advanced through the adoption of intelligent supply chain policies.

Through advanced digital technologies and data analytics, smart supply chain policies also enhance firms' precision in resource management and supply chain operational efficiency [31]. This allows companies to more effectively identify and adopt green innovations, reduce energy consumption and waste, and improve the quality of green innovations [32]. Real-time environmental monitoring further encourages green design practices and the selection of sustainable materials, improving the eco-friendly attributes of innovations [33]. Smart collaboration and information-sharing with suppliers help jointly develop sustainable solutions, enhancing green innovation effectiveness and market competitiveness [34].

Improvements in green innovation quality directly drive the development of eco-friendly technologies and products, helping firms achieve significant progress in environmental sustainability [35]. Such innovations reduce energy use and waste, improve product environmental performance, and boost market competitiveness, thereby accelerating green transformation [36]. High-quality green innovation strengthens operational efficiency and resource use, providing a robust foundation for green transformation [37]. Furthermore, it helps firms meet tightening environmental regulations and increasing consumer demand for green products, enhancing corporate sustainability [38].

Thus, the second hypothesis is proposed:

H2: Smart supply chain policies can enhance corporate green transformation by improving the quality of green innovation.

By increasing supply chain transparency and operational efficiency, smart supply chain policies enable firms to better identify and manage green investment opportunities [39]. These policies promote the implementation of environmentally sustainable technologies and materials, helping companies optimize supply chain resource use and reduce environmental burdens [40]. Digital tools and analytics support real-time tracking of environmental metrics, promoting more effective green investment decision-making [41]. Strengthened collaboration with green suppliers further drives environmental initiatives [42].

Corporate green investments, through the adoption of sustainable technologies and processes, are crucial drivers of green transformation [43]. Facility upgrades and

production process improvements reduce resource waste and carbon emissions while enhancing efficiency and environmental performance [44]. Green investments also facilitate the creation of environmentally sustainable goods and service offerings, strengthening market competitiveness [45]. Moreover, these investments help firms comply with regulations, reduce environmental risks, and support long-term green goals [46].
Therefore, the third hypothesis is proposed:
H3: Smart supply chain policies can enhance corporate green transformation by increasing the level of green investment.
Furthermore, smart supply chain policies boost financial health and operational efficiency by improving supply chain management and transparency, thereby reducing financing risks [47]. By streamlining demand forecasting, inventory control, and logistics, companies lower inventory backlogs and improve cash flow, making themselves more appealing to financiers [48]. Digital supply chains also offer precise performance data and risk analyses, building trust with financial institutions and lowering financing costs [49]. Optimized resource use further enhances profitability, alleviating financing constraints [50].
Lowering corporate debt eases financial pressure, freeing up resources for green transformation initiatives rather than debt servicing [51]. With reduced debt burdens, firms can invest more in green R&D, environmental infrastructure, and green product development [52]. Financial stability resulting from lower debt strengthens firms' confidence in pursuing long-term green strategies [53]. Additionally, a reduced debt ratio enhances corporate reputation and investment attractiveness, facilitating the attraction of further green investments [54].
Thus, the fourth hypothesis is proposed:
H4: Smart supply chain policies can enhance corporate green transformation by reducing firms' financing constraints.

4. Empirical Study

4.1 Research Design

4.1.1 Model construction
This paper uses the Smart Supply Chain Policy as a quasi-experimental framework and applies the Difference-in-Differences (DID) technique to assess the policy’s effect on corporate green transformation. The DID method facilitates the examination of whether notable variations exist in the green transformation outcomes between organizations in the treatment group and those in the control group, focus on and following the execution of the Smart Supply Chain Policy. Thus, the model is structured as follows

$$\mathrm{GTR}_{it} = \alpha_0 + \alpha_1 \mathrm{inter}_{it} + \alpha_4 \mathrm{control}_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (1)$$

In the model, i denotes the individual firm, t denotes the year, the dependent variable is green transformation (GTR), and the core explanatory variable, Smart Supply Chain Policy (inter), is defined as treat*post. The control variables include firm size (SIZE), financial leverage (LEV), ownership concentration (TOP), cash flow (CASH), firm age (AGE), economic development level (GDP), return on assets (ROA), industry structure (INDSTR), and CEO duality (DUAL). treat_i indicates whether the enterprise belongs to the treatment group (assigned 1) or the control group (assigned 0), and post_t is the time dummy variable. δ_i and ρ_t represent firm and time fixed effects respectively, whilst ε_{it} is the random error term.
To explore the transmission mechanisms or possible mediating variables through which the Smart Supply Chain Policy affects corporate green transformation, this section adopts a mediation analysis approach. It selects green innovation quantity (GINN), green investment (GINV), and financing constraints (FINC) as mediators (M), constructing the following model:

$$\mathrm{GTR}_{it} = \alpha_0 + \alpha_1 \mathrm{inter}_{it} + \alpha_4 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (2)$$

$$\mathrm{M}_{it} = \alpha_0 + \alpha_1 \mathrm{inter}_{it} + \alpha_4 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (3)$$

This system of equations aims to test whether there is a transmission path among the core explanatory variable, the mediator, and the dependent variable—i.e., whether the mediators serve as critical channels of influence. Specifically, the first equation examines the effect of the core explanatory variable and other controls on green transformation, verifying whether the core explanatory variable impacts the dependent variable. The second set of equations examines whether the core explanatory variable significantly influences the mediators, answering whether the mediators are affected. Finally, following the two-step method proposed by [55] theoretical analysis is used to clarify the relationship between the mediators and the dependent variable.
When a moderating variable exists, the

coefficient estimates in the regression model must consider not only the direct impact of the independent variable on the dependent variable but also the moderating effect. Therefore, this paper constructs the following moderation model:

$$\mathrm{GTR}_{\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{inter}_{\mathrm{it}} + \alpha_2 \mathrm{inter}_{it} * W_{it} + \alpha_3 \mathrm{W}_{it} + \alpha_4 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (4)$$

Where W represents the moderating variables, namely industry concentration (HHI) and environmental regulation intensity (HJGZ).

4.1.2 Variable definitions and data sources

This study selects A-share listed firms in China between 2010 and 2023 as the sample, comprising 12,030 firm-year observations. Three data-cleaning steps were undertaken: (1) exclusion of financial companies; (2) removal of companies identified as ST and *ST; (3) deletion of companies with a high volume of missing data. To minimize the effect of outliers, continuous variables were winsorized at the 1st and 99th percentiles. The data used in this study are retrieved from the CSMAR database, and all processing and regression analyses are conducted using Stata 16.0.

To improve the clarity of the empirical model and ensure transparency in variable measurement, Table 1 provides comprehensive definitions and explanations of all the variables utilized in this research

Table 1. Variable Explanation

	variable	Variable Description	Variable Explanation
Dependent Variable	GTR	Corporate Green Transformation	Frequency-based index of corporate green transition
Core Independent	inter	Interaction Term	Smart Supply Chain Policy dummy (treat*post)
Control Variables	SIZE	Firm Size	Natural logarithm of total assets
	LEV	Financial leverage	Asset-liability ratio
	CASH	Cash Flow Level	Operating cash flow
	AGE	Firm Age	Number of years since firm establishment
	ROA	Return on Assets	Net income divided by average total assets
	TOP	Ownership Concentration	Shareholding ratio of the largest shareholders
	GDP	Regional Economic Development Level	Natural logarithm of regional GDP
	INDSTR	Industrial Structure	Ratio of tertiary to secondary industry value added
	DUAL	CEO Duality	Dummy variable indicating if CEO also serves as Board Chairperson
Mediating Variables	GINN	Number of Green Innovations	Number of corporate green investment
	GINV	Green Investment	Scale of corporate green investment
	FINC	Financing Constraints	Whited-Wu (WW) Index measuring financing constraints
Moderating Variables	HJGZ	Environmental Regulation Intensity	Regional environmental regulation attention score
	HHI	Industry Concentration	Herfindahl-Hirschman Index (HHI) for measuring industry concentration

Descriptive statistics were first conducted to display the basic characteristics of the selected data, with the results presented in Table 2.

4.2 Empirical Results Analysis

4.2.1 Parallel trend test

An essential condition for using the Difference-in-Differences (DID) method is that, before the implementation of the Smart Supply Chain Policy, there must be no substantial time-dependent differences in green transformation trends between the treatment and control groups, and both groups should exhibit a common trend. Differences between groups should only emerge after the policy intervention. To validate the effectiveness of the research model, this paper conducts a parallel trend test, selecting data from five years before to four years after the policy implementation. As depicted in Figure 1, the coefficients of the interaction terms before the policy implementation do not show significant deviation from zero (with the 95% confidence intervals containing zero), suggesting that there were no notable variations between the treatment and control groups before the policy was enacted. In the first year following the introduction of the Smart Supply Chain Policy, corporate green transformation exhibited a significant improvement, suggesting that the parallel trend assumption is satisfied.

Table 2. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
CKFZD	12030	10.8500	1.3738	0.0000	11.1229	13.8856
inter	12030	0.0209	0.1432	0.0000	0.0000	1.0000
Flex2	12030	0.1529	0.1443	0.0000	0.1197	0.6026
SZH	12030	0.0497	0.0639	0.0000	0.0301	0.5189
HJGZ	12030	3.8214	0.3842	0.6931	3.8501	4.9053
SIZE	12030	22.0372	1.1567	19.5714	21.8989	26.2102
TOP	12030	0.3344	0.1399	0.0838	0.3153	0.7418
LEV	12030	0.3864	0.1945	0.0514	0.3754	0.9747
ROA	12030	0.0468	0.0577	-0.3271	0.0449	0.2074
AGE	12030	2.1701	0.7541	0.6931	2.3026	3.4012
CASH	12030	0.2112	0.1443	0.0137	0.1710	0.7315
GDP	12030	10.6367	0.7650	8.1618	10.7443	11.8180
INDSTR	12030	2.4440	0.1122	2.2127	2.4385	2.8349
DUAL	12030	0.3011	0.4587	0.0000	0.0000	1.0000

The horizontal axis of Figure 1 represents the time window spanning five years before and four years after the implementation of the Smart Supply Chain Policy, with year 0 indicating the policy implementation year.

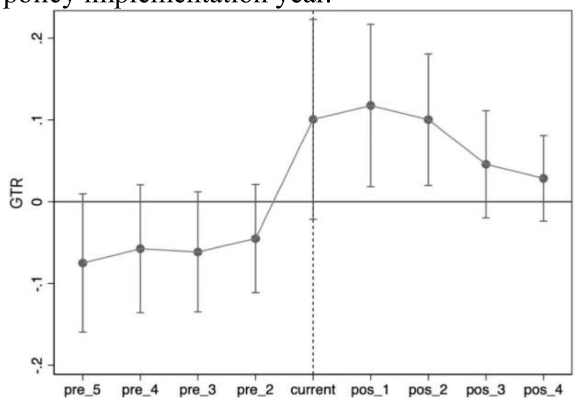

Figure 1. Parallel Trend Test

4.2.2 Baseline regression

Based on panel data, this paper employs the Difference-in-Differences (DID) model for empirical analysis. During the regression process, the Smart Supply Chain Policy is first introduced as the base variable, subsequently, additional control variables were included to strengthen the robustness of the results. According to the regression results presented in Table 3, column (1) regresses only on the Smart Supply Chain Policy variable (inter), revealing that inter passes the 1% significance level with a coefficient of 0.4344. This indicates that the implementation of the Smart Supply Chain Policy promotes corporate green transformation. Table 3 presents the baseline regression findings that analyze the effect of the Smart Supply Chain Policy on corporate green transformation using the DID model. After incorporating the control variables, as demonstrated in column (2) of Table 3, the regression coefficient for the Smart Supply Chain Policy (inter) is 0.4955, which remains significantly positive at the 1% significance level. Although the coefficient slightly changes with the inclusion of control variables, its positive correlation with corporate green transformation remains robust, thus validating Hypothesis 1. Regarding the control variables, firm size (SIZE), cash flow (CASH), and return on assets (ROA) all exhibit significant positive effects on corporate green transformation.

Table 3. Baseline Regression Results

	(1)	(2)
	CKFZD	CKFZD
inter	0.4344***	0.4955***
	(3.881)	(4.466)
SIZE		0.1199***
		(5.720)
TOP		-0.1909
		(-1.421)
LEV		-0.0072
		(-0.084)
ROA		2.2644***
		(12.346)
AGE		0.0417
		(1.055)
CASH		0.3263***
		(3.817)

GDP		-0.0266
		(-0.402)
INDSTR		-0.2985
		(-1.150)
DUAL		0.0169
		(0.659)
_cons	10.3544***	8.5876***
	(228.928)	(9.505)
FE	Yes	Yes
Year	Yes	Yes
N	12030	12030
R^2	0.7164	0.7227

Note: The values in parentheses represent the T-values. '***','**' and '*'indicate that the coefficient is significant at the 1%, 5%, and 10% levels, respectively.

4.3 Robustness Tests

4.3.1 Placebo test

In this study, the placebo test is conducted to rule out the influence of factors other than the Smart Supply Chain Policy on corporate green transformation and to prevent firms in the treatment group from changing their behavior in anticipation of the policy, which could bias the estimation results. To ensure the robustness of the Difference-in-Differences (DID) results, this paper randomly generates 'pseudo-policy dummy variables' and performs 500 regressions, obtaining 500 estimated ficients along with their standard errors and p-values. These are then plotted to observe the distribution of the coefficients, thereby testing the significance of the Smart Supply Chain Policy's effect on corporate green transformation.

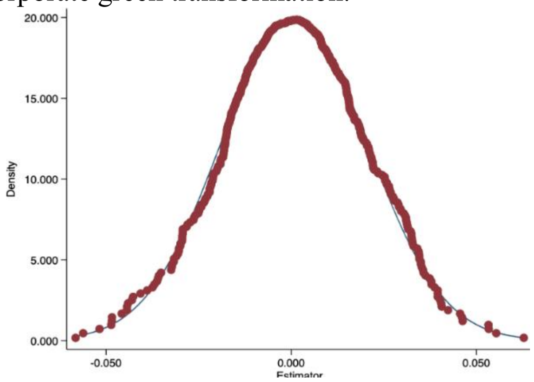

Figure 2. Placebo Test

Figure 2 illustrates the distribution of estimated coefficients from 500 placebo regressions, with the red vertical line representing the actual policy effect estimated in the baseline model.

As shown in Figure 2, most of the estimated coefficients from the placebo regressions are concentrated around zero, and most of their p-values exceed 0.1, indicating that the results are not statistically significant at the 10% level. This suggests that the presented policy effect is unlikely to be due to chance or the influence of other policies or uncontrollable factors, thus confirming the robustness of the model.

4.3.2 PSM-DID

Table 4 presents the regression results after applying the Propensity Score Matching (PSM) method, further validating the robustness of the baseline findings.

Given that the selection into the Smart Supply Chain Policy is not random, there may be initial differences between the treatment and control groups, potentially leading to endogeneity problems. To address the issue of selection bias, this paper adopts the Propensity Score Matching Difference-in-Differences (PSM-DID) method. Following the approach of [56], cities with characteristics most similar to those in the treatment group are selected as the control group at the city level, ensuring the comparability of the two groups in terms of control variables. After matching, the standard deviations of control variables are significantly reduced, and the initial conditions of the treatment and control groups before and after the policy are largely consistent, indicating a good matching quality. The empirical results, both before and after matching, are consistent with expectations, demonstrating that the impact of the Smart Supply Chain Policy on corporate green transformation is robust and that the policy considerably facilities green transformation.

Table 4. Nearest Neighbor Matching 1:3 PSM Regression Results

	(1)	(2)
	GTR	GTR
inter	1.1569***	0.5515***
	(42.576)	(4.535)
SIZE		0.1421***
		(11.731)
TOP		0.1335*
		(1.682)
LEV		-0.0667
		(-1.377)
ROA		0.0984
		(1.061)
AGE		-0.0462
		(-1.605)
CASH		-0.0145
		(-1.115)
GDP		0.2754***

		(2.971)
INDSTR		1.2321***
		(4.860)
DUAL		0.0158
		(1.042)
_cons	1.3221***	-7.3237***
	(61.058)	(-6.037)
FE	Yes	Yes
Year	Yes	Yes
N	17397	17397
R^2	0.7418	0.7453

4.3.3 Other robustness tests

Table 5 displays additional robustness checks using alternative model specifications, including OLS regression, exclusion of pandemic years, and inclusion of new control variables.

(1) Replacing the Regression Method with OLS

To further validate the appropriateness of the model specification and the reliability of the estimation results, the Ordinary Least Squares (OLS) method is employed for regression analysis. According to the results in column (1) of Table 5, the significance of the core explanatory variable remains unaffected after replacing the regression method, and it continues to exhibit statistical significance.

(2) Eliminating the Time Effect

Considering that different data periods might yield different results due to varying calculation methods, this paper further tests the robustness of the empirical results by excluding data from the pandemic period. As shown in column (2) of Table 5, the robustness check confirms that the core explanatory variable remains significantly correlated with corporate green transformation without any notable changes in direction or significance, demonstrating the stability of the regression results.

(3) Adding New Control Variables

By introducing additional control variables such as MBOARD and GROWTH to eliminate potential confounding factors, the results (shown in column (3) of Table 5 indicate that the positive impact of the Smart Supply Chain Policy on corporate green transformation remains robust.

Table 5. Robustness Test Regression Results

	(1)	(2)	(3)
	OLS	Eliminate the Pandemic	New Control Variables
inter	0.6069***	0.6705***	0.6248***
	(53.925)	(7.129)	(6.979)
SIZE	0.1757***	0.1553***	0.1531***
	(39.041)	(17.909)	(18.415)
TOP	-0.0880***	0.1569***	0.1453***
	(-2.751)	(2.711)	(2.643)
LEV	0.0335	-0.0319	-0.0295
	(1.140)	(-0.871)	(-0.851)
ROA	-0.1209	0.1297*	0.0920
	(-1.582)	(1.938)	(1.475)
AGE	-0.1117***	-0.0670***	-0.0598***
	(-13.930)	(-3.199)	(-2.975)
CASH	0.0154	-0.0108	-0.0069
	(1.414)	(-0.999)	(-0.690)
GDP	0.0365***	0.2325***	0.2629***
	(5.256)	(3.189)	(3.804)
INDSTR	-0.3657***	0.7871***	0.8162***
	(-10.787)	(4.039)	(4.372)
DUAL	-0.0224**	0.0064	0.0051
	(-2.116)	(0.549)	(0.468)
MBOARD			-0.0375
			(-1.205)
GROWTH			0.0049
			(0.792)
_cons	-1.5428***	-6.1437***	-6.4009***
	(-11.507)	(-6.481)	(-7.086)

FE	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	28935	26200	28935
R^2	0.1953	0.7150	0.7160

Note: The values in parentheses represent the T-values. '***','**' and '*'indicate that the coefficient is significant at the 1%, 5%, and 10% levels, respectively.

4.4 Heterogeneity Analysis by Subsamples

4.4.1 Heterogeneity by ownership nature

Table 6 investigates whether the policy effects vary by ownership type, comparing state-owned and non-state-owned enterprises.

Column (1) of Table 6 shows that for state-owned enterprises, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.3561 and significant at the 1% level. This depicts that the Smart Supply Chain Policy has a significant positive effect on the green transformation (GTR) of state-owned enterprises. State-owned enterprises may be better positioned to leverage the resources and policy support provided by the Smart Supply Chain Policy, thereby achieving better outcomes in promoting green transformation.

Column (2) of Table 6 shows that for non-state-owned enterprises, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.9210 and also significant at the 1% level. This suggests that the Smart Supply Chain Policy similarly promotes the green transformation (GTR) of non-state-owned enterprises, with an even stronger effect compared to state-owned firms. Non-state-owned firms may achieve more significant progress in green transformation with the assistance of the Smart Supply Chain Policy.

Table 6. Heterogeneity Analysis - State-Owned vs Non-State-Owned

	(1)	(2)
	State-Owned	Non-State-Owned
inter	0.3561***	0.9210***
	(2.748)	(7.174)
SIZE	0.1731***	0.1410***
	(12.151)	(14.011)
TOP	-0.0792	0.3328***
	(-0.933)	(4.572)
LEV	-0.0404	-0.0116
	(-0.693)	(-0.269)
ROA	0.0595	0.1168*
	(0.439)	(1.757)
AGE	-0.0710*	-0.0342
	(-1.850)	(-1.343)
CASH	-0.0153	-0.0040
	(-0.780)	(-0.352)
GDP	0.4226***	0.0724
	(4.308)	(0.724)
INDSTR	0.9418***	0.7042***
	(3.494)	(2.659)
DUAL	-0.0033	0.0116
	(-0.157)	(0.922)
_cons	-8.5727***	-4.2527***
	(-6.591)	(-3.320)
FE	Yes	Yes
Year	Yes	Yes
N	11242	17693
R^2	0.7049	0.7259

Note: The values in parentheses represent the T-values. '***','**' and '*'indicate that the coefficient is significant at the 1%, 5%, and 10% levels, respectively.

4.4.2 Heterogeneity by region

Table 7 examines regional heterogeneity in the policy's effect by comparing firms in eastern versus central and western China.

Column (1) of Table 7 shows that for firms in eastern China, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.8887 and significant at the 1% level. This indicates that the policy has a significant positive impact on green transformation (GTR) in the eastern region. Enterprises in the eastern area may more effectively use the resources and support offered by the Smart Supply Chain Policy, thereby achieving notable results in advancing green transformation.

Column (2) of Table 7 shows that for firms in central and western China, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.6604 and also significant at the 1% level. This implies that the policy similarly promotes green transformation (GTR) in the central and western areas, although the effect is slightly weaker compared to the eastern area. Enterprises in the central and western areas have also made positive progress in green transformation with the support of the Smart Supply Chain Policy.

Table 7. Heterogeneity Analysis

	(1)	(2)
	Eastern	Central and

		Western Regions
inter	0.8887***	0.6604***
	(6.249)	(4.916)
SIZE	0.1573***	0.1433***
	(16.029)	(9.292)
TOP	0.1483**	0.1233
	(2.237)	(1.247)
LEV	0.0535	-0.1930***
	(1.279)	(-3.121)
ROA	0.1115	0.0321
	(1.594)	(0.258)
AGE	-0.0598**	-0.0244
	(-2.569)	(-0.599)
CASH	-0.0120	0.0040
	(-1.079)	(0.174)
GDP	0.0518	0.2678***
	(0.459)	(2.794)
INDSTR	0.4080	0.4343*
	(1.330)	(1.674)
DUAL	0.0135	-0.0126
	(1.076)	(-0.567)
_cons	-3.5711**	-5.1317***
	(-2.279)	(-4.349)
FE	Yes	Yes
Year	Yes	Yes
N	21046	7889
R^2	0.7168	0.7175

Note: The values in parentheses represent the T-values. '***','**' and '*'indicate that the coefficient is significant at the 1%, 5%, and 10% levels, respectively.

4.4.3 Heterogeneity by high-tech industry

Table 8 investigates whether the policy's impact varies between high-tech and non-high-tech industries.

In column (1) of Table 8, it is shown that for high-tech industries, the regression coefficient for the Smart Supply Chain Policy (inter) is 0.5355, which is significant at the 1% level. This demonstrates that the Smart Supply Chain Policy has a substantial positive effect on the green transformation (GTR) of high-tech industries. Enterprises in high-tech sectors may more efficiently leverage the resources and policy support provided by the Smart Supply Chain Policy to advance green transformation.

Column (2) of Table 8 shows that for non-high-tech industries, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.7429 and significant at the 1% level. This suggests that the Smart Supply Chain Policy also significantly promotes green transformation (GTR) in non-high-tech industries, with an even stronger effect compared to high-tech industries. Non-high-tech enterprises may have achieved more significant improvements in green transformation under the influence of the policy, highlighting the differentiated impact across industries.

Table 8. Technology Level Heterogeneity

	(1)	(2)
	High-Tech	Non-High-Tech
inter	0.5355***	0.7429***
	(4.690)	(5.141)
SIZE	0.1456***	0.1627***
	(14.118)	(11.797)
TOP	0.1704**	0.0737
	(2.483)	(0.808)
LEV	0.0155	-0.0791
	(0.361)	(-1.356)
ROA	0.0255	0.2722**
	(0.357)	(2.418)
AGE	-0.0297	-0.0841**
	(-1.186)	(-2.423)
CASH	0.0019	-0.0227
	(0.155)	(-1.352)
GDP	0.2900***	0.2118*
	(3.358)	(1.854)
INDSTR	1.0636***	0.5184*
	(4.451)	(1.739)
DUAL	0.0099	-0.0005
	(0.755)	(-0.027)
_cons	-7.2554***	-5.3775***
	(-6.341)	(-3.683)
FE	Yes	Yes
Year	Yes	Yes
N	17419	11516
R^2	0.7027	0.7314

4.4.4 Heterogeneity by pollution level

Table 9 analyzes the policy's differential effects on pollution-intensive versus non-pollution industries.

In column (1) of Table 9, it is illustrated that for pollution-intensive industries, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.7104, which is significant at the 1% level. This suggests that the policy has a significant positive effect on the green transformation (GTR) of pollution-intensive industries. Through the implementation of the Smart Supply Chain Policy, these firms may have more effectively adopted green technologies and improved environmental management, achieving remarkable progress in green transformation.

Table 9. Pollution Level Heterogeneity

	(1)	(2)
	Pollution	Non-Pollution
inter	0.7104***	0.5946***
	(4.071)	(5.693)
SIZE	0.1522***	0.1566***
	(8.811)	(16.507)
TOP	-0.2236**	0.2984***
	(-2.185)	(4.566)
LEV	-0.0651	-0.0044
	(-0.906)	(-0.111)
ROA	0.1827	0.0462
	(1.465)	(0.657)
AGE	-0.0378	-0.0654***
	(-0.893)	(-2.863)
CASH	0.0041	-0.0109
	(0.181)	(-0.976)
GDP	0.2084	0.2799***
	(1.604)	(3.416)
INDSTR	0.3137	0.9742***
	(0.920)	(4.336)
DUAL	-0.0375	0.0178
	(-1.614)	(1.435)
_cons	-4.2286**	-7.2784***
	(-2.453)	(-6.869)
FE	Yes	Yes
Year	Yes	Yes
N	6783	22152
R2	0.6966	0.7031

Column (2) of Table 9 shows that for non-polluting industries, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.5946 and significant at the 1% level. This suggests that the policy also significantly promotes green transformation (GTR) in non-polluting industries, although the coefficient is slightly lower than that for polluting industries. Enterprises in non-polluting sectors have also improved their green transformation with the help of the Smart Supply Chain Policy, demonstrating the policy's broad effectiveness across different types of industries.

4.4.5 Heterogeneity by corporate life cycle

Table 10 assesses how the policy's impact varies across companies in various life cycle phases: expansion, maturity, and downturn.

Column (1) of Table 10 shows that for growth-stage firms, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.6805 and significant at the 1% level. This indicates that the Smart Supply Chain Policy significantly promotes the green transformation (LSZX) of growth-stage enterprises. These firms may be more proactive in utilizing the resources and policy support provided by the Smart Supply Chain Policy to achieve notable results in green transformation.

Table 10. Lifecycle Heterogeneity

	(1)	(2)	(3)
	Growth	Mature	Decline
inter	0.6805***	0.3417**	0.7544***
	(3.017)	(1.984)	(4.979)
SIZE	0.1703***	0.1360***	0.1435***
	(10.384)	(8.215)	(8.845)
TOP	0.1004	0.1517	0.2707**
	(0.880)	(1.468)	(2.539)
LEV	0.0604	-0.0569	-0.0873
	(0.840)	(-0.802)	(-1.398)
ROA	-0.1602	0.2485**	0.0402
	(-1.351)	(2.052)	(0.302)
AGE	-0.1893***	-0.0699*	0.0009
	(-4.450)	(-1.732)	(0.020)
CASH	0.0218	-0.0193	-0.0141
	(0.949)	(-0.970)	(-0.820)
GDP	0.3555**	0.5047***	0.1679
	(2.040)	(3.841)	(1.424)
INDSTR	1.3979***	0.8505**	0.2967
	(3.316)	(2.427)	(0.890)
DUAL	0.0262	-0.0180	0.0228
	(1.168)	(-0.880)	(1.122)
_cons	-9.1139***	-8.5143***	-4.2590***
	(-4.144)	(-4.952)	(-2.741)
FE	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	8689	10224	10022
R^2	0.7946	0.7813	0.7567

Column (2) of Table 10 shows that for mature-stage firms, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.3417 and significant at the 5% level. This suggests that while the Smart Supply Chain Policy also promotes the green transformation (GTR) of mature firms, the effect is somewhat weaker compared to growth-stage firms. Mature firms may be more conservative in leveraging the policy support but still experience improvements in green transformation.

Column (3) of Table 10 shows that for declining-stage firms, the regression coefficient of the Smart Supply Chain Policy (inter) is 0.7544 and significant at the 1% level. This suggests that the Smart Supply Chain Policy has a highly significant positive effect on the green transformation (GTR) of declining-stage firms, with an impact even stronger than that observed for growth-stage firms. Declining firms may have found new growth drivers and development paths through the Smart Supply Chain Policy, resulting in substantial progress in green transformation.

4.5 Mechanism Analysis

4.5.1 Mediation effect

(1) Green Innovation Quantity (GINN)

Table 11 tests the mediating effect of green innovation quantity in the relationship between the Smart Supply Chain Policy and corporate green transformation.

The regression results using green innovation quantity as the transmission mechanism are shown in the corresponding table. Following the mediation effect testing procedure, the results in column (1) of Table 11 are consistent with the baseline regression and will not be repeated here. In column (2) of Table 11, the estimated coefficient of the Smart Supply Chain Policy on green innovation quantity is 0.4367 and is significant at the 1% level.

The mediation test confirms that green innovation quantity serves as a significant mediator. An increase in green innovation quantity promotes the enhancement of corporate green transformation. Improvements in green innovation quality help firms develop more environmentally friendly and efficient production technologies, reducing resource waste and environmental pollution, thereby facilitating smooth green transformation. High-quality green innovation also drives the production of sustainable products and services, allowing firms to address the market demand for eco-friendly and low-carbon products, thereby improving their market competitiveness. Moreover, green innovation improves operational efficiency by saving energy, reducing emissions, and optimizing resource utilization, thereby lowering costs and strengthening firms' sustainable development capacity [57]. With continuous advancement and application of green technologies, firms can solidify their green transformation and gain competitive advantages in a dynamic market environment [58].

Table 11. Mediation Effect

	(1)	(2)
	GTR	GINN
inter	0.6283***	0.4367***
	(7.023)	(3.985)
SIZE	0.1522***	0.3129***
	(18.424)	(30.922)
TOP	0.1468***	-0.1564**
	(2.672)	(-2.324)
LEV	-0.0268	0.0091
	(-0.775)	(0.215)
ROA	0.1028*	-0.1318*
	(1.687)	(-1.766)
AGE	-0.0597***	-0.2010***
	(-2.972)	(-8.175)
CASH	-0.0071	0.0007
	(-0.712)	(0.060)
GDP	0.2621***	0.0285
	(3.793)	(0.336)
INDSTR	0.8111***	-0.5807**
	(4.346)	(-2.540)
DUAL	0.0058	0.0490***
	(0.526)	(3.658)
_cons	-6.4427***	-5.0619***
	(-7.140)	(-4.580)
FE	Yes	Yes
Year	Yes	Yes
N	28935	28935
R^2	0.7160	0.7243

Note: The values in parentheses represent the T-values. '***','**' and '*'indicate that the coefficient is significant at the 1%, 5%, and 10% levels, respectively.

(2) Green Investment (GINV)

Table 12 examines the mediating role of green investment in linking the Smart Supply Chain Policy to corporate green transformation.

The regression results using green investment as the transmission mechanism are depicted in the corresponding table. According to the mediation effect testing steps, the results in column (1) of Table 12 are consistent with the baseline regression and will not be elaborated further. In column (2) of Table 12, the estimated coefficient of the Smart Supply Chain Policy on green investment is 0.1184 and is significant at the 10% level.

The mediation test confirms that green investment is a significant mediator. Green investment promotes the improvement of corporate green transformation. Through introducing advanced environmental technologies and green production facilities, firms can reduce energy consumption and carbon emissions, therefore realizing green transformation [59]. Green investment also fosters the sustainable development of corporate products and services, meeting market demands for eco-friendly products and enhancing corporate competitiveness [60]. Furthermore, by improving resource utilization efficiency and reducing production costs, green investment strengthens the economic benefits of corporate green transformation [61]. Additionally, green investment assists firms in complying with environmental regulations, reducing environmental risks, and providing robust support for their green transformation efforts.

Table 12. Mediation of Green Investment

	(1)	(2)
	GTR	GINV
inter	0.6283***	0.1184*
	(7.023)	(1.751)
SIZE	0.1522***	0.5840***
	(18.424)	(93.511)
TOP	0.1468***	-0.1489***
	(2.672)	(-3.587)
LEV	-0.0268	0.0879***
	(-0.775)	(3.364)
ROA	0.1028*	-0.8443***
	(1.687)	(-18.327)
AGE	-0.0597***	0.0585***
	(-2.972)	(3.857)
CASH	-0.0071	0.0449***
	(-0.712)	(5.926)
GDP	0.2621***	-0.2019***
	(3.793)	(-3.866)
INDSTR	0.8111***	-1.1469***
	(4.346)	(-8.129)
DUAL	0.0058	-0.0026
	(0.526)	(-0.320)
_cons	-6.4427***	11.3863***
	(-7.140)	(16.692)
FE	Yes	Yes
Year	Yes	Yes
N	28935	28935
R^2	0.7160	0.9016

(3) Financing Constraints (FINC)

Table 13 analyzes whether reductions in financing constraints mediate the effect of the Smart Supply Chain Policy on green transformation.

The regression results using financing constraints as the transmission mechanism are shown in the corresponding table. Following the mediation effect testing procedure, the results in column (1) of Table 13 are consistent with the baseline regression and are not repeated here. In column (2) of Table 13, the estimated coefficient of the Smart Supply Chain Policy on financing constraints is -0.3839 and is significant at the 5% level.

The mediation test confirms that financing constraints act as a significant mediator. Financing constraints inhibit the improvement of corporate green transformation.

Table 13. Mediation of Financing Constraints

	(1)	(2)
	GTR	FINC
inter	0.6283***	-0.3839**
	(7.023)	(-2.409)
SIZE	0.1522***	-0.4151***
	(18.424)	(-28.208)
TOP	0.1468***	-0.3805***
	(2.672)	(-3.889)
LEV	-0.0268	5.1985***
	(-0.775)	(84.441)
ROA	0.1028*	-4.7820***
	(1.687)	(-44.054)
AGE	-0.0597***	0.7136***
	(-2.972)	(19.960)
CASH	-0.0071	-1.4387***
	(-0.712)	(-80.611)
GDP	0.2621***	0.3979***
	(3.793)	(3.234)
INDSTR	0.8111***	0.2618
	(4.346)	(0.788)
DUAL	0.0058	-0.0387**
	(0.526)	(-1.986)
_cons	-6.4427***	3.3568**
	(-7.140)	(2.089)
FE	Yes	Yes
Year	Yes	Yes
N	28935	28935
R^2	0.7160	0.8292

4.5.2 Moderating effect

Table 14 evaluates the moderating effects of environmental regulation intensity and industry concentration on the policy's impact.

Column (2) of Table 14 shows that green transformation (GTR) is significantly influenced by the Smart Supply Chain Policy (inter), with a regression coefficient of 0.6643, significant at the 1% level. This shows that the Smart Supply Chain Policy significantly promotes corporate green transformation. Meanwhile, the coefficient for environmental regulation intensity (HJGZ) is 0.0011 but is not statistically significant, suggesting that environmental regulation intensity alone has little direct effect on corporate green transformation. In addition, the interaction term HJGZ_inter has a coefficient of 0.0442, significant at the 10% level. This depicts that environmental regulation intensity (HJGZ) positively moderates the relationship between the Smart Supply Chain Policy and corporate green transformation. Specifically, higher environmental regulation intensity strengthens the positive impact of the Smart Supply Chain Policy on green transformation, meaning that under stricter environmental regulations, firms are better able to leverage the policy to achieve improved green transformation outcomes.

Column (3) of Table 14 shows that green transformation (GTR) is significantly influenced by the Smart Supply Chain Policy (inter), with a regression coefficient of 0.6251, significant at the 1% level. This again confirms the significant promoting effect of the Smart Supply Chain Policy on corporate green transformation. Moreover, the coefficient for industry concentration (HHI) is -0.1740, significant at the 1% level, indicating that industry concentration has a significant negative effect on corporate green transformation. Additionally, the interaction term HHI_inter has a coefficient of -0.0753, significant at the 10% level. This suggests that industry concentration (HHI) negatively moderates the relationship between the Smart Supply Chain Policy and corporate green transformation. In other words, in industries with higher concentration, the positive influence of the Smart Supply Chain Policy on green transformation is weakened. This implies that firms operating in highly concentrated industries may face greater challenges in utilizing the policy effectively to advance green transformation.

Table 14. Moderating Effect

	(1)	(2)	(3)
	GTR	GTR	GTR
inter	0.6283***	0.6643***	0.6251***
	(7.023)	(7.231)	(6.987)
SIZE	0.1522***	0.1521***	0.1540***
	(18.424)	(18.409)	(18.637)
TOP	0.1468***	0.1467***	0.1522***
	(2.672)	(2.671)	(2.772)
LEV	-0.0268	-0.0274	-0.0258
	(-0.775)	(-0.794)	(-0.747)
ROA	0.1028*	0.1015*	0.0921
	(1.687)	(1.664)	(1.511)
AGE	-0.0597***	-0.0606***	-0.0637***
	(-2.972)	(-3.017)	(-3.173)
CASH	-0.0071	-0.0074	-0.0068
	(-0.712)	(-0.735)	(-0.681)
GDP	0.2621***	0.2323***	0.2636***
	(3.793)	(3.261)	(3.816)
INDSTR	0.8111***	0.8170***	0.7800***
	(4.346)	(4.375)	(4.178)
DUAL	0.0058	0.0058	0.0055
	(0.526)	(0.534)	(0.503)
HJGZ		0.0011	
		(0.079)	
HJGZ_inter		0.0442*	
		(1.736)	
HHI			-0.1740***
			(-5.273)
HHI_inter			-0.0753*
			(-1.783)
_cons	-6.4427***	-6.1670***	-6.3793***
	(-7.140)	(-6.729)	(-7.070)
FE	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	28935	28935	28935
R^2	0.7160	0.7160	0.7163

5. Conclusion and Recommendations

Drawing on the earlier analysis, this research uses the Smart Supply Chain Policy as the primary explanatory factor and corporate green transformation as the outcome variable, carrying out an empirical investigation of their relationship through a Difference-in-Differences (DID) approach. The findings depicts that the Smart Supply Chain Policy has a significant positive effect on advancing corporate green transformation. Specifically, non-state-owned enterprises, firms in eastern regions, non-high-tech industry firms, pollution-intensive industry firms, and firms in the expansion and downturn phases exhibit more pronounced green transformation effects under the support of the Smart Supply Chain Policy. Furthermore, environmental regulation intensity and industry concentration are found to play moderating roles in the linkage between the policy and firms' green transformation, with the former exerting a positive moderating effect and the latter a negative one. Mediation analysis further reveals that green innovation quantity, green investment, and financing constraints serve as key factors in how the Smart Supply Chain Policy facilitates corporate green transformation. Based on these conclusions, the following policy suggestions are proposed:

The government is advised to persist in advancing the rollout of the Smart Supply Chain Policy and provide differentiated support based on firm characteristics. Given that private enterprises, firms located in eastern regions, non-high-tech sector companies, and firms at both the growth and decline phases exhibit more significant green transformation effects under the policy, policymakers should focus on these groups, offering more targeted policy support and resource allocation. For example, financial subsidies and technical assistance can be provided to non-state-owned enterprises; supply chain optimization initiatives can be encouraged for eastern region enterprises; green technological innovation can be promoted among non-high-tech industry firms; and market access and financing convenience can be offered to pollution-intensive industries and firms in the growth and decline stages.

Strengthening environmental regulations to enhance the endogenous motivation for corporate green transformation. The positive moderating effect of environmental regulation intensity suggests that stricter environmental laws and standards help the Smart Supply Chain Policy better promote corporate green transformation. Therefore, the government should continuously improve the environmental legal framework, increase penalties for violations, and adopt market-based instruments such as environmental taxes and carbon emissions trading to incentivize firms to proactively undertake green transformation responsibilities. Thus, creating a mutually beneficial outcome for both economic growth and environmental conservation. Optimizing industry structure to mitigate the negative influence of industry focus on green transformation. The negative moderating effect of industry concentration indicates that excessively high industry concentration may suppress the effectiveness of the Smart Supply Chain Policy. Hence, the government should take measures to promote market competition, prevent monopolistic practices, and create more development opportunities for small and medium-sized enterprises, while directing resources toward green and innovative firms. At the same time, enterprises should be encouraged to enhance the overall green competitiveness of industries through mergers, acquisitions, and industrial chain integration.

Strengthening the guiding role of green innovation and green investment to advance corporate green transformation. The mediation test results show that green innovation quantity and green investment play important roles in the process that the Smart Supply Chain Policy promotes corporate green transformation. The government should increase facilities for green technology research and development, establish green innovation funds, and provide firms with R&D funding and tax incentives. Additionally, a robust green finance system should be developed to offer consistent financial backing for corporate green transformation.

Addressing financing constraints to enhance financial support for corporate green transformation. Financing constraints are a major factor hindering corporate green transformation. The government ought to introduce initiatives to minimize the financing costs of green projects, for example by extending green credit and launching green bond programs. Furthermore, a comprehensive green credit system should be established to improve the ability of financial institution to identify green enterprises. Firms should also be encouraged to diversify their financing channels, including equity financing and bond issuance, to alleviate financing pressure and facilitate smooth corporate green transformation.

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