

Has the innovative city pilot policy improved the level of urban innovation?

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Abstract

Purpose – A city is a spatial carrier of innovation activities. Improving the level of urban innovation can play a significant supporting role in building an innovative country. China began to implement the innovative city pilot policy in 2008 and continued to expand the policy into more areas for exploring the path of innovative urban development with Chinese characteristics and improving urban innovation.

Design/methodology/approach – Based on mechanism analysis, this paper used the panel data of 269 cities from 2003 to 2016 to empirically test the effect of the pilot policy on the level of urban innovation by using different methods, such as the difference-in-differences model.

Findings – The results show that the innovative city pilot policy significantly improves the level of urban innovation. However, according to the findings of the heterogeneity analysis, the effect of the pilot policy on improving the innovation level in direct-controlled municipalities, provincial capitals and sub-provincial cities is weaker than that in ordinary cities, and the effect of the pilot policy on improving the innovation level in cities with a higher quality of science and education resources is weaker than that in cities with lower quality of science and education resources.

Originality/value – Moreover, as the level of urban innovation increases, the effect of the pilot policy on improving the level of urban innovation is an asymmetric inverted V shape, which means the effect is first strengthened and then weakened. The research also finds that the locational heterogeneity of the pilot policy for improving the level of urban innovation is not notable. In addition, the innovative city pilot policy can strengthen the government's strategic guidance, promote the concentration of talent, incentivize corporate investment and optimize the innovation environment, having a positive impact on urban innovation. Moreover, the effect of concentration of talent and the effect of corporate investment incentive are the important reasons for the pilot policy to promote the improvement of the level of urban innovation.

Keywords Innovative city pilot policy, A city's innovation level, Difference-in-differences, Mediation effect

Paper type Research paper

1. Introduction

The Five Major Development Concepts put forward by General Secretary of the Central Committee of the Communist Party of China (CPC) Xi Jinping in October 2015 guides the thinking and development direction of China's development and forms an integral part of the Thought on Socialism with Chinese characteristics. Among these five concepts, innovation-oriented development is regarded as the foremost, which is of major guiding significance for

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China to promote the transformation from old driving forces to the new ones and high-quality development in the new era. Innovation is the number one driving force leading the transformation and development in China's economy. At present, China is not only facing increasing downward pressure on economic growth but also struggles with dual constraints on resources and the environment. Reinforcing the innovation-driven development strategy, promoting comprehensive innovation with scientific and technological (S&T) innovation as the core, speeding up forming the modern economic system and development mode with innovation as the principal guiding and supporting factor, advancing the industrial transformation and upgrading are of important significance to foster new drivers of economic growth and relieve the resource and environment constraints during economic growth. To that end, while increasing innovation input and stimulating the new vitality of enterprises and colleges, China constantly strives to reinforce the construction of the innovative system, accelerate the construction of the innovation ecosystem and increase the national innovation level. For example, in 2006, the State Council issued the "Outline of the National Plan for Medium and Long-term Scientific and Technological Development (2006-2020)", which proposed accelerating the reform of the science and technology system and building a national innovation system. In 2012, with the issuance of "Opinions on Deepening the Reform of the Science and Technology System and Speeding up the Building of a National Innovation System", the State Council brought a sharper focus and a further plan on the reform of the science and technology system and the construction of the innovation system.

The construction of a national innovation system requires the construction of regional innovation systems. Xi Jinping required regions to play an active role and take the initiative in making progress on innovation to join forces for the state's S&T innovation and to build an S&T innovation center with global influence and innovative cities and regional innovation centers with a strong driving force. A city is a space carrier of S&T innovation activities, a hub for innovation resources and elements and an important center for knowledge innovation and application. The urban innovation system is an integral part of the state innovation system. Unleashing the vitality of innovation, exploring the potential of innovation and improving the capabilities of innovation in cities is of significance for cities to give play to their fundamental and supporting role in national innovation activities. China has begun to set up pilot innovative cities step by step since 2008 to explore effective ways to enhance cities' innovation capacity. In 2008, Shenzhen was made the first pilot innovative city in China, and in 2009, another 14 cities, including Dalian and Qingdao, were also included in the pilot list. From 2010 to 2013, more than 40 pilot innovative cities were approved one after another. In April 2018, another 17 cities were approved to become innovative cities. Therefore, the number of pilot innovative cities in China was increased to 78.

The innovative city pilot policy is an important exploration of the Chinese government on participating in and supporting urban innovation activities. The previous literature has extensively studied the effects of government involvement and support for innovation activities, including government subsidies, industrial policies and innovation environment construction, and two kinds of views have been developed mainly, i.e. the promotion theory and the suppression theory. Regarding the promotion theory, at the micro level, by analyzing the data from Korean SMEs and Chinese industrial enterprises, respectively, [Doh and Kim \(2014\)](#) and [Guo et al. \(2016\)](#) found that there is a significant positive correlation between government subsidy policies and patent acquisition of enterprises in the region and that the government support plays a significant role in promoting enterprise innovation. [Yu et al. \(2016\)](#) studied the impact of industrial policies on enterprise innovation activities and found that industrial policies have a significant effect on increasing enterprises' invention patents and a more prominent effect on non-state-owned enterprises. [Wang and Feng \(2018\)](#) used administrative approval policies as a case to study the impact of the government institutional environment construction on enterprise innovation activities and found that the government

institutional environment plays a significant role in promoting corporate innovation. Wang and Xiao (2009) found after sorting out relevant literature that government policy-based finance could effectively get involved in corporate R&D investment, which enhances corporate innovation considerably. At the macro level, Li and Yang (2018) found that government participation is conducive to promoting regional innovation efficiency, and local governments should offer more support to enterprises' innovation activities in their regions. Li *et al.* (2018) discovered that government participation in the construction of an innovation environment could enhance regional innovation efficiency. In terms of the mechanism of impact of the innovative city pilot policy ("mechanism of impact"), Aerts and Schmidt (2008), Hussinger (2008), Zhang *et al.* (2015), Wu and Liu (2014) and other scholars discovered in their studies that subsidy policies would encourage enterprises to increase the scale of R&D expenditures and the degree of innovation activities and thus positively affect the innovation output of enterprises. Yu (2011) found that government innovation policies are conducive to the establishment and development of regional innovation systems. Bai and Bian (2015) asserted that government participation would help create the industry-university-research collaborative innovation system. In addition, Kleer (2010) found that government policies would guide the direction of private investment, optimize the investment structure, promote innovative activities and improve the innovation level of enterprises and even that of industries and cities.

Concerning the suppression theory, some studies found that government participation and support have no significant impact on innovation activities and may even inhibit innovation activities, leading to loss of innovation efficiency (Lin and Xiao, 2014; Guerzoni and Raiteri, 2015). For example, from the micro perspective, Guo and He (2011), based on the data of listed companies in strategic emerging industries, found that government R&D subsidies fail to exert their signal effects effectively and do not play a significant role in guiding corporate R&D investment. Lin *et al.* (2013) found that excessive tax incentives would restrain the output of corporate patents. By analyzing the data of companies listed on China's A-share market, Li and Zheng (2016) argued that although government industrial policies can promote the corporate innovation output to some degree, the effect is only reflected on the non-invention patents. That is, enterprise innovation supported by industrial policies was only a "strategic innovation" with "quantity instead of quality", which had no significant impact on the improvement of enterprise innovation quality. From the macro perspective, the research of Liu and Ye (2018) revealed that, on the whole, government support for innovation activities would inhibit the improvement of the efficiency of S&T innovation. Lin and Xiao (2014) found that government participation and support, direct or indirect, are not conducive to the development of industry innovation activities. There are many reasons why government participation and innovation support policies have not been able to promote the development of innovation activities effectively. For example, as Görg *et al.* (2008), Hottenrott *et al.* (2017) and Boeing (2016) believed, government subsidy policies would inhibit enterprise innovation incentives, crowd the enterprises' R&D expenditures out and curb the improvement of the innovation level of enterprises, industries or regions. Zhang (1997) and Tang *et al.* (2016) asserted that the public ownership nature of government subsidies had not been effectively used by some companies regarding government subsidies as non-operating income, which thereby generated a principal-agent relationship and rendered it difficult for the government to monitor how well companies have used the subsidies effectively. Lin and Xiao (2014) contended that due to adverse selection and information asymmetry, government support resists the improvement of regional innovation efficiency; furthermore, the asymmetric preference of the government and enterprises towards innovation is also an important reason why the government's S&T policies cannot achieve the desired results.

According to previous studies, the effect of government participation in innovation activities is still controversial. There are many reasons for this: differences in variable setting

and sample selection, periodic differences of the sample, different empirical analysis methods and differences in the screening and processing methods for various confounding factors that affect innovation activities, etc. The collaborative interaction between the innovation practices in central and local governments is the important experience and feature of China's implementation of innovation-driven development strategies and the construction of an innovative country. Theoretically speaking, the promotion of innovative city pilot projects will not only help give play to the initiative and regional characteristics of local innovation practices but also stress the coordination and unity with the central government's macro strategies. The incremental reform of "crossing the river by feeling the stones", to a large extent, is a process of "local pilot-central summarization-local promotion". However, little research has been carried out on the innovative city pilot policy and its effects. Hence, in practice, can the state's promotion of the innovative city pilot project really facilitate the improvement of urban innovation? This is the research subject of the paper. We first analyzed the background of innovative city pilot policy and its mechanism of influencing a city's innovation level and then used the difference-in-differences model to test the impact of pilot policies on a city's innovation level. Taking into account the selection bias of samples and other issues, we further conducted the robustness testing with the propensity score matching and difference-in-differences model (PSM-DID) and other methods. The study finds that, from a general standpoint, the innovative city pilot policy can significantly improve the innovation level of cities, but its effect on improving the innovation level of a city varies significantly by the city tier, resources of science and education and the level of innovation. The pilot policy can strengthen the government's strategic guidance, facilitate the gathering of talents, incentivize corporate investment and optimize the innovation environment, thereby promoting the improvement of the innovation level of a city. Therefore, it is necessary to expand the pilot area in an orderly manner based on local conditions to develop the innovation level of cities universally with the summarized experience of pilot practices as a reference and explore the multi-dimensional path for the government to promote urban innovation so as to improve the innovation level of cities with multiple initiatives.

The marginal contribution of this paper is mainly reflected in the following aspects. First, in terms of research content, we conducted theoretical and empirical research on the level of S&T innovation from the urban perspective, which enriches the research in the field of S&T innovation. Due to data availability, previous studies on the effect of government's S&T policies were mainly based on the theoretical and empirical analysis at the provincial level or the micro level of enterprises, leaving out the research on the meso level of cities. However, it is difficult to assess the overall effect of government policies through research into the micro level of enterprises. In addition, compared to the innovation policies at the provincial level and even the national level, those at the city level are often more science-based and targeted and able to be implemented efficiently (Shen and You, 2017). Therefore, the research on the construction of the urban innovation system and its effects should be strengthened. This paper studied the mechanism of how the innovative city pilot policy impacts a city's innovation level, which could enrich the relevant research on the urban innovation system. Second, in terms of research methods, we used modern quantitative analysis methods such as PSM-DID to try to solve the problem of endogeneity as such methods ensure the robustness of research conclusions. Innovation plays an important role in driving economic and social development. It is difficult to overcome the endogeneity problems of the model through traditional estimation methods such as ordinary least squares. The selection of pilot innovative cities was not a random selection process. For this reason, based on creating the difference-in-differences model for testing, we used PSM-DID and other methods to conduct the robustness testing, which could better overcome the selection bias of the model and make the estimation result more robust. Third, in terms of research conclusions, while the effectiveness of the innovative city pilot policy is affirmed, the spatial heterogeneity of the

effect of the pilot policy on a city's innovation level is also found. Moreover, the mechanism of how the pilot policy affects urban innovation has been explored, providing the government with a theoretical foundation and practical guideline for further summarizing the experience of pilot projects and expanding the pilot area. There have been extensive discussions on the effectiveness of government innovation support policies in previous studies, but disputes still exist (Liang and Liu, 2018). We carried out a targeted analysis of the innovative city pilot policy to see through the big picture. Therefore, our conclusion can clarify the dispute on the effect of the government innovation policy to a certain extent.

2. Background and mechanism of impact

2.1 Policy background

At the 2006 National Conference on Science and Technology, Hu Jintao, General Secretary of the Chinese Communist Party from 2002 to 2012, proposed the strategic goals and tasks of building an innovative country. In the same year, the Chinese government issued the "Outline of the National Medium and Long-term Science and Technology Development Plan (2006–2020)" and the "Decision of CPC Central Committee on the Implementation of Science and Technology Program to Enhance the Capability of Independent Innovation", marking the transformation of China's growth from the factor-driven mode to the innovation-driven mode. China is a multi-ethnic country with a vast territory, featuring complex regional characteristics and obvious differences in regional development stages. The promotion of innovative strategies cannot be lumped together. In order to explore the path of regional innovation development with Chinese characteristics, find the general laws, accumulate diversified experience of innovation development and reduce the cost of trial and error during the construction of an innovative country, China has built innovative cities step by step from small areas to large areas with the method of pilot setting, experience accumulating and gradually promoting.

Innovative cities refer to cities with strong independent innovation capabilities, outstanding supporting and leading capabilities in science and technology, a high level of sustainable economic and social development and prominent regional expansion and leading roles [1]. Shenzhen is in the vanguard of China's economic development and reform and opening up with a leading position among domestic cities in terms of GDP, innovation capabilities, reform intensity and system innovation (Lyu, 2014). For this reason, in June 2005, at the "High-level Forum on Independent Innovation and Regional Economic Restructuring" jointly organized by the Ministry of Science and Technology and the government of Shenzhen, Shenzhen raised the goal of building an independent innovation-oriented city, taking independent innovation as the guiding principle of urban development and the priority of its economic development mode. In the same year, the then Chinese Premier Wen Jiabao proposed building the Shenzhen Special Economic Zone into a major domestic high-tech industrial hub and a state-level innovative city. In 2007, at the 9th China High-tech Fair, the Ministry of Science and Technology, the government of Guangdong Province and the Shenzhen municipal government jointly established a strategic research platform and took Shenzhen as a "testbed" for exploring the construction of innovative cities. In 2008, Shenzhen was officially approved as the first pilot city in the country for the construction of state-level innovative cities. At the same time, China has also been aware of the importance of the construction of an urban innovation system in the process of building an innovative country and strived to extend the scope of pilot innovative cities. From 2009 to 2016, China successively set up 61 pilot innovative cities, covering 30 provinces, autonomous regions and direct-controlled municipalities except for Tibet, Taiwan, Hong Kong and Macau. In order to strengthen the unified guidance for innovative city pilot projects, in April 2010, the Ministry of Science and Technology issued the "Guiding Opinions on Further Promoting the

Innovative City Pilot Practices” (“Guiding Opinions”), which clarified the implications, requirements and principles, main tasks and implementation plans for constructing innovative cities as an important document for guiding the construction of innovative cities in China. To meet the needs of innovative city construction under a new situation and thoroughly implementing the innovation-driven development strategy, the National Development and Reform Commission and the Ministry of Science and Technology jointly issued the “Guidelines for the Construction of Innovative Cities” in 2016, in the strategic context of innovation-driven development, further clarifying the general requirements, key tasks, construction procedures, organization and policy guarantees of the pilot innovative city construction. In addition, since 2017, China has begun to evaluate the effects of innovative city construction and at the same time initiated the construction of a new batch of innovative cities. For example, in April 2018, the Ministry of Science and Technology and the National Development and Reform Commission issued the “*The Document Regarding Supporting the New Batch of Cities for the Construction of Innovative Cities*”, listing another 17 cities, including Jilin and Xuzhou, as pilot cities for innovative urban construction. Therefore, the number of national pilot innovative cities has reached 78. The construction of innovative cities in China is an exploratory process developed from a low level to a high level and progressively extended. So how does the innovative city pilot project affect a city’s innovation level? How is the policy performance? We discuss the theoretical mechanism and carry out empirical analysis regarding this issue in the following sections.

2.2 Analysis of the mechanism of impact

Theoretically speaking, the adoption of the innovative city pilot approach by the Chinese government can have a significant effect on the innovation level of the pilot cities mainly due to the following reasons. First, the innovative city pilot project is the pilot promotion initiative of the national innovation-driven development strategy and the strategic goal of building an innovative country, which brings together national and local strategies to improve a city’s innovation level. Innovation is not only caused by the market mechanism but also the result of government participation and government strategy guidance. A regional innovation strategy will not be endogenously created with the growth of the urban economy. Instead, it requires the government to take the comprehensive advantages of regional innovation and development as the starting point, guide urban innovation resources to be allocated in areas with development advantages and improve the usage efficiency of urban innovation elements based on the resource allocation by the market (Li *et al.*, 2018), that is, to play the government’s role in screening and identifying growth and taking advantage of situations (Lin and Monga, 2011). The main pattern of urban S&T innovation is also the result of the integrated effect of the endogenous evolution of the urban economy and the exogenous guidance of the government. For example, companies will choose an innovation pattern suitable for their long-term development based on their development and market competition, while the government will also consider the local economy and technology and guide local innovation entities in the form of subsidies to choose appropriate innovation patterns, such as the introduction of technology, technology-oriented cross-border mergers and acquisitions, or independent innovation so as to help increase the innovation level of innovation entities. One of the main tasks of the innovative city pilot project is to take independent innovation as the core strategy for urban development, which covers all aspects of urban economy, science and technology, education and social development. Local governments will develop science-based overall plans for urban innovation development, enhance urban innovation capabilities, improve urban functions and explore new development patterns. The innovative city pilot project will strengthen the strategic leadership of the central government and local governments in urban innovation activities, thereby effectively improving a city’s innovation level.

Second, the innovative city pilot project improves the city's ability to agglomerate innovation elements, ensures the supply of knowledge elements for local innovation activities and enhances the innovation level by increasing the government's investment in innovation resources in the pilot cities. On the one hand, the government encourages higher education and research institutions to develop basic knowledge and common technology, laying a solid knowledge and technology foundation for urban innovation. The development of basic knowledge and generic technologies is characterized by high risk, strong externality and low direct economic returns, which causes companies' lack of investment incentives in this field (Lin, 2017), leading to a large gap in basic knowledge and generic technologies of urban innovation. This requires the government to provide corresponding basic knowledge and generic technologies in urban innovation activities to ensure the supply of basic knowledge for innovation activities. Therefore, the pilot policy requires the government to strengthen basic research and cutting-edge technology research, enhance technical know-how and on-going innovation capabilities, support higher education and research institutes to establish technology transfer and service institutions and facilitate communication and sharing of achievements in scientific research of higher education and research institutions. On the other hand, the pilot cities have developed talent pools for urban innovation by exploring the introduction and training of innovative talents and the construction of innovation bases. People are the core and most active element in S&T innovation activities. The current competition among countries and regions for economic strength and innovation strength is ultimately the competition for talents. Driven by the pilot policy, many cities have also taken part in the "competition for talents" to bring high-caliber innovative entrepreneurs and outstanding teams to the cities by giving the green light to attracting high-quality talents by offering privileges of household registration, housing settlement, research funding and even building research teams. The exploratory measures of innovative cities in terms of knowledge and talents have laid a solid foundation for urban innovation, which can effectively improve a city's innovation level.

Third, the pilot policy contains a series of policy measures to strengthen the subjective role of enterprises and encourage enterprises to invest in innovation, which is conducive to promoting the establishment of an urban innovation system with enterprises as major players. The externality and risk of innovation activities lead to enterprises' lack of innovation incentives under the market-based regulation (Lin, 2017). The government needs to provide subsidies to a certain extent, internalize the externality of enterprise innovation activities and improve enterprise innovation incentives, improving a city's innovation level (Czarnitzki and Hussinger, 2004). The pilot policy clarifies the dominant position of enterprises in urban innovation activities and requires the government to strengthen its support for enterprise innovation activities, reinforce its guidance on the flow of innovation elements, increase the efficiency of element allocation and actively guide and support the clustering of innovation elements in enterprises and enhance the subjective role of enterprises in innovation activities. The pilot policy inspires enterprises to increase expenditures on S&T innovation, improve their independent innovation capabilities and empower innovative enterprises with independent intellectual property, core technologies, well-known brands and international competitiveness. In addition, the pilot policy encourages enterprises to accelerate the construction of R&D institutions, helps enterprises build R&D platforms and pilot plant centers, establishes urban innovation networks, develops an enterprise-oriented industry-university-research collaborative innovation system and sets up various forms of strategic, long-term and stable cooperation platforms. The above-mentioned policies are conducive to encouraging enterprises to increase investment in the fixed assets for R&D and innovation, strengthening the dominant position of enterprises in the urban innovation system and promoting the improvement of a city's innovation level.

Fourth, the innovative city pilot policy can optimize the urban innovation environment and improve a city's innovation level. On the one hand, China lags behind some advanced Western countries regarding the construction of the innovation system of cities, and the infrastructure conditions for urban innovation activities are relatively backward, which limits the innovation level of cities. The government has thus increased fiscal expenditures on the infrastructure closely related to S&T innovation activities to equip urban innovation with infrastructure, such as transportation and communication, which can break the time and space barriers of S&T innovation activities, reduce information asymmetry in the S&T market and improve the efficiency and level of urban innovation (Ke et al., 2017). For example, the pilot policies include the supporting policies for urban infrastructure construction, supporting cities to strengthen the informatization construction, guiding the construction of industrial clusters and R&D hubs, strengthening the construction of science and technology intermediaries and high-tech service markets, improving the construction of resource sharing networks, etc. The construction of infrastructures characterized by informatization and networking is conducive to promoting the exchange and dissemination of knowledge and technology, optimizing the allocation of innovation elements and improving the efficiency and level of innovation in a city. On the other hand, making more effort in creating a soft environment for urban innovation is an important part of the innovative city pilot policy. A series of explorations of structural reform and cultural innovation can effectively promote the improvement of a city's innovation level. With the focus of stimulating non-governmental creativity and creating a fair market environment in structural reform and management innovation, the pilot policy is aimed to build up a fair market playing field conducive to innovation and entrepreneurship and further stimulate the entrepreneurial innovation vitality and improve a city's innovation level. Innovation results are a core component of corporate competitiveness. However, due to their non-exclusiveness, they are faced with a relatively high risk of infringement. The pilot policy strengthens the protection of the lawful rights and interests of innovative enterprises, such as intellectual property rights, and ensures that the innovation results of innovative entities receive fair and reasonable returns, which can help maintain the expectations of entrepreneurs and researchers, inspire and protect entrepreneurial spirit, allow entrepreneurs and researchers to take more initiative and effort in implementing innovative entrepreneurial activities and enhance entrepreneurs' enthusiasm and motivation for innovation and entrepreneurship. In addition, the pilot cities make breakthroughs in terms of management innovation, including exploring a coordinated and unified plan for economic policies and science and technology policies and optimizing government functions to improve the efficiency and quality of public services, attempting to establish a scientific-and-technological-innovation-oriented assessment mechanism for local authorities to improve their innovation incentives and exploring the efficient operating mechanism of science and technology and regulatory agencies based on their synergistic cooperation and the division of labor. The structural reform and the exploration of management modes, driven by the pilot policy, can effectively stimulate urban innovation vitality and improve a city's innovation level.

In addition, the pilot policy also includes a monitoring and evaluating mechanism for the performance of innovative city construction and meanwhile requires carrying out relevant research and sharing experience on the construction of the pilot innovative cities. Innovative activities are subject to uncertainty and the construction of pilot innovative cities is also subject to uncertainty. Therefore, tracking, monitoring and evaluating efforts need to be strengthened to ensure appropriate allocation and efficient use of the policy and supporting resources. At the same time, tracking, monitoring and evaluating the data provide decision-making references for innovative city construction practices. The relevant research and experience sharing of pilot policies on the construction of innovative cities provide theoretical and practical guidance on developing innovation in a city, which can effectively improve the

innovation level of a city. To sum up, the construction of pilot innovative cities is a complex and systematic project, and the mechanism of impact of the innovative city pilot policy on a city's innovation level is shown in Figure 1. Under ideal conditions, the innovative city pilot projects can improve a city's innovation level through multiple mechanisms. What is the actual effect of these projects? We conduct empirical research on this subject in the following sections.

3. Design of the research

3.1 Setting of the model

From 2008 to 2013, the state government selected 57 pilot innovative cities successively. We conducted a quasi-natural experiment to assess the performance of the innovative city pilot policy, with the pilot cities as the experimental group and the non-pilot cities as the control group. In the process of assessment, it is hard to solve the endogenous problem caused by omitted variables and other reasons with the traditional regression model. For this reason, we adopted the difference-in-differences method to examine the effects of the pilot policy. As the innovative city pilot program in China was gradually rolled out, the traditional difference-in-differences model can only observe the effects of the policy implemented at a single time point. Hence, we drew on the practices of Autor (2003) and Bertrand and Mullainathan *et al.* (2003) and established a difference-in-differences model at multiple time points. First, we set the dummy variable of the policy implementation time indicated by *test*, of which the value is set as 1 regarding the year of the introduction of the pilot policy and the years afterward; otherwise, it is 0. Second, a difference-in-differences model with multiple time points was established as shown in Eqn (1):

$$Innno_{it} = \alpha_0 + \alpha_1 test_{it} + \sum \delta_k year_k + \sum \gamma_j X_{jit} + \mu_{city} + \epsilon_{it} \quad (1)$$

In Eqn (1), *Innno* represents the logarithm value for a city's innovation level, and *test* refers to the innovative city pilot policy, of which the regression coefficient α_1 can reflect the effects of the pilot policy. *X* stands for the entire set of the control variables, *year_k* as time dummy variables, μ_{city} as the fixed effects of a city and ϵ as the random error term. By controlling the two-way fixed effects, the difference-in-differences model with multiple time points shown in Eqn (1) effectively controls the characteristics of cities, including the individual feature differences between the pilot cities and the non-pilot ones, whether the policy has been implemented or not, and how the cities have changed over time.

3.2 Variables and data

The innovation level of a city is the dependent variable in this paper. Limited by the availability of statistical data, limited research has been conducted on the urban innovation

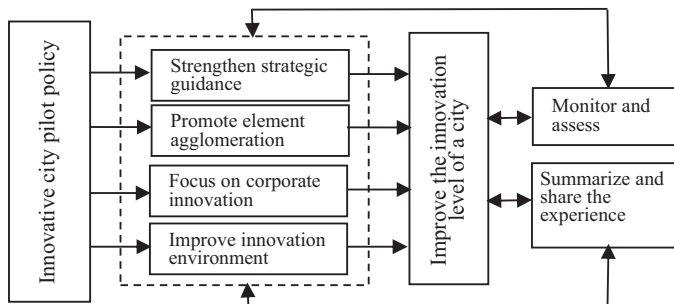


Figure 1.
The mechanism of effect

activities in China. Among the few studies, Zhao and He (2009) studied the allocation situation of the urban innovation resources with the data of a small number of large cities as the samples. However, such studies included few samples and the generality and universality of the conclusions drawn from the empirical analysis that took large cities and sub-provincial cities as the samples remained doubtful. Gao (2015) studied the impact of city size on the level of innovation based on the patent data of cities retrieved from the Patent Search and Construction Center of CNIPA. However, manual retrieval of the data turned out to be heavy workloads and cumbersome, and the number of patents failed to reflect the true value of different innovative activities. Based on patent data released by the China National Intellectual Property Administration, Kou and Liu (2017) estimated the value of patent through the patent update model and aggregated the patent value from the urban perspective to obtain the urban innovation index, which solved the issues of patent quality and value heterogeneity to a certain extent. Therefore, we examined the impact of the pilot policy on a city's innovation level based on these data. The data were obtained from the "Report on Urban and Industrial Innovation in China (2017)", which contains the innovation index of more than 300 prefecture-level cities across China from 2000 to 2016, and the corresponding calculation method is also offered. For detailed information, please refer to the study of Kou and Liu (2017).

The innovative city pilot policy is the core explanatory variable in this paper. As mentioned earlier, it is set as the dummy variable. In addition, drawing on previous research (Gao, 2015), this paper also controls other factors that affect a city's innovation level, including foreign direct investment (*fdi*), expressed as the proportion of foreign direct investment in this city in the regional GDP (Girma *et al.*, 2009); level of human capital (*hum*), measured by the proportion of college students in the city's total population (Earl, 2001; Qian *et al.*, 2010); level of financial development (*fin*), measured by the ratio of the deposits and loans balance of the financial institutions of each city at the end of the year to the local GDP; level of industrial structure (*ind*), expressed by the proportion of the output value of non-agricultural industries in the regional GDP. The data of the control variables are all obtained from the EPS China Data Platform (<https://www.epsnet.com.cn>).

Some cities with seriously deficient data, such as Yanbian Korean Autonomous Prefecture, have been deleted from the samples in this paper. As 17 cities, including Jilin and Xuzhou, were approved by the state government to become the new batch of pilot innovative cities in April 2018, we also deleted these samples to eliminate the impact of these samples on the empirical results. The final samples of this paper contained data from 269 cities in China from 2003 to 2016, comprising 47 pilot cities and 222 non-pilot cities; of which the total number of provincial capital cities, direct-controlled municipalities and sub-provincial cities was 35, and the number of ordinary prefecture-level cities was 234. Table 1 shows the statistical characteristics of the indicators and the correlation coefficients of these indicators on the city's innovation level. According to the last column, the correlation coefficient between the innovative city pilot policy and the city's innovation level appears significant at the level of 1%, and it is preliminarily judged that the pilot policy can effectively promote the improvement of a city's innovation level. Of course, this is only a preliminary judgment based on the superficial characteristics of the data, which requires further empirical testing.

3.3 Model applicability test

The prerequisite for applying the difference-in-differences model is that the experimental and control groups have a common trend before the policy is implemented. In order to test whether this condition was met, a trend chart was created on the levels of urban innovation of the experimental group and the control group [2]. The chart shows that the innovation levels of the two groups almost present the same trend, indicating that the difference-in-differences model is suitable for the evaluation of the effect of the innovative city pilot policy.

Variable name	Variable abbreviation	Sample size	Mean	Sd	Minimum	Maximum	Correlation coefficient
Innovation level of a city	<i>binno</i>	3,766	-0.371	1.908	-5.272	6.967	1
Pilot policy	<i>test</i>	3,766	0.081	0.273	0.000	1.000	0.542***
Foreign direct investment	<i>fdi</i>	3,763	0.029	0.032	0.000	0.454	0.291***
Level of human capital	<i>hum</i>	3,765	0.015	0.022	0.000	0.131	0.572***
Level of financial development	<i>func</i>	3,763	2.053	0.991	0.508	8.877	0.497***
Level of industrial structure	<i>ind</i>	3,766	0.851	0.094	0.000	0.999	0.572***

Note(s): *, ** and *** indicate that the correlation coefficient is significant at the levels of 10%, 5% and 1%, respectively

Table 1.
Descriptive statistics

In addition, we further adopted the regression method to examine the applicability of the difference-in-differences model. First, the regression model is set as shown in Eqn (2):

$$Ininno_{it} = \alpha_0 + \alpha_1 test + \sum_{k=2003}^{2007} \delta_k year_k + \sum_{j=2003}^{2007} \gamma_j year_j \cdot treat + \varepsilon_{it} \quad (2)$$

where *treat* is a dummy variable for grouping, including the pilot cities (*treat* = 1) and the non-pilot cities (*treat* = 0), *year* is the year dummy variable, and the time span is from 2003 to 2007. *year* · *treat* represents the interaction term of the year dummy variables and the dummy variable for grouping. If the interaction term coefficient γ_j is not jointly significant, it means that there is no significant difference between the experimental group and the control group before the policy implementation, and the difference-in-differences model has good applicability. A joint significance test has been conducted on the coefficients γ_j based on the regression analysis for Eqn (2). The result shows $F = 0.48$ ($p_value = 0.753$), which means the original hypothesis that γ_j are jointly equal to 0 is acceptable; that is, there is no significant difference between the experimental group and the control group before the implementation of the policy. Therefore, the difference-in-differences model is applicable.

4. Empirical analysis

4.1 Initial regression

First, in order to test the impact of the pilot policy on the innovation level of cities, we adopted the method of gradually adding control variables to estimate formula (1). The results are shown in Table 2. In regression (1), only the pilot policy dummy variable was added, and estimation was carried out based on the two-way fixed effects model. The result shows that the pilot policy dummy variable coefficient is significantly positive at the level of 1%, indicating that innovative city pilot policy has a positive impact on the innovation level of cities. The control variables that affect the innovation level of cities are added in regressions (2), (3), (4) and (5) successively, that is, the level of human capital, the level of foreign direct investment, the scale of financial development and the industrial structure of the city. The result shows that the regression coefficient of the pilot policy variable remains significantly positive at the level of 1%, indicating that the innovative city pilot policy can effectively improve the innovation level of a city.

	(1)	(2)	(3)	(4)	(5)
<i>test</i>	0.345*** (0.031)	0.339*** (0.033)	0.319*** (0.033)	0.320*** (0.033)	0.357*** (0.033)
<i>hum</i>			0.177 (1.071)	-0.631 (1.079)	-0.145 (1.071)
<i>fid</i>		0.736 (1.069)	-1.778*** (0.335)	-1.703*** (0.334)	-1.545*** (0.331)
<i>finc</i>				0.093*** (0.018)	0.110*** (0.018)
<i>ind</i>					1.935*** (0.244)
<i>constant</i>	-1.903*** (0.022)	-1.911*** (0.024)	-1.844*** (0.027)	-2.032*** (0.046)	-3.645*** (0.208)
Fixed time	YES	YES	YES	YES	YES
Individual fixation	YES	YES	YES	YES	YES
<i>N</i>	3,766	3,765	3,763	3,763	3,763
<i>R</i> ²	0.896	0.896	0.897	0.897	0.899

Note(s): *, ** and *** indicate that the regression coefficient is significant at the levels of 10%, 5% and 1%, respectively

Table 2.
Benchmark regression

According to the regression results of control variables, the regression coefficients of the level of human capital are not significant in regressions (2) to (5), indicating that the development of higher education in a city fails to provide a foundation of human capital for S&T innovation in the city, which may be attributed to the fact that colleges and universities in this city attach too much significance to scale expansion and neglect the improvement of the quality of education and the capacity of higher education to serve the real economy. Therefore, while expanding the scale of training talents in colleges and universities, cities should focus on improving the quality of talents to provide a good human capital foundation for urban innovation. The regression coefficients of foreign direct investment on a city's innovation level are significantly negative at the level of 1% in regressions (3) to (5), indicating that foreign direct investment inhibits the improvement of a city's innovation level. This result is similar to the conclusions of [Jiang and Xia \(2015\)](#) and [Lee \(2006\)](#). The reason for this may be as follows. On the one hand, local governments blindly introduced foreign investment to promote rapid economic expansion with little attention to the quality of foreign investment, and the inflow of low-quality foreign direct investment inhibited the improvement of a city's innovation level. On the other hand, foreign direct investment, to a certain extent, produced the competitive effect, crowding-out effect and predatory effect on local industries, causing local enterprises to reduce R&D expenditures or even withdraw from the market, which is not conducive to the improvement of a city's innovation level. The regression coefficients of the scale of financial development are significantly positive at the level of 1% in regressions (4) and (5), indicating that the growth of the financial industry provides good financial services for urban S&T innovation and alleviates the financing constraints faced by innovation activities, thus promoting the improvement of the innovation level of a city. The regression coefficient of the industrial structure of a city on the innovation level of the city is significantly positive at the level of 1% in regression (5), indicating that increasing the proportion of non-agricultural industries can effectively facilitate innovation in a city. Also, it is necessary to develop the innovation level of agricultural technologies while expanding the scale of non-agricultural development appropriately to realize the development driven by agricultural innovation.

4.2 Robustness test

- (1) Robustness test I: A regression analysis based on the PSM-DID method. As was pointed out in the "Guiding Opinions", in order to explore the construction mode of innovative cities and summarize successful experiences, China has purposefully selected some cities well-positioned for innovation and with a higher level of economic and social development to make pilot trials in mechanisms, institutions and innovation policies, thus helping make them the pioneers in transforming into innovative cities. Therefore, the selection of the pilot innovative cities was not a random selection process. Those with a higher level of innovation and better economic development were more likely to be selected as pilot cities. This selection mechanism led to the problem of selection bias in the above model. For this reason, we further introduced the propensity score matching and difference-in-differences method for the robustness test, which could better deal with the problem of sample selection bias. Referring to the method of [Heckman et al. \(1997\)](#), we selected the city's level of opening-up (*fdi*), level of human capital (*hum*), level of economic development (*pgdp*), level of financial development (*finc*), level of industrial development (*ind*) and government support (*g_tec*) as the matching variables and calculated the probability of a city selected as a pilot innovative city. In other words, a logit regression model was built as shown in [Eqn \(3\)](#), where p is the propensity score value.

$$p(\text{treat}_i = 1) = f(\text{fdi}_{it}, \text{hum}_{it}, \text{pgdp}_{it}, \text{finc}_{it}, \text{ind}_{it}, \text{g_tec}_{it}) \quad (3)$$

Regarding the equation, the level of economic development is measured by GDP per capita (unit: RMB 10,000/person), and the government support was measured by the proportion of government expenditures on science and technology. This paper uses the nearest neighbor matching method for matching, and Eqn (3) is estimated based on the logit model. Finally, the sample size after matching is 867. After the matching process, the *t*-test results of each variable accept the null hypothesis that there is no systematic difference between the experimental group and the control group. Compared with the pre-matching data, the standardized deviations of all variables are significantly reduced—except for the relatively high standardized deviation of the financial development scale, the absolute values of the standardized deviations of all variables after the matching are less than 10%, and the absolute value of the standardized deviation of financial development scale is also less than 13%, so the assumption of parallelism is basically satisfied. Based on the above matching samples, Eqn (1) has been further estimated, and the results are shown in the regression (1) in Table 3. The regression coefficient of *treat* is significantly positive at the level of 1%, indicating that the innovative city pilot policy can significantly improve a city's innovation level (see Table 3). Therefore, the above conclusions are robust.

- (2) Robustness test II: To change the defining standard of the experimental group. As mentioned above, in 2008, the government of China selected Shenzhen as a pilot innovative city and in 2009 selected another 15 cities, including Dalian and Qingdao, into the list of pilot innovative cities. We set the pilot cities selected in 2009 and before as the experimental group and those that had not yet identified as pilot cities before 2009 as the control group. Meanwhile, after 2009, some cities were selected to be pilot innovative cities successively. In order to avoid these samples from interfering with the empirical results, the samples of the pilot cities approved after 2009 were deleted from the control group. Based on the above processing method, we further changed the breakpoints of the pilot years to 2010, 2011, 2012 and 2013 and thus obtained five samples. According to the different policy implementation years set above, we conducted a difference-in-differences analysis with the five samples, respectively, and the results are shown in Table 3 from regression (2) to regression (6). Similar to the aforementioned results, the regression coefficients of the pilot policy dummy variables are all positive in the five sets of regressions, and all of them passed the test at the level of 1%, indicating that the innovative city pilot policy can significantly improve a city's innovation level (see Table 3). The robustness of the aforementioned results has been affirmed again.
- (3) Robustness test III: To change the measurement method of urban innovation. The patents are one of the most direct outputs of R&D and innovation activities, so previous studies have mostly adopted the patent output as an important indicator to measure the level of innovation (Griliches, 1990; Gao, 2015). Drawing on this approach, we used the number of patent applications granted per million urban population of a city as a measurable indicator of the innovation level of a city to perform regression analysis. Specifically, the number of patent applications granted in each city was obtained from the Patentcloud database (<http://www.patentcloud.net>), and the total population data were from EPS China Data Platform (<https://www.epsnet.com.cn>). The estimation results are shown as regression (7) in Table 3. The regression coefficient of the pilot policy dummy variable is also significantly positive at the level of 1%, suggesting that the innovative city pilot policy has significantly improved a city's innovation level (see Table 3). Thus, the foregoing conclusions are robust.

Table 3.
Robustness test

Pilot year	(1) Over years	(2) 2009	(3) 2010	(4) 2011	(5) 2012	(6) 2013	(7) Multiple years
<i>Test</i>	0.373*** (0.043)	0.524*** (0.056)	0.387*** (0.040)	0.276*** (0.038)	0.225*** (0.038)	0.232*** (0.036)	0.135*** (0.008)
<i>Constant</i>	-2.782*** (0.505)	-1.788*** (0.253)	1.138*** (0.306)	1.410*** (0.302)	1.463*** (0.300)	1.492*** (0.298)	0.334*** (0.049)
Control variable	YES	YES	YES	YES	YES	YES	YES
Individual fixation	YES	YES	YES	YES	YES	YES	YES
Fixed time	YES	YES	YES	YES	YES	YES	YES
<i>N</i>	867	3,315	3,525	3,581	3,623	3,763	3,414
<i>R</i> ²	0.929	0.961	0.968	0.967	0.967	0.967	0.307

Note(s): *, ** and *** indicate that the regression coefficient is significant at the levels of 10%, 5% and 1%, respectively

As can be seen, both the robustness test based on the propensity score matching difference-in-differences model and the robustness test based on adjusting the implementation time of the pilot policy and changing the measurement method of a city's innovation level show that the regression coefficients of the innovative city pilot policy on the innovation level of a city are all significantly positive at a higher level. Therefore, we believe that the innovative city pilot policy can significantly improve a city's innovation level, which is a robust conclusion.

4.3 Analysis of heterogeneity

- (1) The heterogeneity of city tiers. Cities at different tiers vary significantly in economic size, agglomeration of innovation elements and the efficiency of innovation resource allocation. These differences may further lead to greater differences in the effects of the innovative city pilot policy among different cities. Generally speaking, key cities (for convenience, direct-controlled municipalities, provincial capitals and sub-provincial cities are collectively defined as “key cities” in this paper) are often the focal points and pioneers of national or regional economic development strategies. Under the innovation-driven development strategy, compared with ordinary cities (in this paper, “ordinary cities” refer to prefecture-level cities other than direct-controlled municipalities, provincial capitals and sub-provincial cities), key cities usually have a strong ability to gather innovation elements and rely on their create urban innovation competitiveness and improve the level of innovation by virtue of their advantages in the scale of economic development, policies, gathering innovation elements and so forth (Zhao and He, 2009). In such a differentiated context, is there any heterogeneity in the impact of innovative city pilot policy on the innovation level of key cities and ordinary cities? To answer this question, we set the city level dummy variable (*level*). Therefore, key cities were assigned the value of 1, and ordinary cities were assigned the value of 0; the interaction term of the city level dummy variable and the innovative city pilot policy dummy variable was set and added to Eqn (1) for regression, and the results are shown as regression (1) in Table 4. The regression coefficient of the pilot policy dummy variable is significantly positive at the level of 1%, and the regression coefficient of the interaction term of the pilot policy variable and the city level variable is significantly negative at the level of 5%, indicating that the effect of the innovative city pilot policy on the improvement of the innovation level in key cities is weaker than that in ordinary cities (see Table 4). The reason for this may be the fact that China's key cities are currently in the mid-term or even mature stage of S&T innovation development with relatively well-built innovation ecosystems. These cities have a high agglomeration of innovation resources, and under the conditions of adequate regulation of market mechanism and efficient government macro governance, they stand at the forefront of the country regarding the innovation level. Meanwhile, the inputs of innovation elements in key cities are to a certain extent characterized by diminishing marginal output, and the innovative city pilot policy and the accompanying factor agglomeration have relatively small marginal effects on the improvement of innovation level of these cities. By contrast, the ordinary cities are still in the early and catch-up stage of S&T innovation development, and their innovation level is generally lower than that of key cities. However, the S&T innovation in ordinary cities has the characteristics of latecomer advantage and economy of scale. The innovative city pilot policy can fully tap the innovation potential of ordinary cities, drive the concentration of urban innovation elements and have a greater marginal effect on the improvement of the innovation level of these cities.

Table 4.
Analysis of
heterogeneity

Analysis perspective	(1) Urban hierarchy	(2) Urban location	(3) Science and education resources	(4) Level of innovation	(5)	(6)
Quantile	—	—	—	25%	50%	75%
<i>test</i>	0.430*** (0.047)	0.324*** (0.039)	0.433*** (0.047)	0.362*** (0.054)	0.318*** (0.041)	0.176*** (0.034)
<i>test × level</i>	-0.130** (0.060)					
<i>test × region</i>		0.093 (0.061)				
<i>test × edu</i>						
<i>constant</i>	-3.638*** (0.208)	-3.633*** (0.209)	-0.136** (0.060)	1.480*** (0.460)	1.239*** (0.506)	2.521*** (0.428)
Control variable	YES	YES	YES	YES	YES	YES
Individual fixation	YES	YES	YES	YES	YES	YES
Fixed time	YES	YES	YES	YES	YES	YES
N	3,763	3,763	3,763		3,763	
R ²	0.899	0.899	0.899	0.834	0.834	0.863

Note(s): *, ** and *** indicate that the regression coefficient is significant at the levels of 10%, 5% and 1%, respectively

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- (2) The heterogeneity of urban location. Cities in East China have certain locational advantages in open-end innovation by virtue of their coastal and convenient transportation location and the introduction of advanced foreign technologies through trade and other means, coupled with the policy dividends of the country's continuous strengthening of the opening-up of coastal areas. On the contrary, due to the relatively backward transportation infrastructure and the weak technological and economic foundations, the central and western parts of China lag behind the eastern part in terms of innovative economic growth. This gap of location advantages may lead to significant differences in the effects of the innovative city pilot policy in the eastern region and the central and western regions. In order to verify whether this locational heterogeneity exists, a location feature dummy variable was introduced in the paper. Therefore, the cities in eastern China were assigned the value of 1, and the cities in central and western China were assigned the value of 0, which were multiplied by the pilot policy dummy variable and then added to [equation \(1\)](#) for regression. The results are shown as regression (2) in [Table 4](#). The regression coefficient of the pilot policy dummy variable is significantly positive at the level of 1%, while the regression coefficient of the interaction term of the pilot policy and the location feature dummy variables is positive, but not significant, indicating that the effect of the pilot policy on a city's innovation level in the eastern region is not significantly different from that in the central and western regions (see [Table 4](#)). The reason for this may be attributed to China's formulation and implementation of the Great Western Development Strategy since 2000 and the Rise of Central China Plan proposed by Chinese Premier Wen Jiabao in 2004. These strategies and policies have offset the location disadvantage of innovation-driven development in the central and western regions to a certain extent and diminished or even eliminated the locational heterogeneity in the effects of the pilot policy.
- (3) The heterogeneity of science and education resources. Colleges and universities play a significant role in nurturing talent and conducting scientific research and provide good scientific and educational resources for S&T innovation. They are key players in the development of China's innovative economy. Project 211 launched by the Ministry of Education in 1995 is a major project aimed at institutions of higher education to raise the research and education standards in China, with the focus on supporting the discipline construction and improving scientific research in universities. After years of development, whether it is selected for Project 211 has become an important criterion for measuring the quality of science and education development of universities and colleges. Based on this, we set a dummy variable for the quality of science and education resources in a city based on whether there are Project 211 schools in the city, that is, dividing cities into cities with a relatively high level of science and education development and cities with a relatively low level of science and education development and assigning a value of 1 to the former and 0 to the latter. The dummy variable of the quality of science and education resources was multiplied by the pilot policy dummy variable and then added to [Eqn \(1\)](#) for regression. The results are shown as regression (3) in [Table 4](#). The regression coefficient of the pilot policy dummy variable is still significantly positive at the 1% level, and the regression coefficient of the interaction term of the pilot policy and science and education resources is significantly negative at the level of 5%, indicating that the effect of the innovative city pilot policy on the improvement of a city's innovation level in the cities with a relatively high level of science and education development is considerably weaker than that in the cities with a relatively low level of science and education development (see [Table 4](#)). Also, from the perspective of the

stage of innovative economy, in the cities with a high level of science and education development, they are currently in their S&T innovation is at a relatively mature stage with a high level of innovation, strong ability to gather innovation elements and fully tapped potential of the urban innovation. In this case, the pilot policy has a relatively small marginal effect on the improvement of the innovation level, presenting the features of diseconomies of scale. As to cities with a relatively low level of science and education development, they are at the early stage of the innovative economy with latecomer advantages, where the innovative city pilot policy and the associated innovation element input can better tap their innovation potential and improve their innovation vitality with the characteristic of economy of scale and a stronger marginal effect on the improvement of the innovation level of these cities.

- (4) The heterogeneity of the innovation level. The results of the above heterogeneity examination indicate that there is heterogeneity in the city tier and resources of science and education in the impact of the innovative city pilot policy on a city's innovation level. The reason for this is probably that key cities and cities with a relatively high level of science and education development are in the mid-term or even mature stage of S&T innovation development, so their innovation level should be higher than that of ordinary cities and cities with a relatively low level of science and education development, leading to a higher marginal effect of the innovative city pilot policy on the urban innovation in ordinary cities and cities with a relatively low level of science and education development than that in key cities and cities with a relatively high level of science and education development. To verify this conjecture, we drew on the research method of [Shao *et al.* \(2018\)](#), selected three quantiles—25%, 50% and 75%—and estimated [equation \(1\)](#) with the panel quantile regression model. The results are shown as regression (4), (5) and (6) in [Table 4](#). At these three quantiles, the regression coefficients of the innovative city pilot policy are always significantly positive at the level of 1%, indicating that in cities with different levels of innovation, the innovative city pilot policy can effectively promote the improvement of a city's innovation level (see [Table 4](#)). As the quantile got larger, the regression coefficient of the pilot policy gradually decreased; in addition, whether the coefficients on the three quantiles are equal has also been tested. The results show that $P(q_{25} = q_{50} = q_{75}) = 0.0013$, which denies the null hypothesis that the regression coefficients of the pilot policy at the three quantiles are equal. Based on the above results, it can be preliminarily judged that with the improvement of a city's innovation level, the marginal effect of the innovative city pilot policy on a city's innovation level presents a gradually diminishing trend.

In addition, we further drew the regression coefficient line of the pilot policy at all quantiles to observe the impact of the pilot policy on a city's innovation level at different quantiles more directly, and the results are shown in [Figure 2](#). With the improvement of a city's innovation level, the promotion effect of the innovative city pilot policy on a city's innovation level presents an “asymmetric inverted V-shaped” feature (see [Figure 2](#)), which indicates that the improving effect is followed by a decreasing trend. That is, when urban innovation is in the initial stage with a low level of S&T development, the effect of the pilot policy gradually gets stronger with the improvement of a city's innovation level. This may be because the economies of scale show its effect due to the pilot policy, its associated advantages and the agglomeration of resources and elements, leading to a gradually enhanced effect of the pilot policy on a city's innovation level. When urban innovation reaches a certain level, the urban innovative economy will approach the middle stage or even the mature stage, featured by fully tapped innovation potential, gradually increasing innovation vitality, less dependence of urban innovation on government support and decreasing returns to scale of innovation

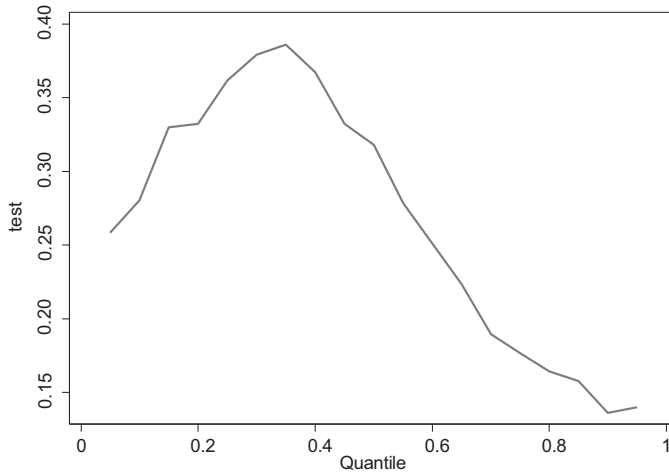


Figure 2.
Heterogeneity of a
city's innovation level

element input. In this case, the impact of the pilot policy on a city's innovation level is gradually diminishing. This result sufficiently explained why the effect of the pilot policy on the innovation level in key cities and cities with high-quality science and education resources is weaker than that in ordinary cities and cities with unfavorable science and education resources.

5. Analysis of the mechanism of impact

The foregoing results all indicate that the innovative city pilot policy can significantly improve the innovation level of pilot cities. So how does the pilot policy improve a city's innovation level? We followed the way in which [Baron and Kenny \(1986\)](#) and others analyzed the mediation effect model for testing the mechanism of how the pilot policy affects a city's innovation level and build the mediation effect model as shown in [Eqns \(4\) to \(6\)](#):

$$Ininno_{it} = \beta_0 + \beta_1 test_{it} + \sum \delta_k year_k + \mu_{city} + \varepsilon_{it} \quad (4)$$

$$M_{it} = \lambda_0 + \lambda_1 test_{it} + \sum \delta_k year_k + \mu_{city} + \varepsilon_{it} \quad (5)$$

$$Ininno_{it} = \phi_0 + \phi_1 test_{it} + \phi_2 M_{it} + \sum \delta_k year_k + \mu_{city} + \varepsilon_{it} \quad (6)$$

where M represents a mediating variable. We took four factors into consideration: guidance of the Chinese government's innovation strategy, agglomeration of elements, corporate innovation investment and innovation environment. Regarding how to quantify the government's innovation strategy, according to [Lee \(2006\)](#) and [Li et al. \(2018\)](#), fiscal expenditures on science and technology are the basic approach for the government to participate in innovation activities as well as the basic carrier for the government to implement innovation strategy. Therefore, we use the proportion of the expenditures on science and technology in government fiscal expenditures to reflect the government's leadership in urban innovation (g_tec). Human capital is the most basic and active element in S&T innovation activities as well as an important carrier for the agglomeration of innovation elements, such as knowledge. Previous studies have suggested that there is a big education gap between workers in agriculture and workers in other sectors, so it is somewhat reasonable that non-agricultural workers are regarded as highly skilled workers ([Lei et al., 2014](#)). Therefore, we use the

proportion of the non-agricultural working population in the total urban population to reflect the concentration of talent in a city (*talent*). Enterprises are the main players of innovation activities. In 2017, the R&D expenditures of Chinese enterprises accounted for 77.6% of the nation's total R&D expenditures. However, the data on the proportion of corporate science and technology expenditures at the city level are unavailable. Investment in fixed assets is an important way for enterprises to generate fixed assets, including the renewal, transformation and expansion of existing assets as well as construction of new fixed assets. Investment in fixed assets can facilitate the installation and use of advanced technology and equipment, the emergence of new sectors and the disruption of traditional industries. To this end, we adopt the agglomeration of whole society's fixed-asset investment as a substitute index for corporate innovation investment, which is measured by the ratio of whole society's fixed-asset investment in urban areas to the gross area of urban areas (abbreviation: *inv*; unit: 100 million yuan/square kilometer). Urban innovation environment consists of soft environment and hard environment, forming the two perspectives from which this paper examined the mediation effect of urban innovation environment. Regarding the hard environment of urban innovation activities, we examined it from the perspectives of the regional informatization development and the regional transportation infrastructure construction. This is because, on the one hand, the development of informatization relying on Internet construction has gradually become the most important medium for knowledge exchange and dissemination and indispensable environmental support for cities to carry out S&T innovation activities; on the other hand, transportation infrastructure is an important part of the regional innovation system. Although information technology can greatly meet the needs of knowledge exchange, some special fields or highly confidential innovation activities still rely on the face-to-face interactions of R&D professionals. The sharing of some R&D infrastructure also increases the mobility of "people" in innovation activities. Therefore, the "flow of knowledge" based on modern information technology in innovation activities still cannot replace the "flow of people" based on transportation infrastructure, and urban transportation infrastructure has become an indispensable criterion for the development of innovative activities. Therefore, this paper uses the number of international Internet users per 10,000 people in a city to reflect the level of informatization development of a city (abbreviation: *i.e.* unit: household/10,000 people) and the density of urban highways (*i.e.* the proportion of highway mileage in the area of a city) was adopted to reflect the conditions of urban transportation infrastructure (abbreviation: *road*; unit: kilometer/square kilometer). As for the soft environment of urban innovation activities, it mainly includes the public service environment of innovation activities. Generally speaking, fiscal revenue directly determines the ability, quality and level of public services provided by government agencies. In this sense, we adopted local government's fiscal revenue as a percentage of the gross regional product (GRP) to reflect the government or non-governmental agencies' capability of providing services for urban innovation activities (*rev*). The above-mentioned data were all collected from the EPS China Data Platform.

The above-mentioned mediation effect model was regressed, and a test on the significance of the mechanism of impact based on the bootstrap method was conducted. The results are shown in [Tables 5 and 6](#). According to regression (1) in [Table 5](#), the total effect of the pilot policy on a city's innovation level is 0.357, which is significantly positive at the level of 1%. That is to say, the innovative city pilot policy has significantly improved a city's innovation level. This conclusion is consistent with the foregoing ones. This may be because the pilot policy has indirectly promoted the improvement of a city's innovation level by strengthening the guidance of the innovation strategy, driving the agglomeration of urban innovation elements, encouraging enterprises to carry out R&D innovation and fostering an environment conducive to S&T innovation.

First, regressions (2) and (3) respectively give the regression results of the pilot policy on the government expenditures on science and technology and of the pilot policy and

Explained variable	(1) <i>harmo</i>	(2) <i>g_tec</i>	(3) <i>harmo</i>	(4) <i>talent</i>	(5) <i>harmo</i>	(6) <i>inv</i>	(7) <i>harmo</i>
<i>test</i>	0.357*** (0.033)	0.008*** (0.001)	0.238*** (0.032) 15.34*** (0.826)	0.043*** (0.003)	0.239*** (0.034)	0.129*** (0.006)	0.171*** (0.034)
<i>g_tec</i>					3.309*** (0.203)		
<i>talent</i>							1.448*** (0.090)
<i>inv</i>							0.506*** (0.290)
constant	1.181*** (0.297)	0.044*** (0.006)	0.503*** (0.285)	0.341*** (0.023)	-1.730*** (0.282)	0.445*** (0.054)	
Sobel test	—	0.119	0.119	0.143		0.187	
Bootstrapping (indirect effect)	—	(<i>z</i> = 10.14, <i>p</i> = 0.000) (<i>Z</i> = 10.14, <i>p</i> = 0.000)	(<i>z</i> = 10.14, <i>p</i> = 0.000) (<i>Z</i> = 10.14, <i>p</i> = 0.000)	(<i>z</i> = 11.37, <i>p</i> = 0.000) (<i>Z</i> = 11.37, <i>p</i> = 0.000)	(<i>z</i> = 11.37, <i>p</i> = 0.000) (<i>Z</i> = 11.37, <i>p</i> = 0.000)	(<i>z</i> = 12.91, <i>p</i> = 0.000) (<i>Z</i> = 12.91, <i>p</i> = 0.000)	(<i>z</i> = 12.91, <i>p</i> = 0.000) (<i>Z</i> = 12.91, <i>p</i> = 0.000)
Bootstrapping (direct effect)	—	0.119	0.119	0.143		0.187	
Percentage of indirect effect	—	(<i>z</i> = 3.55, <i>p</i> = 0.000) (<i>Z</i> = 3.55, <i>p</i> = 0.000)	(<i>z</i> = 3.55, <i>p</i> = 0.000) (<i>Z</i> = 3.55, <i>p</i> = 0.000)	(<i>z</i> = 5.00, <i>p</i> = 0.000) (<i>Z</i> = 5.00, <i>p</i> = 0.000)	(<i>z</i> = 5.00, <i>p</i> = 0.000) (<i>Z</i> = 5.00, <i>p</i> = 0.000)	(<i>z</i> = 9.71, <i>p</i> = 0.000) (<i>Z</i> = 9.71, <i>p</i> = 0.000)	(<i>z</i> = 9.71, <i>p</i> = 0.000) (<i>Z</i> = 9.71, <i>p</i> = 0.000)
Percentage of indirect effect	—	(<i>z</i> = 5.78, <i>p</i> = 0.000) (<i>Z</i> = 5.78, <i>p</i> = 0.000)	(<i>z</i> = 5.78, <i>p</i> = 0.000) (<i>Z</i> = 5.78, <i>p</i> = 0.000)	(<i>z</i> = 7.52, <i>p</i> = 0.000) (<i>Z</i> = 7.52, <i>p</i> = 0.000)	(<i>z</i> = 7.52, <i>p</i> = 0.000) (<i>Z</i> = 7.52, <i>p</i> = 0.000)	(<i>z</i> = 5.22, <i>p</i> = 0.000) (<i>Z</i> = 5.22, <i>p</i> = 0.000)	(<i>z</i> = 5.22, <i>p</i> = 0.000) (<i>Z</i> = 5.22, <i>p</i> = 0.000)
<i>N</i>	3,763	3,763	3,763	3,722	3,722	3,759	3,759
<i>R</i> ²	0.968	0.674	0.971	0.921	0.968	0.847	0.970

Note(s): *, **, and *** indicate that the regression coefficient is significant at the levels of 10%, 5% and 1%, respectively

Table 5. Test I for the mechanism of impact

Table 6.
Test II for the
mechanism of
impact [3]

Explained variable	(1) <i>Ie</i>	(2) <i>hmmo</i>	(3) <i>road</i>	(4) <i>hmmo</i>	(5) <i>rev</i>	(6) <i>hmmo</i>
<i>test</i>	0.026*** (0.008)	0.347*** (0.032)	0.075*** (0.020)	0.435*** (0.044)	0.005*** (0.001)	0.480*** (0.040)
<i>road</i>		0.372*** (0.070)		0.357*** (0.042)		
<i>rev</i>						
<i>constant</i>	0.562*** (0.071)	0.972*** (0.289)	-0.402*** (0.099)	1.900*** (0.318)	-0.001 (0.006)	5.324*** (0.589)
Sobel test	0.010 (<i>z</i> = 2.79, <i>p</i> = 0.005) (<i>Z</i> = 2.79, <i>p</i> = 0.005)		0.027 (<i>z</i> = 3.45, <i>p</i> = 0.001) (<i>Z</i> = 3.45, <i>p</i> = 0.001)		0.026 (<i>z</i> = 3.88, <i>p</i> = 0.000) (<i>Z</i> = 3.88, <i>p</i> = 0.000)	-8.551*** (0.206)
Bootstrapping (indirect effect)	0.010 (<i>z</i> = 1.99, <i>p</i> = 0.046) (<i>Z</i> = 1.99, <i>p</i> = 0.046)		0.027 (<i>z</i> = 3.43, <i>p</i> = 0.001) (<i>Z</i> = 3.43, <i>p</i> = 0.001)		0.026 (<i>z</i> = 2.98, <i>p</i> = 0.003) (<i>Z</i> = 2.98, <i>p</i> = 0.003)	
Bootstrapping (direct effect)	0.347 (<i>z</i> = 10.80, <i>p</i> = 0.000) (<i>Z</i> = 10.80, <i>p</i> = 0.000)		0.435 (<i>z</i> = 7.25, <i>p</i> = 0.000) (<i>Z</i> = 7.25, <i>p</i> = 0.000)		0.480 (<i>z</i> = 9.32, <i>p</i> = 0.000) (<i>Z</i> = 9.32, <i>p</i> = 0.000)	
Proportion of indirect effects	2.69%		5.83%		5.16%	
<i>N</i>	3,763	3,763	2,946	2,946	3,761	3,761
<i>R</i> ²	0.716	0.968	0.873	0.956	0.823	0.952

Note(s): *, **, and *** indicate that the regression coefficient is significant at the levels of 10%, 5% and 1%, respectively

government expenditures on science and technology on a city's innovation level. Specifically, regression (2) shows that the regression coefficient of the innovative city pilot policy on the proportion of government expenditures on science and technology is significantly positive at the level of 1%, indicating that the pilot policy can help strengthen the local government's strategic guidance on urban innovation activities; in regression (3), the regression coefficient of the government expenditures on science and technology on a city's innovation level is also significantly positive at the level of 1%, indicating that the national innovation strategy can effectively promote the improvement of a city's innovation level. The above results suggest that the innovative city pilot policy can strengthen the government's strategic guidance on urban innovation activities, thereby promoting the improvement of a city's innovation level, with the mediation effect of 0.119 accounting for 33.27% of the total effect or so. Both Sobel test and bootstrapping show the result below the level of 1%, testifying to the existence of the mediation effect of government expenditures on science and technology.

Second, regression (4) and regression (5) give the regression results of the pilot policy on the concentration of talent in a city and of the pilot policy and the talent density on a city's innovation level, respectively. According to regression (4), the regression coefficient of the innovative city pilot policy on the talent density in a city is significantly positive at the level of 1%, indicating that the pilot policy is conducive to facilitating the concentration of talent in cities. In regression (5), the regression coefficient of the talent density in a city on the innovation level is significantly positive at the level of 1%, indicating that the concentration of talent can effectively promote the improvement of a city's innovation level. Concerning the results in regression (4), the innovative city pilot policy can effectively promote the concentration of talent in a city, lay a good foundation of human capital for urban innovation and promote the improvement of a city's innovation level. The mediation effect of the concentration of talent is 0.143, accounting for about 37.53% of the total effect. The results of the Sobel test and bootstrapping both confirm the mediation effect of the concentration of talent.

Third, regression (6) and regression (7) respectively give the regression results of the pilot policy on the intensity of the whole society's fixed-asset investment in a city and of the pilot policy and the investment intensity on a city's innovation level. In regression (6), the regression coefficient of the pilot policy on the investment intensity of a city is significantly positive at the level of 1%, indicating that the innovative city pilot policy is conducive to promoting the agglomeration of investment in a city. In regression (7), the regression coefficient of the investment agglomeration on a city's innovation level is significantly positive at the level of 1%, indicating that the increase in investment intensity in a city has driven the improvement of a city's innovation level. Concerning the results of regression (6), the innovative city pilot policy can encourage enterprises to increase investment, stimulate the emergence of new technologies and new industries and thus promote the improvement of a city's innovation level. The mediation effect of the agglomeration of urban investment is 0.187, accounting for about 52.24% of the total effect. In addition, the results of the Sobel test and bootstrapping show that the mediation effect of investment agglomeration exists significantly.

Finally, [Table 6](#) shows the results of the test on the pilot policy's mechanism of improving a city's innovation level by enhancing the urban innovation environment. Regression (1) and regression (2) respectively give the regression results of the pilot policy on a city's informatization level and of the pilot policy and the level of informatization on a city's innovation level. Regression (1) shows that the regression coefficient of the pilot policy variable on a city's innovation level is significantly positive at the level of 1%, indicating that innovative city pilot policy has driven the progress of urban informatization. Likewise, in regression (2), the regression coefficient of a city's informatization level and the level of innovation is also significantly positive at the level of 1%, indicating that urban information development can provide a good information environment for urban innovation and help improve a city's innovation level. Concerning the results of regression (1), the innovative city

pilot policy can facilitate the improvement of a city's informatization level and help improve the urban innovation environment, thereby leading to a significant effect on promoting a city's innovation level. The mediation effect of a city's informatization is 0.010, accounting for about 2.69% of the total effect, and results of the Sobel test and bootstrapping both confirm the existence of the mediation effect of a city's informatization at a relatively high level.

Regression (3) and regression (4) respectively give the regression results of the pilot policy on the urban transportation infrastructure construction and of the pilot policy and urban transportation infrastructure on the level of innovation. In regression (3), the regression coefficient of the pilot policy on urban transportation infrastructure construction is significantly positive at the level of 1%, indicating that the innovative city pilot policy can significantly promote the urban transportation infrastructure construction and meet the basic requirements of urban innovation activities on road transportation. In regression (4), the regression coefficient of urban transportation infrastructure construction on the level of innovation is also significantly positive at the level of 1%, indicating that a city's innovation level is inherently dependent on the transportation infrastructure construction and that the continuous improvement of transportation infrastructure plays a role as a catalyst in urban innovation. Concerning the results of regression (3), the pilot policy can promote urban innovation significantly by facilitating urban transportation infrastructure construction. Specifically, the mediation effect of urban transportation infrastructure construction is 0.027, accounting for about 5.83% of the total effect, and the results of the Sobel test and bootstrapping both support the existence of the mediation effect of the urban transportation infrastructure construction.

Regression (5) and regression (6) show the regression results of the pilot policy on the government's public service capacity and the pilot policy and government's public service capacity on the innovation level of a city, respectively. In regression (5), the regression coefficient of the pilot policy on the government's public service capacity is significantly positive at the level of 1%, indicating that innovative city pilot policy can significantly improve the public service capacity of local governments. Regression (6) shows that the regression coefficient of the government's public service capacity on the innovation level of a city is significantly positive at the level of 1%, indicating that enhancing and improving the government's public service capacity and effectively exerting the government's public service functions can significantly promote urban innovation. Taking the results of regression (5) into consideration, we found that the pilot policy can strengthen the public service functions of local governments and have a significant effect on promoting urban innovation. Specifically, the mediation effect of government public services is 0.026, accounting for about 5.16% of the total effect, and the results of the Sobel test and bootstrapping both support the existence of the mediation effect of government public services.

6. Brief conclusions and practical implications

6.1 Brief conclusions

Innovation is a long-term driving force of economic growth while cities serve as a spatial carrier of S&T innovation and an important hub for carrying out innovation activities and monetizing innovation output. Improving the innovation level of cities plays a fundamental role in China's efforts to build an innovative nation. To this end, China has rolled out a series of measures to improve the innovation level of cities. As an approach to realize the goal of building an innovative nation and promote the innovation-driven development strategy, the innovative city pilot policy is an important initiative for the Chinese government to promote urban innovation and provide effective support when building an innovative nation. Some might wonder whether the innovative city pilot policy in real-life practice can effectively improve a city's innovation level. The answer to this question, to some extent, can resolve the dispute on the effect of the national innovation policy in the current research, thereby

providing theoretical and practical guidance for the government on the development of reasonable support policies.

Based on theoretical analysis, we conducted an empirical test on the impact of the innovative city pilot policy on a city's innovation level with selected methods, such as the difference-in-differences model. The main conclusions are as follows: (1) On the whole, the pilot policy can effectively increase a city's innovation level. This conclusion testifies the effectiveness of government support, which suggests that government should play an active role in providing guidance and ensure the smooth implementation of urban S&T innovation. (2) The impact of the innovative city pilot policy on a city's innovation level varies among different cities. More specifically, the effect of the pilot policy on improving the innovation level in direct-controlled municipalities, provincial capitals and sub-provincial cities is weaker than that in ordinary cities; in addition, the effect of the pilot policy on improving the innovation level in the cities with a higher quality of science and education resources is weaker than that in cities with relatively low quality of science and education resources. Moreover, as a city's innovation level is increased, the promotion effect of the pilot policy on a city's innovation level presents an "asymmetric inverted V-shaped" feature, which indicates that the improving effect is followed by a decreasing trend. It is also found in the study that the heterogeneity of urban location in the effect of the pilot policy is not significant. (3) The innovative city pilot policy can indirectly promote urban innovation by strengthening the government's strategic guidance on urban innovation activities, facilitating the concentration of talent in urban areas, encouraging enterprises to increase investment, optimizing the urban innovation environment, etc. the concentration of talent promoted by the pilot policy and the incentive effect on enterprise investment are the major reasons why the innovative city pilot policy can promote the improvement of a city's innovation level.

6.2 Practical implications

Based on the above conclusions, the main practical implications of this paper are as follows:

First, summarize the experience of the existing pilot innovative cities, expand the scope of pilot innovative cities in a well-organized manner and promote the overall improvement of a city's innovation level. It has been found in the study that the innovative city pilot policy can effectively improve a city's innovation level. Therefore, the improvement of the pilot system of "local pilot-central summarization-local promotion" should be accelerated, the relationship between the responsibilities of the central and local governments regarding building an innovative nation should be clarified, and more efforts should be made to speed up the development of the interaction mechanism under which the central government provides guidance for the innovation strategy and offers local governments institutional incentives, and in return, the local governments contribute experience in innovation practices and a pool of knowledge. Previously, China had seen successful implementation of the innovative city pilot policy and further expanded the scope of the pilot policy in April 2018. In the future, lessons learned from the pilot innovative cities should be summarized at a quicker pace to form general rules and diversified experience and develop them to a central government policy accordingly, expediting the implementation of the pilot policy.

Second, in order to promote the innovative city pilot policy, efforts should be made to stick to the principles of adapting measures to local conditions and policy on an individual place by place basis, enhance the inclusiveness and flexibility of the national innovation system and expedite to establish an effective mechanism of tracking, evaluating and monitoring the pilot cities. Due to the environmental differences in the economic system, such as economic development level, resource agglomeration capacity and policy environment, the effect of the innovative city pilot policy on the innovation level of different cities also has different characteristics. Therefore, in the process of promoting the experience of building pilot

innovative cities, it is necessary to avoid simplified, generalized and unified practices, advocate diversified development strategies, learn from the prior experience in combination with local conditions and establish the urban innovation system with local characteristics so that the construction of China's innovation system can be more diversified and inclusive. Meanwhile, it is required to track, evaluate and monitor the effect of the pilot policy and adjust the pilot measures on time. The withdrawal mechanism may be adopted when necessary to remove cities with poor pilot performance from the list of pilot cities.

Third, explore the multi-dimensional pathways of the pilot policy to promote the improvement of a city's innovation level for improving the urban innovation system and enhancing the innovation level of a city with multiple measures. It has been found in the study that the pilot policy can indirectly promote the improvement of a city's innovation level by strengthening the government's strategic guidance on urban innovation activities, promoting the concentration of high-quality workers, stimulating corporate investment and optimizing the environment for innovation. Therefore, it is necessary to further strengthen the government's strategic guidance on urban innovation by increasing government spending on science and technology and enhancing the role of government spending on science and technology in promoting urban innovation activities, formulate more favorable policies for attracting talents to lay a good human capital foundation for urban innovation, encourage enterprises to increase R&D expenditures, strengthen their subjective role in the urban innovation system and optimize the soft and hard environment of urban infrastructures to create a supportive environment for urban innovation.

Notes

1. Ministry of Science and Technology of the P. R. China (2010), Guiding Opinions on Further Promoting the Innovative City Pilot Practices. Available at: http://www.gov.cn/gzdt/2010-04/17/content_1584432.htm [Accessed April 20, 2010]
2. Due to the limited space, the chart is not provided in the paper. It can be obtained from the author if necessary.
3. The sum of all the mediation variables accounting for the total mediation effect shown in Tables 5 and 6 is higher than 1. This is because we estimated the mediation effect of each variable separately, which made it difficult to solve the overlapping problem of the mediation effects of different mediation variables. For example, guidance of the government innovation strategy, and the performance of functions including innovation environment construction can also play a part in promoting the agglomeration of urban innovation elements.

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