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Unlocking the Potential of Chinese Urban Innovation: The Role of Support Policies for New R&D Institutions from an Innovation Chain Management Perspective

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ABSTRACT

The enactment of policies that bolster new research and development (R&D) institutions stands as a pivotal strategy to catalyze urban innovation and development. Adopting a strategic lens of innovation chain management and employing the Differences-in-Differences (DID) method to scrutinize panel data from 43 Chinese cities spanning 2008 to 2019, this study probes the efficacy and underlying mechanisms of policies designed to support nascent R&D institutions in facilitating urban innovation. Empirical findings reveal that policies in support of new R&D institutions have markedly enhanced the three integral stages of the urban innovation chain: research and development, transfer, and application. Furthermore, the innovation ambiance within cities and the innovative activities of enterprises emerge as significant mediators between support policies and the output of urban innovation across these stages. A regional heterogeneity analysis unveils that the impact of support policies on the output of urban innovation diverges across regions, with a notably more pronounced effect observed in the eastern region compared to central and western regions. An objective appraisal of the policy's impact on urban innovation not only aids in delving into the profound implementation effects of policy instruments but also furnishes policy-makers with decision-making references for optimizing the utilization of support policies for new R&D institutions to advance the edification of the national innovation system.

KEYWORDS

New R&D institutions; urban innovation; innovation chain management; Differences-in-Differences

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1. Introduction

New Research and Development (R&D) institutions, characterized as legally autonomous entities with a primary focus on scientific and technological innovations, engage in scientific research, proffer R&D services, implement modernized management systems, operate with a market-oriented approach, adopt flexible employment mechanisms, and are subject to diversified investments. The inception of China's new R&D institutions in 1996, symbolized by the establishment of the Tsinghua University Research Institute in Shenzhen, heralded the official commencement of R&D institutions co-founded by universities and local communities. New R&D organizations, epitomized by these institutions, have swiftly proliferated to adapt to the intricate and perpetually evolving global technological and industrial revolution, promoting the profound integration of innovative entities and expediting the amalgamation of creative resources. This has efficaciously buttressed the high-quality development of urban innovation (Liu & Ding et al., 2023). In 2018, the Chinese government report explicitly delineated the status of new R&D institutions, formally incorporating them into the national innovation system for the first time. Subsequently, in 2019, the Ministry of Science and Technology of China promulgated the 'Guidance on Promoting the Development of New R&D Institutions,' reiterating the developmental positioning and trajectory of new R&D institutions within China. The 20th National Congress of the Communist Party of China further underscored the imperative to 'enhance the scientific and technological innovation system' and 'adhere to the core position of innovation in China’s comprehensive modernization'. Local governments at all levels have also devised a series of policy documents to stimulate innovation within the scientific and technological system and foster the development of new R&D institutions, providing institutional assurances for the establishment of new R&D institutions. New R&D institutions constitute a crucial component of China's strategy to propel innovation-driven development and expedite the construction of independent innovation demonstration zones. By robustly developing strategic national scientific and technological capabilities, such as new R&D institutions, collaborative endeavors of industry, academia, and research institutions can be effectively integrated, driving breakthroughs in fundamental research and critical core technology development from 'zero to one.' This is pivotal for hastening the construction of China's scientific and technological innovation system and collaborative innovation capabilities, addressing the bottleneck issue of critical core technologies, and achieving high-level technological self-reliance and self-improvement. In the construction, cultivation, operation, and evaluation of new R&D institutions across various regions, local governments, serving as the primary policy body, have played an indispensable role in providing policy guidance and guarantees. New R&D institutions, with multiple advantages concerning policy support, practical operations, and relevant theories, can further enhance China's urban innovation level and facilitate the progression of economic transformation and upgrading.

China's emergent research institutions significantly catalyze the unlocking of urban innovative potential. Predominantly, these entities encompass public institutions, orchestrated and overseen by governmental bodies or universities, while a subset is constituted by private institutions, inaugurated by corporate enterprises. In the context of organizational morphology, research institutions in China span an extensive array of domains, including research centers embedded within research institutes and higher educational entities, state key laboratories, and innovation and entrepreneurial incubators. These organizations typically assemble a cadre of professionals, comprising researchers, engineers, and technologists, who bring forth a wealth of research experience and specialized expertise. Pertaining to funding avenues, Chinese research entities predominantly draw financial sustenance from a multifaceted array of channels, inclusive of governmental allocations, industry grants, and research funds. Governmental allocation emerges as the paramount funding source, with governments at various levels furnishing research organizations with project financing and operational budgets. Additionally, certain research organizations engage in collaborative endeavors with enterprises to execute projects and secure financial backing. Research funds, such as the National Natural Science Foundation of China and the National Social Science

Foundation of China, also emerge as pivotal funding sources. Chinese research organizations typically wield a degree of autonomy in policy and goal formulation. While the government delineates the overarching innovation policy framework and objectives, research institutions, during the execution phase, are empowered to establish specific research trajectories, topic selections, and collaborations, anchored in their intrinsic characteristics and strengths. This autonomy facilitates a nimble response to research requisites across diverse domains and fosters the evolution of the innovation chain.

Innovation serves as the quintessential propellant transitioning from scale augmentation to high-quality development (Xiao et al., 2022). Urban environments, acting as pivotal spatial carriers for innovation activities, emerge as premier destinations and conglomerations for innovation factors, thereby constituting an indispensable locale for the market-oriented allocation of factors (Rothwell & Robertson, 1973). Not only is urban innovation crucial for economic proliferation, but it also plays a vital role in realizing regional green development (Liu & Zheng et al., 2023). To streamline the implementation of innovative urban construction, governments have proactively promulgated pertinent support policies at the urban echelon, robustly fostering the inception and evolution of new R&D institutions. Such policies facilitate a comprehensive and efficacious amalgamation of innovation factors, thereby catalyzing the confluence of innovation, industrial, and capital chains. Cities, as the principal executors of the support policies for new R&D institutions, pose a significant research query within the expansive context of urban development: How precisely do they accrue benefits from these policies? To probe this issue further, this study adopts the lens of innovation chain management, aspiring to address the ensuing pivotal inquiries: Does the support policy for new R&D institutions veritably augment the innovation caliber of cities? If affirmative, how is this impact articulated? Initially, we scrutinize the direct effects of the policy on urban innovation outcomes. Subsequently, we delve deeper into the relationship between the support policies for new R&D institutions and urban innovation outputs, accentuating the role of innovation atmosphere and corporate innovative behaviors, to unveil the underlying mechanisms.

Contrasted with preceding studies, the potential marginal contributions of this paper can be delineated across the following three facets:

(1) This study transcends the methodological constraints of extant literature by quantitatively appraising the policy impacts of new R&D institutions through the Differences-in-Differences method. It furnishes direct empirical substantiation for the urban innovation dividends engendered by policies supportive of new R&D institutions. Predominantly, academic inquiries into new R&D institutions have been institution-centric, scrutinizing aspects such as performance evaluation, organizational and functional positioning (Lin Jiang & Zhu Jianjun, 2021), knowledge transfer logic (Belderbos et al., 2018), and the profound integration of industry, academia, and research. The research conclusions proffer theoretical scaffolding for enhancing urban innovation development via supportive policies for new R&D institutions.

(2) This paper punctures previous research perspective limitations by adopting the philosophy of innovation chain management to dissect how supportive policies for new R&D institutions bolster urban innovation. The policy effects are meticulously analyzed across the three stages of urban innovation output: research and development, transformation, and application. The paper renders a holistic depiction of the policy dividends elicited by supportive policies for new R&D institutions. Whereas prior analyses of the role of supportive policies for new R&D institutions at the urban level have lingered at a theoretical echelon, the actual impact remains elusive. Thus, this paper intertwines the challenges faced in urban innovation development with specific policy content, addressing pivotal questions from an empirical standpoint, such as why and how supportive policies for new R&D institutions can be beneficial to urban innovation. It serves as a reference for future policy optimization.

(3) The research, initiating with the characteristics of integrating industry, academia, and research resources in new R&D institutions, embeds the innovation atmosphere and enterprise innovation behavior into the research

framework. It scrutinizes whether supportive policies for new R&D institutions further influence urban innovation development through the aforementioned channels. Utilizing the fixed effects of the DID model, the paper discerns the policy effects with utmost clarity to enhance result credibility. Methodologically, it offers a benchmark and guidance for ensuing policy evaluation studies. In summation, this paper provides authoritative and directive insights for amplifying the formulation and execution of policies for new R&D institutions, propelling the efficient functioning of urban innovation chains, and augmenting national and local innovation capacities.

2. Literature Review and Research Hypotheses

The innovation chain has emerged as a focal point in innovation management research, both nationally and globally. This concept dissects the innovation process from a comprehensive viewpoint, concentrating on value creation at each juncture and pinpointing the predominant strategies for value generation (Hansen et al., 2007), ultimately giving rise to the innovation value chain model. Numerous scholars employ this model to scrutinize the innovation mode within specific industries or the efficacy of pertinent innovation policies (Roper et al., 2008). Nonetheless, the academic community has yet to reach a consensus regarding the fundamental connotations of innovation chain theory, with various methodologies proposed for segmenting the stages of the innovation chain, including divisions into 3, 4, and 7 stages. The tripartite division method prevails in academic research. This paper adopts the three-stage division concept to analyze the intimate relationship between policy support for new R&D institutions and urban innovation through the lens of the innovation value chain. Specifically, adhering to the innovation process delineated by Stephen and Spyros, we categorize the urban innovation chain into three stages: R&D, transformation, and application.

The Theory of Knowledge Spillover meticulously delineates the mechanisms underlying the flow and dissemination of knowledge amongst organizations and regions. Policies bolstering new R&D institutions indispensably permeate all facets of the urban innovation chain, fostering knowledge exchange and propelling the judicious allocation of resources pivotal for urban industrial metamorphosis and enhancement. At the R&D juncture, policy instruments shepherd new R&D institutions through the "valley of death" (Ellwood et al., 2022), catalyzing the progression of both foundational and applied research. Beyond proffering incentives, such as fiscal subsidies and tax alleviations, to stimulate innovation entities to partake in knowledge exchange and amplify the agglomeration of urban innovation factors (Li et al., 2022), policies also efficaciously cultivate the congregation of innovative talent (Sarpong et al., 2023) and capital, thereby elevating the comprehensive caliber of urban innovation (Fan et al., 2021; Zhang et al., 2023). In the transformation phase, the policy's impact is manifested in the enhancement of alignment and collaboration between new R&D institutions and the industry, thereby augmenting the capacity to amalgamate, allocate, and assimilate other elements of the industrial chain and facilitating potential strategic recalibrations and technological advancements among innovation agents. This engenders the integration, configuration, and absorption capacity of other elements in the industrial chain, enabling strategic adjustments and technological progress among innovative entities (Liu, Y et al., 2023). The innovation breakthrough of core technology often commences from specific domains, triggering profound alterations in specific industries through the transformation and industrialization of results. Furthermore, industries exhibit a correlation-driven effect, thereby instigating profound shifts in numerous industrial domains and ultimately propelling the high-quality development of urban innovation. The urban innovation application link perpetually confronts the risk of innovation result failure. New R&D institutions, established through the cross-border integration by government, academia, and industry, embody platform attributes such as resource integration, function integration, and network amplification (Cennamo & Santalo, 2019). The policy of new R&D institutions promotes the efficacious flow and allocation of innovation resources and factors within and outside the city, augmenting the network effect and agglomeration effect of urban innovation by fostering synergistic linkage with innovation subjects such as

universities, research institutes, and enterprises, creating an open and shared innovation platform, and constructing a multi-level incubation service system (Zhou & Wang, 2023). With the support and guidance of the government and the optimal allocation of the market, a series of integrated advantages such as its information and financing service platform and institutional guarantee mechanism are fully relied on to reduce and avoid to a certain extent all kinds of risks that may exist in the innovation process (Henriques & Larédo, 2013). The protection and management of scientific and technological achievements are strengthened through measures such as intellectual property protection, promoting the landing of innovative achievements to industrial applications, and opening the last mile of transformation of scientific and technological achievements to further enhance the level of urban innovation (Dvir & Pasher, 2004). It can be posited that the interaction between different links in the urban innovation chain, promoted by the policy of new R&D institutions, affects the combination, flow, and diffusion of innovation factors, and the coupled and coordinated development of each link assists in enhancing the overall urban innovation level. Consequently, the following hypothesis is proposed:

H1. Supportive policies for new research institutions significantly amplify the generation of innovation knowledge across all three stages of urban innovation.

Policies advocating for new R&D institutions disseminate propitious innovation signals throughout society, engendering a creative urban milieu that invigorates the zeal of all innovation stakeholders. The Innovation Systems theory underscores the systemic essence of innovation and the symbiotic interactions amongst myriad stakeholders. On one flank, a vibrant urban innovation environment can efficaciously kindle and nurture the vitality and creativity of all innovation entities by magnetizing and clustering a diverse array of innovation actors, thereby perpetuating an upward trajectory in the city's innovation caliber and engendering a virtuous cycle within the urban innovation ecosystem (Walrave et al., 2018). Conversely, through the assiduous promotion of an innovative soft environment in cities via supportive policies, the government establishes a positive institutional and cultural climate, thereby fostering a conducive atmosphere for urban innovative vitality. Numerous scholars have affirmed the salutary impact of an innovative environment on the innovation performance of individuals and corporations within organizational innovation (Jing & Cisheng, 2021). The innovation environment exhibits a significant correlation with the level of urban innovation within the urban carrier. Amidst urban policy support, diverse innovation actors increasingly interdepend to realize organizational innovation. A more supportive urban innovation environment facilitates inter-organizational knowledge sharing and collaboration (Ankrah et al., 2013). Consequently, adequate policy support and a dynamic innovation environment in cities proffer a sustained propellant for the evolution of urban innovation. Predicated on these findings, this paper posits:

H2a. Supportive policies for new research institutions can catalyze urban innovation by fostering an innovative environment within urban locales.

Enterprises, as pivotal agents in urban innovative endeavors, significantly influence the trajectory of urban innovation through their innovative behaviors and outcomes (Zhao, Q et al, 2023). New R&D institutions, categorizable into various types based on their founding entities—such as government-led, university-led, research institute-led, enterprise-led, and collaborative models—play a crucial role in this context. The 2022 Report on the Development of New R&D Institutions underscores that over 50% of China's new R&D institutions are enterprise-led, spotlighting their cardinal role in national innovation and establishing a robust linkage between new R&D institutions and enterprise innovation activities (Borrás & Edquist, 2013). Policy orientation emerges as a fundamental catalyst in propelling urban innovation (Liu et al., 2022). Policies in support of new R&D institutions furnish enterprises with pivotal incentives and backing to undertake vigorous innovative activities, thereby fostering an augmentation in the urban innovation output. On the one hand, the innovation management and organizational structure of new R&D institutions are not unilaterally directed by the government but are a confluence of enterprise proposers, pivotal project collaborative promotion, and R&D activity amalgamation,

culminating in an "innovation consortium" model (Van Beers et al., 2014). Pertaining to innovation chain management, the efficacy of crucial links such as R&D, transformation, and application is predominantly contingent upon the collaboration among enterprise-led innovative entities, logical task allocation, and systematic segmentation of disparate strategic technological forces, ultimately giving rise to "organized scientific research" (Zhou & Wang, 2023; Zhu, T et al., 2022). On the other hand, incentivizing urban enterprises to establish new R&D institutions can afford them augmented developmental space and opportunities, thereby fostering their proactive participation in innovative activities. The ramifications of policies can permeate from the enterprise level to urban and regional echelons (Zor, S et al., 2023). As urban enterprises engage in a spectrum of innovative activities, exchange insights, and forge a salubrious competitive and cooperative milieu, the overarching level of innovation is enhanced, thereby catalyzing urban economic development and transformation and bolstering its comprehensive competitiveness and allure (Wang, L et al., 2023). Thus, amidst the prevailing wave of digitization, policies supporting new R&D institutions stimulate and back enterprises to engage in innovative activities in a myriad of ways, thereby invigorating corporate innovation in cities. Subsequently, these policies render positive contributions to amplifying the innovation caliber of cities (Ding et al., 2023). Consequently, this paper posits:

H2b. Supportive policies for new research institutions can galvanize enterprise innovation and substantively contribute to urban innovation.

3. Model specifications and data sources

3.1. Data sources

China encompasses a vast array of cities, presenting inherent challenges and constraints when utilizing a comprehensive sample for research. To assure the research's feasibility and precision, this study initially selects the top 50 cities, as ranked in the China Digital City Competitiveness Research Report 2022, subsequently excluding cities characterized by substantial data omissions and ultimately focusing on 43 cities spanning from 2008 to 2019. Esteemed and authoritative in its domain, the study provides a thorough evaluation and ranking of individual cities nationwide, ensuring the findings are both representative and universally applicable, thereby holding substantial significance for exploring urban innovation potential. Patent data have been sourced from the State Intellectual Property Office (SIPO) database and the Patent Cloud Platform, while additional data have been extracted from the China Science and Technology Statistical Yearbook, China Urban Statistical Yearbook, local municipal science and technology bureau websites, and statistical bulletins pertaining to the national economic and social development of select cities. For indicators with absent or singular values, data were supplemented utilizing the linear interpolation method.

3.2. Variable Selection and Measurement

3.2.1. Dependent variable

Innovation output of urban (Inn). The variable is typically evaluated using a variety of methods and indicators. Commonly employed techniques include factor analysis, the DEA method, and others. The evolution of evaluation indicators has transitioned from a simplistic, linear model, which was focused on individual innovation entities, to a more comprehensive framework that accommodates multiple innovation entities. Accordingly, this study partitions the innovation output of urban areas into three stages - Research and Development (R&D), Transformation, and Application - building on the innovation output indicators outlined in the "China Innovation Urban Evaluation Report" and the innovation chain proposed by Zhang Rui et al (2022). In the R&D stage, the methodology of HAGEDOORN J and CLOODT M (2003) is adhered to, measuring innovation output via the quantity

of patent applications. In the Transformation stage, the approach of Li Fanbo and Zhang Hongfeng (2022) is adopted, utilizing the number of patent transfers to gauge innovation output. Meanwhile, in the Application stage, sales revenue from new products is employed as an indicator, following the methodology articulated by Jie Yang and Liu ChangYung et al. (2006).

3.2.2. Independent variable

New R&D institutions support policies (DID). The variable, *Urban × Policy*, models the interaction between the supportive policies for new R&D institutions and urban entities. Here, 'Policy' is a dummy variable, assigned a value of 1 in the year of policy implementation and thereafter, and 0 otherwise. 'Urban' characterizes the city where the policy is implemented. If the city is where the policy is enacted, it is identified as the experimental group (*Urban = 1*); otherwise, it is designated as the control group (*Urban = 0*). The coefficient of primary interest, *Urban × Policy,* investigates the impact of supportive policies for new R&D institutions on innovation in cities and non-cities, pre- and post-policy implementation.

3.2.3. Mediating variable

Urban Innovation Atmosphere (UIA). The variable 'Urban Innovation Atmosphere (UIA)' encapsulates a spectrum of indicators utilized to evaluate the urban innovation ecosystem. This investigation integrates innovation environment indicators, as advocated by Paskaleva and Cooper (2018), which envelop fundamental innovation policies and innovation development capacities. To mitigate dimensionality, principal component analysis is employed, with the resultant score mirroring the magnitude of the innovation climate within the urban milieu.

Firm Innovation Behavior (FIB). The variable 'Firm Innovation Behavior (FIB)' gauges the extent of research and innovation activities undertaken by large-scale enterprises within urban locales, quantified by their R&D investment intensity, adhering to the methodology delineated by Lee, Hsing-fen, and Miozzo, Marcela (2019).

3.2.4. Control variables

Considering the significant disparities in talent concentration, industrial structure, and level of openness across urban areas, this study incorporates technology talent aggregation, industrial structure, degree of openness, and human capital as control variables to facilitate a more impartial evaluation of the impact of supportive policies for new R&D institutions. This approach aligns with the methods employed by previous studies conducted by Caragliu, A and Del Bo, CF (2019).

To ensure the accuracy of our study, we took into consideration the timing of policy implementation across different cities. It's noteworthy that while the overall objectives and framework of the policy were consistent nationwide, the specific timing of its implementation might vary due to particular conditions and needs of different locales. Hence, we employed a multi-period Differences-in-Differences model to capture this temporal variation and ensure that our estimates are robust.Using the Differences-in-Differences model as a framework, this paper proposes the following model to investigate the influence of supportive policies for new R&D institutions on urban innovation:

$$Inn_{it} = \alpha_0 + \alpha_1 DID_{it} + \sum \gamma_j x_{jit} + v_{year} + \mu_{urban} + \varepsilon_{it} \quad (1)$$

In the aforementioned model, the subscripts i and t represent the urban and years, respectively. DID represents the virtual policy variable, with α_0 being the constant term and α_1 reflecting the estimated coefficient of the corresponding variable. X represents a series of introduced control variables, with v_{year} controlling for time-fixed effects, μ_{urban} controlling for fixed effects of urban individuals, and ε_{ij} being the random disturbance term.

Table 1. Key Variables and Variable Definitions.

Variable type	Variable name		Variable symbol	Variable definition
Dependent Variable	Policy effects of new R&D institutions		DID	DID is set to 1 for the year in which the policy is introduced and thereafter, otherwise set it to 0
Explained Variable	Urban Innovation	R&D Stage	UIRS	Per Capita Patent Applications
		Conversion Stage	UICS	Per Capita Patent Transfers
		Application Stage	UIAS	Per Capita Sales Revenue of New Products
Mediating Variables	Urban Innovation Atmosphere	Innovation Policy Support	UIA	The Proportion of Education Expenditure in Fiscal Expenditure
				The Proportion of Science and Technology Expenditure in Fiscal Expenditure
		Innovation Development Capability		Total Expenditure on Technology Introduction Funds
				Total Expenditure on Technology Digestion Funds
				Total Expenditure on Technology Renovation Funds
	Firm Innovation Behavior		FIB	The Proportion of R&D Activities in Firms Above Designated Size
	Agglomeration of Scientific and Technological Talents		TTC	The Proportion of Employees Engaged in Scientific and Technological Industries to the Total Urban Employment
Control Variables	Industrial Structure		IS	The Ratio of Added Value of Tertiary Industry to the Total Regional GDP
	Human Capital		HC	The Proportion of Employees in Computer Software and Information Industry to the Total Urban Employment
	Openness to Foreign Countries		OW	The Proportion of Total Import and Export Volume to the Total Regional GDP in the Current Year

4. Empirical Results and Analysis

4.1. Descriptive Statistics

The principal variables underwent statistical analysis, with the results delineated in Table 2. The mean value of supportive policies for new R&D institutions (DID) registers at 0.155, accompanied by a standard deviation of 0.362, signifying that 15.5% of urban areas within the sample were beneficiaries of support and encouragement pertaining to new R&D institutional policies.The R&D stage in urban innovation exhibits a mean value of 0.624 and a standard deviation of 0.663, unveiling pronounced disparities among the R&D stages of the urban areas sampled.The transformation stage manifests a mean value of 0.027, coupled with a standard deviation of 0.041, indicating relatively subdued variations among the transformation stages within the sampled urban areas. Conversely, the application stage presents a mean value of 0.037, alongside a standard deviation of 0.048, implying a relatively diminished variation across the application stages of the urban areas sampled. All remaining variables are congruent with extant literature and necessitate no additional elucidation.

4.2. Model Applicability Analysis: Parallel Trend Test

Ensuring comparability between the control and experimental groups prior to policy implementation is pivotal, serving as a prerequisite for deploying the Difference-in-Differences (DID) empirical analysis. In order to exclude other non-policy factors that might contribute to a significant enhancement in the innovation knowledge output of

Table 2. Descriptive Statistics of Key Variables.

Variable Names		Variable	Obs	Mean	Std	Min	Max
New R&D Institution Policy Dummy Variable		DID	506	0.155	0.362	0	1
Urban Innovation Output	R&D Stage	UIRS	506	0.624	0.663	0.020	5.024
	ConversionStage	UICS	506	0.027	0.041	0.000	0.359
	Application Stage	UIAS	506	0.037	0.048	0.001	0.388
Agglomeration of Scientific and Technological Talents		TTC	506	0.024	0.016	0.0016	0.088
Industrial Structure		IS	506	0.488	0.090	0.303	0.835
Human Capital		HC	506	0.020	0.018	0.003	0.107
Openness to Foreign Countries"		OW	506	0.636	0.759	0.057	5.699

cities due to the policy of supporting new R&D institutions, it becomes imperative to scrutinize whether the innovation scenario of cities in the experimental group had already exhibited improvement even before the policy was unveiled. Consequently, this paper investigates whether the experimental and control groups adhere to the parallel trends hypothesis during the application of the DID model analysis, thereby safeguarding the reliability and validity of the policy treatment effect. Employing a multi-temporal DID approach, this paper adheres to established practices by extending the time period both preceding and succeeding the policy's introduction. Specifically, window periods of one year before policy release, the year of release, and one year post-release have been designated for testing purposes.

Figure 1 displays the results of parallel trend tests conducted across the three stages of urban innovation. Prior to the treatment point, the coefficient estimates were insignificant, indicating no discernible difference in the developmental trends between the control and experimental groups before the implementation of supportive policies for new R&D institutions. This substantiates that the multi-time-point Differences-in-Differences method utilized in this study adheres to the necessary parallel trend conditions. The policy's effects during its year of implementation remained inconsequential, suggesting it did not exert an immediate impact on the output across the three stages of innovation within that year. However, subsequent to the policy's implementation, the innovation level within the experimental group cities transitioned from a negative to a positive impact, maintaining a consistent upward trajectory thereafter. This observation intimates that supportive policies for new R&D institutions manifested a substantial and sustained positive influence on the output across the three stages of urban innovation, albeit with a certain lag.

4.3. Baseline Regression Using Fixed Effects Model

Investigating the impact of supportive policies for new R&D institutions on the output at various stages of urban innovation, this study employs a two-way fixed effects model, with Table 3 illustrating the baseline regression results from the Differences-in-Differences model. Columns (1) and (2) designate the R&D stage of urban innovation (UITS) as the dependent variable, with column (2) introducing relevant control variables subsequent to column (1). Post the incorporation of control variables, the regression results reveal that the DID term coefficient in column (2) is 0.155, achieving significance at the 1% level, thereby suggesting that the enactment of supportive policies for new R&D institutions markedly fosters the R&D stage of urban innovation by amplifying enthusiasm for urban innovation R&D activities. Columns (3) and (4) assign the transformation stage of urban innovation (UICS) as the dependent variable, with column (4) introducing additional control variables subsequent to column (3). The regression results indicate that the DID coefficient in column (4) attains the 1% significance test at 0.013, implying that the supportive policies for new R&D institutions can facilitate knowledge transfer among innovation entities and expedite the transformation of urban innovation. Columns (5) and (6) utilize the application stage of urban

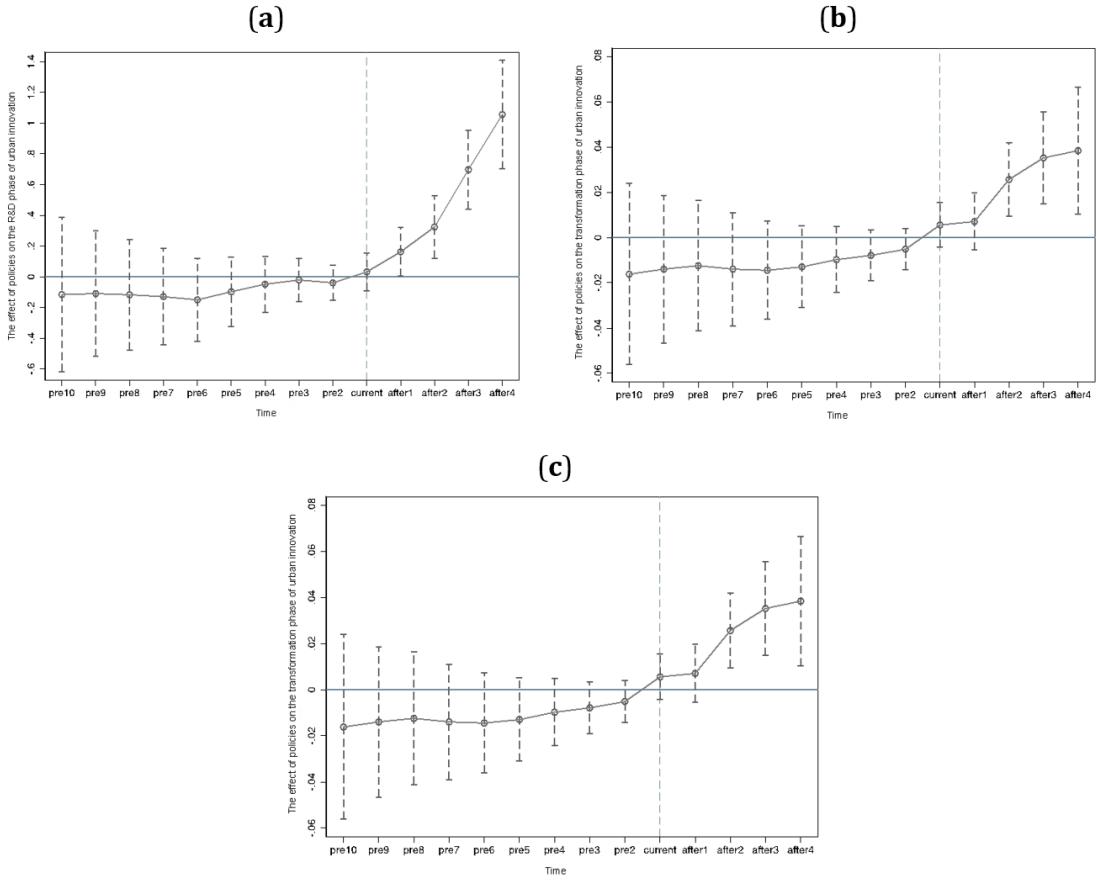

Figure 1. (a) The changes in innovation output and R&D stages in cities before and after the implementation of policies; (b) The changes in the conversion stage of innovation output in cities before and after the implementation of policies; (c) The changes in the application stage of innovation output in cities before and after the implementation of policies.

innovation (UIAS) as the dependent variable, with column (6) incorporating related control variables subsequent to column (5). The regression results demonstrate that the DID coefficient in column (6) achieves the 1% significance test at 0.121, suggesting that the policies can catalyze the transformation of knowledge into directly applicable technical forms and engender a positive feedback effect on the sales revenue of new products. Collectively, these results signify that supportive policies for new R&D institutions exert a significant and positive influence on the output across various stages of urban innovation, with a more pronounced promotional effect observed at the R&D stage. Consequently, Hypothesis H1 is substantiated.

4.4. Robustness Checks

4.4.1. Placebo Test

In an endeavor to further validate the robustness of the research findings, this study deploys a quintessential counterfactual analysis model, fabricating a 'counterfactual' policy virtual variable corresponding to the policy implementation time point to facilitate a placebo test. A significant discovery at the virtual policy time point would corroborate the robustness of the baseline regression results. Consequently, this study amalgamates pertinent support policies for new research and development institutions one year, two years, and three years in advance into the original model, scrutinizing the coefficient alterations of the policy virtual variable (DID). The regression outcomes are articulated in Table 4, spanning columns (1)-(9). In a comprehensive view, as policy implementation

Table 3. Baseline Regression Using Difference-in-Differences Method.

Variable	Model(1)	Model(2)	Model(3)	Model(4)	Model(5)	Model(6)
	UIRS	UIRS	UICS	UICS	UIAS	UIAS
DID	0.677***	0.155***	0.051***	0.013***	0.032***	0.121***
	(0.044)	(0.044)	(0.003)	(0.003)	(0.004)	(0.004)
TTC		-0.154		-0.036*		-0.005
		(0.273)		(0.020)		(0.027)
IS		-0.198***		-0.021***		-0.347***
		(0.050)		(0.004)		(0.050)
HC		-0.359		-0.110		-0.034***
		(1.292)		(0.097)		(0.013)
OW		-0.647***		-0.046***		-0.160***
		(0.061)		(0.005)		(0.006)
Constant	0.519***	1.654***	0.019***	0.143***	0.032***	0.188***
	(0.016)	(0.229)	(0.001)	(0.017)	(0.001)	(0.332)
Controls	NO	YES	NO	YES	NO	YES
Year	NO	YES	NO	YES	NO	YES
Urban	NO	YES	NO	YES	NO	YES
R^2	0.332	0.673	0.358	0.645	0.169	0.397

*Notes: Standard Errors are displayed in parentheses. *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively. The same applies to the following tables.*

nears, the counterfactual policy virtual variable exerted no influence on the output of the urban innovation research and development or application stages. Column (2) reveals that one year prior to policy implementation, the counterfactual policy variable significantly impacted the urban innovation transfer stage, albeit its influence dissipated as the virtual policy implementation year progressed. This phenomenon might be attributable to the dissemination of consultation drafts or drafts supporting the construction and development of new research and development institutions preceding formal policy implementation. Typically, these drafts elucidate the overarching objectives and backdrop of new research and development institutions, proffering tax incentives, financial support, talent incentives, etc., guiding and stimulating research institutions to perpetually realize results transformation and foster high-quality economic development. This observation underscores the perpetual pivotal significance of technology achievement transformation policy orientation. Therefore, when probing the impact of support policies for new research and development institutions on the output of the urban innovation transfer stage, the findings denote a certain degree of 'policy foresight effect.' Given the inconsequential impact of the counterfactual policy virtual variable on the urban innovation research and development and application stages and its confined influence on the transfer stage, the research conclusion maintains a certain degree of robustness.

Table 4. Placebo Test.

Variable	Advance Implementation of Policy by One Year			Advance Implementation of Policy by Two Year			Advance Implementation of Policy by Three Year		
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)	Model (9)
	UIRS	UICS	UIAS	UIRS	UICS	UIAS	UIRS	UICS	UIAS
DID	0.028	0.008**	0.007	-0.037	0.004	0.003	-0.042	-0.000	0.000
	(0.042)	(0.003)	(0.004)	(0.040)	(0.003)	(0.004)	(0.040)	(0.003)	(0.004)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES
Urban	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.663	0.635	0.390	0.663	0.635	0.386	0.664	0.632	0.386

4.4.2. Replacement of Dependent Variable

In scrutinizing the impact of supportive policies for new R&D institutions on the innovation output across various stages of urban innovation, this study delineated the dependent variable utilizing the three stages of urban innovation output within the innovation chain. Several scholars have employed the China Innovation and Entrepreneurship Regional Index (IRIEC), derived from the Enterprise Big Data Research Center of Peking University, as a metric for gauging urban innovation output. Thus, this study substituted its initial measure of urban innovation with the IRIEC. The China Innovation and Entrepreneurship Regional Index encompasses seven sub-dimensions, including enterprise entry, investment, patent disclosure, and trademark authorization, each reflecting the outcomes of innovation at disparate stages to a certain degree. Moreover, to mitigate the potential impact of urban size on the overall innovation index score, the innovation and entrepreneurship index per capita for each urban area was utilized to depict the comprehensive innovation level of the urban area. Table 5 elucidates the regression results. Upon substituting the dependent variable, the estimated coefficient of supportive policies for new R&D institutions on the comprehensive index of urban innovation output underwent a change; nonetheless, it persists in being significant at the 10% level. This result intimates that supportive policies for new R&D institutions robustly propel urban innovation output.

Table 5. Replacement of Dependent Variable.

Variable	Model (1)
	IRIEC
DID	0.799*
	(0.424)
Controls	YES
Year	YES
Urban	YES
R^2	0.027

4.5. Mechanism Test

The research findings mentioned above demonstrate that supportive policies for new research and development institutions have a positive impact on urban innovation output. As such, this leads to the question of how this policy affects urban innovation output. As discussed in the theoretical analysis, supportive policies for new research and development institutions can improve urban innovation output through both the overall urban innovation atmosphere and corporate innovation behavior. Therefore, referring to the practice of Wing et al. (2018), this paper employs stepwise regression analysis to test the intermediary mechanism with the following specified model:

$$Inn_{it} = \alpha_0 + \alpha_1 DID_{it} + \sum \gamma_j x_{jit} + v_{year} + \mu_{urban} + \varepsilon_{it} \quad (2)$$

$$Mediator_{it} = \beta_0 + \beta_1 DID_{it} + \sum \gamma_j x_{jit} + v_{year} + \mu_{urban} + \varepsilon_{it} \quad (3)$$

$$Inn_{it} = \theta_0 + \theta_1 DID_{it} + \theta_2 Mediator_{it} + \sum \gamma_j x_{jit} + v_{year} + \mu_{urban} + \varepsilon_{it} \quad (4)$$

Equation (2) represents the baseline regression. Equation (3) represents the expression using $Mediator_{it}$ as the dependent variable. Equation (4) represents the baseline regression with the inclusion of the mediating variable.

The chosen mediating variables are urban innovation atmosphere (UIA) and corporate innovation behavior (FIB), while other variables remain consistent with those specified in the baseline model.

4.5.1. Test of the Effect of Overall Innovation Atmosphere

The insights pertaining to the impact of the urban innovation atmosphere are elucidated in Table 6. Column (1) denotes that supportive policies for new research and development institutions exert a positive influence on amplifying the urban innovation atmosphere. Columns (2) through (4) unveil that this atmosphere significantly fosters the three-stage innovation output of urban centers. These outcomes insinuate that the urban innovation atmosphere serves as a partial mediator between supportive policies for new research and development institutions and the three-stage innovation output of urban centers. Additionally, the Sobel test affirms the pertinence of this mediation mechanism. In sum, these findings intimate that the enactment of supportive policies for new research and development institutions can fortify the urban innovation atmosphere, subsequently culminating in an augmentation of urban innovation output; thus, Hypothesis H2A is corroborated.

4.5.2. Test of the Effect of Corporate Innovation Behavior

According to Column (5) in Table 6, supportive policies for new research and development institutions drive companies to innovate. Columns (6) to (8) demonstrate a significant positive impact of corporate innovation behavior on the three-stage innovation output of urban, and all results pass the Sobel test. Therefore, it can be concluded that corporate innovation behavior mediates the relationship between supportive policies for new research and development institutions and the three-stage innovation output of urban. Moreover, additional research indicates that corporate innovation behavior fully mediates the relationship between policies and the output of urban innovation's research and application stages but only partially mediates the production of the transfer stage. In conclusion, these findings demonstrate that supportive policies for new research and development institutions can stimulate companies to engage in research and development activities, improve their scientific research capabilities, and boost urban innovation output. Consequently, hypothesis H2B is validated.

Table 6. Verification of the Impact Mechanism.

Variable	Model(1)	Model(2)	Model(3)	Model(4)	Model(5)	Model(6)	Model(7)	Model(8)
	UIA	UIRS	UICS	UIAS	FIB	UIRS	UICS	UIAS
DID	0.223*	0.183***	0.007**	0.010**	0.070***	0.034	0.008**	0.005
	(0.115)	(0.024)	(0.003)	(0.005)	(0.015)	(0.043)	(0.003)	(0.005)
UIA		0.161***	0.007***	0.025***				
		(0.048)	(0.002)	(0.002)				
FIB						1.564***	0.068***	0.110***
						(0.147)	(0. 012)	(0.015)
Sobel Z		Z=3.268	Z=3.129	Z=3.345		Z=6.169	Z=4.159	Z=4.32
		P=0.001	P=0.002	P=0.001		P=0.000	P=0.000	P=0.000
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES
urban	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.564	0.688	0.720	0.572	0.520	0.733	0.695	0.484

In summary, supportive policies for new research and development institutions play a significant role in promoting the creation of an urban innovation atmosphere and developing corporate innovation activities. It also confirms that the development of an urban innovation atmosphere and promotion of corporate innovation behavior are important ways in which supportive policies for new research and development institutions can enhance urban innovation.

4.6. Heterogeneity Analysis

While the manuscript has underscored the efficacy of supportive policies for nascent research and development institutions, it is imperative to acknowledge the substantial regional disparities in geographical attributes, natural resources, and economic development across the expansive nation of China (Ding et al., 2022). Does the policy impact fluctuate across diverse regions? Probing this query can elucidate a more profound comprehension of the mechanisms and boundary conditions of supportive policies for new research and development institutions. Consequently, predicated upon the empirical research delineated in the preceding section, this study embarked on an additional heterogeneity analysis through regional segmentation. The efficacy of supportive policies for new research and development institutions in the eastern, central, and western regions was scrutinized independently, and the pertinent regression outcomes are articulated in Table 7.

Per the estimations delineated in Table 7, discernible regional disparities permeate the impacts of supportive policies for emergent research and development institutions upon the tripartite innovation output of urban locales. Specifically, supportive policies for novel research and development institutions exert a substantial positive impetus on the three-stage innovation output within eastern urban territories. In contrast, within central urban zones, such policies manifest significant positive repercussions exclusively at the research and development juncture of urban innovation. Conversely, within western urban domains, such policies do not wield considerable influence. Subsequently, the cumulative impact of policies on innovation attenuates in the sequence of eastern, central, and western regions. The geographical positioning of the urban district emerges as a pivotal element engendering regional development disparities within China's urban sectors. The advantageous geographical locale and abundance of resources in the Eastern regions perpetually furnish a propitious milieu for economic proliferation. This conclusion resonates with China's overarching national development strategy, offering an analysis of the regional heterogeneity of policy impacts. Hence, propelling the evolution of new research and development institutions in China's central and western regions should be accorded precedence in forthcoming policy planning and enactment phases.

Table 7. Results of Regional Heterogeneity Test.

Variable	UIRS			UICS			UIAS		
	East	Central	West	East	Central	West	East	Central	West
DID	0.141***	0.082**	-0.273	0.014***	-0.000	-0.017	0.011**	0.006	-0.113
	(0.047)	(0.077)	(0.186)	(0.003)	(0.006)	(0.014)	(0.004)	(0.007)	(0.017)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES
Urban	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.673	0.662	0.662	0.645	0.633	0.635	0.397	0.385	0.386

5. Research Conclusions and Policy Recommendations

5.1. Research Conclusions

The establishment of new R&D institutions has injected fresh momentum into urban innovative development and also shoulders the significant historical mission of achieving high-level technology during the "Fourteenth Five-Year" period. This paper adopts a strategic perspective of the innovation chain and employs the multi-period DID model to explore how the support policies for new R&D institutions facilitate urban innovation and its underlying mechanisms.Key Innovations and Findings of this Study:

1. The support policies for new R&D institutions have significantly promoted the R&D, transfer, and application

stages of the urban innovation chain. The reliability of this conclusion has been verified through multiple robustness checks. For the first time, this study uses the multi-period DID model to delve into how the support policies for new R&D institutions promote urban innovation. An objective evaluation of the policy's impact on urban innovation contributes to strengthening the core competitiveness of cities.

2. Mechanism tests reveal that the support policies for new R&D institutions not only directly promote urban innovation but also indirectly drive it by improving the urban innovation ecosystem and fostering collaboration between enterprises and R&D institutions. This mechanism indicates that mere direct financial support is insufficient. A healthy and vibrant innovation ecosystem is equally crucial for propelling urban innovation.

3. Regional heterogeneity analysis shows that the impact of support policies for new R&D institutions on the innovative outputs of cities varies across regions. The eastern region experiences the most significant impact due to its mature economic development and abundant resources. In contrast, the growth of innovative outputs in the central and western regions is relatively slower for various reasons. This suggests that when formulating and implementing support policies for new R&D institutions, differentiated strategies should be adopted based on the actual conditions of different regions.

In conclusion, new R&D institutions can integrate high-quality innovation resources from both domestic and international sources, focus on industry needs and cutting-edge technologies, and conduct specialized, integrated, and market-oriented research activities, thereby accelerating the transformation of scientific and technological achievements. The policy support for new R&D institutions offers a more flexible, efficient, and open form of innovation organization for urban innovation, bridging the R&D and innovation chains from technology to industry, and ensuring precise alignment between technological innovation and industrial development.

5.2. Policy recommendations

Innovation Chain Management Perspective emphasizes the bidirectional feedback mechanism between the innovation chain and the industrial chain. Specifically, fundamental research effectively supports the transformation of results, and the realization of the value of these results, in turn, feeds back into fundamental research. This necessitates that when governments formulate and implement innovation policies, they should construct an integrated "policy chain" or "policy combination" of science and technology policies and industrial policies. Especially in areas where the adhesion of the innovation chain is weak or even entirely absent, policy design should play the role of "completing the chain." Based on this, the following countermeasures are proposed:

Firstly, in the current technological innovation environment, new R&D institutions have become a pivotal force in promoting urban innovation. To ensure that these institutions can maximize their role at every stage of the innovation chain, the government should increase financial support for new R&D institutions during the R&D phase of the innovation chain. This ensures they can engage in cutting-edge technology research and development. Simultaneously, these institutions should be encouraged to establish close R&D partnerships with universities and enterprises to collaboratively tackle technological challenges. To ensure that new R&D institutions possess adequate R&D capabilities, the government should also support talent training and recruitment, especially in high-tech fields. As technological R&D concludes, the key becomes how to transform it into tangible products and services. During this transfer phase, the government should streamline the technology transfer process for new R&D institutions, ensuring efficient and rapid transition of technology from R&D institutions to enterprises. Additionally, to ensure successful technology transfer, the government should provide new R&D institutions with technology assessment, market analysis, and other transfer support, strengthening intellectual property protection and encouraging technology transfers. Regarding the application and promotion of technology, the government should encourage the application and promotion of technology by new R&D institutions, ensuring its widespread use in actual production and services. To assist new R&D institutions in applying technology practically, the government

should also offer application training and establish technology application demonstration projects to showcase the application effects. New R&D institutions play a crucial role in urban innovation. Targeted policy support can ensure that new R&D institutions make more significant contributions to urban innovation.

Secondly, the support policy for new R&D institutions enhances urban innovation output in all three innovation phases by improving the urban innovation atmosphere. This indicates that policy support alone is insufficient for comprehensive urban innovation advancement. Creating a favorable urban innovation environment is more conducive to stimulating urban innovation initiative and enthusiasm. Therefore, during the implementation of support policies, the integration of new R&D institutions with the overall urban innovation system should be emphasized. Alongside supporting new R&D institutions, the government should further optimize the intellectual property protection system, protect the intellectual property of innovators, encourage innovative activities, and boost confidence and enthusiasm for innovation. Improving the urban innovation ecological environment and business environment, promoting the integration of industry, academia, and research, enhancing the urban innovation atmosphere, and providing more robust guarantees for urban innovation are also essential. Furthermore, the support policy for new R&D institutions should continue to guide the strengthening of relationships between institutions and enterprises to address current technological challenges and development bottlenecks, promoting urban innovation development.

Thirdly, based on the innovation ecological layout of different regions, select the corresponding new R&D institution layout mode. For areas with weak R&D but concentrated entities, adopt the "academic and research entity introduction and cultivation" mode; for areas with mature technology but needing fundamental research breakthroughs, adopt the "industry-academia-research entity co-construction" mode; for areas where a particular university or research institution has a good foundation at the front end of the innovation chain, but the transformation and application in the middle and later stages are relatively weak, adopt the "single academic and research entity leading" mode; for areas where multiple universities or research institutions are dispersed and need joint development, adopt the "multi-academic and research entity co-construction" mode. Only by adapting measures to local conditions and implementing the correct layout can new institutions play their due role.

In conclusion, as a pivotal force in urban innovation, the role of new R&D institutions in urban innovation development is indispensable. When formulating related policies, the government needs to fully consider the characteristics and needs of new R&D institutions, ensuring the pertinence and effectiveness of policies, thereby providing robust support for urban innovation and industrial development.

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Conflict of interest

The author claims that the manuscript is completely original. The author also declares no conflict of interest.

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