

Article

Research on the Sustainable Improvement of Industrial Chain Resilience Driven by Sci-Tech Financial Policy: Evidence from China

Xiaowen Wang and Wenxin Zhang *

School of Economics, Lanzhou University, Lanzhou 730000, China; wxwen@lzu.edu.cn

* Correspondence: zhwenxin2025@lzu.edu.cn

Abstract

With the acceleration of global economic integration and the continuous rise of external uncertainties, the resilience and security of industrial and supply chains have become core benchmarks for measuring an economy's risk resistance and sustainable development capacity, which is crucial to the stable operation of the modern economic system. Based on panel data covering 279 prefecture-level and above cities in China from 2003 to 2023, this paper takes the Pilot Program for Integrating Science, Technology and Finance as a quasi-natural experiment, and adopts a multi-period DID model to empirically examine the correlation between sci-tech finance policies and urban industrial chain resilience, as well as explore its potential transmission pathways. The results show that the pilot policy significantly improves urban industrial chain resilience. Financial deepening level, high-tech application level, and urban informatization level may serve as potential transmission channels through which the policy functions. Further heterogeneity analysis indicates that the policy effect varies markedly across cities in terms of location, scale, urban resource endowments, and industrial foundation. This study enriches relevant research on sci-tech finance policy effects and industrial chain resilience and provides theoretical basis and practical reference for optimizing sci-tech finance system design and consolidating industrial chain security.

Keywords: sci-tech financial policy; industrial chain resilience; financial deepening; high and new technology; informatization level



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1. Introduction

Industrial and supply chains are the core guarantee for the smooth economic circulation of major countries and the lifeline of safeguarding economic security and sustainable development. Against the backdrop of accelerated technological revolution and industrial transformation, consolidating stable industrial chains is an inherent requirement for high-quality economic development and a core strategy to strengthen the risk resistance of economic systems [1]. Currently, the world is witnessing profound restructuring of industrial patterns and geo-economic order, which has greatly reshaped the traditional global industrial chain dominated by free trade [2]. The International Monetary Fund has pointed out that geo-economic fragmentation and policy-driven industrial separation have triggered global economic volatility and hindered international trade and cross-border investment, severely undermining the stable operation of global industrial systems. Affected by intensified geopolitical conflicts, rising trade protectionism, and public health crises, the

global industrial development environment and spatial layout of industrial chains have been profoundly restructured [3].

As a core manufacturing hub and key participant in global value chains, China has steadily consolidated its pivotal position in global industrial division of labor. Nevertheless, it is confronted with severe external pressures, including anti-globalization sentiment, core technology blockades, and accelerated industrial relocation, as well as internal dilemmas, such as unbalanced regional resource allocation and insufficient momentum for industrial upgrading, which continuously accumulate systemic industrial chain risks. Under such complex circumstances, enhancing the capacity of industrial chains to resist risks, achieve rapid recovery and realize dynamic upgrading, and build an independent, safe, efficient, and sustainable modern industrial system have become essential research issues for China to maintain steady economic growth and pursue high-quality development amid the reconstruction of global value chains.

Technological innovation serves as the fundamental driving force to foster industrial chain resilience, and sci-tech finance acts as crucial support for innovation advancement. Sci-tech finance refers to the combination of financial instruments [4], institutional arrangements, and service systems designed to facilitate technological innovation and accelerate the commercialization of research achievements. To ease capital constraints on innovative industries, the Chinese government launched the pilot policy for integrating science, technology, and finance in 2011 and 2016. This policy aims to relieve fiscal investment constraints, optimize the allocation of technological and financial resources, and build an innovation-oriented economic development model. It effectively addresses the inherent high investment, high risk, and high uncertainty characteristics of innovation activities [5], improves regional industrial innovation capacity, and promotes industrial structure upgrading. In addition, a sound sci-tech financial ecosystem can establish diversified investment and financing mechanisms, guide social capital to flow into core industrial sectors, consolidate industrial chain foundations, and provide steady financial support for industrial chain stability and long-term resilience improvement.

Against this realistic background, this paper explores the internal mechanism and transmission paths of sci-tech finance affecting urban industrial chain resilience. The research conclusions can provide theoretical foundations and empirical evidence for optimizing sci-tech financial layout, improving industrial chain resilience, and maintaining the security and stability of modern industrial systems.

2. Literature Review

2.1. Research on Industrial Chain Resilience

The term “resilience” first emerged within natural science research, describing a system’s capacity to recover and revert to its steady pre-disturbance equilibrium [6]. At the start of the 21st century, Reggiani pioneered the formal introduction of resilience into economic research, defining economic resilience as an economic system’s capacity to withstand external disruptive shocks [7]. Subsequent scholarly explorations targeting industrial chain resilience can be categorized into three core strands of inquiry: conceptual connotation clarification, quantitative measurement approaches, and feasible promotion pathways for resilience enhancement.

First, we will discuss the conceptual definition. Duan [8] argued that industrial chain resilience refers to the capacity of interconnected upstream and downstream industries to maintain stability and resist external shocks amid risks and challenges. Specifically, when facing internal and external disturbances, industrial chains can quickly mitigate disruptions, adapt to new environments, and eventually restore equilibrium [9]. Li et al. [10] proposed that the connotation of industrial chain resilience should cover not only resistance and

recovery capacity but also integration and innovation capacity. When coping with shocks, industrial chains can continuously improve adaptability and flexibility and even turn crises into opportunities to achieve industrial chain upgrading after external impacts [11].

Second, we will discuss measurement methods. Scholars have constructed evaluation indicators for industrial chain resilience from multiple perspectives. Chen et al. [11] adopted the ratio of imported intermediate inputs to the total output of industrial chains to measure industrial chain autonomous controllability. By comparison, Li et al. [10] applied the entropy weight method to evaluate industrial chain resilience from the dimensions of industrial diversification and industrial innovation capacity, which has become a mainstream empirical approach in existing literature. Subsequent studies have incorporated more dimensions into the evaluation framework, including a comprehensive indicator system covering industrial chain resistance, recovery capacity, and sustainability [12,13], as well as a four-dimensional system involving industrial chain foundation, shock resistance, shock adaptability, and recovery and restructuring capacity [9,14]. Regardless of the method adopted, the measurement of industrial chain resilience is rooted in its conceptual connotation and ultimately revolves around two core dimensions: resistance and recovery capacity.

Third, we will discuss improvement paths of industrial chain resilience. You [15] pointed out that the influencing factors of industrial chain resilience mainly include economic, social, and ecological dimensions. From an economic perspective, the primary influencing factors concentrate on technological innovation, industrial structure, and human capital. In terms of technological innovation, conventional innovative approaches can enhance industrial chain resilience by raising supply-side labor productivity, reducing human capital input, or accelerating demand-side industrial upgrading [16]. For emerging industries, alleviating technological bottlenecks in core key fields and leveraging intelligent technologies are essential to strengthen modern industrial chain resilience [17]. In terms of industrial structure, numerous empirical findings confirm that industrial structure optimization significantly promotes industrial chain resilience [18,19], while different forms of industrial agglomeration exhibit heterogeneous resilience against internal and external shocks due to structural discrepancies [20]. David [21] noted that specialized industrial agglomeration can generate self-reinforcing effects through cumulative causation, thereby helping enhance industrial chain resilience. In terms of human capital, both structural changes and population mobility of human capital can reshape industrial structure by improving workers' professional skills and labor productivity [22,23]. Further mechanism tests by Xing et al. [19] verified the positive effect of human capital upgrading on industrial chain resilience. In addition, overall macroeconomic development trends, such as digital finance [18], industrial digital transformation [24], and the development of new quality productive forces [1,25], exert both direct and indirect promoting effects on strengthening industrial chain resilience.

2.2. Research on Sci-Tech Finance Policies

The pilot policy for integrating science, technology, and finance centers on innovating the fiscal allocation of scientific and technological resources [26]. It guides securities, banking, insurance, and other financial institutions to explore innovative financial products, upgraded service models, and specialized service platforms. By integrating diversified financial resources, such as venture capital, bank credit, and sci-tech insurance, the policy provides strong backing for corporate technological innovation [27]. Targeting the deep coupling of innovation value chains and capital supply chains, this pilot scheme acts as a core policy lever to cultivate strategic emerging sectors and advance the high-quality coordinated growth of technology and financial sectors.

The existing literature evaluates the policy effects of science-technology and finance integration mainly at the micro-level of firm development and the macro-level of regional economic growth. At the micro-level, sci-tech financial policies strengthen technological credit support, directly facilitating corporate innovation by easing financing conditions [28], and indirectly alleviating corporate financing constraints by improving the allocation efficiency of sci-tech financial resources [29]. In addition, the policy screens, examines, and conducts full-process supervision on high-quality innovation projects, ensuring research progress and achievement quality. Improved management efficiency of funded projects further elevates the overall innovation performance of enterprises in pilot regions [30]. From the perspective of firm performance, the implementation of sci-tech financial policies significantly boosts total factor productivity [31], corporate ESG performance [32], high-quality development [29], and global value chain position upgrading [33]. These effects operate through broadening financing channels, reducing capital costs, and stimulating innovative vitality.

At the macro-level, the pilot policy functions as an economic regulation tool that influences the real economy to advance technological progress, stimulate innovative activity, and drive economic growth. Existing studies confirm that by increasing fiscal sci-tech investment and expanding market-oriented financial resources, the policy effectively promotes regional technological innovation [34], attracts talent agglomeration [35], and accelerates industrial structural upgrading [36]. Furthermore, advancements in technology, the development of local financial sectors, and the upgrading of human capital and industrial structures jointly facilitate progress toward common prosperity [26], urban green economic transformation [4], and high-quality economic development [37].

Although abundant studies have separately explored industrial chain resilience and sci-tech finance policies, certain limitations remain. First, most scholars examine the two topics independently, with few studies exploring their correlation and systematically analyzing the policy impacts and internal transmission mechanisms on urban industrial chain resilience. Second, the prior literature lacks in-depth discussion on policy heterogeneity and ignores varying policy effects across cities. Third, existing research fails to fully integrate multiple transmission paths and mainly focuses on micro-firm perspectives, with insufficient evidence at the city level. To fill these research gaps, this paper theoretically and empirically examines the direct impacts, heterogeneous effects, and three-dimensional indirect mechanisms of sci-tech finance policies so as to enrich relevant research from new perspectives and mechanism analyses.

2.3. Research Gaps and Contributions

The existing literature has examined the microeconomic effects of science and technology finance policy from multiple dimensions, yet research on its impact on urban industrial chain resilience remains relatively limited. Some scholars have focused on the promotional effects of the science and technology finance pilot policy on regional innovation, talent agglomeration, and industrial structure upgrading. However, industrial chain resilience, as a comprehensive concept encompassing shock resistance, recovery capacity, and dynamic adaptability, has received insufficient attention in the evaluation of science and technology finance policy effects. Among the few studies that incorporate both into a unified analytical framework, Xing et al. were among the first to explore the impact of science and technology finance policy on industrial chain resilience [19], providing an important reference for subsequent research. Building on this foundation, this paper constructs a different analytical framework, extends the sample period of research in this field, and further expands the study along two dimensions: mechanism analysis and heterogeneity analysis. In terms of mechanism analysis, this paper examines the potential transmission channels of financial

deepening, high-tech application, and urban informatization from the three perspectives of finance, technology, and urban infrastructure environment, thereby offering richer empirical clues for the underlying mechanisms. In terms of heterogeneity analysis, this paper avoids the potential information overlap issues associated with the grouping dimensions commonly used in traditional literature, such as economic development level and marketization degree, and instead conducts heterogeneity tests along four dimensions, region, scale, resource endowment, and industrial base, aiming to provide new empirical evidence for understanding the differentiated effects of science and technology finance policy.

3. Theoretical Analysis

3.1. Direct Impact

As an accelerator for the in-depth integration of technological and financial innovation, the sci-tech finance pilot policy builds a multi-level and differentiated sci-tech investment and financing service system, providing strong support for optimizing market access, constructing risk-sharing mechanisms, and promoting industrial chain collaboration, thereby enhancing urban industrial chain resilience.

First, by improving the multi-level capital market, the policy lowers entry thresholds for innovative enterprises and investors, attracts more emerging firms, and broadens financing channels for technology enterprises [38]. On the one hand, it encourages technology enterprises to list on the Main Board, Growth Enterprise Market, STAR Market, and New Third Board by simplifying procedures and reducing thresholds, boosting high-growth enterprises' listing efficiency and industrial competitiveness; it also stimulates more SMEs to engage in technological innovation, accelerates R&D and achievement transformation [39], and enhances overall industrial chain innovation capacity. On the other hand, the policy promotes venture capital, private equity investment, and overseas financing for technology enterprises, launches sci-tech innovation bonds and green bonds to open diversified, low-cost financing paths, and leverages the New Third Board to attract capital for small and medium-sized technology enterprises, ensuring capital supply and strengthening industrial chain risk resistance. Second, the policy strengthens sci-tech investment and financing risk management by improving the financing guarantee system, establishing risk compensation funds, and enhancing sci-tech insurance functions [40]. This risk-sharing mechanism reduces financial institutions' credit risks and improves enterprises' financing access: increasing fiscal support to optimize policy-oriented guarantee institutions, setting up local sci-tech financial risk compensation funds to boost credit willingness, and building a full-chain sci-tech insurance system with a co-insurance mechanism to reduce insurers' risk exposure [41]. These measures optimize the industrial chain's financial ecology and effectively promote its resilience. Finally, the policy facilitates collaboration within industrial chains and with external institutions through flexible financing support and policy guidance. It integrates upstream and downstream resources, provides supply chain financial services to improve capital operation efficiency, and encourages leading enterprises to drive collaborative innovation [42]. It also builds information sharing platforms to connect technology enterprises, financial institutions, and research institutes, guides capital to strategic emerging and high-tech industries, and promotes enterprise clustering [43], triggering synergies to enhance industrial chain strength and resilience. Based on the above analysis, this paper proposes the following hypothesis.

Hypothesis 1. *The sci-tech finance pilot policy significantly improves the resilience of urban industrial chains.*

3.2. Indirect Transmission Mechanism

3.2.1. Financial Sector: Regional Financial Deepening Level

From the perspective of the financial transmission channel, the sci-tech finance pilot scheme elevates the regional financial deepening level by constructing a diversified multi-layered tech-finance service ecosystem, which further lifts the resilience level of regional industrial chains.

First, the policy enforces standardized information release rules for R&D-oriented innovative firms. Such institutional arrangements ease the information gap between funding suppliers and real-sector enterprises to a considerable degree, raise the transparency of capital markets, and guide more financial capital to flow into high-potential innovative firms and promising technical programs [44]. The improvement of information transparency expands the overall credit supply scale of financial institutions and reduces friction costs in the financial market, further smoothing investment and financing activities along industrial chains [45].

Meanwhile, supported by digital technology and big data analytics, the new financial system under the sci-tech finance policy compensates for the shortcomings of traditional financial institutions in risk pricing and credit coverage. Such technologies can identify and assess the risks of innovative entities more accurately, expand credit coverage for enterprises with high growth potential, and drive coordinated growth of upstream and downstream industrial chains led by core technological enterprises.

In addition, the policy encourages financial institutions to develop financial products and services tailored to the demands of technological innovation, such as pilot equity-linked loans and flexible interest rate schemes with an initial low rate followed by gradual adjustment. These measures raise the investment enthusiasm of financial institutions while alleviating financing pressure on start-ups and growing enterprises. Reduced transaction costs and expanded credit supply help enterprises break through technical bottlenecks, alleviate the risks of industrial chain disruption and disconnection, and ultimately strengthen industrial chain resilience [46].

Hypothesis 2. *The sci-tech finance pilot policy can enhance urban industrial chain resilience by lifting the regional financial deepening level.*

3.2.2. Technological Sector: The Application Level of High and New Technology of Enterprises

In the technological domain, the core objective of sci-tech finance policy is to accelerate the growth of high-tech enterprises and elevate their innovation capability [28]. The advancement of high-technology application within enterprises further enhances industrial chain resilience. Specifically, local governments play a pivotal role in policy implementation. By expanding fiscal expenditure on science and technology, governments actively guide enterprises and research institutions to engage in technological innovation activities [47]. Increased research funding and innovation projects not only accelerate scientific research progress and enrich technological achievements but also facilitate the efficient transformation and application of research outcomes into the real economy, driving overall industrial development led by emerging technologies. Meanwhile, the sci-tech finance policy provides high-tech enterprises in pilot regions with institutional benefits such as tax incentives, fiscal subsidies, and financing support. These measures facilitate the rapid expansion of high-tech firms and generate spillover effects along the industrial chain in terms of talent agglomeration, market expansion, and technological innovation, effectively motivating upstream and downstream enterprises to upgrade their own high-technology application capabilities [48] and thereby improving the comprehensive competitiveness of

industrial chains. As the scale and technological maturity of high-tech industries continue to expand, their strategic position within industrial chains becomes increasingly prominent, providing solid guarantees for the secure and stable operation of industrial chains. Furthermore, the rollout of the pilot policy encourages enterprises to adopt intelligent risk control systems. By harnessing big data, artificial intelligence, cloud computing, and other cutting-edge digital technologies, enterprises carry out deep excavation and statistical sorting of mass data so as to track investment and operational hazards dynamically and lift industrial chains' capability to foresee potential risks. In addition, artificial intelligence enables the automation of business processes and reduces manual involvement. Such applications effectively cut labor costs, improve operational efficiency and docking precision, mitigate operational risks to a certain extent, and enhance the production efficiency and risk resistance of industrial chains.

Hypothesis 3. *The sci-tech finance pilot policy can enhance urban industrial chain resilience by raising the application level of high and new technology of enterprises.*

3.2.3. Urban Basic Environment: Urban Informatization Level

From the perspective of urban basic environment, sci-tech finance policy can enhance industrial chain resilience by optimizing the overall level of urban informatization. First, the policy requires enterprises to improve information disclosure standards, facilitates the integration of data resources between financial institutions and technology enterprises, and constructs city-wide data sharing platforms. On the premise of ensuring data interaction security, usage compliance, and controllable access scope, the policy realizes the shared application of data and information resources [49], laying a solid data and platform foundation for urban informatization development. The overall progress of urban informatization improves market operational efficiency, strengthens collaborative cooperation between financial institutions and industrial chains, and further supports industrial technological innovation and economic growth. Second, local governments provide fiscal subsidies and tax incentives for technological innovation enterprises to support the upgrading of information infrastructure within industrial chains. With the advancement of enterprise informatization, production efficiency and risk-resisting capacity are improved, thereby consolidating industrial chain resilience. Finally, driven by the policy, financial institutions devote themselves to building immersive smart service outlets and online financial service platforms, realizing the informatization of financial services and providing more diversified and convenient financing channels for all links of industrial chains. Meanwhile, enterprises adopt information-based tools to conduct business operations, which enables them to accurately capture market dynamics, customer demands, and operational conditions. This allows firms to formulate reasonable business objectives and development strategies, effectively reduce operational risks, and fully meet the supply demands of downstream enterprises and clients, ultimately promoting the improvement of industrial chain resilience.

Hypothesis 4. *The sci-tech finance pilot policy can enhance urban industrial chain resilience by raising the level of urban informatization.*

4. Research Design

4.1. Data and Sample

This study conducts empirical analysis based on panel data of 279 prefecture-level and above cities in China from 2003 to 2023. The main variables are sourced from the China Urban Statistical Yearbook, local statistical yearbooks, municipal government work

reports, the National Intellectual Property Administration, and the enterprise credit inquiry platform Qichacha. Linear interpolation is adopted to supplement individual missing values. Table 1 presents the descriptive statistics. The explained variable industrial chain resilience (ICR) ranges from 0.0006 to 0.9831, with a mean value of 0.0360 and a standard deviation of 0.0548, implying obvious disparities in industrial chain resilience across different cities. Overall, the statistical characteristics of all variables are consistent with practical economic conditions.

Table 1. Descriptive statistics.

VarName	Obs	Mean	SD	Min	Median	Max
DID	5859	0.1033	0.3043	0.0000	0.0000	1.0000
ICR	5859	0.0360	0.0548	0.0006	0.0239	0.9831
Gdp	5859	4.4694	3.5092	0.1929	3.5996	26.4699
Gov	5859	0.1719	0.0938	0.0135	0.1496	1.5927
HCL	5859	0.0176	0.0233	0.0000	0.0093	0.1848
Open	5859	0.2055	0.5156	0.0000	0.0810	28.3684
FIR	5859	2.3502	1.1584	0.2066	2.0268	14.4199
CLD	5859	995.5952	5030.3790	−10,193.8447	390.0514	131,837.4531
AIL	5859	954.9986	4704.5503	0.0000	61.0000	102,692.0000
Employee	5859	0.0799	0.1799	0.0037	0.0594	2.9580
Internet	5859	89.1287	125.5905	0.0237	46.3600	1739.7699

4.2. Variable Description

4.2.1. Dependent Variable

There is no unified standard for measuring industrial chain resilience in the existing literature. It is defined as the capacity of industrial chains to resist adverse shocks and rapidly restore stable operation after disturbances [10,50], which can be divided into resistance capacity and recovery capacity.

In terms of resistance capacity, industrial chains can absorb and avoid risks via industrial structure optimization, resource reallocation, and upstream–downstream coordination to maintain stable operation. In terms of recovery capacity, industrial chains can remedy operational defects through innovation and technological progress to regain steady or even better development after being hit by external shocks.

Referring to Chen et al., Li et al., and Chen et al. [11,51,52], this paper adopts industrial diversification to reflect resistance capacity and industrial innovation to represent recovery capacity so as to comprehensively measure urban industrial chain resilience. Following Henderson [53], industrial diversification (Indiv) is calculated as the reciprocal of the Herfindahl–Hirschman Index (HHI), as shown in Formula (1). Industrial innovation (Inno) is measured by the number of authorized invention patents.

$$Indiv = \frac{1}{HHI} = \frac{1}{\sum_{i=1}^3 S_i^2} \quad (1)$$

Subsequently, the entropy weight method was employed to assign appropriate weights to the above two indicators and calculate their composite scores. The specific procedures are as follows:

First, we have preprocessing of the raw indicator data. To ensure consistency in the treatment of the two indicators, this paper did not apply any additional preprocessing operations—such as winsorizing or logarithmic transformation—to the reciprocal of industry concentration or the number of patent grants; instead, the raw data were directly incorporated into the subsequent standardization process. The primary reason is that, in this study, the dispersion of the number of invention patent grants and the reciprocal of

the HHI index can genuinely reflect the differences in the resilience and recoverability of industrial chains across cities, whereas additional preprocessing might distort the informational characteristics of the indicators themselves and undermine the objectivity of the weighting determined by the entropy weight method.

Second, the preprocessed raw data are standardized to eliminate the influence of dimensional differences on the weighting results. Since both indicators selected in this paper are positive indicators, the standardization formula for positive indicators is adopted for processing, with the specific formula as follows :

$$X_{ij}^* = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (2)$$

where X_{ij}^* denotes the standardized value of the j -th indicator for city i , X_{ij} represents the original raw value of the j -th indicator for city i , and $\max(X_j)$ and $\min(X_j)$ refer to the maximum and minimum values of the j -th indicator across all samples, respectively. After this transformation, the standardized values of all indicators are scaled to the range of 0 to 1, which effectively eliminates differences in dimension and magnitude.

Following standardization, the information entropy and objective weight of each indicator are calculated to quantify the information discrimination capacity of each indicator. The formula for information entropy is specified as:

$$H_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij}, \text{ where } p_{ij} = \frac{X_{ij}^*}{\sum_{i=1}^n X_{ij}^*} \quad (3)$$

On this basis, the entropy weight of each indicator is derived via the following formula:

$$w_j = \frac{1 - H_j}{\sum_{j=1}^m (1 - H_j)} \quad (4)$$

In the formula, w_j stands for the weight of the j -th indicator, and m is the total number of evaluation indicators.

Finally, the standardized value of each indicator is multiplied by its corresponding entropy weight, and the weighted values are summed to obtain the composite index of urban industrial chain resilience, as shown below:

$$ICR_i = \sum_{j=1}^m w_j X_{ij}^* \quad (5)$$

ICR_i represents the composite industrial chain resilience score of city i . A higher value of ICR_i indicates stronger industrial chain resilience of the corresponding city. The specific weight of each indicator is reported in Table 2.

Table 2. Weights of the industrial chain resilience evaluation index system.

Indicator	Direction	Entropy	Deviation	Weight
Industrial Diversification	+	0.9952035	0.0047965	0.0267684
Industrial Innovation	+	0.825611	0.174389	0.9732316

Note: The symbol “+” denotes positive indicators, meaning a higher value of the indicator contributes to stronger industrial chain resilience.

It should be noted that there remains substantial divergence in academia regarding the construction of resilience measurement systems, as the existing literature varies greatly in dimension division and indicator selection. The two-dimensional “resistance-recovery” framework adopted for our baseline model has been widely applied and validated by the aforementioned scholars, enjoying high recognition and comparability. Taking this

simplified index as the core explained variable helps guarantee the continuity and horizontal comparability of research conclusions. Meanwhile, although some studies attempt to introduce more dimensions to enrich the connotation of resilience measurement, such multi-dimensional extended indices lack universally recognized standards in secondary indicator selection, calculation criteria, and weight setting, leading to substantial discrepancies among indices constructed in different papers. If incorporated directly into baseline regressions, the subjectivity and inconsistency of measurement standards may impair the robustness and reliability of the core estimation results. Accordingly, this study adopts the mainstream two-dimensional simplified index for baseline regressions, while the four-dimensional extended resilience index is only presented in the robustness test as an auxiliary verification tool. This design tests the sensitivity of baseline conclusions to different measurement methods and strikes a reasonable balance between measurement breadth and standard consistency.

4.2.2. Independent Variable

The pilot policy of integrating science, technology, and finance was implemented in two batches in 2011 and 2016, covering 41 first-batch pilot cities including Beijing, Tianjin, Shanghai, and Nanjing, and 9 second-batch cities such as Zhengzhou, Xiamen, and Ningbo. This study classifies the 50 pilot cities as the treatment group with $treat = 1$, and other cities as the control group with $treat = 0$. We set $post = 1$ for years after policy implementation and $post = 0$ for earlier years. The interaction term of $treat$ and $post$ serves as the DID policy dummy variable.

4.2.3. Mechanism Variables

The transmission channels examined in this study fall into three categories: financial deepening level, high-tech application level, and informatization level.

(1) Financial Deepening Level

Financial deepening level reflects the overall scale, liquidity supply, and credit expansion capacity of a regional financial system, which characterizes the extent to which financial institutions can mobilize social idle funds to support real economic investment.

Goldsmith first put forward the financial interrelations ratio (FIR) [54], defined as the ratio of total financial asset value to national wealth, to quantify a country's financial development stage. His theory argues that the financial interrelations ratio rises correspondingly alongside national economic advancement. Subsequent financial deepening theory further demonstrates that mature financial systems can expand aggregate social savings and investment, reallocate scarce resources to their most productive uses, and ultimately lift overall investment volume.

Domestic empirical studies widely adopt FIR to measure regional financial development and financial deepening degree [55,56]. Based on the above theoretical logic and classic measurement methods in the existing literature, this paper selects the financial interrelation ratio (FIR) as the core proxy indicator for financial deepening level. Specifically, this indicator is calculated as the sum of total deposits and loans of local financial institutions divided by regional gross domestic product, following the measurement standard proposed by Cui [56].

The second proxy indicator is the deposit–loan gap (DLG), calculated as the difference between year-end total deposits and year-end total loans of financial institutions. This indicator mirrors the stock of spare lendable funds and liquidity reserves within the banking sector. Given China's bank-centered indirect financing system, a larger deposit–loan gap means commercial banks possess greater space for credit expansion after satisfying statutory deposit reserve requirements and daily settlement demands. Such surplus credit supply

capacity effectively alleviates financing constraints of technology-intensive enterprises. Existing relevant research has adopted the deposit–loan gap, deposit–loan ratio, and other similar indicators to describe regional financial deepening and the overall lending capacity of the financial system [57].

(2) High-tech Application Level

This study adopts the stock of regional artificial intelligence enterprises to quantify the high-tech application level (AIL).

Referring to the textual keyword identification approach proposed by Wang et al. [58], we construct a keyword lexicon covering artificial intelligence and high-tech sectors based on nationwide micro-firm registration data sourced from the Tianyancha database. The dictionary incorporates 73 technical terms such as intelligence, cloud computing, machine learning, big data, image recognition, sensors, and deep learning. Next, we extract the business scope field from the registration information of all active enterprises. Any firm whose business scope contains at least one of the above technical keywords is classified as a high-tech enterprise engaged in intelligent technology R&D, digital product manufacturing, or intelligent technical services. By contrast, shell companies and commercial intermediaries that only include relevant technical words in their firm names without substantive intelligent businesses listed in the business scope are excluded from the sample. Finally, we match each firm's registered address to its corresponding prefecture-level administrative division and aggregate the total number of qualified intelligent enterprises for each city on an annual basis. This aggregated stock of eligible firms serves as the proxy variable for regional high-tech application level.

(3) Informatization Level.

A city's informatization level captures the comprehensive developmental status of its digital resources and information networks. This paper measures this indicator from two dimensions: information human resources and digital infrastructure construction.

The first dimension is information human capital. We adopt the proportion of employees in computer services and software industries among all urban institutional employees at year-end (Employee) as the proxy variable. Staff engaged in computer and software sectors act as core carriers for urban digital transformation, information technology R&D, and digital service provision. A higher proportion of such employees indicates a larger pool of specialized digital technicians gathered within the region, which delivers sufficient human support for industrial digitalization and the implementation of intelligent technologies, and directly mirrors the talent foundation underpinning urban informatization progress.

The second dimension refers to information infrastructure. The total number of year-end internet broadband access subscribers (Internet) is used to measure the popularization scale of regional network hardware. As the fundamental hardware carrier for all digital applications, online production and operation, and the growth of digital industries, a larger stock of urban broadband subscribers signals broader network coverage for local enterprises, public institutions, and residents as well as more complete supporting digital infrastructure. This indicator objectively captures the maturity of a city's informatization hardware construction.

4.2.4. Control Variables

Referring to existing studies [19,59], we adopt the following control variables: economic development level (Gdp), measured by per capita GDP; government intervention (Gov), expressed as the ratio of local fiscal expenditure to GDP; opening-up level (Open), calculated by the proportion of total import and export volume in GDP; and human capital level (HCL), represented by the ratio of college students to registered population.

The definitions, symbols and measurement methods of all variables mentioned above are summarized in Table 3.

Table 3. Variable definitions and descriptions.

Variable Type	Symbol	Definition
Explained Variable	ICR	Constructed index system via the entropy weight method
Explanatory Variable	DID	Policy dummy variable
Control Variables	Gdp	Urban per capita GDP
	Gov	Local fiscal expenditure/GDP
	Open	Total regional import and export volume/GDP
	HCL	Number of enrolled college students/registered population
Mechanism Variables	FIR	Total deposits and loans of financial institutions/GDP
	CLD	Year-end total deposits minus total loans of financial institutions
	AIL	Stock of enterprises engaged in intelligent technology-related businesses
	Employee	Employees in computer and software industries/total employment
	Internet	Number of broadband Internet access subscribers

4.3. Model

To identify how science and technology finance policies affect urban industrial chain resilience and unpack its underlying transmission channels, this study leverages China's two batches of pilot programs launched in 2011 and 2016 as a quasi-exogenous shock. We construct a multi-period DID regression framework that absorbs city-level and yearly time-invariant unobserved heterogeneity. The baseline regression specification is structured as Equation (6):

$$ICR_{it} = \alpha + \beta DID_{it} + \gamma Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (6)$$

In this equation, ICR_{it} measures the resilience level of industrial chains for city i observed in year t ; DID_{it} represents the dummy variable of sci-tech finance policy; and $Controls_{it}$ refers to a set of control variables. α is the constant term, μ_i stands for city fixed effect, θ_t denotes year fixed effect, and ε_{it} is the random disturbance term. To address within-city serial correlation and heteroskedasticity, all regressions in this paper adopt robust standard errors clustered at the city level for statistical inference.

5. Empirical Results

5.1. Baseline Regression

Table 4 reports the baseline regression results. Specification (1) omits covariates and two-way fixed effects, with the DID coefficient significantly positive at the 1% level. Specification (2) adds city-year fixed effects without losing significance, and Specification (3) further includes all city-level controls while retaining a positive and significant DID estimate at 1%. Specification (4) adopts the full set of controls plus two-way fixed effects, yielding a DID point estimate of 0.0591, which is significant at the 1% level. Overall, the baseline results robustly confirm that sci-tech finance pilots boost urban industrial chain resilience, which empirically validates Hypothesis 1.

5.2. Robustness Test

5.2.1. Parallel Trend Test

The core precondition for credible staggered DID estimation requires that treated and untreated cities display identical evolutionary patterns prior to policy rollout, which is formally known as the parallel trends identification assumption [60,61]. Accordingly, we conduct the parallel trend test within a time window covering 5 years before and 6 years after policy rollout, with the period one year prior to policy implementation set as the omitted benchmark period. To further eliminate baseline shifts caused by inherent differences in urban development levels and to align the comparison benchmark across groups, this paper applies within-group demeaning to the regression coefficients, with

the results presented in Figure 1. At the 95% confidence level, the demeaned pre-policy coefficients are not statistically significant, indicating that the industrial chain resilience of cities in the treatment and control groups followed highly consistent evolutionary paths before the policy shock, thereby validating the parallel trends assumption. The coefficient for the current period is not significant, which may suggest a lag in the policy effect; while the coefficients for the subsequent post-policy periods are significantly positive and show an overall upward trend, further supporting that the science and technology finance pilot can continuously and effectively enhance urban industrial chain resilience.

Table 4. The results of baseline regression.

	(1)	(2)	(3)	(4)
	ICR	ICR	ICR	ICR
DID	0.0942 *** (16.97)	0.0760 *** (5.91)	0.0648 *** (16.45)	0.0591 *** (6.03)
Gdp			0.00536 *** (11.10)	0.00799 *** (3.90)
Gov			−0.00760 (−1.50)	0.0188 (1.34)
HCL			0.0444 (0.85)	0.129 (0.46)
Open			0.00926 * (1.72)	−0.0101 (−1.10)
Constant	0.0263 *** (110.82)	0.0213 *** (11.88)	0.00399 ** (1.98)	0.0109 ** (2.47)
City FE	NO	YES	NO	YES
Year FE	NO	YES	NO	YES
R ²	0.2730	0.2979	0.3930	0.3663
N	5859	5859	5859	5859

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

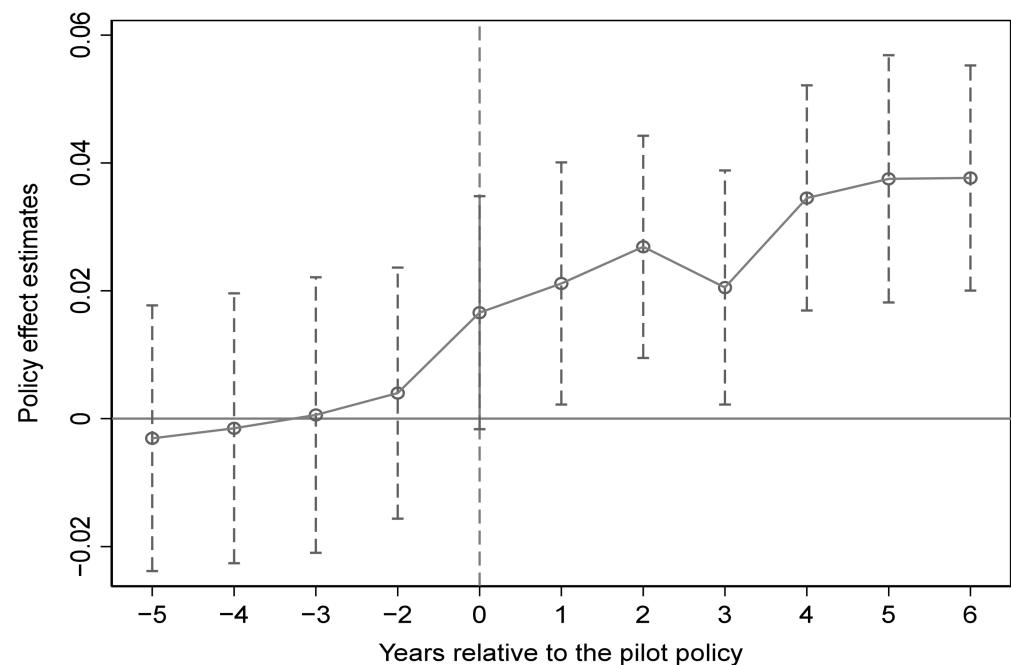


Figure 1. Parallel trend test.

5.2.2. Placebo Test

To eliminate the interference of unobservable omitted variables and confirm that the improvement of industrial chain resilience is driven by the sci-tech finance policy rather than random factors, this study conducts a placebo test [62]. Following Bai et al. [63], we

randomly select 50 cities as the false treatment group and randomly assign fictitious policy implementation years within 2003–2023 to these samples. We then perform regression analysis and repeat this random sampling procedure 500 times. Figure 2 displays the placebo test results. The kernel density distribution of estimated coefficients approximates a normal distribution centered at zero, and most coefficients have p -values higher than 0.1, indicating statistical insignificance at the 10% level. Meanwhile, the actual policy coefficient is 0.0591, marked by the solid black line on the right, which is far larger than most simulated coefficients. The results verify the reliability of the baseline findings and pass the placebo test.

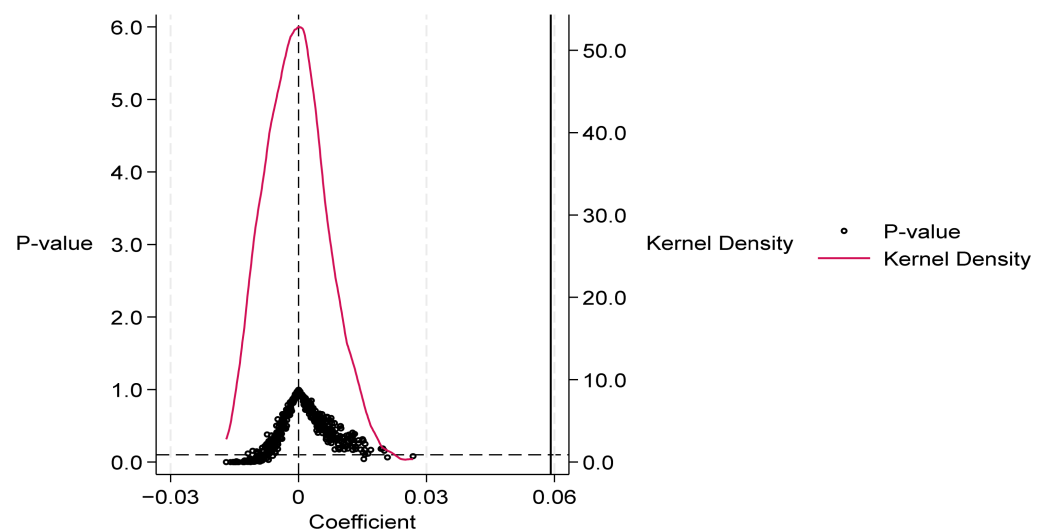


Figure 2. Placebo test.

5.2.3. PSM-DID

To mitigate the potential endogeneity arising from sample self-selection in the baseline regression and eliminate estimation bias caused by inherent inter-city characteristic gaps, this paper further adopts the PSM-DID approach for robustness checks [64]. All control variables included in the model are selected as matching covariates to calculate propensity scores. Based on the estimated scores, we match treated cities with control cities bearing highly similar attributes and re-estimate the difference-in-differences model using the balanced matched sample to isolate the disturbance of sample selection bias on core findings.

To guarantee the comparability between treated and control groups after matching, we first verify whether the propensity score matching satisfies the balancing assumption. A comparison graph of standardized covariate bias is plotted to visually illustrate changes in characteristic disparities across the two groups before and after matching. Figures 3 and 4 display standardized bias under kernel matching and radius matching, respectively. It is evident that the standardized bias of the openness variable (Open) deviates far from the zero benchmark prior to matching, indicating substantial divergence in urban attributes between treated and control groups. After matching, however, the standardized bias of all covariates converges sharply toward zero and remains below 10%, which implies inter-group characteristic gaps are effectively eliminated, and the matching passes the balancing test.

Columns (1) and (2) in Table 5 report the results using kernel matching and radius matching, respectively. Both coefficients are significantly positive at the 1% level, confirming that the positive effect of sci-tech finance policy on industrial chain resilience remains significant after correcting for selection bias, and thus the baseline result is robust.

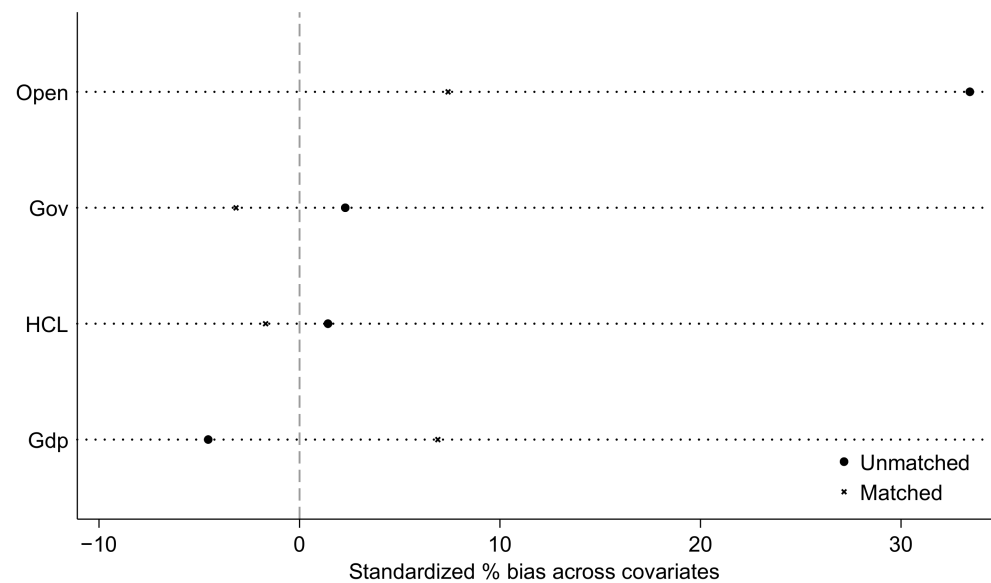


Figure 3. Balance test based on kernel matching.

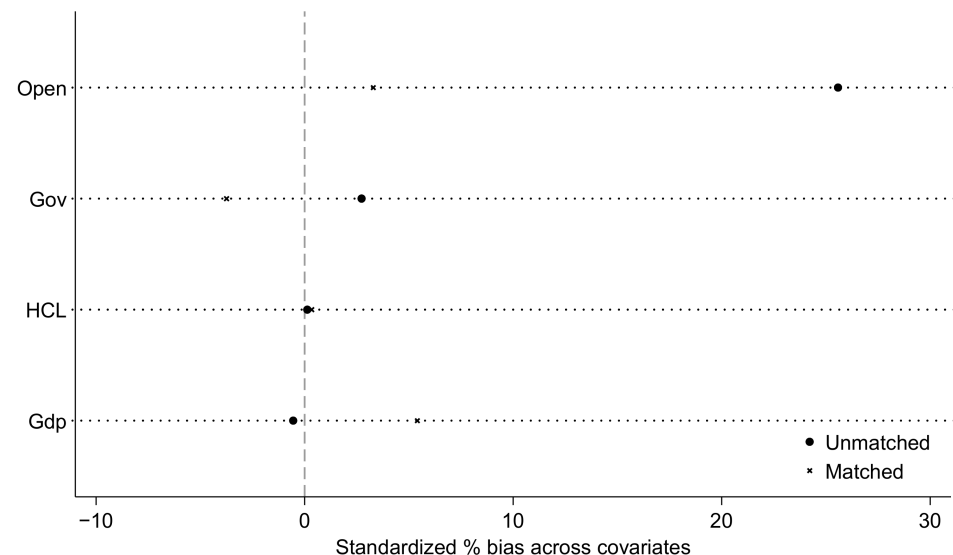


Figure 4. Balance test based on radius matching.

5.2.4. Winsorization

To mitigate estimation bias stemming from extreme sample values, we apply two-sided winsorization to all continuous dependent and explanatory variables in the benchmark regression. Columns (3) and (4) of Table 5 separately report regression outputs after applying 1% and 5% two-sided winsorization. The policy coefficients still retain statistical significance at the 1% critical level, proving that our core benchmark conclusions are not distorted by abnormal sample observations.

5.2.5. Excluding Direct-Controlled Municipalities

As provincial-level administrative units, municipalities (Beijing, Shanghai, Chongqing, and Tianjin) enjoy overwhelming advantages in financial development, technological innovation, resource allocation, and industrial output compared with ordinary prefecture-level cities, which may lead to extreme values and biased estimates. For this reason, we drop the four municipalities from the sample and rerun the empirical model solely based on ordinary prefecture-level cities. The regression outputs listed in Column (5) of Table 5

align closely with the benchmark regression outcomes, which solidifies the robustness of our core research findings.

Table 5. Robustness test.

	(1)	(2)	(3)	(4)	(5)
	Kernel Matching	Radius Matching	1% Two-Tailed Winsorization	5% Two-Tailed Winsorization	Excluding Direct-Controlled Municipalities
DID	0.0415 *** (4.99)	0.0384 *** (4.95)	0.0467 *** (7.02)	0.0241 *** (7.77)	0.0520 *** (5.37)
Constant	0.0380 ** (2.13)	0.0462 ** (2.16)	0.0182 *** (5.81)	0.0171 *** (7.56)	0.0129 *** (3.80)
Controls	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
R ²	0.4804	0.4920	0.519	0.560	0.3417
N	1406	1376	5859	5859	5775

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.2.6. Excluding Interference of Other Policies

During the sample period from 2003 to 2023, policies including Smart City, Broadband China, public data opening, and national big data comprehensive pilot zones may also affect industrial chain resilience. To eliminate such confounding effects, this study incorporates the above policies into the baseline model as additional control variables. Columns (1) to (4) in Table 6 report the regression results after controlling for Broadband China strategy (Internet), national public data opening policy (Public_data), national big data comprehensive pilot policy (Big_data), and Smart City pilot policy (Smart_city), respectively. The core explanatory variable remains significantly positive at the 1% significance level, which verifies the robustness of the findings. Furthermore, all aforementioned policies are simultaneously included in the model, and the results in Column (5) still hold stable.

Table 6. Excluding interference of other policies.

	(1)	(2)	(3)	(4)	(5)
	ICR	ICR	ICR	ICR	ICR
DID	0.0566 *** (6.03)	0.0589 *** (6.06)	0.0582 *** (6.23)	0.0595 *** (6.05)	0.0560 *** (6.26)
Internet	0.0152 *** (3.09)				0.0158 *** (3.27)
Public_data		0.00592 (1.55)			0.00236 (0.60)
Big_data			0.0269 *** (2.90)		0.0263 *** (2.86)
Smart_city				−0.00734 (−1.59)	−0.00695 (−1.55)
Constant	0.0115 *** (2.65)	0.0107 ** (2.44)	0.00959 ** (2.13)	0.0105 ** (2.41)	0.00985 ** (2.27)
Controls	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
R ²	0.3743	0.3673	0.3883	0.3682	0.3985
N	5859	5859	5859	5859	5859

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.2.7. Alternative Estimation Based on CSDID Framework

Given the staggered rollout of the policy, the conventional two-way fixed-effects (TWFE) regression framework may yield ambiguous results when policy impacts exhibit heterogeneous magnitudes across cohorts of pilot cities and over different time horizons.

To address this concern, this study employs the state-of-the-art staggered difference-in-differences (DID) estimator developed by Callaway and Sant’Anna to re-estimate our baseline specification [65]. Figure 5 plots the corresponding dynamic treatment effects. Pre-policy coefficient estimates fluctuate modestly around the zero reference line and are statistically indistinguishable from zero at the 95% confidence level. By contrast, ATT coefficients turn statistically significant and rise monotonically two years post-implementation, implying that the policy generates a lagged positive effect that intensifies over time. This further validates the robustness of our baseline regression results.

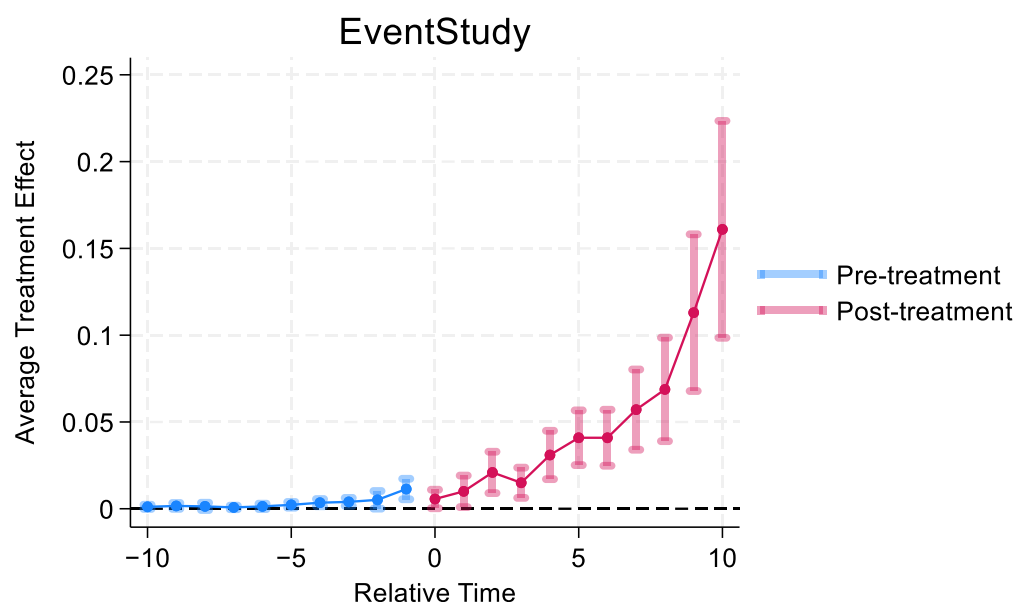


Figure 5. Alternative estimation.

5.2.8. Alternative Measure of the Dependent Variable

While the vast majority of existing studies measure industrial chain resilience solely from two dimensions, namely, industrial diversification and industrial innovation capacity, this two-dimensional measurement framework suffers from inherent limitations. Accordingly, drawing on the multi-dimensional indicator construction logic of the prior literature [9,66], this paper establishes a comprehensive evaluation index system covering four dimensions, industrial chain foundation, shock resistance, shock adaptability, and recovery and reconstruction capacity, with detailed sub-indicators presented in Table 7. We further employ the entropy weight method to recalculate the composite index of industrial chain resilience. Column (1) of Table 8 reports the regression results based on the alternative dependent variable. The core coefficient remains significantly positive at the 1% statistical level, which verifies the robustness of our baseline findings.

Table 7. Evaluation index system of industrial chain resilience.

Primary Indicator	Secondary Indicator	Direction	Weight
Industrial Chain Foundation	Per Capita Total Highway Freight Volume	+	0.0720125
	Per Capita Road Area	+	0.0185475
Shock Resistance Capacity	Industrial Diversification Index	+	0.0051765
	Ratio of Total Retail Sales of Social Consumer Goods to Gross Regional Product	+	0.0056693

Table 7. Cont.

Primary Indicator	Secondary Indicator	Direction	Weight
Shock Adaptability Capacity	Number of Authorized Invention Patents	+	0.1882037
	Ratio of Industrial Added Value to Gross Regional Product	+	0.6823632
	Comprehensive Utilization Rate of General Industrial Solid Waste	+	0.0070955
Recovery and Reconstruction Capacity	Ratio of Total Fixed Asset Investment to Gross Regional Product	+	0.0160685
	Ratio of Employed Persons in the Tertiary Industry to Total Employed Persons	+	0.0048634

Note: The symbol “+” denotes positive indicators, meaning a higher value of the indicator contributes to stronger industrial chain resilience.

Table 8. Robustness test results.

	(1)	(2)
	Alternative Measure of the Dependent Variable	Alternative Fixed Effect Specifications
DID	0.0116 *** (6.14)	0.0605 *** (15.43)
Constant	0.00986 *** (8.24)	−0.00672 (−1.54)
Controls	YES	YES
City FE	YES	NO
Province FE	NO	YES
Year FE	YES	YES
R ²	0.1052	0.5153
N	5859	5859

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.2.9. Alternative Fixed Effect Specifications

To further verify the reliability of our empirical findings, we adjust the fixed-effect structure of the baseline specification by replacing the original city and year two-way fixed effects with province-by-year interactive fixed effects and re-estimate the DID model. As shown in Column (2) of Table 8, the coefficient of the core policy variable remains statistically significant with no material change after modifying the dimensions of fixed-effect controls, which further confirms the robustness of our baseline regression results.

5.2.10. Instrumental Variable Method

Considering that the selection of pilot cities may not be entirely exogenous but rather correlated with cities’ own industrial foundations, development levels, and other factors, this may give rise to endogeneity concerns due to two-way causality. To mitigate this estimation bias, this paper employs the annual year-end stock of bank branches in each city as an instrumental variable for the science and technology finance policy [67]. The choice of this instrumental variable is based on the following two considerations:

First, we discuss the relevance condition. Bank branches serve as the fundamental carriers of financial service provision, and their stock directly reflects a region’s financial infrastructure level and financial accessibility. Generally speaking, cities with higher levels of financial development are more likely to foster local science and technology finance, thereby satisfying the relevance requirement.

Second, we discuss the exogeneity condition. The stock of bank outlets is largely determined by long-term factors, such as regional population size, economic development history, and administrative boundary adjustments, and it exhibits strong inertia in the short

term. Relative to the contemporaneous shock of science and technology finance policy, it can be regarded as approximately exogenous. Nevertheless, we cautiously acknowledge that the stock of bank outlets may also affect industrial chain resilience through channels such as credit availability, implying that the exclusion restriction is not perfectly satisfied. Therefore, this paper places greater emphasis on using the instrument as an auxiliary identification device to mitigate biases arising from omitted variables and reverse causality, rather than as a strict causal identification strategy.

Table 9 presents the regression results after addressing endogeneity using the instrumental variable approach. The first-stage results show that the instrumental variable is significantly correlated with the endogenous variable at the 1% level. The Kleibergen–Paap rk LM statistic rejects the null hypothesis of under-identification at the 1% level, and the Cragg–Donald Wald F statistic (655.772) and the Kleibergen–Paap rk Wald F statistic (20.211) are both well above the Stock–Yogo 10% critical value of 16.38, ruling out concerns about weak instruments. The second-stage regression results indicate that the coefficient on the fitted value of the core explanatory variable is 0.219, which is significant at the 1% level, suggesting that after controlling for endogeneity using the instrumental variable, the promoting effect of the science and technology finance policy on industrial chain resilience remains robust.

Table 9. Instrumental variable method.

	(1)	(2)
	DID	ICR
Bank	0.000 *** (4.50)	
DID		0.219 *** (6.50)
Constant	0.00986 *** (8.24)	−0.00672 (−1.54)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
N	5859	5859
Kleibergen–Paap rk LM		15.929 ***
Cragg–Donald_Wald_F		655.772
Kleibergen–Paap Wald rk F		20.211

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3. Heterogeneity Analysis

5.3.1. Regional Heterogeneity

Given that the impacts of policies on industrial chain resilience may vary across regions, this research partitions all city samples into southeast and northwest subgroups according to the Hu Huanyong Line and then performs separate grouped regressions for the two subgroups. The corresponding results are presented in Table 10. The empirical outcomes show that the policy exerts a significant positive effect on industrial chain resilience in southeastern cities, while such an effect is insignificant in northwestern regions. The underlying reasons are summarized as follows. First, the southeast boasts a higher level of economic development, diversified industrial structures, and larger industrial scale, and it is undergoing accelerated industrial upgrading, which endows it with inherent advantages in enhancing industrial chain resilience. Second, this region has superior financial and technological endowments as well as broader market space, which can amplify the transmission effect of policies. Additionally, the higher proportion of secondary and tertiary industries raises local reliance on financial resources and technological innovations, thereby enabling the policy effects to be fully exerted. Third, industrial development in the northwest remains relatively backward. Although the policy can boost scientific

and technological research and development, relevant achievements fail to be efficiently transformed into practical production capacity, which weakens the policy influence on industrial chain resilience.

Table 10. Analysis of urban regional heterogeneity.

	(1)	(2)
	Southeast Region	Northwest Region
DID	0.0659 *** (5.86)	0.0211 (1.62)
Constant	0.00897 * (1.85)	0.0150 *** (3.57)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
R ²	0.4062	0.2280
N	4641	1218

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3.2. City Size Heterogeneity

In accordance with the State Council's circular that revises the categorization criteria for city population scales, we split the full sample into two subsample groups, mega and large cities, as well as small and medium urban areas, and run separate regression estimations for each group. Corresponding regression outputs are laid out in Table 11. The findings reveal that the promoting effect is significant at the 1% level for large and above-sized cities, while no obvious effect is observed for small and medium-sized cities. A plausible explanation is that, compared with small- and medium-sized cities, large cities are endowed with more abundant capital and human resources. The sci-tech finance policy can be effectively transmitted through the capital and labor markets, increasing investment in R&D and attracting innovative talents, thereby significantly enhancing urban industrial chain resilience.

Table 11. Analysis of urban size heterogeneity.

	(1)	(2)
	Large	Small and Medium
DID	0.0570 *** (5.31)	0.00310 (0.79)
Constant	0.00240 (0.28)	0.0201 *** (14.89)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
R ²	0.4904	0.3483
N	2142	3717

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3.3. Urban Resource Endowment Heterogeneity

Following the classification criteria set out in the National Plan for the Sustainable Development of Resource-Based Cities (2013–2020), this study divides the full city sample into two groups—resource-based cities and non-resource-based cities—and conducts subsample regressions. The regression results (see Table 12) show that the science and technology finance policy exerts a significant positive effect on industrial chain resilience in cities with relatively scarce resource endowments, whereas no such significant promotion effect is observed in resource-abundant cities. This disparity may be attributed to the following three reasons. First, resource-based cities are deeply trapped in resource-dependent development paths, characterized by monolithic industrial structures and limited industrial

chain extension, which hinder their ability to effectively absorb and translate the supportive resources provided by science and technology finance. In contrast, non-resource-based cities, lacking inherent resource dividends, are compelled to proactively diversify into high-tech and emerging industries, thereby more fully capturing policy benefits and enhancing the risk resistance capacity of their industrial chains. Second, credit resources in resource-based cities have long been entrenched in resource extraction and related traditional sectors, making it difficult for policy interventions to fundamentally reverse the entrenched allocation bias, leaving persistent financing gaps in innovation-driven fields. Conversely, the financial systems of non-resource-dependent cities are better aligned with the imperatives of science- and technology-driven development, enabling precise policy-led capital supplementation in key areas, such as R&D and collaborative linkages along the industrial chain. Third, resource-based cities typically have fewer innovation actors and lagging industry–university–research translation mechanisms, lacking the complementary innovation ecosystem necessary for science and technology finance to function effectively. Non-resource-based cities, by contrast, have consistently cultivated innovation platforms and talent systems, allowing financial capital to be swiftly channeled into tangible industrial upgrading and technological advancement, thereby significantly strengthening the capacity for industrial recovery and adaptive response to external shocks.

Table 12. Analysis of urban resource endowment heterogeneity.

	(1)	(2)
	Resource-Based Cities	Non-Resource-Based Cities
DID	0.00487 (0.91)	0.0624 *** (5.80)
Constant	0.0197 *** (17.60)	0.00761 (1.28)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
R ²	0.3923	0.4359
N	2394	3465

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3.4. Urban Industrial Base Heterogeneity

Drawing on the official list defined in the National Adjustment and Transformation Plan for Old Industrial Bases (2013–2022) issued by the National Development and Reform Commission of China, we divide all city observations into two subsamples, old industrial base cities and non-old industrial base cities, followed by subsample regression estimations. The regression outcomes (see Table 13) reveal that the coefficient on the DID is significantly positive in both groups, yet notable disparities emerge in the magnitude and statistical significance of policy effects. For non-old industrial base cities, the DID coefficient stands at 0.0700 and is statistically significant at the 1% level. By contrast, the coefficient for old industrial base cities only reaches 0.0133, with significance merely at the 5% threshold, indicating a far weaker policy-enabled promotion effect on industrial chain resilience. Moreover, the Fisher permutation test for cross-group coefficient differences yields a p -value significant at the 1% level, verifying that the policy impacts differ materially across the two subgroups.

We attribute such heterogeneous patterns to structural discrepancies in industrial endowments. Non-old industrial base cities are dominated by private emerging manufacturing sectors with flexible industrial ecosystems and concentrated innovative enterprises. Credit support and innovation subsidies delivered by the technology and finance policy can be efficiently allocated to satisfy the upgrading demands of industrial chains, thereby generating pronounced policy dividends. In comparison, old industrial base cities suffer

from path dependence on traditional heavy chemical industries, high sunk costs associated with heavy asset transformation, and inadequate science and innovation supporting facilities. These frictions hinder the transmission of technology and financial resources to real industrial sectors, substantially diminishing the marginal contribution of the policy to strengthening industrial chain resilience.

Table 13. Analysis of urban industrial base heterogeneity.

	(1)	(2)
	Old Industrial Base	Non-Old Industrial Base
DID	0.0133 ** (2.31)	0.0700 *** (5.92)
Constant	0.0164 *** (6.07)	0.0103 * (1.80)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
R ²	0.5120	0.3996
N	1974	3885
Empirical <i>p</i> -value of the Fisher test	0.000 ***	

Note: *t* statistics in parentheses; * *p* < 0.1, ** *p* < 0.05, and *** *p* < 0.01.

6. Mechanism Analysis

6.1. Model Specification

We adopt stepwise regression to identify potential transmission channels through which sci-tech finance policies affect industrial chain resilience [68]. It should be noted that all mediators in this study are contemporaneous variables observed after policy rollout, which are subject to both the impact of the pilot policy and unobserved time-varying city-level confounding factors. Restricted by model specification and data availability of proxy variables, the mediation regression results presented below only constitute preliminary exploratory evidence that reveals correlational linkages among variables. These findings are intended to provide suggestive clues for subsequent policy refinement and further rigorous research on causal mechanisms.

The mediation models are constructed as follows:

$$MV_{it} = \alpha_1 + \alpha_2 DID_{it} + \gamma Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (7)$$

$$ICR_{it} = \rho_1 + \rho_2 DID_{it} + \rho_3 MV_{it} + \gamma Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (8)$$

where MV_{it} denotes the mediation variables, including the financial interrelations ratio (FIR), deposit–loan gap of financial institutions (CLD), proportion of employees engaged in computer and software industries (Employee), internet penetration rate (IPR), and high-tech application level (AIL).

A significant coefficient α_2 in Equation (7) indicates that sci-tech finance policy exerts remarkable impacts on mediation variables. On this premise, if ρ_3 is statistically significant, the corresponding variable serves as a vital transmission channel linking sci-tech finance policy and urban industrial chain resilience. Specifically, a significant ρ_2 suggests a partial mediation effect, while an insignificant ρ_2 implies a full mediation effect.

6.2. Financial Deepening Level

This paper adopts the financial interrelation ratio (FIR) and deposit–loan gap (CLD) as proxy variables for the level of financial deepening to conduct mechanism tests. The two indicators are substituted into Equation (3) for regression, and the corresponding estimation

results are reported in Columns (1) and (3) of Table 14. The regression outcomes reveal that the sci-tech finance pilot policy exerts a statistically significant positive impact on regional financial deepening, which delivers preliminary correlational evidence for Hypothesis H2. Further observation of Columns (2) and (4) demonstrates that after incorporating the mediating variable, the coefficients of the core explanatory variable (the DID interaction term) and the mediator of financial deepening level are both significantly positive. This preliminary evidence implies that the sci-tech finance policy may boost urban industrial chain resilience by lifting the degree of regional financial deepening.

Table 14. Mechanism test of financial deepening level.

	(1)	(2)	(3)	(4)
	FIR	ICR	CLD	ICR
DID	0.144 * (1.90)	0.0571 *** (6.14)	1637.3 * (1.70)	0.0502 *** (6.42)
FIR		0.0133 *** (2.60)		
CLD				0.00000541 *** (5.42)
Constant	1.586 *** (30.65)	−0.0103 (−1.07)	41.98 (0.08)	0.0106 *** (3.17)
Controls	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
R ²	0.6505	0.3844	0.0882	0.5167
N	5859	5859	5859	5859
Bootstrap (1000 replications) confidence interval	[0.000582, 0.003589]		[0.0087716, 0.0167147]	

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

To further identify this potential transmission channel, this study follows the classic mediation testing frameworks proposed by Preacher and Hayes [69]. We employ the Bootstrap resampling method with 1000 repeated samplings to calculate indirect effects and construct 95% confidence intervals, which serve as auxiliary references to judge potential mediating transmission links. As shown in Table 14, at the 95% confidence level, the confidence interval of the indirect effect corresponding to FIR is [0.000582, 0.003589], while the interval for the deposit–loan gap CLD is [0.0087716, 0.0167147]; neither interval contains zero. This result indicates that the financial deepening level presents certain mediating correlation characteristics. It preliminarily reflects that the sci-tech finance pilot policy can expand the scale of regional financial deepening to strengthen urban industrial chain resilience, providing suggestive empirical clues for Hypothesis H2.

6.3. High-Tech Application Level

Table 15 presents the estimation results for the mediating channel of high-tech application level. The regression result in Column (1) indicates that the sci-tech finance pilot policy is positively and significantly correlated with regional high-tech application level at the 1% significance level. Further results in Column (2) show that the coefficients of the core DID term and the mediating variable (AIL) are both significantly positive at the 1% level. The Bootstrap test with 1000 repeated samplings yields a 95% confidence interval of [0.0168698, 0.028845], which does not contain zero. These suggestive correlational clues preliminarily imply that the sci-tech finance policy may boost urban industrial chain resilience via lifting the local high-tech application level, offering partial empirical support for Hypothesis H3.

Table 15. Mechanism test of high-tech application level.

	(1)	(2)
	AIL	ICR
DID	3899.4 *** (5.41)	0.0351 *** (5.47)
AIL		0.00000614 *** (8.28)
Constant	−1186.6 *** (−2.94)	0.0182 *** (6.56)
Controls	YES	YES
City FE	YES	YES
Year FE	YES	YES
R ²	0.2353	0.6779
N	5859	5859
Bootstrap (1000 replications) confidence interval	[0.0168698, 0.028845]	

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

6.4. Informatization Level

Based on the foregoing theoretical analysis, this paper carries out mechanism tests for the informatization level channel, with the corresponding results presented in Table 16. Columns (1) and (2) report the empirical findings using the proportion of employees in the computer and software industries (Employee) as the mediating variable, while Columns (3) and (4) employ the number of broadband Internet access subscribers (Internet) for relevant verification. All core coefficients pass the significance test, which provides preliminary correlational clues for the potential existence of this transmission channel.

Table 16. Mechanism test of informatization level.

	(1)	(2)	(3)	(4)
	Employee	ICR	Internet	ICR
DID	0.0309 ** (2.17)	0.0487 *** (5.31)	92.67 *** (4.89)	0.0348 *** (4.92)
Employee		0.337 *** (4.61)		
Internet				0.000262 *** (4.50)
Constant	0.0516 *** (9.28)	−0.00652 (−1.10)	11.96 * (1.78)	0.00773 ** (1.97)
Controls	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
R ²	0.1996	0.4474	0.6140	0.4910
N	5859	5859	5859	5859
Bootstrap (1000 replications) confidence interval	[0.0057419, 0.013285]		[0.0265809, 0.0377736]	

Note: t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

To further identify the potential mediating correlation, this study conducts a Bootstrap resampling test with 1000 replications for supplementary validation. The estimation results show that the 95% confidence intervals of the indirect effects corresponding to the two proxy variables are [0.0057419, 0.013285] and [0.0265809, 0.0377736], respectively, and neither interval contains zero. This evidence tentatively suggests that, regardless of the measurement dimension of informatization adopted, the sci-tech finance policy may enhance urban industrial chain resilience by raising the urban informatization level, offering empirical support for Hypothesis H4.

7. Conclusions and Policy Implications

7.1. Main Conclusions

Taking the pilot policy for integrating science, technology, and finance as a quasi-natural experiment, this paper adopts the multi-period DID model to conduct empirical analysis based on the policy implementation information in 2011 and 2016, as well as panel data of 279 prefecture-level cities from 2003 to 2023. This study systematically explores the influence effect, transmission mechanism, and heterogeneous characteristics of sci-tech finance policies on urban industrial chain resilience. The main conclusions are drawn as follows.

First, the pilot policy exerts a significant positive effect on the improvement of urban industrial chain resilience.

Second, preliminary evidence suggests that such policies may help enhance urban industrial chain resilience by elevating the regional financial deepening level, promoting the application of high and new technologies, and raising the urban informatization level.

Third, the policy impact presents obvious heterogeneity across different city characteristics. In terms of geographical location, the policy significantly boosts industrial chain resilience in southeastern cities, while no evident effect is observed in northwestern cities. In terms of city scale, the policy effect is significant in large and super-large cities but insignificant in small and medium-sized cities. From the perspective of urban resource endowments, prominent policy effects exist in non-resource-based cities rather than resource-based cities. Regarding industrial foundation heterogeneity, the policy's enabling effect is substantially weaker in cities designated as old industrial bases than in non-old industrial base cities.

7.2. Policy Recommendations

First, further deepen the in-depth integration of science and technology with finance and amplify the enabling role of relevant policies. Taking pilot demonstrations as the key vehicle, governments shall guide the concentration of financial resources in technological innovation sectors. The two-way empowerment between technology and finance consolidates industrial chain resilience, thereby establishing a long-term sustainable virtuous cycle where finance empowers scientific and technological innovation, innovation advances industrial upgrading, and industrial development underpins economic growth. On one hand, a multi-tiered tech-finance service system and investment guarantee mechanism shall be refined. Governments may guide financial institutions to develop tailored financial products for tech firms and deliver targeted services. Stable financial supply addresses industrial bottlenecks and consolidates industrial foundations to sustain long-term economic expansion. Policy implementation can be boosted via authorized specialized tech-finance branches and higher performance appraisal weights for tech lending, enabling regular financial backing for industrial upgrading and steady economic growth. Meanwhile, financial institutions and regulators shall optimize investment and guarantee rules: moderately raise non-performing loan tolerance for tech enterprises, extend loan tenors, and refine credit risk management. These measures secure steady R&D funding, prevent short-term capital volatility from hindering R&D and industrial upgrading, and sustain consistent technological iteration and economic progress. On the other hand, policy support and rights protection for innovative enterprises shall be enhanced. Governments should scale up fiscal R&D investment and set up special funds to build a tech-finance framework led by fiscal funds and supplemented by credit loans. Institutionalized long-term funding nurtures innovative entities, stimulates industrial momentum, reinforces industrial chain resilience, and sustains macroeconomic development. Tax incentives can motivate corporate technological innovation and industrial transformation, deepen university–research–industry

collaboration, and accelerate the commercialization of scientific achievements. Sustained technological innovation optimizes industrial structures, breaks developmental constraints, builds long-term industrial competitiveness, and consolidates core drivers of sustainable economic growth. Additionally, improved intellectual property protection, comprehensive databases of scientific achievements and patents, and a permanent innovation safeguard system support continuous corporate innovation and industrial chain upgrading, advancing the transformation of economic development models.

Second, comprehensively improve the institutional environment under which sci-tech finance strengthens industrial chain resilience. All stakeholders shall deepen information-sharing mechanisms on sci-tech financial cooperation platforms to alleviate information asymmetry between financial institutions and enterprises, as well as among enterprises. This helps channel financial resources toward high-efficiency and high-potential tech-innovative firms. By elevating the regional financial deepening level, such measures may help consolidate the foundation for the long-term stable operation of industries and support the sustainable development of regional industries and economies. Furthermore, governments shall incentivize traditional enterprises to absorb and integrate advanced technologies while supporting emerging firms to research and deploy cutting-edge technologies. These efforts raise the penetration and utilization rate of technologies such as artificial intelligence across cities, expand the spillover effects of relevant policies, strengthen the shock resistance of industrial chains via industry-wide technological iteration, and maintain sustained growth momentum for industries. In addition, local governments should prioritize the construction of information infrastructure to deliver sound digital conditions for institutions and enterprises. This amplifies the policy impacts of sci-tech finance on urban digitalization and lays a solid foundation for long-term economic growth.

Third, attach importance to the matching between policy implementation and local institutional environment and resource endowments and implement policies in light of local conditions. For underdeveloped northwestern cities and small and medium-sized cities, local governments should focus on building a sound innovation and industrial environment, encourage universities and research institutions to carry out technological innovation, and support advantageous industries to upgrade technologies and expand scales to connect sci-tech finance policies with industrial development. For resource-based cities with abundant resource endowments, break the path dependence on resource industries, optimize the allocation of sci-tech financial capital, and guide financial resources to shift toward emerging industries and technological innovation sectors to unlock the policy-driven potential of industrial chain resilience. For cities designated as old industrial bases, which are often constrained by rigid industrial structures and historical legacies, the transmission effect of sci-tech finance policies tends to be weaker. Accordingly, local governments should fully leverage their guiding role by establishing special transformation funds, providing targeted support for technological upgrading and green transformation of traditional industries, and facilitating the deep integration of financial resources with the real economy. Meanwhile, efforts should be made to encourage the restructuring and reorganization of traditional industrial chains, foster the synergy between emerging industries and traditional advantageous sectors, and gradually enhance the sensitivity and responsiveness of old industrial base cities to sci-tech finance policies.

7.3. Limitations and Future Research Directions

This study adopts the multi-period DID model to empirically examine the impacts, transmission mechanisms, and heterogeneous characteristics of sci-tech finance policies on urban industrial chain resilience. Although the research findings provide valuable references, several limitations remain. First, this analysis is conducted based on city-level data,

which fails to capture heterogeneous performances of micro-entities, such as individual firms and segmented industries, as well as the internal differences and micro-mechanisms within cities. Second, industrial chain resilience is measured merely from industrial diversification and innovation capacity to reflect its resistance and recovery capabilities, which is one-sided and cannot fully interpret the comprehensive connotation of industrial chain resilience. Third, although the selection of pilot cities is widely distributed across economically developed first-tier cities and relatively underdeveloped second-, third-, and fourth-tier cities, which alleviates the concern that “the policy only selects central large cities for piloting” to a certain extent, and we adopt methods such as propensity score matching difference in differences (PSM-DID) and placebo tests to enhance the credibility of the research findings, these methods still cannot effectively address the sample self-selection problem caused by unobservable political and institutional factors. The existing identification strategies cannot completely eliminate the interference of these factors, which may lead to potential endogeneity problems and further affect the causal interpretability of the research conclusions. Fourth, this paper identifies three potential transmission channels, including financial deepening level, high-tech application, and urban informatization, while overlooking potential pathways such as talent agglomeration, industrial collaboration, and innovation ecosystem. Fifth, the extended analysis is insufficient. This study does not conduct further discussions combined with industrial structure and innovation endowments, nor does it fully account for other external shocks, which to some extent weakens the identification accuracy of the net policy effect.

Future research can broaden the research perspective and analytical dimensions. Researchers may extend the research sample to micro-enterprises and segmented industries and establish a multi-dimensional evaluation system for industrial chain resilience that incorporates industrial linkage, emergency adjustment capacity, and collaborative development level. In-depth exploration can also be conducted on the moderating effects and interactive relationships of various influencing factors. Additionally, comparative analyses based on diverse policy portfolios and external environments are recommended. Future studies could seek more credible instrumental variables to mitigate potential endogeneity issues arising from sample selection, thereby strengthening the robustness of causal identification. Moreover, further investigations into the long-term dynamic effects of sci-tech finance policies will enrich relevant theoretical research and offer more practical implications for the high-quality upgrading of regional industrial chains.

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