Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

# Dual-Pilot Policies and Corporate Supply Chain Resilience: Evidence from Commercial Logistics Node Cities and Supply Chain Innovation Pilot Cities

**Wei Luo**
Guilin University of Technology
**Jinli Du**
150380889980163.com

Guilin University of Technology
**Hengwu Li**
Guilin University of Technology

**Research Article**

**Keywords:** Commercial logistics node cities, Supply chain innovation and application, Dual-pilot policy, Supply chain resilience, Double machine learning

**Posted Date:** August 20th, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-10574794/v1

**License:** This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

**Additional Declarations:** No competing interests reported.

# Abstract

Supply chain resilience is essential to the sustainable and secure operation of industrial systems, yet evidence on how complementary public policies jointly shape firm resilience remains limited. This study examines the coordinated implementation of China's commercial logistics node city policy and supply chain innovation and application pilot policy. Using 32,208 firm-year observations for Shanghai- and Shenzhen-listed A-share companies from 2012 to 2024, we construct a quasi-natural experiment and estimate the effect of dual-pilot exposure on corporate supply chain resilience using double machine learning. The results show that firms located in cities covered by both pilots exhibit significantly higher supply chain resilience. This finding remains robust to PSM-DID, placebo tests, alternative machine-learning algorithms, sample-split adjustments, exclusion of 2020, controls for overlapping policies, and an instrumental-variable analysis. Dual-pilot exposure is also associated with greater supply chain digitalization, lower supply chain risk, higher information-disclosure quality, and greater innovation efficiency. The effect is stronger for non-polluting firms, firms in highly marketized regions, and technology-intensive firms. These findings show how coordinated logistics-infrastructure and supply-chain governance policies can strengthen resilient industrial systems and provide practical evidence for policy design that supports sustainable industrial development.


# 1 Introduction

At present, the global industrial chain and supply chain system is undergoing a deep adjustment, and the uncertainty, complexity and impact of the external environment have significantly increased. Factors such as changes in the international trade environment, regional industrial chain restructuring, major external shocks, disruptions in international logistics, and fluctuations in market demand continue to disrupt the stable operation of enterprise supply chains, presenting enterprises with multiple risks such as supply disruptions, delivery delays, inventory overstock, and rising costs (Alessandria et al. 2023) .In this context, enterprises not only have to deal with operational risks such as insufficient supply of raw materials, delayed transportation and distribution, blocked inventory turnover and unstable order delivery, but also face management challenges such as information asymmetry between upstream and downstream, reduced efficiency of supply and demand matching and increased difficulty of supply chain coordination. Once these risks continue to spread through the supply chain network, they can easily lead to supply disruptions, rising costs, production halts and unstable customer relationships, thereby weakening enterprises' ability to sustain operations and their competitive edge in the market. Therefore, how enterprises can identify potential risks in a timely manner before external shocks occur, maintain the basic operation of the supply chain during the shock, and achieve rapid recovery and dynamic adjustment after the shock has become an important issue for improving the stability and security level of the supply chain.

Supply chain resilience is an important ability for enterprises to maintain stable operation of supply chains, absorb risk disturbances and achieve recovery and adjustment under external shocks, and is also an important foundation for improving the security level of industrial chains and supply chains

(Tukamuhabwa et al., 2015). Early research suggests that building resilient supply chains helps enterprises maintain continuous operations, enhance responsiveness and preserve value creation in an uncertain environment (Wieland & Wallenburg, 2013) ; Subsequent studies further emphasize that external shocks can alter the stability and survivability of supply chain networks, and enterprises need to enhance their shock response capabilities through risk identification, resource adjustment, and network synergy (Ivanov & Dolgui, 2020). Under the impact of global emergencies, supply chain resilience is no longer just a matter of enterprise operation and management, but an important issue related to the security of industrial systems and the stability of economic cycles (Belhadi et al., 2021). In terms of connotation expansion, supply chain resilience is not only reflected in the ability to recover after the shock, but also in the ability to prepare before the shock and to respond during the shock (Ponomarov & Holcomb, 2009); Related studies also emphasize from a quantitative measurement perspective that supply chain resilience should reflect risk exposure, shock response and recovery adjustment capabilities simultaneously (Hosseini et al., 2019). From the perspective of formation mechanism, supply chain disruption orientation, resource allocation capacity and operational flexibility can enhance the ability of enterprises to cope with supply chain disruptions (Ambulkar et al., 2015) Information sharing, relationship coordination and co-governance also contribute to reducing risk transmission and enhancing system resilience (Brandon-Jones et al., 2014). Digital technology empowerment has become an important direction in supply chain resilience research in recent years. The use of information technology can improve information processing and collaboration capabilities among supply chain partners, thereby enhancing supplier resilience and customer resilience (Gu et al., 2021); Supply chain digitalization can enhance supply chain resilience by improving information transparency and collaborative response efficiency (Zouari et al., 2020); Digital transformation can also enhance enterprise supply chain resilience by improving information processing capabilities, increasing supply chain transparency, and improving resource coordination efficiency (Li et al., 2025). Furthermore, dynamic digital capabilities can enhance supply chain resilience by improving digital adaptability and digital agility, and institutional environment and government support can also influence this process (Dubey et al., 2023). Overall, existing research provides an important basis for understanding the connotation, measurement, and formation mechanism of supply chain resilience, but most studies still focus on internal capabilities of enterprises, supply chain relationships, or digital transformation itself, and there is still relatively insufficient attention to how the joint implementation of external circulation system construction and supply chain innovation policies affects enterprise supply chain resilience.

The policies for the construction of commercial and logistics node cities and the pilot policies for supply chain innovation and application provide an important policy context for examining the improvement of enterprise supply chain resilience. The commercial logistics system is an important external foundation for the stable operation of the enterprise supply chain. A well-developed commercial logistics system can reduce transportation delays, order delivery uncertainties and regional circulation frictions, and enhance the enterprise's ability to identify and respond to risk shocks by improving supply chain visibility (Jia et al., 2025). The improvement of logistics capabilities also helps to enhance enterprise resource scheduling and operational recovery capabilities, thereby improving supply chain agility and resilience

(Song et al., 2022). At the same time, supply chain visibility can help enterprises obtain information such as orders, inventory, transportation and demand changes in a timely manner, reduce information opacity and coordination costs, and enhance enterprises' ability to identify and respond to abnormal fluctuations in the supply chain (Kalaiarasan et al., 2022). Unlike commercial logistics systems which mainly improve the external circulation environment, supply chain innovation and application pilot policies can promote the digitalization of enterprise supply chains (Han & Wei, 2025),enhance supply chain connectivity and information sharing levels, And by improving corporate governance, increasing total factor productivity, easing financing constraints and optimizing energy performance, it can influence business performance and sustainability (Qing et al., 2025; Zhu & Zhang, 2024). Therefore, the policies for the construction of commercial and logistics node cities mainly provide external support for the stable operation of enterprise supply chains by improving the external circulation network, reducing circulation frictions and enhancing supply guarantee capabilities; Supply chain innovation and application pilot policies enhance the perception and response capabilities of enterprises to changes in orders, inventories, logistics and demand through platform construction, digital technology application and upstream and downstream collaboration. The combination of the two types of policies may form a policy synergy between *improving the external circulation system* and *enhancing internal supply chain synergy*, and jointly act on the entire process of enterprise supply chain risk identification, shock resistance and recovery and reconstruction through improving information visibility, synergy efficiency and risk response capabilities(Zhao et al., 2023).Thereby enhancing the resilience of the enterprise supply chain.

However, existing research still lacks a systematic examination of the policy mix mentioned above. Can trade logistics node city construction policies and supply chain innovation and application pilot policies significantly enhance the resilience of enterprise supply chains through the improvement of external circulation systems and the enhancement of internal supply chain synergy? How will this dual-pilot effect be achieved? Are there differences in the impact of the dual pilot policy on supply chain resilience across different industries, enterprise types and market conditions? Based on this, this paper takes Chinese A-share listed firms on the Shanghai and Shenzhen stock exchanges from 2012 to 2024 as the research sample, incorporates the two types of pilot policies into A unified analytical framework, constructs a quasi-natural experiment of dual pilot policies, and uses double machine learning models to identify its impact on the resilience of enterprise supply chains.

The possible marginal contributions of this paper are mainly reflected in three aspects. First, in terms of the research perspective, starting from policy synergy, it reveals how external logistics infrastructure policies and internal supply chain innovation policies jointly shape enterprise supply chain resilience, expanding previous research on supply chain resilience that mainly focused on enterprise capabilities, digital transformation, or single policy shocks. Second, in terms of research content, it places enterprise supply chain resilience in the cross-scenario of the improvement of external logistics networks and the enhancement of internal supply chain synergy, revealing the combined effect of the dual pilot policies on enterprise supply chain resilience and its transmission mechanism, providing micro-empirical evidence for understanding how the improvement of the commercial logistics system serves the security of industrial chains and supply chains. Third, in terms of research methods, a double machine learning

model is used to evaluate the effects of the dual pilot policy, more flexibly dealing with the possible complex nonlinear relationships among control variables, policy variables and outcome variables, reducing model setting bias and improving the reliability of policy effect estimation.

# 2 Theoretical Analysis and Research Hypotheses

# 2.1 Policy Context and Theoretical Logic

## 2.1.1 Policy Context

The policy of building commercial and logistics node cities and the pilot policy of supply chain innovation and application are important policy carriers for China to promote the improvement of the commercial and logistics system and the construction of the modern supply chain system. In 2017, five departments including the Ministry of Commerce of China issued the *13th Five-Year Plan for the Development of Trade and Logistics*, proposing to support the construction and transformation of a number of comprehensive and specialized logistics distribution centers based on trade and logistics node cities, improve urban distribution networks, accelerate the sinking of logistics distribution channels, and promote the construction of an integrated urban-rural logistics network. The policy is not a simple logistics facility construction policy, but a commercial logistics system construction policy centered on commodity distribution, regional distribution, warehousing and distribution, information management and the optimization of urban and rural distribution networks, which can reduce circulation frictions in the procurement, warehousing, transportation and sales links of enterprises by enhancing the logistics organization capacity, commodity allocation capacity and distribution service capacity of node cities. The supply chain innovation and application pilot policy originated from the "Guiding Opinions on Actively Promoting Supply Chain Innovation and Application" issued by The General Office of the State Council of China in 2017 and was piloted in cities and enterprises by eight departments including the Ministry of Commerce in 2018, focusing on supply chain platform construction, digital technology application, upstream and downstream collaboration and supply chain governance capacity improvement. To promote real-time sharing of demand, inventory and logistics information, improve circulation efficiency and reduce circulation costs. As a result, the policy for building commercial and trade logistics node cities mainly focuses on the external circulation environment to enhance the external support for the operation of enterprises' supply chains; Supply chain innovation and application pilot policies mainly focus on internal supply chain organization to enhance enterprises' risk identification, resource integration and recovery and reconstruction capabilities. When combined, the two can form a policy synergy between *improving the external circulation system* and *enhancing internal supply chain synergy*, providing an institutional basis for enhancing the resilience of enterprise supply chains.

### 2.1.2 The theoretical logic of the impact of the dual pilot policy on the resilience of enterprise supply chains

Supply chain resilience is the dynamic ability of enterprises to identify risks, absorb disturbances, maintain operations and achieve recovery and adjustment in the face of external shocks. The core lies in enhancing the risk perception ability, resource scheduling ability, collaborative response ability and recovery and reconfiguration ability of the supply chain system (Ponomarov & Holcomb, 2009).It depends not only on internal resource allocation and operational flexibility, but also on external circulation conditions, upstream and downstream synergistic relationships and information processing capabilities (Brandon-Jones et al., 2014).

The dual pilot policy can enhance the resilience of the enterprise supply chain mainly because it can simultaneously improve the external support conditions and internal synergy capabilities for the operation of the enterprise supply chain. On the one hand, the policy of building commercial and logistics node cities, relying on the commodity distribution, logistics distribution and regional delivery functions of node cities, can reduce the spatial matching costs and delivery uncertainties between enterprises and suppliers, customers and regional markets (Braunscheidel & Suresh, 2009).It enables enterprises to have stronger alternative distribution, inventory allocation and supply guarantee capabilities in the event of demand fluctuations, transportation delays or local supply disruptions, and enhances their rapid response capabilities to market changes and supply chain disturbances (Gligor & Holcomb, 2012) ; On the other hand, supply chain innovation and application pilot policies can alleviate information asymmetry among supply chain partners through supply chain platform construction, digital technology application and information sharing upstream and downstream (Swafford et al., 2008).Promoting collaboration and joint decision-making among supply chain members (Scholten & Schilder, 2015), enhancing enterprises' ability to identify order demand, inventory changes, logistics status and supply chain risks to strengthen supply chain resilience. Therefore, the combination of the two types of policies can enhance the ability of enterprises to identify, absorb and recover from external shocks through the transmission chain of "circulation node support - supply chain collaborative governance - risk response capacity improvement". Based on the above analysis, this paper puts forward the following hypotheses:

H1: The dual-pilot policy can significantly enhance the resilience of enterprises' supply chains.

## 2.2 The mechanism by which the dual pilot policy affects supply chain resilience

## 2.2.1 Supply chain digitalization mechanism

The degree of digitalization of the supply chain reflects the ability of enterprises to use digital technologies to achieve data collection, information connection and collaborative management in links such as procurement, production, inventory, logistics and sales. It is an important foundation for improving the visualization, response speed and resource allocation efficiency of the supply chain (Tiwari et al., 2024; Zouari et al., 2020).Under the dual pilot policy, the construction of commercial and logistics node cities can promote the informatization transformation of logistics nodes, distribution

networks and circulation links, providing an external data basis for enterprises to obtain order, inventory, logistics and market demand information; The supply chain innovation and application pilot policy promotes information connectivity and business collaboration among supply chain entities through the construction of supply chain platforms, the application of digital technologies, and data sharing between upstream and downstream. As a result, the dual pilot policy will enable enterprises to shift their supply chain management from traditional experience-driven to data-driven, and enhance their real-time perception of demand changes, inventory fluctuations, logistics status and supply chain anomalies. Research has shown that digital supply chain management can drive supply chain systems to evolve towards connectivity, data, and agility (Tiwari et al., 2024).And enhance enterprise supply chain resilience by improving information transparency, risk identification capabilities, and collaborative response speed (Zhao et al., 2023). Meanwhile, procurement digitalization and data analysis capabilities can also improve supply chain performance, providing a technical basis for enterprises to enhance supply chain response efficiency and resilience levels (Hallikas et al., 2021). Therefore, an increase in the degree of supply chain digitalization helps enterprises identify external disturbances more promptly, adjust procurement and inventory arrangements, optimize logistics distribution and upstream-downstream collaboration, thereby enhancing the stability and resilience of the supply chain in the face of external shocks. Based on this, the following hypotheses are made:

H2a: The dual-pilot policy enhances supply chain resilience by increasing the degree of digitalization of the supply chain.

## 2.2.2 Supply chain risk level mechanism

Supply chain risk level reflects the extent of uncertainty and potential loss faced by enterprises in the processes of raw material procurement, production organization, logistics transportation, order delivery and upstream and downstream cooperation. The higher the risk level, the more vulnerable the enterprise supply chain is to external shocks and disruption transmission (Hosseini et al., 2019). The dual pilot policy can jointly reduce supply chain risks through the improvement of the external circulation system and the enhancement of internal supply chain synergy. On the one hand, the construction of commercial and logistics node cities can reduce transportation delays, delivery uncertainties and regional circulation frictions by improving the layout of logistics nodes, regional distribution networks and urban distribution systems, and enhance the alternative distribution and supply guarantee capabilities of enterprises in the event of demand fluctuations or local supply disruptions (Jia et al., 2025; Song et al., 2022).On the other hand, supply chain innovation and application pilot policies, through platform building, information sharing and upstream-downstream collaboration, help enhance enterprises' ability to identify and warn of order changes, inventory anomalies and logistics fluctuations, and reduce the possibility of supply-demand mismatch, inventory overstock and risk diffusion. When supply chain risks are reduced, enterprises will be able to complete resource scheduling and operational adjustments more quickly in the face of external shocks, reducing problems such as supply disruptions, rising costs and unstable customer relationships. Operational flexibility and risk response capabilities can help enterprises maintain stable operating performance during major supply chain disruptions (Shi et al., 2025), and

supply chain visibility can also enhance enterprise risk identification and response capabilities by reducing uncertainty (Kalaiarasan et al., 2022). As a result, the dual-pilot policy may enhance the resilience to shocks and recovery and adjustment capabilities of enterprises by reducing the level of supply chain risk. Based on this, the following hypotheses are made:

H2b: The dual-pilot policy enhances supply chain resilience by reducing supply chain risk levels.

## 2.2.3. Information disclosure quality mechanism

The quality of information disclosure reflects the authenticity, timeliness and sufficiency of business conditions, financial information and risk information that enterprises convey to external investors, suppliers, customers and other stakeholders. It is an important foundation for alleviating information asymmetry, stabilizing market expectations and improving corporate governance (Zhang et al., 2023). In supply chain relationships, the higher the quality of information disclosure by enterprises, the easier it is for supply chain partners to identify the operational stability, performance capacity and potential risks of enterprises, thereby reducing transaction uncertainty and cooperation frictions. By promoting the improvement of the commercial circulation network, the construction of supply chain platforms and the sharing of upstream and downstream data, the dual pilot policy can facilitate the more standardized generation and transmission of business operation information, logistics information and supply chain collaboration information, thereby improving the quality of enterprise information disclosure. Industry-specific information disclosure regulation can alleviate the supply chain bullwhip effect by improving accounting information quality, improving corporate governance and reducing environmental uncertainty, indicating that information disclosure quality plays an important role in supply chain coordination (Zheng & Zou, 2025); The distortion of information during supply chain transmission and uncertainty in demand forecasting can exacerbate order fluctuations and trigger the bullwhip effect (Saoud et al., 2025); Higher levels of information disclosure can improve the efficiency of information transmission and coordination among supply chain members, thereby alleviating the bullwhip effect and enhancing supply chain operational efficiency (Bray & Mendelson, 2012). Therefore, after the dual pilot policy improves the quality of enterprise information disclosure, it can reduce information asymmetry among supply chain partners, enhance the ability of upstream and downstream entities to judge the business status and risk situation of enterprises, reduce demand misjudgment, cooperation disruption and risk transmission, and thereby enhance the collaborative governance capacity and resilience of enterprise supply chains. Based on this, the following hypotheses are made:

H2c: The dual pilot policy enhances supply chain resilience by improving the quality of corporate information disclosure.

## 2.2.4 Enterprise innovation efficiency mechanism

Enterprise innovation efficiency reflects the ability of an enterprise to convert R&D investment, knowledge resources and technological resources into innovation output, and is an important manifestation of enterprise process optimization, technological upgrading and organizational restructuring (Griffin et al., 2018). Higher innovation efficiency not only helps enterprises improve

production and operational efficiency, but also enhances their adaptability and resilience in response to changes in the external environment. The dual pilot policy can enhance the innovation efficiency of enterprises by optimizing external circulation conditions and strengthening internal supply chain synergy. On the one hand, the construction of commercial and logistics node cities improves the connection conditions between enterprises and suppliers, customers and regional markets, reduces transaction and circulation costs in the process of innovation transformation, and provides a better external environment for enterprises to promote new products, improve processes and respond to the market. On the other hand, the supply chain innovation and application pilot policy promotes resource sharing, knowledge exchange and joint improvement between enterprises and supply chain partners through platform building, digital application and upstream and downstream collaboration. Supply chain integration can facilitate resource sharing and knowledge collaboration among upstream and downstream entities, thereby promoting enterprise innovation activities and improving business performance (Junaid et al., 2022); Reasonable policy incentives can also enhance the input-output efficiency and quality of innovation (J. Lin et al., 2021). When innovation efficiency is enhanced, enterprises can respond more quickly to supply chain shocks through technological improvements, process optimizations, and organizational adjustments, and enhance supply chain recovery and reconfiguration capabilities. Supplier relationships and external resource dependencies can also affect a company's digital innovation capabilities and, in turn, its ability to adapt to external changes(S. Lin & Deng, 2024). Therefore, the dual pilot policy may enhance the resilience and capacity reconfiguration of enterprises after external shocks by improving their innovation efficiency. Based on this, the following hypotheses are made:

H2d: The dual pilot policy enhances the resilience of enterprise supply chains by improving enterprise innovation efficiency

## 3 Research Design

# 3.1 Sample selection and data sources

This paper takes Chinese A-share listed firms on the Shanghai and Shenzhen stock exchanges from 2012 to 2024 as the research sample. In terms of data sources, the core mainly comes from databases such as CSMAR, Wind, annual reports of listed companies, and supply chain relationship disclosure information; And policy documents publicly released by government departments such as the Ministry of Finance and the Ministry of Commerce. In terms of sample processing, the initial samples were processed to exclude financial, ST, *ST and PT listed companies; Continuous variables are winsorized at the 1% and 99% levels; Exclude samples with missing core variables; For a small number of missing city-level control variables, linear interpolation is used to supplement them, and the interpolation samples are excluded in the robustness test for verification. After the above processing, the final benchmark regression sample size was 32,208 company-year observations.

# 3.2 Variable Definitions

### 3.2.1 The explained variable

Supply Chain Resilience (SCR) Supply chain resilience reflects the ability of an enterprise's supply chain system to maintain stable operation, absorb risk disturbances and achieve recovery and adjustment in the face of external shocks. Referring to the research in (Qi et al., 2024), this paper constructs an indicator system of enterprise supply chain resilience from two dimensions: supply chain resistance and supply chain resilience. Indicators such as the ratio of accounts receivable to operating income, continuous cooperation with the top five customers, and inventory turnover rate are selected for positive and standardized processing of each indicator first. The entropy method is used to determine the weights of the indicators, and the supply chain resilience index is obtained by weighting.

### 3.2.2 Core explanatory variables

This paper focuses on the superimposed synergy of the two types of policies, incorporating policies for the construction of commercial and logistics node cities and pilot policies for supply chain innovation and application into a unified analytical framework. Among them, the policy on the construction of commercial and logistics node cities was released in 2017, and the policy on the pilot of supply chain innovation and application was released in 2018. Considering the time point when both types of policies start to have a substantial impact on the operation of the enterprise supply chain, this paper sets the policy start year as 2018. If the city where the enterprise is located is both a commercial and logistics node city and a pilot city for supply chain innovation and application, the diff of the enterprise for 2018 and subsequent years is assigned a value of 1; otherwise, it is assigned a value of 0.

### 3.2.3 Control variables

To estimate policy effects more accurately, introduce the following control variables in the model that may affect supply chain resilience: Equity concentration (Top1), measured by the shareholding ratio of the largest shareholder; Enterprise growth (TobinQ), measured by the TobinQ value; Profitability (Roa), measured by return on total assets; Size, measured by the natural logarithm of total assets of the enterprise; Debt-to-asset ratio (Lev), measured by the ratio of total liabilities to total assets; Property rights nature (Soe) is assigned a value of 1 if the enterprise is state-owned and 0 otherwise; Fiscal investment intensity (Inv), that is, the ratio of fixed asset investment to general government fiscal expenditure.

## 3.3 Model Settings

Based on the policies for the construction of commercial and logistics node cities and the pilot policies for supply chain innovation and application, this paper constructs a compound quasi-natural experiment of the dual pilot policies. To identify the impact of the dual pilot policy on the resilience of enterprise supply chains, this paper uses a double machine learning model for estimation. Compared with traditional linear regression models, double machine learning models can flexibly fit the possible nonlinear relationships between control variables and explained variables and core explanatory variables with the help of machine learning algorithms, and reduce model setting bias and control variable

selection bias through orthogonalization. To more robustably identify the net effect of the dual-pilot policy on supply chain resilience (Chernozhukov et al., 2018). This paper sets up the following partial linear double machine learning model:

$$\mathrm{SCR}_{\mathrm{it}}=\theta_0 \mathrm{diff}_{\mathrm{it}}+\mathrm{g}(\mathrm{X}_{\mathrm{it}})+\mathrm{U}_{\mathrm{it}}(1)$$

$$\mathrm{E}[\mathrm{U}_{\mathrm{it}}|\mathrm{X}_{\mathrm{it}},\mathrm{diff}_{\mathrm{it}}]=0(2)$$

$$\mathrm{diff}_{\mathrm{it}}=\mathrm{f}(\mathrm{X}_{\mathrm{it}})+\mathrm{V}_{\mathrm{it}},\mathrm{E}[\mathrm{V}_{\mathrm{it}}|\mathrm{X}_{\mathrm{it}}]=0(3)$$

Where i represents the enterprise and t represents the year; SCR stands for supply chain resilience of enterprises; diff is a dual-pilot policy variable; X is the set of control variables; g(X) and f(X) represent the non-parametric impact functions of the control variables on supply chain resilience and dual-pilot policy variables, respectively; U and V are random disruption terms; θ is the policy effect parameter that this paper focuses on.

In the specific estimation process, this paper uses the cross-fitting method to divide the samples into training samples and estimation samples, uses random forests to fit the nonlinear effects of control variables on enterprise supply chain resilience and dual-pilot policy variables respectively, and estimates the policy effects based on the residual variables. To control for unobserved heterogeneity of enterprises and macro-time shocks, the model further incorporates enterprise fixed effects and year fixed effects. The estimation results depend on specific sample partitioning or algorithm selection by adjusting the sample segmentation ratio and changing the machine learning algorithm.

## 4 Empirical Analysis

# 4.1 Descriptive Statistics

Table 1 reports the descriptive statistics of the main variables. The mean of enterprise supply chain resilience (SCR) was 0.465, and the standard deviation was 0.122, indicating some differences in supply chain resilience levels among the sample enterprises. The mean of the dual pilot policy variable (diff) was 0.384, indicating that approximately 38.4% of the company - annual sample was affected by the superimposed impact of the trade logistics node city construction policy and the supply chain innovation and application pilot policy, with good discrimination between the treatment group and the control group. In terms of mechanism variables, the average value of supply chain digitalization (digit) was 0.062, indicating that there is still room for improvement in the digitalization level of enterprise supply chains; The average level of supply chain risk (sc_risk) was 0.758, with a large standard deviation, indicating significant differences in supply chain risk exposure among enterprises; The mean values of information disclosure quality (KV) and enterprise innovation efficiency (InnoEff1) were 0.516 and 0.154 respectively, reflecting that there was also a certain degree of differentiation among sample enterprises in terms of information transparency and innovation transformation capabilities. Overall, the distribution of the main

variable values was reasonable, in line with the actual characteristics of A-share listed companies, providing A good data basis for the subsequent empirical analysis.

Table 1
Descriptive Statistics

| Variable Types | Variable names and symbols | Observations | Mean | Standard deviation | Minimum value | Maximum |
|---|---|---|---|---|---|---|
| Core explanatory variables | Dual-pilot Policy (diff) | 32208 | .3841592 | .4864034 | 0 | 1 |
| Explained variable | Supply Chain Resilience (SCR) | 32208 | .4653471 | .1224527 | .1476285 | .759263 |
| Control variables | Equity concentration (Top1) | 32208 | .3326242 | .1459768 | .074872 | .757854 |
| | Corporate growth (TobinQ) | 32208 | 1.983259 | 1.309347 | .794597 | 17.67593 |
| | Profitability (ROA) | 32208 | .0279323 | .0658041 | − .5562487 | .2223428 |
| | Business Size | 32208 | 22.37406 | 1.283338 | 19.52454 | 26.45228 |
| | Debt-to-asset ratio (Lev) | 32208 | .4391764 | .2003249 | .0381211 | .910388 |
| | Property Rights Nature (SOE | 32208 | .3247951 | .4683055 | 0 | 1 |
| | Financial investment intensity (Inv) | 32208 | .1375772 | .1259627 | 0 | .7733767 |
| Mechanism variables | Supply chain risk level (sc_risk) | 32208 | .7575241 | .3783956 | .0202036 | 25.71596 |
| | Enterprise Innovation efficiency (InnoEff1) | 32208 | .154134 | .0909153 | 0 | .4410994 |
| | Degree of supply chain digitalization (digit) | 32180 | .061561 | .1305635 | 0 | 2.703929 |
| | Corporate information disclosure quality (KV) | 32062 | .5162109 | .2006379 | .0010756 | 2.032672 |

# 4.2 Benchmark Regression

To test the impact of the dual pilot policy on enterprise supply chain resilience, this paper takes enterprise supply chain resilience (SCR) as the explained variable and the dual pilot policy variable (diff) as the core explanatory variable, and is incorporated into a partial linear double machine learning model for estimation. Based on the previous model settings, this paper performs sample segmentation at a ratio of 1:4 and uses the random forest algorithm to evaluate the effects of the primary regression equation and the auxiliary regression equation respectively.

Table 2 reports the benchmark regression results of the dual pilot policy on the resilience of the enterprise supply chain. Column (1) Uncontrolled enterprise and year fixed effects, column (2) further controlled enterprise and year fixed effects. The results show that the estimated coefficients of the dual pilot policy variable (diff) are both significantly positive, indicating that the joint implementation of the trade logistics node city construction policy and the supply chain innovation and application pilot policy can significantly enhance the resilience of the enterprise supply chain. As a result, hypothesis H1 is validated.

Table 2
Benchmark Regression Results

| **Variables** | **(1)** | **(2)** |
|---|---|---|
| | **SCR** | **SCR** |
| Dual Pilot Policy (diff) | 0.0177 * * * | 0.0125 * * * |
| | (0.00143) | (0.00180) |
| Machine learning models | Random Forest | Random Forest |
| Control variables | Control | Control |
| Industry/time fixed effects | No | Yes |
| Sample segmentation ratio | 1:4 | 1:4 |
| Observations | 32,208 | 32,208 |
| Note: *p < 0.05, **p < 0.01, ***p < 0.001. The values in parentheses are standard errors. | | |

# 4.3 Robustness test

# 4.3.1 Parallel trend test

To test whether the treatment group and the control group met the parallel trend hypothesis before policy implementation, this paper draws on the common practice of the event study method (Autor, 2003; Sun & Abraham, 2021)with 2018 as the policy implementation base year, construct multiple dummy variables before and after policy implementation, and control for enterprise characteristics, industry fixed effects, and year fixed effects. Figure 1 reports the results of the parallel trend test. From

the pre-policy estimates, the estimated coefficients corresponding to pre_5, pre_4, pre_3, and pre_2 fluctuated around 0 overall, with confidence intervals basically covering 0, and did not show a sustained upward or downward trend, indicating that there were no significant systemic differences between the treatment group and the control group before policy implementation, and the parallel trend hypothesis was basically satisfied. From the dynamic effect after the implementation of the policy, the estimated coefficients from post_1 to post_5 turned positive overall, indicating that the supply chain resilience of enterprises showed an increasing trend after the implementation of the dual pilot policy.

## 4.3.2 Placebo test

To further eliminate the interference of random factors, omitted variables, or unobservable shocks on the baseline results, this paper uses a placebo test based on random permutation of treatment variables. While keeping the sample structure, control variables, and fixed effects by industry and year unchanged, the double-pilot policy variable (diff) was randomly replaced and the estimates were repeated 500 times, with the policy effect estimates recorded after each random replacement. If the baseline results are mainly driven by random factors, the estimated coefficients after random replacement may also show systemically significant characteristics; Conversely, if the random estimated coefficients are concentrated around 0 and the real policy effect deviates significantly from the random distribution, it indicates that the benchmark conclusion is highly credible.

Figure 2 reports the results of the placebo test. The estimated coefficients derived from the random replacement are mainly concentrated around 0, with a mean of about 0.000016 and a standard deviation of about 0.00133 for the fitted distribution, indicating that the random policy shock did not have a systemic impact on the resilience of the enterprise supply chain. At the same time, the real policy effect is located in the right side of the random estimated distribution, which is significantly different from the random replacement results. This indicates that the promoting effect of the dual-pilot policy on the resilience of the enterprise supply chain is not driven by random grouping, accidental factors, or unobserved shocks, and the benchmark regression results are relatively robust.

## 4.3.3 PSM-DID test

To further alleviate the sample selection bias that may result from differences in enterprise characteristics between the treatment group and the control group, this paper uses the PSM-DID method combining propensity score matching and difference-in-differences for the robustness test. The results in Table 3 show that the estimated coefficient of the dual pilot policy variable (diff) is 0.00518 and is significantly positive at the 5% level, indicating that the dual pilot policy can still significantly enhance the resilience of the enterprise supply chain after reducing the differences in observable characteristics of enterprises between the treatment group and the control group through propensity score matching. The coefficients of the control variables are significantly positive at the 10% level, indicating that corporate governance structure, growth characteristics, profitability, and property rights attributes all have an impact on corporate supply chain resilience. The sample size after matching was 16,354 observations, and the model goodness-of-fit was 0.089, indicating that there were still sufficient valid samples retained

after sample matching. The results suggest that the promotion of supply chain resilience by the dual-pilot policy in the benchmark regression was not driven by systematic differences in initial characteristics between the treatment group and the control group.

Table 3
Results of the PSM-DID test

| **Variables** | **SCR** |
|---|---|
| Dual Pilot Policy (diff) | 0.00518 * * |
| | (0.00246) |
| Control variable | Control |
| Industry/year fixed effects | yes |
| Observations | 16,354 |
| Adjusted R-squared | 0.089 |
| Note: *p < 0.05, **p < 0.01, ***p < 0.001, and the values in parentheses are standard errors. | |

# 4.3.4 Other robustness tests

(1) Change the sample segmentation ratio

Estimates from double machine learning models may be influenced by the sample segmentation ratio. To verify the robustness of the results, this paper further adjusted the sample segmentation ratio of the double machine learning model, changing the baseline 1:4 to 1:2 and 1:6 respectively for re-estimation. The empirical results are shown in columns (1) to (2) of Table 4. The coefficients of the core explanatory variables are significantly positive, and the research conclusion remains robust.

(2) Replace the machine learning model

To avoid the benchmark results being influenced by the specific machine learning model selection, this paper further replaces the random forest model in the double machine learning model with lasso regression and elastic network regression respectively. The results in columns (3) to (4) of Table 4 show that even with the change of machine learning algorithms, the impact of the dual-pilot policy on the resilience of enterprise supply chains remains significantly positive, indicating that the conclusions of this paper are not driven by specific algorithm Settings.

(3) Excluding disruptions caused by the pandemic

Taking into account the impact of public emergencies in 2020, in order to eliminate the interference of special year shocks, this paper re-estimates after excluding the 2020 sample. The results in column (5) of Table 4 show that after excluding 2020, the results remain significant. The promoting effect of the

dual pilot policy on the resilience of enterprise supply chains is not driven by the special shock year of 2020, and the regression results remain robust.

(4) Exclude other policy disruptions

The creation of e-commerce demonstration cities, initiated in 2011, aims to improve the e-commerce development environment, strengthen information infrastructure construction and promote the integration of e-commerce with the circulation system. As the policy may affect the resilience of enterprises' supply chains by improving digital infrastructure, enhancing logistics and distribution efficiency, and promoting the synergy of online and offline circulation, if sample enterprises are affected by the policy at the same time, it may interfere with the identification of the policy effect of the dual pilot. Based on this, in order to further mitigate the possible effects of other similar policies, this paper re-estimates after excluding the e-commerce demonstration city sample. The results in column (6) of Table 4 show that the estimated coefficient of the dual-pilot policy remains significantly positive, indicating that the conclusions of this paper are not driven by similar policies such as the e-commerce demonstration city policy, further verifying the robustness of the benchmark results.

Table 4
Other Robustness Tests

| **Variables** | **Change the sample split ratio** | | **Change the machine learning model** | **Eliminate pandemic disruptions** | **Rule out other policy disruptions** | |
|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
| Dual Pilot Policy (diff) | 0.0113 * * * | 0.0125 * * * | 0.00575 * * * | 0.00574 * * * | 0.00555 * * * | 0.0250 * * * |
| | (0.00177) | (0.00180) | (0.00174) | (0.00174) | (0.00183) | (0.00482) |
| Machine learning models | Random Forest | Random Forest | Lasso regression | Elastic network regression | Random forest | Random Forest |
| Control variables | Control | Control | Control | Control | Control | Control |
| Industry/year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample segmentation ratio | 1:2 | 1:6 | 1:4 | 1:4 | 1:4 | 1:4 |
| Observations | 32208 | 32208 | 32208 | 32208 | 30155 | 18153 |
| Note: Note: *p < 0.05, **p < 0.01, ***p < 0.001. The values in parentheses are standard errors. | | | | | | |

# 4.4 Endogeneity treatment

To ensure the rigor of the research conclusions, this paper further considers the potential endogeneity between the dual pilot policy and the resilience of the enterprise supply chain. On the one hand, the implementation of trade logistics node city construction policies and supply chain innovation and application pilot policies may not be completely random. The digital infrastructure, geographical location, circulation network and industrial foundation of the city itself may simultaneously affect the choice of policy pilot and the resilience of enterprise supply chains; On the other hand, enterprise supply chain resilience may also be affected by some hard-to-observe regional environment and enterprise characteristics, resulting in omitted variable bias. To alleviate this problem, this paper draws on the idea of (Jiang & Qi, 2025), selects the interaction term between urban terrain undulation and the logarithm of the number of national Internet broadband access ports in the previous year as the instrumental variable for the dual pilot policy, and constructs a partial linear instrumental variable model based on double machine learning for verification. The specific model settings are as follows:

$$\mathrm{SCR}_{\mathrm{it}}=\theta_0\mathrm{diff}_{\mathrm{it}}+\mathrm{g}(\mathrm{X}_{\mathrm{it}})+\mathrm{U}_{\mathrm{it}}(4)$$

$$\mathrm{IV}_{\mathrm{ct}}=\mathrm{m}(\mathrm{X}_{\mathrm{it}})+\mathrm{V}_{\mathrm{it}}(5)$$

Here, $SCR_{it}$ represents the supply chain resilience of enterprise i in year t, $diff_{it}$ represents the dual-pilot policy variable, $X_{it}$ is the set of control variables, $IV_{ct}$ is the instrumental variable, and $g(X_{it})$ and $m(X_{it})$ represent the non-parametric influence functions of the control variable on the explained variable and the instrumental variable, respectively.

The reasonableness of the instrumental variable is mainly reflected in two aspects: correlation and exogeneity. In terms of correlation, the undulation of urban terrain affects the cost of digital infrastructure construction, the layout of logistics networks, and the completeness of the commercial circulation system, thereby affecting the ability of cities to undertake the dual pilot policy (Nunn & Puga, 2012); Meanwhile, the number of Internet broadband access ports across the country in the previous year can reflect the temporal trend of the development of digital infrastructure across the country, and when interacting with terrain undulation, it can introduce temporal changes to relatively stable geographical variables (Falck et al., 2014). From an exogenous perspective, terrain undulation is a natural geographical feature, while the number of Internet broadband access ports in the previous year is a macro variable at the national level, and it is difficult for a single enterprise to have an impact on it. Therefore, after controlling for the characteristics of enterprises and the fixed effects of enterprises and years, this interaction term is unlikely to directly affect the resilience of enterprise supply chains, and its role is more likely to be played through the capacity of dual pilot policies and the construction of digital circulation systems.

Table 5 reports the results of the instrumental variable test. After using the interaction term as an instrumental variable, the estimated coefficient of the dual pilot policy variable (diff) was 0.0609, which was significantly positive at the 5% level, indicating that the dual pilot policy can still significantly enhance the resilience of enterprise supply chains after alleviating potential endogenous biases.

Table 5
Endogeneity Test

| **Dual Pilot Policy (diff)** | **SCR** |
|---|---|
| | **0.0609 * *** |
| | **(0.0256)** |
| Constant term | 0.000310 |
| | (0.000618) |
| Machine learning models | Random Forest |
| Control variables | Control |
| Industry/year fixed effects | Yes |
| Sample segmentation ratio | 1:4 |
| Observations | 32155 |

**Note:** Note: *p < 0.05, **p < 0.01, ***p < 0.001. The values in parentheses are standard errors.

# 5 Further Analysis

# 5.1 Mechanism Testing

To further reveal the internal path by which the dual-pilot policy affects the resilience of enterprise supply chains, this paper, based on the theoretical analysis in the previous text, conducts mechanism tests from both the supply chain level and the enterprise level. At the supply chain level, it includes the degree of supply chain digitalization (digit) and supply chain risk level (sc_risk), and at the enterprise level, it includes the quality of enterprise information disclosure (KV) and the efficiency of enterprise innovation (InnoEff1).

In terms of mechanism variable measurement, supply chain digitalization draws on (Guo & Kuang, 2025)research ideas on text measurement of supply chain digitalization, using text analysis for measurement, that is, on the basis of word segmentation processing of annual reports of listed companies, the number of occurrences of keywords related to supply chain digitalization is counted, The indicator was obtained by dividing it by the total number of words in the annual report. Supply chain risk levels draw on the research of (Saoud et al., 2025)to measure the amplification of production fluctuations relative to demand fluctuations, specifically calculated by the ratio of the quarterly standard deviation of enterprise production volume to the quarterly standard deviation of enterprise demand volume. Enterprise information disclosure quality reference (Zhang et al., 2023)on the measurement of market information quality, the KV index based on the relationship between stock price changes and trading volume is used for measurement, and information disclosure quality indicators are constructed based on the relevant regression residuals. Enterprise innovation efficiency reference (Griffin et al.,

2018), measured by the ratio of innovation output to R&D investment, specifically calculated by the ratio of the number of patent applications to R&D expenditure, namely Patent1/ln (1 + R&D expenditure). To validate the hypothesis, the following econometric model is constructed:

$$JZ_{it}=\theta_0 diff_{it}+g(X_{it})+U_{it}||E(U_{it}|X_{it}，diff_{it})=0\#(6)$$

Auxiliary regression:

$$diff_{it}=m(X_{it})+V_{it}||E(V_{it}|X_{it})=0\#(7)$$

Where JZit is the mechanism variable and diffit is the double-pilot policy variable; Xit is the set of control variables; μi and λt represent individual fixed effects and year fixed effects, respectively; εit is the random perturbation term.

(1) Supply chain level mechanism. Columns (1)–(2) in Table 6 show the regression results of the supply chain-level mechanisms. The results show that the dual pilot policy significantly enhanced the digitalization of enterprise supply chains and significantly reduced supply chain risk levels. On the one hand, the trade logistics node city construction policy provides external support for enterprises to obtain order, inventory, logistics and market demand information by promoting the digitalization of circulation networks, the intelligence of distribution systems and the synergy of trade entities; The supply chain innovation and application pilot policy enhances the ability of enterprises to identify and respond to abnormal fluctuations in the supply chain through platform building and information sharing between upstream and downstream. On the other hand, the dual pilot policy reduces uncertainties in logistics transportation, inventory turnover and order delivery by improving the urban and rural commercial circulation network, enhancing distribution efficiency and strengthening circulation supply guarantee capacity. As a result, the dual pilot policy not only enhances the visibility of enterprise supply chain information and the efficiency of collaborative response, but also reduces the level of supply chain risk exposure, enabling enterprises to have a stronger ability to operate stably and recover and adjust under external shocks. To sum up, hypotheses H2a and H2b have been validated.

(2) Enterprise-level mechanisms. The regression results of enterprise-level mechanisms are presented in columns (3)–(4) of Table 6. The results show that the dual pilot policy has significantly improved the quality of corporate information disclosure and corporate innovation efficiency. In terms of information governance, the dual pilot policy, by promoting the construction of supply chain platforms, data sharing and transparency of circulation systems, prompts enterprises to disclose business information and supply chain-related information in a more standardized manner, thereby alleviating information asymmetry among supply chain partners and reducing demand misjudgment and risk transmission. In terms of innovation transformation, the policy on the construction of commercial and logistics node cities has improved external market connections and circulation conditions for enterprises, providing a better market environment for the transformation of innovation achievements; The supply chain innovation and application pilot policy promotes process and organizational innovation in procurement, production, logistics and sales through digitalization, platformization and collaboration. As a result, the

dual pilot policy not only improves the transparency of enterprise information, but also enhances the ability of enterprise resource reconstruction and recovery adjustment, enabling enterprises to respond more effectively to supply chain shocks. To sum up, the hypotheses H2c and H2d have been validated.

Table 6
Mechanism Test Results

| **Levels of action** | **Supply chain** | | **Enterprises** | |
|---|---|---|---|---|
| Variables | (1) | (2) | (3) | (4) |
| | Degree of digitalization of supply chains | Supply chain risk level | Quality of information disclosure | Innovation Efficiency |
| Dual Pilot Policy (diff) | 0.0194 * * * | -0.0166 * * * | 0.0208 * * * | 0.0096 * * * |
| | (10.828) | (-2.806) | (7.471) | (9.352) |
| Machine learning models | Random Forest | Random Forest | Random Forest | Random Forest |
| Control variables | Control | Control | Control | Control |
| Industry/year fixed effects | Yes | Yes | Yes | Yes |
| Sample segmentation ratio | 1:4 | 1:4 | 1:4 | 1:4 |
| Observations | 32180 | 32208 | 32062 | 32208 |
| Note: *p < 0.05, **p < 0.01, ***p < 0.001. The t-statistic is in parentheses. | | | | |

# 5.2 Heterogeneity Analysis

The previous regression indicates that the dual pilot policy can significantly enhance the resilience of the enterprise supply chain. Given the differences in the industry attributes of enterprises, regional market environments and factor input structures, the policy effects may not be homogeneous. Based on this, this paper conducts heterogeneity tests from three aspects: the attributes of polluting industries, the degree of regional marketization, and the factor input structure of enterprises.

(1) Industry pollution attributes. In this paper, referring to the classification standards of the environmental regulatory authorities for heavily polluting industries and in combination with the industry classification information of listed companies, enterprises belonging to heavily polluting industries are classified as polluting enterprises and assigned a value of 1; The rest of the enterprises are classified as non-polluting enterprises and assigned a value of 0. The results in columns (1)–(2) of Table 7 show that the effect of the dual pilot policy on enhancing supply chain resilience is mainly reflected in non-polluting enterprises. The possible reason is that enterprises in polluting industries typically face higher compliance costs and stronger production adjustment constraints, and their efficiency in absorbing

policy dividends may be somewhat limited (Huang et al., 2026).Therefore, compared with polluting enterprises, non-polluting enterprises are more flexible in production organization and supply chain adjustment, and are more likely to translate the improvements in circulation efficiency and supply chain synergy brought about by the dual pilot policy into improvements in supply chain resilience.

(2) Degree of regional marketization. In this paper, provinces are classified into regions with high and low levels of marketization based on the median of all provinces in the country in the current year. A company is assigned a value of 1 if it is located in a region with a high level of marketization, and 0 if it is located in a region with a low level of marketization. The results in columns (3) to (4) of Table 7 show that the resilience enhancement effect of the dual pilot policy is more significant in high-marketization regions. The possible reason is that in highly marketized regions, factor flows are smoother, transaction costs are lower, resource allocation efficiency is higher, and the improvement of the commercial logistics system and the application of supply chain innovation are more likely to translate into the improvement of enterprise supply chain resilience through the improvement of circulation efficiency, platform construction and data sharing.

(3) Factor intensity. Based on the factor input characteristics of the industry to which the enterprise belongs, enterprises in industries with a higher degree of dependence on technology input, R&D intensity and knowledge capital are classified as technology-intensive enterprises and assigned a value of 1; Enterprises that mainly rely on labor input and have a relatively low level of technology capital are classified as labor-intensive enterprises and assigned a value of 0. The results in columns (5)–(6) of Table 7 show that the dual pilot policy has a more prominent promoting effect on the resilience of enterprise supply chains in technology-intensive enterprises. The possible reason is that technology-intensive enterprises have stronger data processing, technology absorption and organizational adjustment capabilities, which can help enterprises maintain inventory, employment and stable operating performance during major supply chain shocks (Shi et al., 2025).More quickly translate the improvement of the external circulation environment and the enhancement of internal supply chain synergy into risk response and recovery reconstruction capabilities.

Table 7
Heterogeneity Analysis

| Variables | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Polluting enterprises | Non-polluting enterprises | Low-market areas | Highly marketized regions | Technology-intensive | Labor-intensive |
| Dual Pilot Policy (diff) | 0.0034<br>(0.862) | 0.0134 * * *<br>(6.400) | 0.00730<br>(0.00475) | 0.0107 * * *<br>(5.424) | 0.0190 * * *<br>(7.461) | 0.0039<br>(1.153) |
| Machine learning models | Random Forest | Random Forest | Random Forest | Random Forest | Random Forest | Random Forest |
| Control variables | Control | Control | Control | Control | Control | Control |
| Industry/year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample segmentation ratio | 1:4 | 1:4 | 1:4 | 1:4 | 1:4 | 1:4 |
| Observations | 7,279 | 24,754 | 4,775 | 27,433 | 15,347 | 10,544 |

Note: Note: *p < 0.05, **p < 0.01, ***p < 0.001. The t-statistic is in parentheses.

## 6 Research Conclusions and Policy Implications

# 6.1 Research Conclusions

Based on the policy context of the coordinated advancement of the improvement of the commercial and trade logistics system and the innovative application of supply chains, this paper incorporates the policies for the construction of commercial and trade logistics node cities and the pilot policies for supply chain innovation and application into A unified analytical framework. Using the data of Chinese A-share listed firms on the Shanghai and Shenzhen stock exchanges from 2012 to 2024, a quasi-natural experiment of the dual pilot policies was constructed, and a double machine learning model was adopted. To analyze and test the impact of the dual pilot policy on the resilience of enterprises' supply chains. The main conclusions of the study are: First, the dual pilot policy can significantly enhance the resilience of the enterprise supply chain. The trade and logistics node city policy improves the external environment for the operation of enterprise supply chains by improving the urban and rural circulation network, enhancing distribution efficiency and strengthening supply guarantee capacity; The supply chain innovation and application pilot policy strengthens the supply chain governance capacity of enterprises by promoting the construction of supply chain platforms, information sharing and upstream

and downstream collaboration. When combined, they create a joint policy effect of "improved external circulation system - enhanced internal supply chain synergy - improved enterprise supply chain resilience". Second, the dual pilot policy enhances the resilience of enterprise supply chains through multiple mechanisms at both the supply chain level and the enterprise level. At the supply chain level, the dual pilot policy enhances the visibility of supply chain information, risk identification capabilities and collaborative response efficiency of enterprises by increasing the digitalization of supply chains and reducing supply chain risk levels; At the enterprise level, the dual pilot policy improves enterprise information governance and recovery and reconstruction capabilities by enhancing the quality of enterprise information disclosure and the efficiency of enterprise innovation. Thirdly, heterogeneity analysis results show that the dual pilot policy does not have exactly the same impact on all enterprises, and its policy effect is jointly influenced by the pollution attributes of enterprises, the regional market environment and the technical characteristics of industries. This suggests that in the process of promoting the improvement of the commercial logistics system and the application of supply chain innovation, differentiated policy arrangements should be implemented based on different enterprise types, regional market environments and industry characteristics to improve the efficiency of policy resource allocation and the effect of supply chain resilience improvement. In summary, the coordinated advancement of policies for the construction of commercial and logistics node cities and pilot policies for supply chain innovation and application can enhance the risk-resistance capacity, stable operation capacity and recovery and adjustment capacity of enterprises in an uncertain environment, and provide micro-empirical evidence for improving the modern circulation system and enhancing the resilience and security level of industrial and supply chains.

## 6.2 Policy Implications

First, strengthen the coordinated advancement of the construction of commercial and logistics node cities and the innovative application of supply chains. Government departments should enhance coordination in terms of policy goals, pilot layout, financial support and performance evaluation to promote the linkage between the construction of commercial and logistics node cities and the pilot application of supply chain innovation. They should not only improve the layout of logistics nodes, urban distribution networks and urban-rural integrated logistics systems, but also promote the construction of supply chain platforms, information sharing and upstream and downstream collaborative governance. To amplify the combined effect of policies.

Second, focus on the key paths through which policies work and enhance the digital supply chain, risk governance, and innovation reconstruction capabilities of enterprises. The government should encourage pilot cities to improve data sharing systems in areas such as logistics distribution, order processing, inventory management and emergency supply guarantee, and enhance supply chain information visibility and risk early warning capabilities. Enterprises should also use the dual pilot policy as an opportunity to strengthen dynamic monitoring of supplier delivery, customer demand, inventory fluctuations and logistics status, establish alternative suppliers, flexible inventory and emergency

delivery solutions, and transform risk response experience into institutionalized capabilities through process optimization and organizational innovation.

Third, push enterprises to shift from passive risk response to proactive resilient governance. Supply chain resilience is not only reflected in the ability to recover after a crisis, but also in the ability to identify risks before a crisis and respond quickly during a crisis. Therefore, enterprises should build a supply chain resilience governance system around "early warning - response - recovery" : Strengthen risk identification and early warning in advance, improve resource scheduling and emergency coordination capabilities in the middle of the event, and optimize procurement, production, logistics and sales processes through post-event review, thereby transforming external policy support into supply chain resilience advantages of stable operation, rapid recovery and continuous adaptation.

## 6.3 Shortcomings and Prospects

This article still has some shortcomings. First, in terms of variable measurement, this paper mainly builds relevant indicators based on financial data, operating data and annual report texts of listed companies. It is difficult to fully capture the real-time response of enterprises to sudden shocks and the process of supply chain recovery. In the future, supply chain transaction data, logistics trajectory data and supplier-customer network data can be combined for more refined measurement. Second, in terms of the research subjects and mechanism expansion, the sample of this paper is mainly limited to Shanghai and Shenzhen A-share listed companies, and the applicability of the conclusions in small and medium-sized enterprises, unlisted enterprises and platform-based circulation enterprises remains to be tested. In the future, the analysis can be further expanded from the perspectives of supply chain relationship stability, supplier diversification and logistics service capabilities.

## Declarations

# Funding

This work was supported by National Natural Science Fundation of China (72064008) and Guangxi Philosophy and Social Sciences Annual Research Project (24GLF020)

Data availibility

The authors confim that the data supporting the findings of this study are available within the article.

Ethics, Consent to Participate, and Consent to Publish declarations:

not applicable.

# Author Contribution

J.D.was responsible for drafting the initial manuscript and conducting the formal analysis. Subsequently, and H.L.reviewed and edited the manuscript. J.D. and W.L. were in charge of conceptualization and methodology, while J.D.and H.Lwere responsible for software and resources. J.D. and H.L. participated in the investigation and data curation. W,L,undertook the visualization, supervision, and funding acquisition. Finally, W.L. and J.D.were responsible for project management.All authors have reviewed the manuscript.

# Acknowledgement

We sincerely thank all the individuals who have provided help and support for this research. At the same time, we express our gratitude to the relevant foundations for their funding and support.

## References

1. Alessandria G, Khan SY, Khederlarian A, Mix C, Ruhl KJ. (2023). The aggregate effects of global and local supply chain disruptions: 2020–2022. *Journal of International Economics, NBER International Seminar on Macroeconomics 2022*, *146*, 103788.
2. Ambulkar S, Blackhurst J, Grawe S. Firm's resilience to supply chain disruptions: Scale development and empirical examination. J Oper Manag. 2015;33–34:111–22.
3. Autor DH. Outsourcing at Will: The Contribution of Unjust Dismissal Doctrine to the Growth of Employment Outsourcing. J Labor Econ. 2003;21(1):1–42.
4. Belhadi A, Kamble S, Jabbour CJC, Gunasekaran A, Ndubisi NO, Venkatesh M. Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries. Technol Forecast Soc Chang. 2021;163:120447.
5. Brandon-Jones E, Squire B, Autry CW, Petersen KJ. A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. J Supply Chain Manage. 2014;50(3):55–73.
6. Braunscheidel MJ, Suresh NC. The organizational antecedents of a firm's supply chain agility for risk mitigation and response. J Oper Manage Special Issue: Perspect Risk Manage Supply Chains. 2009;27(2):119–40.
7. Bray RL, Mendelson H. Information Transmission and the Bullbullwhip effect: An Empirical Investigation. Manage Sci. 2012;58(5):860–75.
8. Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C, Newey W, Robins J. Double/debiased machine learning for treatment and structural parameters. Econometrics J. 2018;21(1):C1–68.
9. Dubey R, Bryde DJ, Dwivedi YK, Graham G, Foropon C, Papadopoulos T. Dynamic digital capabilities and supply chain resilience: The role of government effectiveness. Int J Prod Econ. 2023;258:108790.
10. Falck O, Gold R, Heblich S. E-lections: Voting Behavior and the Internet. Am Econ Rev. 2014;104(7):2238–65.

11. Gligor DM, Holcomb MC. Understanding the role of logistics capabilities in achieving supply chain agility: A systematic literature review. Supply Chain Management: Int J. 2012;17(4):438–53.
12. Griffin PA, Hong HA, Ryou JW. Corporate innovative efficiency: Evidence of effects on credit ratings. J Corp Finance. 2018;51:352–73.
13. Gu M, Yang L, Huo B. The impact of information technology usage on supply chain resilience and performance: An ambidexterous view. Int J Prod Econ. 2021;232:107956.
14. Guo L, Kuang Z. How does digitalization of the supply chain accelerate the sustainable development of listed companies in the new energy sector? Int Rev Econ Finance. 2025;103:104505.
15. Hallikas J, Immonen M, Brax S. Digitalizing procurement: The impact of data analytics on supply chain performance. Supply Chain Management: Int J. 2021;26(5):629–46.
16. Han Y, Wei T. Supply chain digitization and corporate carbon emissions: A chain mediation examination based on digital transformation and green innovation. J Environ Manage. 2025;379:124825.
17. Hosseini S, Ivanov D, Dolgui A. Review of quantitative methods for supply chain resilience analysis. Transp Res E. 2019;125:285–307.
18. Huang W, Tao J, Wei Z. Participate in My Green: How and When Supplier Concentration Affects Firm Green Innovation. J Prod Innov Manage. 2026;43(3):474–94.
19. Ivanov D, Dolgui A. Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. Int J Prod Res. 2020;58(10):2904–15.
20. Jia F, Hu S, Chen L. Does supply chain visibility improve firm resilience: An organizational information processing theory perspective. Transp Res E. 2025;204:104428.
21. Jiang W, Qi C. Can government data openness promote firms' inter-regional investment? Int Rev Econ Finance. 2025;104:104742.
22. Junaid M, Zhang Q, Syed MW. Effects of sustainable supply chain integration on green innovation and firm performance. Sustainable Prod Consum. 2022;30:145–57.
23. Kalaiarasan R, Olhager J, Agrawal TK, Wiktorsson M. The ABCDE of supply chain visibility: A systematic literature review and framework. Int J Prod Econ. 2022;248:108464.
24. Li P, Chen Y, Guo X. Digital transformation and supply chain resilience. Int Rev Econ Finance. 2025;99:104033.
25. Lin J, Wu H-M, Wu H. Could government lead the way? Evaluation of China's patent subsidy policy on patent quality. China Econ Rev. 2021;69:101663. https://doi.org/10.1016/j.chieco.2021.101663.
26. Lin S, Deng J. Does supplier concentration impede firms' digital innovation? A resource dependence perspective. Int J Prod Econ. 2024;273:109276.
27. Nunn N, Puga D. Ruggedness: The Blessing of Bad Geography in Africa. Rev Econ Stat. 2012;94(1):20–36.

28. Ponomarov SY, Holcomb MC. Understanding the concept of supply chain resilience. Int J Logistics Manage. 2009;20(1):124–43.
29. Qi R, Ma G, Liu C, Zhang Q, Wang Q. Enterprise digital transformation and supply chain resilience. Finance Res Lett. 2024;66:105564.
30. Qing L, Shen P, Nam E-Y, Ma X. Does supply chain digitalization improve corporate energy performance? A quasi-natural experiment from Chinese supply chain innovation and application pilot policy. Energy Econ. 2025;147:108567.
31. Saoud P, Kourentzes N, Boylan JE. The importance of forecast uncertainty in understanding the Bullbullwhip effect. Int J Prod Res. 2025;0(0):1–22.
32. Scholten K, Schilder S. The role of collaboration in supply chain resilience. Supply Chain Management: Int J. 2015;20(4):471–84.
33. Shi X, Prajogo D, Fan D, Oke A. Is operational flexibility a viable strategy during major supply chain disruptions? Evidence from the COVID-19 pandemic. Transp Res E. 2025;195:103952.
34. Song M, Ma X, Zhao X, Zhang L. How to enhance supply chain resilience: A logistics approach. Int J Logistics Manage. 2022;33(4):1408–36.
35. Sun L, Abraham S. Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. J Econometrics Themed Issue: Treat Effect. 2021;1(2):175–99. *225*.
36. Swafford PM, Ghosh S, Murthy N. Achieving supply chain agility through IT integration and flexibility. Int J Prod Econ. 2008;116(2):288–97.
37. Tiwari M, Bryde DJ, Stavropoulou F, Dubey R, Kumari S, Foropon C. Modelling supply chain Visibility, digital Technologies, environmental dynamism and healthcare supply chain Resilience: An organisation information processing theory perspective. Transp Res E. 2024;188:103613.
38. Tukamuhabwa BR, Stevenson M, Busby J, Zorzini M. Supply chain resilience: Definition, review and theoretical foundations for further study. Int J Prod Res. 2015;53(18):5592–623.
39. Wieland A, Wallenburg CM. The influence of relational competencies on supply chain resilience: A relational view. Int J Phys Distribution Logistics Manage. 2013;43(4):300–20.
40. Zhang L, Li Z, Liao Y, Wang Y, Hu N. Foreign investment and information quality – A quasi-experiment from China. Int Rev Financial Anal. 2023;90:102796.
41. Zhao N, Hong J, Lau KH. Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. Int J Prod Econ. 2023;259:108817.
42. Zheng J, Zou M. Can industry-specific information disclosure regulation mitigate the bullbullwhip effect in supply chain? Evidence from Chinese listed companies. Int Rev Financial Anal. 2025;103:104244.
43. Zhu Y, Zhang Z. Supply chain digitalization and corporate ESG performance: Evidence from supply chain innovation and application pilot policy. Finance Res Lett. 2024;67:105818.
44. Zouari D, Ruel S, Viale L. Does digitalising the supply chain contribute to its resilience? Int J Phys Distribution Logistics Manage. 2020;51(2):149–80.

# Figures

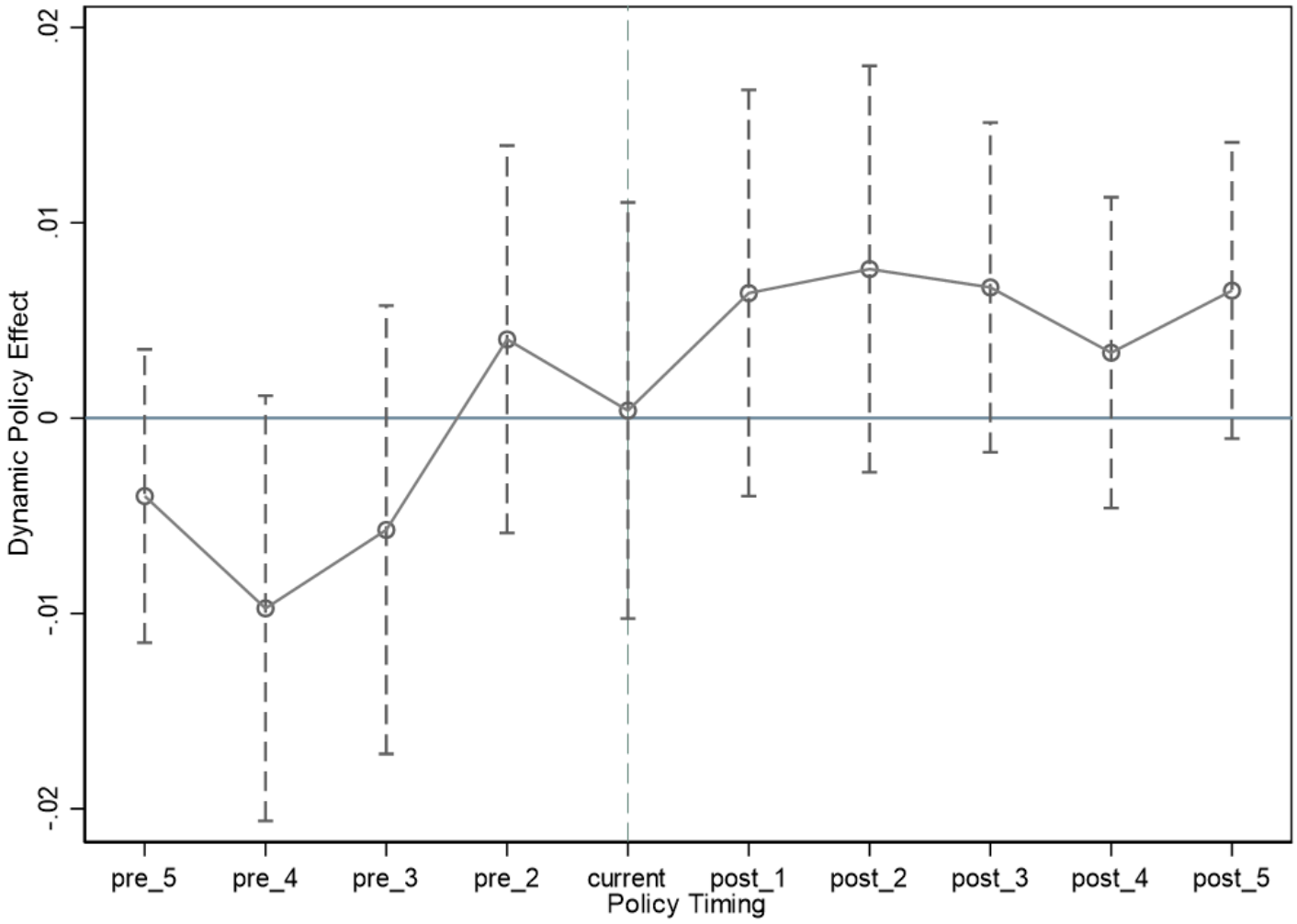



**Figure 1**

Parallel trend test

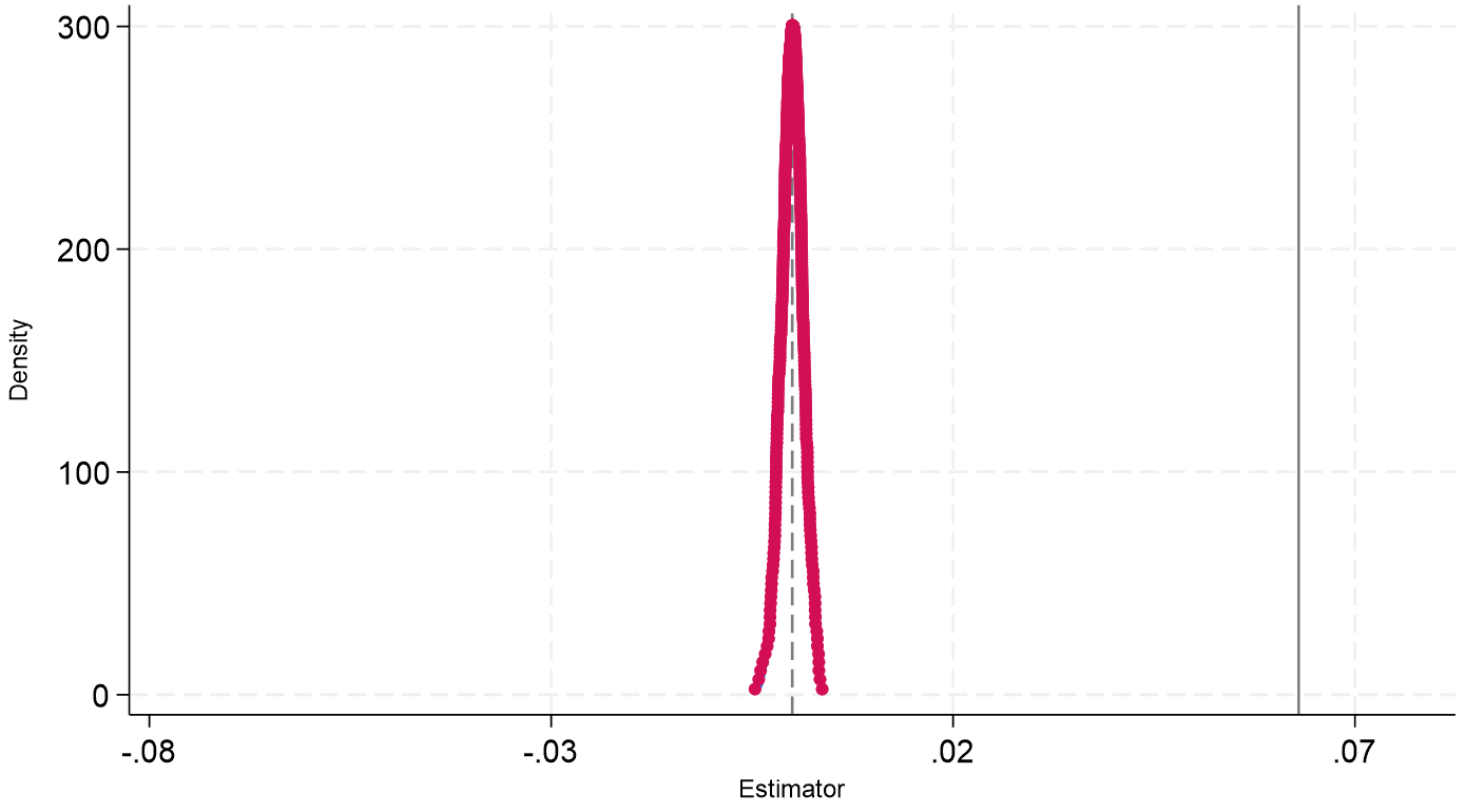



**Figure 2**

Placebo Test