Available Online: 29 October 2025 DOI: 10.54254/2977-5701/2025.28584

Can national independent innovation demonstration zones enhance manufacturing supply chain resilience?— evidence from Chinese A-share listed manufacturing companies

***Ping Han*[1], *Keqing Su*[1*], *Siyi Zeng*[1], *Xiaotian Yan*[1]**

[1]Harbin University of Commerce, Harbin, China

*Corresponding Author. Email: hl250627@163.com

Abstract. Studying the resilience of manufacturing enterprise supply chains helps enhance firms' ability to cope with external shocks and uncertainties, thereby safeguarding national economic security and promoting the sustainable development of the manufacturing sector. This study focuses on Chinese A-share listed manufacturing companies from 2011 to 2023 and employs a multi-period difference-in-differences (DID) approach to examine the impact of the National Independent Innovation Demonstration Zone (NIIDZ) policy pilot on the supply chain resilience of manufacturing listed companies. The results indicate that the NIIDZ policy pilot significantly improves manufacturing supply chain resilience, and this enhancement is primarily achieved by promoting enterprise adoption of artificial intelligence and accelerating digital transformation. Further heterogeneity analysis reveals that the policy has a significant positive effect on technology-intensive and non-polluting enterprises. These findings suggest that the NIIDZ policy plays an active role in strengthening manufacturing supply chain resilience and provide important policy implications for the government in promoting digitalization and enhancing the risk-resistance capacity of manufacturing supply chains.

Keywords: manufacturing supply chain resilience, national independent innovation demonstration zone, artificial intelligence, digital transformation, difference-in-differences

1. Introduction

Continuous external shocks are key external factors driving the construction of supply chain resilience in China's advanced manufacturing enterprises [1]. Currently, manufacturing firms often outsource components from multiple locations to assemble a single product, making them highly dependent on logistics and import-export channels. This reliance poses severe challenges to supply chain resilience. In particular, recent shocks such as the COVID-19 pandemic, global political and economic turbulence, and natural disasters have exposed unprecedented vulnerabilities in traditional supply chains, resulting in global supply chain disruptions and systemic chaos that have seriously affected both enterprise production and national economic security. The Chinese "Decision of the Central Committee of the Communist Party of China on Further Deepening Comprehensive Reform and Promoting Chinese-Style Modernization" emphasizes the need to "improve the resilience and security level of industrial and supply chains" and proposes systematic measures to achieve this. To address persistent issues such as difficulties in transforming scientific and technological achievements, insufficient incentives for researchers, and cumbersome approval processes, the State Council has authorized the National Independent Innovation Demonstration Zones (NIIDZs) to "break through existing policies," allowing them to formulate local regulations and detailed rules that better align with innovation principles. Once replicable institutional experiences are established, these can be promoted nationwide. The goal is to drive frontier technological breakthroughs and optimize industrial structures, injecting sustainable innovative momentum into the national economy. Relying on technological innovation and development, NIIDZs can promote innovations and transformations in supply chains in terms of technology, management, and operational models. Therefore, exploring how NIIDZs enhance supply chain resilience through technological, policy, and industrial support not only has significant academic value but also provides practical guidance for the nation to respond to external shocks and strengthen economic robustness.

Current research and this study mainly focus on the following aspects. Supply chain development faces four major challenges: (1) disruptions in raw materials and weaknesses in supply networks [2], which exacerbate the bullwhip effect; (2) uncertainties in transportation and logistics systems, where structural disruptions across national or regional supply chains lead to

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risk propagation [3]; (3) interruptions in enterprise production planning and operations. Firms typically allocate substantial resources to medium- and long-term production plans, yet supply shortages, energy constraints, and mechanical failures may cause unexpected production disruptions; (4) intensified changes in customer demand, as consumers increasingly pursue diversified, personalized products and new requirements, placing stress on existing supply chains. Enterprises must therefore develop higher-level inventory management capabilities and delivery networks to meet customer needs. Accordingly, enhancing supply chain resilience has become an urgent problem and a key research focus. A review of the literature reveals that previous research on supply chain resilience has concentrated on natural disasters, factory accidents, and transportation interruptions [3]. Research on supply chain resilience generally emphasizes two dimensions: the recovery capability of a supply chain, i.e., its ability to return to its initial stable state after disruption, and the adaptive capability, i.e., its ability to survive in the face of external shocks [4]. Regarding the relationship between innovation and supply chain resilience, some scholars argue that innovation can enhance internal knowledge-sharing, agility, and flexibility, thereby improving supply chain resilience [5]. For China's NIIDZs, these technological policies have increased innovation activities in pilot areas of central China to stimulate economic development and growth [6]. Furthermore, studies indicate that NIIDZs, through government support and subsidies, significantly enhance urban innovation levels [7].

A review of the literature shows that while research exists on innovation and related aspects in NIIDZs, studies specifically examining the impact of NIIDZ pilots on manufacturing supply chain resilience are scarce. The mechanisms through which these pilots affect supply chain resilience remain largely unexplored. This study makes several marginal contributions: First, it systematically investigates the impact of the NIIDZ policy pilot on manufacturing supply chain resilience, providing new empirical evidence for understanding the relationship between macro-level innovation policies and micro-level supply chain capabilities. Compared with existing studies that often focus on single enterprise-level innovation factors, this study integrates institutional innovation pilots with supply chain resilience, enriching the intersection of supply chain management and policy effect research. Second, this study explores the mechanisms through which NIIDZs enhance manufacturing supply chain resilience, extending research on the pathways of supply chain resilience formation from the perspective of "technology empowerment." Third, this study conducts heterogeneity analyses of policy effects across enterprise environments, technological intensity, addressing variations in policy responses among different types of firms. The findings provide empirical evidence to guide more targeted resource allocation and precise policy implementation.

2. Theoretical analysis and research hypotheses

2.1. National Independent Innovation Demonstration Zones can significantly enhance manufacturing supply chain resilience

Currently, the primary prerequisite for measuring supply chain resilience across countries is to avoid being "choked" by external technologies. The establishment of National Independent Innovation Demonstration Zones (NIIDZs) aims to focus on key areas for independent research and development. For example, in response to U.S. restrictions on chips, enterprises in Shenzhen have concentrated on developing third-generation semiconductors, thereby enhancing the competitiveness of domestically produced chips. Demonstration zones continuously achieve breakthroughs in high-end chips, core components, and critical materials, fundamentally reducing dependence on single external sources and mitigating the risk of supply disruption. Enterprises within the zones systematically map key industries such as electronic information, new energy, and high-end equipment, identifying weaknesses and gaps along the upstream and downstream supply chains. Guided by leading chain enterprises, the zones selectively attract or cultivate supporting firms, constructing "multi-region, multi-node" backup systems to address supply chain interruption risks caused by natural disasters, pandemics, or policy changes. The zones also encourage core enterprises to establish both "primary" and "backup" supply chains across different domestic regions. When the primary chain is blocked, backup chains can quickly step in. Facing challenges such as global trade frictions and geopolitical conflicts, the zones reduce reliance on any single country or region by "expanding emerging markets, establishing overseas hubs, and optimizing trade channels," thus achieving diversification and stabilization of international supply chains. The supply chain optimization path in NIIDZs includes spatial clustering, industrial chain strengthening and collaboration, diversified international layout and channel construction, technological upgrades and digital enablement, as well as policy guidance and resource support. This establishes a supply chain ecosystem characterized by "domestic circulation as the mainstay, with domestic and international dual circulation mutually reinforcing." The ultimate goal is to transform supply chains from "linear dependency" to "networked collaboration," shifting from "passive risk response" to "active risk mitigation," providing enterprises with secure, efficient, and resilient supply chain support and promoting high-quality regional industrial development.

Hypothesis 1: National Independent Innovation Demonstration Zones can significantly enhance manufacturing supply chain resilience.

2.2. National Independent Innovation Demonstration Zones can enhance supply chain resilience through Artificial Intelligence

First, NIIDZs have a policy pilot function. Under national strategic support, enterprises in these zones can enjoy tax reductions, R&D subsidies, industrial fund support, and data openness. These institutional arrangements effectively lower the threshold and cost of AI application, increasing the willingness and feasibility of enterprises to adopt AI. Demonstration zones typically gather national key laboratories, major scientific infrastructure, and top research institutions. These high-level research resources not only enhance AI technology supply but also shorten the cycle for translating research results into enterprise applications. Enterprises can more quickly integrate cutting-edge algorithms, models, and tools into business processes, accelerating AI implementation. AI applications heavily depend on computing power and data. NIIDZs focus on building computing centers, industrial internet platforms, and industry data-sharing platforms to provide enterprises with high-quality computational resources and data environments. This infrastructure advantage offers strong support for AI adoption, especially reducing the burden on small and medium-sized enterprises to independently build computing platforms.

On the other hand, enterprise AI usage can significantly enhance supply chain resilience [8]. Currently, emerging technologies such as AI can optimize data flows within supply chains, reduce risks in IoT forecasting, and overcome misinformation [9]. AI plays a key role in mitigating adverse impacts and supports decision-makers in formulating appropriate actions to address challenging situations [9]. AI can use deep learning and data analysis techniques to help enterprises predict market demand. Through machine learning algorithms, firms can dynamically adjust inventory and resource allocation based on market demand, production capacity, and supply chain fluctuations [10]. Additionally, AI can intelligently analyze supplier performance, production capacity, and other key factors to identify potential risks and bottlenecks in advance, such as raw material shortages or logistics delays. AI can also monitor all stages, including warehousing, transportation, and production, in real time. In the event of supply chain disruptions or anomalies, the system can automatically issue alerts and provide decision-makers with response plans. This real-time response mechanism helps quickly adjust supply chain plans, minimizing the impact of unexpected events.

Hypothesis 2: National Independent Innovation Demonstration Zones can enhance manufacturing supply chain resilience by promoting enterprise AI development.

2.3. National Independent Innovation Demonstration Zones can promote enterprise digital transformation to enhance supply chain resilience

Transparency has become a critical issue in corporate reputation management. Leading firms disclose supplier information and use digital platforms to ensure ethical and sustainable procurement, demonstrating compliance and social responsibility to stakeholders [11]. As key platforms for technological innovation and industrial upgrading, NIIDZs require enterprises within the zones to meet domestic and international compliance standards while achieving efficient management, optimized resource allocation, and enhanced transparency through digital transformation. Guided by national policies, enterprises are compelled to implement digital tools, such as supply chain management platforms and intelligent traceability systems, to meet societal and consumer expectations, increase transparency in ethical procurement, and thereby enhance supply chain agility and sustainability.

NIIDZs typically benefit from government policy support, including tax incentives, funding, and innovation incentives. These policies reduce financial pressure during digital transformation, particularly for small and medium-sized enterprises, which often require substantial investment. Demonstration zones are generally at the forefront of technological innovation. Many high-tech companies, R&D institutions, and innovation centers are concentrated in these zones, focusing on digital technologies such as AI, big data, cloud computing, 5G, and IoT. Enterprises can leverage these opportunities to access cutting-edge technologies and innovative thinking, facilitating digital transformation. Digital transformation enables enterprises to effectively extract and integrate internal and external data, enhance the handling of non-standardized and unstructured data, and thereby improve supply chain resilience [12]. Research also indicates that digital transformation increases supply chain transparency, further strengthening supply chain resilience [11]. Specifically, manufacturers can monitor upstream suppliers' raw material stock and production progress in real time, avoiding production line stoppages caused by delayed deliveries. Downstream distributors can simultaneously provide feedback on terminal inventory consumption, helping manufacturers accurately forecast demand and reduce issues such as "overproduction leading to inventory accumulation" or "underproduction causing stockouts."

Hypothesis 3: National Independent Innovation Demonstration Zones can promote enterprise digital transformation to significantly enhance supply chain resilience.

3. Model construction and data sources

3.1. Model construction

To test Hypothesis 1, this study establishes a baseline econometric model linking National Independent Innovation Demonstration Zones (NIIDZs) with manufacturing supply chain resilience. The model is specified as follows:

$$Scr_{it} = \delta_0 + \delta_1 \times did_{i,t} + \delta_2 \times Control_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (1)$$

In the equation, Scr_{it} represents manufacturing supply chain resilience, and $did_{i,t}$ denotes the core explanatory variable of this study, namely the National Independent Innovation Demonstration Zone (NIIDZ) policy. If city i is selected as a pilot city of the NIIDZ in year t, $did_{i,t}$ is assigned a value of 1; otherwise, it is 0. $Control$ represents the control variables, μ_i and $\lambda_t$denote individual fixed effects and time fixed effects, respectively, and ϵ_{it} is the random error term.

3.2. Variable definition

3.2.1. Dependent variable

Manufacturing Supply Chain Resilience (Scr). Following Yao et al. [13], this study defines supply chain resilience as the ability of a supply chain to respond to risk shocks, encompassing adaptive capacity, resistance capacity, recovery capacity, human capital, and governmental support. The indicator system for manufacturing supply chain resilience is shown in Table 1.

Adaptive Capacity is the foundation of supply chain resilience. It measures the stability and responsiveness of the supply chain under external shocks, providing the fundamental guarantee for risk response. Key components include stability and supply chain visibility. Stability reflects the enterprise’s integrated mechanism of operational adaptability, structural robustness, and liquidity management, ensuring stable supply chain operations in a dynamic environment. Sales performance indicates the basic market response capability; efficient capital management ensures financial flexibility under shocks; production capacity supports continuous supply chain operations; and information technology improves supply chain visibility and regulation efficiency. Together, these indicators constitute the measurement of adaptive capacity, forming the primary dimension for analyzing supply chain resilience.

Resistance Capacity focuses on the supply chain’s stability when risk shocks occur, serving as the core defensive capability. When external shocks arise, the supply chain’s ability to maintain operations and minimize fluctuations depends directly on its resistance capacity. Intangible assets such as brands and patents consolidate market positions and strengthen shock resistance; the enterprise’s comprehensive strength in sales, management, and finance provides a solid foundation for resilience. Indicators such as innovation output, equity multiplier, and net sales margin measure this comprehensive resistance capacity, making it an essential dimension of supply chain resilience.

Recovery Capacity concerns the efficiency of restoring and rebounding after a risk shock and is a key measure of resilience. The ability of the supply chain to quickly overcome adversity and resume normal operations directly affects enterprise survival and development. Healthy financial status provides funding for recovery, enabling rapid resource reallocation; efficient supply chain management ensures production continuity and reduces losses from supply disruptions. Indicators such as return on equity, inventory turnover, and current ratio reflect financial health and supply chain management effectiveness, serving as important bases for assessing recovery capacity and thus key aspects of resilience analysis.

Human Capital is the core driver enabling the supply chain to respond to risk shocks and permeates the entire risk response process. The quality and capability of personnel in the supply chain are crucial for gaining competitive advantages and maintaining collaborative relationships to mitigate risk. Highly skilled staff can better predict risks, implement resistance strategies, and expedite recovery. Indicators such as the proportion of employees with a bachelor’s degree or above and the proportion of R&D personnel directly reflect human capital quality, which influences the effectiveness of risk response across supply chain stages and must be included in resilience analysis.

Governmental Support serves as an external environmental factor, providing both support and constraints to supply chain risk response. Government aid policies, such as subsidies, offer direct support to enterprises, enhancing supply chain resilience; regulatory measures, such as income tax enforcement, maintain market order and create a stable external environment, indirectly supporting risk mitigation. Therefore, analyzing the impact of governmental support on supply chain resilience is essential for a comprehensive assessment of risk response capabilities.

3.2.2. Explanatory variable

The explanatory variable in this study is the NIIDZ pilot. The core explanatory variable reflecting the policy implementation effect is defined as the interaction between the NIIDZ experimental group dummy and the time dummy, which is used to examine the impact of the policy on manufacturing supply chain resilience.

3.2.3. Control variables and data sources

Control variables include: (1) Board size (Board): natural logarithm of the number of board members. (2) Firm age (FirmAge): ln (current year – establishment year + 1). (3) Fixed assets ratio (Fixed): net fixed assets divided by total assets. (4) Top five shareholders' stake (Top5): shareholding ratio of the top five shareholders. (5) Firm size (Size): natural logarithm of total assets. (6) Leverage (Lev): total liabilities divided by total assets. (7) Return on assets (ROA): net profit to total assets ratio. (8) Cash flow ratio (Cashflow): net cash flow from operating activities divided by total assets. (9) Dual role (Dual): 1 if chairman and CEO are the same person, 0 otherwise. (10) Big Four auditor (Big4): 1 if audited by one of the Big Four (PwC, Deloitte, KPMG, EY), 0 otherwise. Data are sourced from the CSMAR database. NIIDZ information comes from the Torch High Technology Industry Development Center of the Ministry of Industry and Information Technology of China. Some firm-level data were obtained via annual report web-scraping techniques.

3.3. Variable setting

Table 1. Evaluation indicator system for enterprise supply chain resilience

Primary Dimension	Secondary Dimension	Indicator Definition	Indicator Feature
Adaptive Capacity	Sales Level	Operating revenue	+
	Capital Management Efficiency	Operating revenue / Accounts receivable	+
	Production Capacity	Total number of employees	+
	Informatization Level	Degree of digital transformation	+
	Innovation Output	Total number of independently granted patents in the year	+
Resistance Capacity	Equity Multiplier	Total assets / Owners' equity	-
	Debt-to-Equity Ratio	Total liabilities / Owners' equity	-
	Fixed Assets	Original value of fixed assets minus accumulated depreciation and impairment	+
	Risk-Taking Level	Three-period rolling standard deviation of industry-adjusted ROA	-
	Supply Chain Concentration	Average of top five suppliers' and customers' purchase/sales ratio	+
Recovery Capacity	Net Sales Margin	Net profit / Operating revenue	+
	Return on Equity	Net profit / Shareholders' equity	+
	Inventory Turnover	Cost of goods sold / Inventory	+
	Current Ratio	Current assets / Current liabilities	+
	Cash Generation Capacity	Firm's ability to generate cash flow	+
	Supplier Purchase Amount	Amount purchased from suppliers in the current period	+
	Customer Sales Amount	Amount sold to customers in the current period	+
Human Capital	Proportion of Employees with Bachelor's Degree or Above	Proportion of employees with bachelor's degree or above	+
	R&D Staff Ratio	Proportion of R&D staff to total employees	+
Governmental Support	Government Subsidy	Total amount of government subsidies	+
	Income Tax Payable	Amount of income tax	+

3.4. Descriptive statistics and baseline regression

Table 2. Descriptive statistics

	count	mean	sd	min	p50	max
Scr	24934	0.8957	0.5501	0.1241	0.7973	2.9973
did	24934	0.4865	0.4998	0.0000	0.0000	1.0000
Board	24934	2.1055	0.1906	1.6094	2.1972	2.7081
FirmAge	24934	2.9052	0.3314	1.3863	2.9444	3.6376
FIXED	24934	0.2184	0.1326	0.0016	0.1943	0.7246
Top5	24934	0.5365	0.1500	0.1756	0.5363	0.8921
Size	24934	22.0279	1.1862	19.5850	21.8589	26.4403
Lev	24934	0.3833	0.1925	0.0319	0.3720	0.9246
ROA	24934	0.0472	0.0668	-0.3750	0.0452	0.2539
Cashflow	24934	0.0503	0.0668	-0.1994	0.0484	0.2656
Dual	24934	0.3308	0.4705	0.0000	0.0000	1.0000
Big4	24934	0.0493	0.2166	0.0000	0.0000	1.0000

The descriptive statistics are presented in Table 2. To empirically test the effect of the NIIDZ policy on enterprise supply chain resilience, this study constructs a multi-period difference-in-differences (DID) model for baseline regression. The results are shown in Table 3. Columns (1) to (3) in Table 3 employ a stepwise inclusion of control variables and fixed effects to enhance the robustness of the results. The coefficients of the policy variable $did_{i,t}$ are significantly positive at the 1% level across all model specifications, indicating that the implementation of the NIIDZ policy significantly enhances manufacturing firms' supply chain resilience (Scr).

Table 3. Baseline regression results

VARIABLES	(1)	(2)	(3)
	Scr	Scr	Scr
did	0.3606***	0.1757***	0.0774***
	(0.0150)	(0.0131)	(0.0137)
Board		0.0159	0.0482*
		(0.0283)	(0.0265)
FirmAge		0.5932***	-0.0831
		(0.0295)	(0.0629)
FIXED		-0.2190***	-0.1564***
		(0.0451)	(0.0430)
Top5		0.1271**	0.0186
		(0.0607)	(0.0603)
Size		0.1913***	0.1717***
		(0.0119)	(0.0120)
Lev		-0.1902***	-0.0971***
		(0.0339)	(0.0331)
ROA		-0.0608	-0.0085
		(0.0494)	(0.0481)
Cashflow		0.0277	0.0006
		(0.0387)	(0.0380)
Dual		0.0081	0.0101
		(0.0092)	(0.0086)
Big4		0.0089	0.0214
		(0.0390)	(0.0377)

Table 3.(continued)

Constant	0.7203***	-5.1090***	-2.7267***
	(0.0095)	(0.2410)	(0.3232)
Observations	24,934	24,934	24,934
Adjusted R-squared	0.1073	0.7878	0.8175
Firm FE	NO	YES	YES
Year FE	NO	NO	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.5. Parallel trend test

The parallel trend assumption is a core premise of the DID model. If the treatment and control groups exhibit different development trends prior to the policy intervention, the DID estimates may be confounded by inherent differences between the groups, leading to invalid causal inference. Therefore, this study employs an event study approach to test the parallel trend.

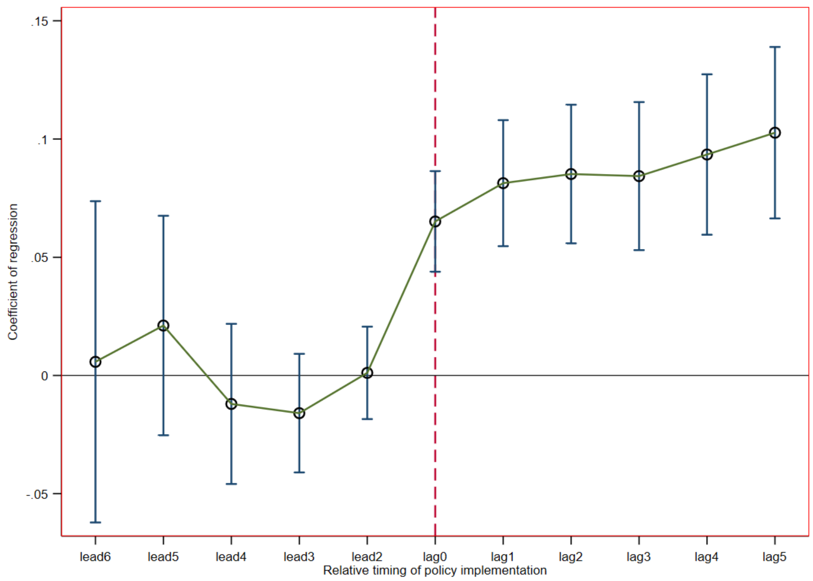

Figure 1. Parallel trend test

As shown in Figure 1, before the policy pilot implementation (i.e., during periods lead6 to lead2), the estimated coefficients fluctuate slightly around zero, and the confidence intervals of all estimated coefficients include zero. This indicates that prior to the policy shock, there was no significant difference in supply chain resilience between the treatment and control groups, and their trends over time were essentially consistent. This result strongly supports the "parallel trend" assumption of this study, providing a reliable basis for subsequent causal inference. The estimated coefficients at and after the policy implementation provide evidence of the dynamic effects of the policy. As shown, immediately following the policy implementation, the coefficients jump from near zero to significantly positive. In subsequent periods (lag1 to lag5), the positive effect persists and gradually strengthens. This dynamic pattern clearly demonstrates that the implementation of the National Independent Innovation Demonstration Zone (NIIDZ) policy has a significant and sustained positive impact on regional supply chain resilience. The policy effect is not an instantaneous spike but deepens and consolidates over time.

3.6. Mediation test

Previous empirical results have confirmed that the NIIDZ policy significantly enhances the supply chain resilience of manufacturing firms. This section aims to verify the mechanisms through which this occurs, focusing on (i) the level of artificial intelligence and (ii) digital transformation.

$$M_{it} = \alpha_0 + \alpha_1 did_{it} + Control + \mu_i + \lambda_t + \epsilon_{it} \quad (2)$$

Where M_{it} denotes the mediating variable, while other variables are the same as in Equation (1). Based on the theoretical analysis above, the mediating variables chosen are corporate AI adoption and digital transformation. One mediating variable is the level of corporate AI adoption.

Following Yao et al. [14], this study collected annual reports of listed companies from 2011 to 2023, extracting the MD&A sections and organizing them into panel data. The total length of MD&A texts, including both Chinese and English portions, was calculated. Next, an AI terminology dictionary was constructed and integrated with Python's jieba library after removing stopwords. The frequency of AI-related terms was calculated, and the natural logarithm of this frequency plus one was taken to measure corporate AI adoption. Similarly, following Zhen et al. [15], 139 digital-related keywords across categories such as technology classification, organizational enablement, and digital application were counted to measure corporate digital transformation. The natural logarithm of the frequency plus one was taken as the metric for digital transformation. Table 4 presents the effects of the NIIDZ pilot on these mediating variables. Column (1) shows the effect on corporate AI adoption, while Column (2) shows the effect on digital transformation. The coefficients of DID for the mediators AI and digital transformation are 0.1251 and 0.1490, respectively, both highly significant at the 1% level. This indicates that the core explanatory variable (DID) effectively promotes corporate AI development and digital transformation.

Table 4. Mediation effects

VARIABLES	(1)	(2)
	AI	digital
did	0.1251***	0.1490***
	(0.0318)	(0.0381)
Board	0.1829***	0.0111
	(0.0600)	(0.0699)
FirmAge	0.0055	-0.0263
	(0.1572)	(0.1676)
FIXED	-0.3182***	-0.3824***
	(0.0987)	(0.1189)
Top5	-0.3655***	-0.1784
	(0.1187)	(0.1459)
Size	0.2154***	0.2477***
	(0.0223)	(0.0264)
Lev	0.0851	-0.0240
	(0.0772)	(0.0934)
ROA	-0.3351***	-0.2343*
	(0.1133)	(0.1297)
Cashflow	-0.0646	0.0410
	(0.0843)	(0.1016)
Dual	0.0123	0.0247
	(0.0204)	(0.0238)
Big4	-0.0837	-0.0540
	(0.0710)	(0.0827)
Constant	-4.0799***	-3.4107***
	(0.6538)	(0.7325)
Observations	24,934	24,934
Adjusted R-squared	0.7566	0.7602
Firm FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4. Robustness checks

The baseline regression results have already supported that the National Independent Innovation Demonstration Zone (NIIDZ) policy helps enhance corporate supply chain resilience. However, empirical results may be affected by variable measurement errors, policy anticipation, and model misspecification, potentially leading to biased estimates. Therefore, this section conducts robustness checks.

4.1. PSM-DID test

This study employs the propensity score matching (PSM) method, using 1:1 nearest-neighbor matching with replacement to match NIIDZ pilot cities with non-pilot cities on an annual basis. To mitigate systematic differences between the treatment group (treat = 1) and the control group (treat = 0) and to avoid sample selection bias affecting the estimation, a 1:1 nearest-neighbor matching approach is adopted. As shown in Column (1) of Table 5, the coefficient of the core explanatory variable is significantly positive at the 1% level, indicating that the policy significantly enhances supply chain resilience.

4.2. Excluding the impact of pandemic years

The COVID-19 pandemic directly caused disruptions in international logistics, upstream factory shutdowns, and raw material shortages. Production interruptions (e.g., personnel quarantine, park lockdowns) and downstream demand reductions (e.g., consumer halt, order cancellations) even triggered “supply chain break panic,” forcing firms to make reactive adjustments, such as seeking alternative suppliers, increasing inventory, or localizing supply chains. These adjustments are survival-driven responses rather than policy-guided effects (e.g., R&D subsidies, innovation platform support, or industrial collaboration policies). After excluding pandemic years, Column (2) of Table 5 shows that the DID coefficient remains significantly positive at the 1% level, indicating that the policy’s promotion of manufacturing supply chain resilience is robust.

4.3. Excluding other policy interference

This study also considers the potential influence of three other policies on corporate supply chain resilience: the National Big Data Open Demonstration Zone, the “Broadband China” initiative, and the Supply Chain Innovation Pilot policy. The National Big Data Open Demonstration Zone policy improves the efficiency of information flows within the industrial chain by opening data resources. Efficient information flows help firms accurately forecast demand, quickly match alternative suppliers, and enhance risk warning capabilities and resource reconfiguration efficiency, thereby strengthening supply chain resilience. The “Broadband China” policy promotes high-speed broadband coverage and application in enterprises, supporting supply chain digitalization (e.g., real-time inventory monitoring, remote collaborative production), addressing information transmission lags, and enhancing digital resilience. The Supply Chain Innovation Pilot policy directly targets supply chain optimization, providing participating firms with support such as collaborative platforms and multi-source supply system subsidies, guiding them to build more resilient supply chains through diversified suppliers and emergency reserves. These three policies have mechanisms similar to the target policy in improving supply chain resilience. If not excluded, it would be difficult to distinguish whether the observed improvement in resilience is due to the NIIDZ policy or these other policies. Columns (3)–(5) of Table 5 present the results after excluding the effects of the “Broadband China,” National Big Data Open Demonstration Zone, and Supply Chain Innovation Pilot policies, respectively. The results show that the NIIDZ policy still significantly enhances manufacturing supply chain resilience.

Table 5. Robustness check results

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Scr	Scr	Scr	Scr	Scr
did	0.0514***	0.0741***	0.0754***	0.0772***	0.0765***
	(0.0170)	(0.0134)	(0.0142)	(0.0137)	(0.0136)
Board	0.0704*	0.0677**	0.0483*	0.0488*	0.0475*
	(0.0367)	(0.0326)	(0.0265)	(0.0264)	(0.0265)
FirmAge	-0.1057	-0.0057	-0.0820	-0.0841	-0.0864
	(0.0772)	(0.0793)	(0.0629)	(0.0626)	(0.0627)
FIXED	-0.1560***	-0.1826***	-0.1571***	-0.1561***	-0.1569***
	(0.0545)	(0.0504)	(0.0430)	(0.0430)	(0.0430)

Table 5.(Continued)

Top5	0.0136	-0.1358**	0.0190	0.0195	0.0173
	(0.0798)	(0.0656)	(0.0603)	(0.0603)	(0.0604)
Size	0.1700***	0.1682***	0.1716***	0.1712***	0.1715***
	(0.0154)	(0.0136)	(0.0120)	(0.0120)	(0.0119)
Lev	-0.1144***	-0.0682*	-0.0976***	-0.0973***	-0.0964***
	(0.0404)	(0.0409)	(0.0331)	(0.0331)	(0.0331)
ROA	-0.0329	-0.0395	-0.0078	-0.0053	-0.0028
	(0.0636)	(0.0612)	(0.0482)	(0.0482)	(0.0483)
Cashflow	0.0115	-0.0106	0.0009	0.0005	0.0022
	(0.0527)	(0.0500)	(0.0380)	(0.0381)	(0.0380)
Dual	0.0211*	0.0071	0.0099	0.0100	0.0097
	(0.0114)	(0.0110)	(0.0086)	(0.0086)	(0.0086)
Big4	0.0366	-0.0303	0.0218	0.0223	0.0216
	(0.0565)	(0.0435)	(0.0376)	(0.0377)	(0.0374)
Broadband China			0.0112		
			(0.0146)		
Digital				0.0217	
				(0.0162)	
SCR polot					0.0322**
					(0.0134)
Constant	-2.7001***	-2.9193***	-2.7322***	-2.7204***	-2.7177***
	(0.4225)	(0.3685)	(0.3235)	(0.3231)	(0.3223)
Observations	11,952	15,177	24,934	24,934	24,934
Adjusted R-squared	0.7994	0.8065	0.8175	0.8175	0.8176
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4.4. Placebo test

Following Chen et al. [16], the sample firms are divided into several “groups” based on the timing when each individual begins to receive treatment. While keeping the treatment timing and group structure unchanged, individual group assignments are randomly permuted, and two-way fixed effects (TWFE) estimations are conducted. This procedure is repeated 500 times to generate the distribution of placebo effects. The results show that the placebo effect coefficients roughly follow a normal distribution centered at 0, with the density peaking around zero. This indicates that under random assignment of treatment identities, the estimated effects are highly likely to be statistically insignificant, consistent with our expectations. Moreover, the true estimated treatment effect (red dashed line) lies at the far right end of the entire placebo distribution, well separated from the main body of the placebo coefficients. This demonstrates that the significant positive treatment effect observed in our baseline regressions is highly unlikely to be driven by unknown spatial heterogeneity or random factors, strongly confirming the robustness and reliability of the baseline results.

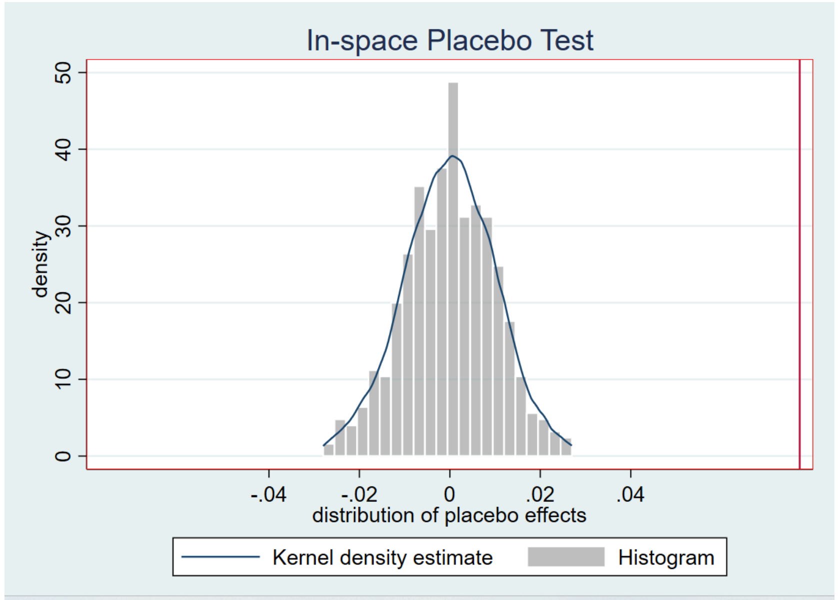

Figure 2. Placebo test results

4.5. Heterogeneous treatment effects in difference-in-differences

The NIIDZ policy is implemented gradually in stages. Staggered DID TWFE estimators may produce biased estimates if treatment effects are heterogeneous [17]. Specifically, when units that receive treatment earlier are used as control groups for later-treated units, time-varying treatment effects may lead to biased estimates [17]. To address this, we employ the Bacon decomposition method. The results are presented in Table 6. According to the decomposition, the weight of "Later Treatment vs. Earlier Comparison" is only 5%, indicating that the staggered DID estimation in this study is largely accurate and unbiased.

Table 6. Bacon decomposition results

DD Comparison	Weight	Avg DD Est
Earlier T vs. Later C	0.036	0.095
Later T vs. Earlier C	0.050	0.023
T vs. Never treated	0.535	0.109
T vs. Already treated	0.379	0.056

T = Treatment; C = Comparison

5. Further analysis

5.1. Pollution status of manufacturing enterprises

Following Wang and He [18], the sample firms are classified into heavily polluting and non-polluting manufacturing enterprises according to the secondary industry classification in the 2012 "Guidelines for Industry Classification of Listed Companies" issued by the China Securities Regulatory Commission. Heavily polluting firms are listed in Column (1) of Table 7, while non-polluting firms are listed in Column (2). The regression results in Columns (1)–(2) of Table 7 show that the NIIDZ policy significantly improves the supply chain resilience of non-polluting manufacturing enterprises, whereas its effect on heavily polluting enterprises is not significant. The potential reasons are: (1) China currently emphasizes green manufacturing, carbon reduction, and sustainable production, imposing stronger external constraints on polluting firms. To comply, these firms often need to invest substantial resources in facility upgrades, pollution control, and standard compliance, which limits their ability to allocate resources for supply chain resilience enhancements (e.g., digitalization, risk management, redundancy). (2) Non-polluting firms' supply chain risks are often concentrated in core technologies or reliance on imported production components. The NIIDZ policy, with its R&D subsidies, intellectual property protections, and industry–academia–research collaborative platforms, directly addresses these pain points, reducing dependence on external suppliers and enhancing "anti-disruption capacity" in the supply chain.

5.2. Industry heterogeneity of manufacturing enterprises

Following Yin et al. [19], all sample firms are classified according to the 2012 CSRC industry standards into labor-intensive, technology-intensive, and asset-intensive enterprises based on the concentration of production factors. Columns (3)–(5) of Table 7 report the heterogeneity results for labor-intensive, technology-intensive, and asset-intensive firms, respectively. The results indicate that the NIIDZ policy significantly enhances the supply chain resilience of technology-intensive manufacturing enterprises. Possible reasons include: (1) The NIIDZ policy emphasizes technological innovation and industrial upgrading, which aligns closely with the development needs of technology-intensive manufacturing enterprises. Policy support, such as R&D subsidies and tax incentives, directly encourages firms to increase R&D investment, tackle key technologies, and strengthen independent innovation capabilities, thereby enhancing supply chain autonomy and controllability. (2) Technology-intensive firms typically occupy key nodes in the industrial chain, and their technological innovations can drive upstream and downstream development. In contrast, non-technology-intensive firms often focus on cost control and production efficiency rather than innovation.

Table 7. Heterogeneity analysis

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Scr	Scr	Scr	Scr	Scr
did	0.0318	0.0818***	0.0248	0.0895***	0.0462
	(0.0265)	(0.0154)	(0.0246)	(0.0174)	(0.0353)
Board	0.0725	0.0343	0.0849*	0.0234	0.0810
	(0.0538)	(0.0300)	(0.0454)	(0.0342)	(0.0689)
FirmAge	-0.1171	-0.0582	-0.0340	-0.0919	-0.0178
	(0.1209)	(0.0738)	(0.1315)	(0.0809)	(0.1542)
FIXED	-0.1302*	-0.1154**	-0.0090	-0.1755***	-0.1507*
	(0.0719)	(0.0486)	(0.0808)	(0.0534)	(0.0854)
Top5	0.1490	-0.0522	0.0144	-0.0398	0.2056
	(0.1237)	(0.0644)	(0.1070)	(0.0712)	(0.1479)
Size	0.1747***	0.1659***	0.1821***	0.1689***	0.1640***
	(0.0222)	(0.0132)	(0.0176)	(0.0148)	(0.0297)
Lev	-0.2292***	-0.0702*	-0.1655**	-0.0673	-0.1950**
	(0.0588)	(0.0387)	(0.0671)	(0.0433)	(0.0755)
ROA	0.0203	0.0302	0.0591	0.0408	-0.0493
	(0.0974)	(0.0543)	(0.0934)	(0.0588)	(0.1298)
Cashflow	-0.0543	0.0304	-0.0484	0.0722	-0.1020
	(0.0654)	(0.0459)	(0.0687)	(0.0515)	(0.0836)
Dual	0.0081	0.0083	0.0277*	0.0015	0.0021
	(0.0147)	(0.0103)	(0.0166)	(0.0114)	(0.0178)
Big4	0.0154	0.0208	0.0076	0.0484	-0.1077*
	(0.0701)	(0.0444)	(0.0723)	(0.0505)	(0.0599)
Constant	-2.9212***	-2.5611***	-3.2803***	-2.4759***	-3.0284***
	(0.6129)	(0.3593)	(0.5775)	(0.3968)	(0.7964)
Observations	6,877	18,018	5,127	14,957	4,729
Adjusted R-squared	0.7600	0.8306	0.7683	0.8355	0.7642
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion and policy implications

Based on an empirical analysis of the NIIDZ policy in China, this study examines its impact on manufacturing supply chain resilience. The results indicate that the policy significantly enhances supply chain resilience and reveals its mechanisms: by promoting corporate artificial intelligence adoption and digital transformation, the policy strengthens the supply chain's ability to withstand and recover from shocks. Further heterogeneity analysis shows that the policy's effect is particularly pronounced for non-polluting and technology-intensive manufacturing enterprises. The study contributes both theoretically and practically. Theoretically, it enriches research on the relationship between national innovation policies, corporate digital transformation, and supply chain resilience, highlighting the crucial role of institutional innovation in promoting supply chain stability and sustainability. Practically, it provides guidance for policymakers and enterprises. Governments should optimize the construction of NIIDZs, align policies with firm characteristics, and promote AI and digital infrastructure development to enhance inter-firm information sharing. Enterprises should actively strengthen technological innovation and digital capabilities, increase supply chain transparency, and leverage policy incentives to improve supply chain resilience. Based on these findings, the following policy recommendations are proposed: First, promote supply chain transparency and data sharing: Establish unified data standards and information-sharing platforms within NIIDZs. Utilize technologies such as blockchain and the Internet of Things (IoT) to enable traceable, highly transparent supply chain operations, reducing risks from information asymmetry and amplifying policy effects on resilience. Second, focus on differentiated support for enterprises: In addition to universal support, provide preferential incentives to technology-intensive and non-polluting firms, including R&D subsidies, green financing, and smart manufacturing upgrades, to leverage their leading role in enhancing supply chain resilience. Third, strengthen policy coordination and dissemination: Align NIIDZ institutional innovations with regional economic policies and explore policy experiences that can be scaled nationwide, encouraging more manufacturing firms to improve supply chain resilience and innovation capacity.

Funding support

Funding Projects: National Social Science Fund Project:(1)Central Government Support Fund for Reform and Development of Local Universities High-Level Talent Project: 'Research on Digital Technology Empowering High-Quality Development of Heilongjiang Province's Manufacturing Sector'; (2)Key Project of the Heilongjiang Provincial Philosophy and Social Sciences Research Planning Programme: 'Research on Enhancing the Resilience and Security of Heilongjiang's Manufacturing Industry Chain and Supply Chain', Project No.: 23JYA260.(3)Research on Key Issues by the People's Government of Heilongjiang Province Research on the Future Industrial Development and Policy Support System of Heilongjiang Province, Project No.:SKGW-ZDKT2024017

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