

# Assessment Study on Innovation Ecology Construction in Shanxi Province

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**Abstract.** The present invention discloses a cathode frame of an electrostatic precipitator, comprising a rectangular frame composed of four horizontal bars and five vertical bars; The horizontal and vertical bars are perpendicular to each other and located in the same plane, and four horizontal bars are arranged parallel to each other, while five vertical bars are arranged parallel to each other; Four horizontal bars divide the longitudinal length of the rectangular box into three equal parts, five vertical bars divide the transverse length of the rectangular box into 2:1:1:2, and one of the vertical bars is located on the vertical centerline of the rectangular box; The upper section of the two outermost vertical rods on the rectangular frame is a reinforced vertical rod, and there are two horizontal through-holes on the reinforced vertical rod for installing the cathode frame support. The cathode frame of the electrostatic precipitator has a simple structure and convenient assembly, which can effectively prevent the cathode frame of the electrostatic precipitator from bending, deformation, or even sliding and collapsing from the overall cathode support, greatly improving the safety and stability of the operation of the electrostatic precipitator.

**Keywords:** Electrostatic precipitator; Cathode frame; Anti bending deformation; Anti slip collapse; high safety and stability.

## 1. Introduction

At present, China has entered the stage of high-quality development, and in the face of the opportunities and challenges brought about by the new round of scientific and technological revolution and industrial change, the ability of scientific and technological innovation has increasingly become a decisive factor. Shanxi Province, as one of the important energy bases and industrial bases in China, also has certain experience and achievements in innovation ecological construction. In recent years, Shanxi Province has firmly established the development concept of "innovation as the top", actively implemented the innovation-driven development strategy, constructed a favorable innovation ecological environment, promoted enterprises, universities and scientific research institutions to strengthen innovation and entrepreneurship, and facilitated the rapid transformation and high-quality development of Shanxi's economy, which has made a positive contribution to the improvement of industrial level and the improvement of people's living standard. However, can it realize the homogeneity of innovation-driven development strategy and urban innovation and entrepreneurship output? What is the intrinsic mechanism of policy influence on innovation output? In order to explore the effectiveness of innovation ecological construction in Shanxi Province, this paper will combine the current economic and social development background of Shanxi Province, take the introduction of the pilot policy of "Interim Management Measures on National Smart City Pilot" in 2012 as a quasi-natural experimental environment, objectively evaluate its policy effect on the performance of urban innovation outputs, and study how to formulate and implement measures related to innovation policies to contribute to the transformation of the economy of Shanxi's resource-based cities and to advance the Shanxi's sustainable development ability, and further do a good job in urban innovation ecological construction to provide certain theoretical reference significance.

## 2. Literature review

### 2.1 Government influence on innovation activism

As one of the important main bodies of the regional innovation system, the government usually participates in urban innovation activities through financial subsidies, tax incentives, industrial policies to promote research institutions, universities and enterprises to strengthen cooperation, improve the conversion rate of scientific and technological achievements and market competitiveness, and promote the development of the local economy. It has been found that government support is an important guarantee for the efficient operation of the urban innovation system (Li Zheng et al., 2018) [3]. At the same time, the dominant position of the government in the social innovation system determines the important role of the government in promoting social innovation and thus social development (Jiang Hong, 2018) [4]. However, the influence of government on urban innovation output remains controversial. Some studies in the literature suggest that there may be a positive effect of government policy support on the level of urban innovation (Hong et al, 2016) [5]. Ding, Haibo (2022) [6] Based on the real problems faced by the innovation development of Chinese enterprises, the role mechanism of government innovation preference on the innovation efficiency of high-tech enterprises was empirically examined by using a two-way fixed-effects model, and it was found that government innovation preference can significantly improve the innovation efficiency of high-tech enterprises.

Wang Yafeng (2022) [7] empirically analyzed the reality pattern and formation mechanism of the insufficient sustainability of participatory budget innovation in China, and found that the district government and the district finance bureau are the dominant and coordinator of innovation, while the actions of the street offices, village (neighborhood) committees and the people are more passive. Some other researchers and scholars have studied from the perspective of government expenditure and found that government expenditure on science and technology has a significant incentive effect on regional innovation capacity (Ha Meifang et al., 2023) [8].

Qi Yongxin (2021) [10] It is found that China's innovation subsidies have an inverted U-shaped effect on both innovation dynamics and innovation performance, after a certain level of innovation subsidies, innovation subsidies begin to inhibit firms from innovating. While Wang Q. et al. (2022) [11] found that the impact of different local government competition models on urban innovation: in general, the local government competition model with a single GDP as the development target is unfavorable to local urban innovation and has a negative spatial spillover effect on the innovation of neighboring cities; the local government competition model with science and technology innovation as the development target is favorable to local urban innovation and has a positive spatial spillover effect on the innovation of neighboring cities. In addition scholars Shen Yu (2021) [12] explores whether official turnover affects regional innovation and analyzes its underlying mechanisms under China's special state-owned system situation. The study shows that official turnover inhibits regional innovation, and it is found that the departure of officials negatively affects regional innovation by weakening the government's innovation preference, and the government's innovation preference plays a mediating role as a bridge. The promotion incentive mechanism of science and technology management officials inhibits corporate innovation, and this inhibition is moderated by the regional market governance environment, and the inhibition effect is not significant in regions with relatively good market governance environment, and the inhibition effect is more significant in regions with relatively poor market governance environment (Anzhi, 2019) [13].

### 2.2 Impact of innovation policies on innovation activism

Chinese government has put forward a number of innovation policy programs. It has been found that innovation policies can have a significant positive impact on the innovation capability of enterprises (He Ying, 2021) [14]. Cheng Conghui et al. (2023) [15] Analyzed the causal path of science and technology talent policies affecting urban innovation, and studied the development of innovation policies to support the promotion of urban innovation through three paths: dual-creation

oriented path, circular-driven path, and normative-guaranteed path. Hou Linqi (2022) [16] The impact of innovative city construction on urban innovation capacity was analyzed using double difference model. The study found that the policy effects of different batches of policies have different effects on the promotion of urban innovation capacity, and the whole shows a decreasing trend. This may be related to factors such as the time and quality of policy implementation, the city's initial innovation capacity and resource endowment. In addition, the study points out that there is also some variability in the promotion effect of different types of innovative city pilot projects on the city's innovation capacity, which requires targeted measures for management and optimization. Jia Yongfei et al. (2023) [17] Research on the issue of symbiotic policy influencing factors affecting regional innovation capacity, the results of the study show that it is the coordination and cooperation between externally-led policies and internally-driven policies that can effectively improve regional innovation capacity.

The promotion of economic development through technological innovation has received widespread attention and recognition, however, there is a relative lack of research related to negative impacts. The existence of some scholars found that innovation policy has a negative impact on innovation activities. The government innovation policy increases the rent-seeking behavior of enterprises, which inhibits the innovation enthusiasm of enterprises and even leads to the reduction of urban innovation efficiency (Wang et al, 2017) [18]. The impact of innovation policy has a weaker negative impact on innovation output, indicating that the space for innovation policy to play a role is gradually shrinking (Yu Liping, 2022) [19]. An Zhi (2019) [20] Empirical researchers based on microenterprise research data in Suzhou City, Jiangsu Province, show that government innovation incentive policies do not show a significant effect on both private R&D investment and patent output. When firms or enterprises are stimulated by innovation policies, their number of patent applications increases significantly. However, such an increase in the number of non-invention patent applications only, pursuing the "quantity" of innovation while ignoring the "quality" of innovation, does not mean a significant increase in innovation output (Lai, 2016) [21]. However, this does not mean that the impact of government innovation policy on the innovation capacity of enterprises and urban innovation efficiency is negative or necessarily negative. The government needs to consider how to stimulate the intrinsic innovation motivation of enterprises when formulating innovation policies, so as to avoid rent-seeking behavior that is overly dependent on government support.

### **2.3 Methodology for assessing the level of innovation-driven policies and innovation outputs**

#### **2.3.1 Evaluation studies on innovation-driven policies**

Public policy evaluation has undergone a process of continuous development and improvement since its emergence, and the evolution can be roughly divided into the following stages: the period of scientization, the period of normative and empirical unity, the period of constructivism, the period of policy debates, and the period of complex adaptive systems (Li et al., 2023) [22]. The specific assessment methods of some scholars are as follows: Yang Jian et al. (2021) [23] Evaluating regional innovation policies at the provincial level from the dimensions of policy intensity, policy synergy and policy perfection. Yao Xiaoqiu et al. (2021) [24] Analyzed and researched the science and technology innovation policies of Zhejiang Province by using the whole process evaluation method of policies, and focused on the synergy effect of policies by drawing on the three-dimensional evaluation model in terms of policy evaluation. S. Yang et al. (2016) [25] By designing a questionnaire, assessed the government's policy formulation, administrative execution ability, and enterprise implementation effect, and constructed an index system according to these three aspects, after which the implementation effect of science and technology innovation policies in Jilin Province was studied and analyzed by using the SEM method.

Specifically for the innovation policy, this paper focuses on the smart city pilot policy, and the innovative city pilot policy, so the reference analysis starts from these two aspects. Yao Shengwen et al. (2022) [26] Used double difference model to explore the relationship between smart city pilot policy and city innovation level, and to explore its influence mechanism and role principle. Yan Sen (2022) [27] By establishing a multi-period double-difference model for policy assessment, analyzed

the impact mechanism and role path of the introduction of national innovative city pilot policy on urban innovation capacity using the mediation effect test. And Bai Junhong et al. (2022) [28] investigated the impact of innovation-driven policies on entrepreneurial activity by constructing a multi-temporal double-difference model and quasi-natural experiments with innovative city pilot policies. Wu Xingzong (2022) [29] Taking the Outline (The Outline of the National Medium- and Long-Term Scientific and Technological Development Plan (2006-2020), referred to as the Outline) as an exogenous innovative policy experiment, we utilize the DID double difference method to conduct an empirical investigation for the impact of innovation policies on the innovation capacity of enterprises.

### **2.3.2 Evaluation studies of innovation outputs**

Patent is one of the important indicators reflecting the innovation level of an enterprise or a country, and in the research, for the measurement of innovation output level, there are many scholars who use the number of patent applications or the number of patents granted for invention patents as the explanatory variables for analysis and research. In addition to the number of patents, there are other indicators that can be used to measure the level of innovation output of an enterprise or a country, which need to be selected according to the specific situation. Li Xuesong et al. (2022) [30] believe that invention patents can better reflect the "qualitative change" characteristics of enterprise innovation, so the number of invention patent applications is used to measure the innovation performance of enterprises. Chen Yuanyan et al. [31] Using the number of patents granted to measure innovation output, and considering that there is a lag of about three years between the time of patent application and the time of patent grant, the dependent variable in the empirical model advances the data by three periods in the study (Li Xibao, 2007) [32].

And Wang et al. (2021) [33] argued that the number of patent applications or the number of patents granted as innovation output indicators have different degrees of error and missing data problems, and the number of patent applications and the number of patents granted in China do not take into account the value of the patents themselves, which may lead to bias in the assessment of the performance of innovation outputs, and so his study adopted Kou Zonglai and Liu Xueyue (2017) [34] The four-digit industry innovation index measured as an indicator of city-level innovation performance. Xie, Chengyang et al. (2020) [35] also used the same innovation index to measure city innovation.

## **3. Research hypotheses**

### **3.1 Impact of smart city pilot policies and urban innovation**

With the development of information technology, the smart city strategy has become a hotspot and trend in urban development in countries around the world, covering a wide range of areas such as urban infrastructure, public services, urban management and economic development. The construction of smart cities is both developed under the support of science and technology innovation and in line with the actual needs of cities. An analysis of domestic and international smart city pilot cases reveals that the central government usually cooperates with multiple parties, including local governments, professional organizations and enterprises, to jointly promote the construction of smart cities. The Chinese government also takes smart cities as an important means to promote the deep integration of informatization and urbanization, and through the implementation of the smart city pilot policy, it takes this as an entry point to mobilize the innovation and entrepreneurial enthusiasm of innovation main bodies and influence the level of innovation output of cities.

Based on this, the following research hypotheses are proposed in this paper:

H1: Pilot smart city policies can increase innovation activity in cities.

### **3.2 Heterogeneity in the impact of smart city pilot policies on city innovation activity**

According to the theory of regional economic development, the development of cities is influenced by the administrative level of cities and their geographical location. The city's original scale of development and original resource reserves will have an impact on the implementation of policies, which will lead to the heterogeneity of the city's level of innovation and development. Taking into account the common practice of previous studies, this paper examines the effect of policy implementation from two perspectives: the heterogeneity of cities' location and the heterogeneity of their initial level of innovation.

In terms of city location, the eastern region is more open and faster than the western region, and a good urban environment, whether for economic trade or transportation, will facilitate the implementation of innovation policies, reduce costs, and be more conducive to the implementation of innovation activities. Shanxi Province, as a large resource city with rich resource reserves, is located in the central part of the country, close to the capital city, and has an excellent geographic location, so this paper divides the 11 prefectural-level cities in Shanxi in the northeast and southwest directions.

In terms of initial innovation level, on the one hand, cities with higher initial innovation level have more excellent innovation conditions and innovation environment, and the rapid development of innovation can in turn accelerate the economic development of the region, and the government will pay more attention to scientific and technological innovation. On the other hand, the advancement of smart city construction constantly generates the emergence of new industries, improves the city's industrial structure, further creates a good innovation ecology, and provides a better economic development environment and innovation ecosystem for policy implementation and development.

Based on this, the following research hypotheses are proposed.

H2: The smart city pilot policy has a more significant effect on increasing the level of innovation in cities in the northeast of Shanxi Province.

H3: Smart city pilot policies are more effective in increasing the innovation level of cities with higher initial innovation levels, and smart city pilot policies will reduce the gap in innovation capacity between cities.

### **3.3 Mechanisms by which smart cities influence the level of urban innovation**

Innovation is a process that requires long-term investment and continuous support, and needs to be pursued and promoted relentlessly. The mechanisms by which the national smart city pilot policy affects the innovation activity of cities are mainly reflected in the following three aspects.

**Talent pooling effect.** The smart city pilot policy can enhance the city's innovation activity through the talent agglomeration effect. The smart city pilot policy can enhance the city's innovation vitality through the talent gathering effect. According to the entrepreneurship theory of the innovation school, talent is the key main body to carry out innovative activities, so the number of innovative and entrepreneurial talents in a region will directly affect the level of innovation and entrepreneurship in the region. The agglomeration of innovative and entrepreneurial talents not only helps to enhance the regional knowledge reserve and expand the entrepreneurial talent pool, but also reduces the cost of knowledge transfer. It facilitates the learning and dissemination of new knowledge through formal and informal network exchanges, which helps talents to better understand market information, produce more innovations and improve the level of innovation in the region.

In addition, talent aggregation also helps the pilot cities to attract more innovative and entrepreneurial talents under the effect of cyclic accumulation of causality, realizing the self-reinforcement of talent aggregation, and thus promoting the further improvement of the city's innovation level.

Based on this, the following research hypotheses are proposed.

H4: Smart City Pilot Policies Increase the level of innovation activity in cities through the talent pooling effect.

## 4. Study Design and Description of Variables

### 4.1 Modeling

In this paper, the national smart city pilot policy is regarded as a quasi-natural experiment of innovation-driven policy, focusing on the impact effect of the policy implementation on the innovation output of Shanxi Province, which is investigated using the double-difference method, taking into account the fact that the smart city pilot policy is a batch expansion of the scope of the pilot cities. Drawing on Beck et al. (2010)[38] approach, the model is designed as follows:

$$ina_{i,t} = \alpha + \beta policy_{i,t} + \gamma control_{i,t} + cityfe + yearfe + \varepsilon_{i,t} \quad (1)$$

where *ina* denotes city innovation activity, *policy* denotes smart city pilot policy implementation effects, and is the set of control variables. *cityfe* is the city fixed effect, *yearfe* is the year fixed effect, and  $\varepsilon$  is the randomized disturbance term.

### 4.2 Variable Selection

(1) Explained variable. Innovation ecological activeness (*ina*). Refer to Kortum & Lerner [39] 's study, this paper selects the number of patents granted to measure the innovation ecological activity. Further, this paper refers to Zhou et al. [40] 's study, in the empirical model test, the population method is adopted, i.e., the city population is used as the standardized base, and the number of new patents granted per 100 people in the city is used as the measure of innovation activity. Meanwhile, in the robustness test, the national division of patent types is adopted, and then the number of invention patents granted per 100 people and the number of utility model patents granted per 100 people are used to measure the innovation output of the city respectively, which are recorded as *patent1* ,*patent2* in turn.

(2) Core Explanatory Variables. Policy implementation effects (*policy*). The smart city pilot policy implementation effect (*policy*) is characterized by the interaction term between the dummy variable for the scope of urban policy implementation and the dummy variable for the duration of urban policy implementation (*treat \* post*).

(3) Control variables. ① Human capital level (*edu*). This paper adopts the ratio of the number of students enrolled in colleges and universities to the number of urban resident population to measure the level of human capital. ② Economic development level (*gdp*). The level of economic development is measured by GDP per capita. (iii) Intensity of scientific research investment (*R&D* ). The intensity of scientific research investment is measured by the ratio of expenditure on scientific programs to regional GDP. (iv) Level of industrial structure (*is*). The ratio of GDP of tertiary industry to GDP of regional economy is used to measure the difference in industrial structure level of cities. ⑤ Financial development level (*fin*). The ratio of the balance of deposits and loans of financial institutions at the end of the year to the regional GDP is used to measure the level of financial development of cities. (6) Level of technological development (*ti*). The ratio of the number of Internet users to the city's resident population is used to measure the level of technological development. (vii) Scale of urban infrastructure (*city*). The size of urban infrastructure is measured by the area of roads per capita.

### 4.3 Data sources

Based on the panel data of 11 cities in Shanxi Province from 2001 to 2020, this paper utilizes the multi-temporal double-double-difference method and the triple-difference method to assess and study the innovation ecological construction in Shanxi Province. Also drawing on Shi Dachian et al. (2018) [41] scholars' practice to process the data as follows: (1) delete the sample of cities that individually selected a city's district and a county as a pilot in the smart city pilot policy; and (2) fill in the cities with fewer missing data by linear interpolation.

Balanced panel data of 11 prefecture-level cities in Shanxi Province from 2001 to 2020 are finally obtained, and the data processing software is stata17.0. The data of all kinds of patent authorizations

for the data of the explanatory variables are from the CNRDS platform, and the data of the main control variables are from the China Statistical Yearbook of each year from 2002 to 2021, the Shanxi Statistical Yearbook, and China Urban Statistical Yearbook.

## 5. Empirical tests and analysis of results

### 5.1 Benchmark regression results

Table 1 presents the regression results of the effects of the national smart city pilot policy on the city's innovation activity. The results show that the regression coefficients of *policy* are significantly positive in all cases, indicating to some extent that the introduction of the National Smart City Pilot Policy significantly enhances the city's innovation activity. In particular, the regression coefficient of the policy implementation effect becomes larger when controlling for city and year fixed effects, while at the same time, the policy impact effect of the experimental group is significantly positive at the 5% level, which suggests that the introduction of the Interim Management Measures on National Smart City Pilot significantly promotes the enhancement of the city's innovation activity to a certain extent. Thus, hypothesis H1 is verified.

### 5.2 Robustness Tests

#### (1) Parallel trend test

Parallel trend tests for multi-temporal DID draw on Beck et al. (2010) [38] 's idea, since the time when the pilot cities were selected as smart city pilots varies, it is not possible to simply set a time dummy variable for a particular year as the threshold for the policy to occur, but rather it is necessary to set a dummy variable for the relative time value of the implementation of the smart city pilot policy for each of the pilot cities. This paper constructs equation (2) and uses the event study method to conduct a parallel trend test as follows.

$$ina_{i,t} = \alpha + \beta_1pre6_{i,t} + \beta_2pre5_{i,t} + \beta_3pre4_{i,t} + \beta_4pre3_{i,t} + \beta_5pre2_{i,t} + \beta_6pre1_{i,t} + \beta_7current_{i,t} + \beta_8post1_{i,t} + \beta_9post2_{i,t} + \beta_{10}post3_{i,t} + \beta_{11}post4_{i,t} + \beta_{12}post5_{i,t} + \beta_{13}post6_{i,t} + cityFE + yearFE + \varepsilon_{i,t} \quad (2)$$

The results of the parallel trend test are shown in Figure 1.

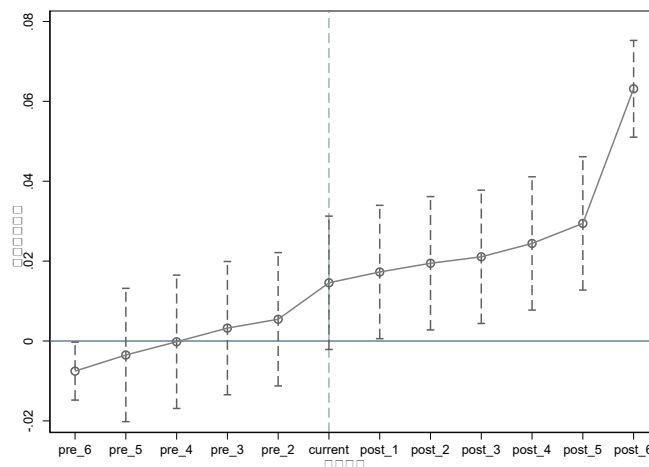


Figure 1

#### (2) PSM-DID test

In order to avoid systematic bias in the trend of comparison between the selected experimental group and the control group, which reduces the credibility of the double-difference results, this paper further conducts a robustness test of the underlying model based on the multi-temporal PSM-DID model.

Using PSM-DID to logistic regression on the selected smart cities, the propensity score matching is re-run, and the closest scores become the best experimental and control groups, which is a validation and supplementation of the DID conclusions. Before the robustness test advanced correlation test, the nearest neighbor matching is performed for all the cities' innovation activity, and the probability density of the experimental and control groups before and after the matching is also plotted, and the results are shown in Figures 2 and 3.

By comparing the empirical results of DID and PSM-DID, it can be seen that the regression coefficients before and after are significantly positive, especially after adding the control variables, the pilot policy has a more obvious effect on the promotion of innovation activity in cities.

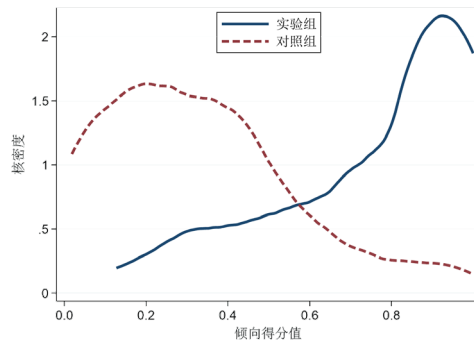


Fig. 2 Comparison of kernel probability density of propensity score values before matching

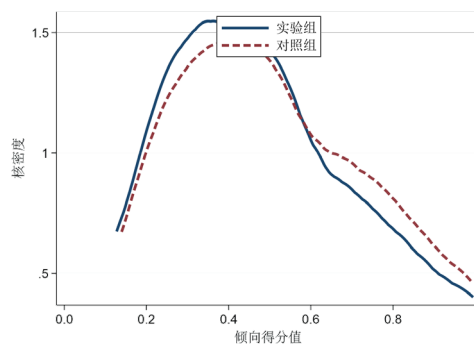


Fig. 3 Comparison of kernel probability density of propensity score values after matching  
(3) Replacement of core variables

As mentioned earlier, innovation activity is measured using the number of patents granted per 100 people. For the sake of comparison, this paper tries to use the number of green patents granted per 100 people to measure innovation activity. Green patent refers to invention patents, utility model patents and design patents that are conducive to saving resources, improving energy efficiency, preventing and controlling pollution and other green technology as the subject of invention, this paper does not use the green patent for design, because invention patents and utility model patents are more valuable, so we use the number of invention and utility model patents per 100 people (green patent) to conduct the regression. patent) is used for regression. The regression results are shown in result, from which it can be seen that the regression coefficients of the policy implementation effect POLICY are significantly positive regardless of the metrics used to measure the city's innovation output, indicating that the smart city pilot policy has significantly enhanced the city's innovation activeness and positively affected the city's innovation activities, which suggests the robustness of the results. In addition, comparing column (4) in Table 6 with column (4) in Table 3, the interaction term POLICY is significant at the 5% level, with coefficients of 0.00136 and 0.00731, and the regression coefficients of the number of green patents granted per 100 people are smaller, which suggests that the implementation effect of the smart city pilot policy is weakened after the stringent requirements of the explanatory variables.

(4) Placebo test



The placebo test is to exclude the influence of non-policy factors on the results of the study, so as to avoid the subjective changes of the research subjects due to the signal of the policy to be implemented in advance, which will lead to the error of the "policy effect". In the placebo test, the most commonly used is the individual placebo test, observed by plotting the kernel density graph, in general, the more points are concentrated near the zero point of the horizontal axis, indicating that the placebo test has been passed, the more reliable the "policy effect" of the DID model.

Based on this, to further ensure the robustness of the estimation results, this paper refers to Bai, Junhong et al. (2022) [28] The placebo test method of whether innovation-driven policy enhances urban entrepreneurial activity research in general is tested as follows: in order to ensure that the policy cannot have a real impact on urban innovation activity, Stata software is used to construct 500 random shocks of the pseudo-smart city pilot policy on 11 sample cities, and each time, 4 cities are randomly selected as the experimental group and the time of the policy is given randomly, so that we can get the group Dummy variables  $policy^{random}$  (i.e.  $treat^{random} \times post^{random}$ ); the 500  $\beta^{random}$  kernel densities and their p-value distributions are presented in Figure 8. The results show that the generated during the on-the-fly process  $\beta^{random}$  are mainly concentrated around the zero point of the horizontal axis, which also indicates, to some extent, the robustness of the results.

### 5.3 Heterogeneity test

The different geographic locations of cities lead to different conditions of geographic environment conditions, economic development conditions and other conditions, which may lead to inconsistent effects of smart city pilot policies on urban innovation output. Therefore, this paper designs the following econometric model, where  $loca_i$  is a locational dummy variable, which is 1 when the city is located in the northeast of Shanxi Province, and 0 when it is located in the southwest of the country. the reason for such a division is that the northeast region is closer to the first-tier developed cities such as Beijing, Tianjin, etc., and the proximity to the developed cities may participate in the diffusion effect, which will have a certain positive impact on the innovation output of the cities located in the northeast of Shanxi Province. The design of the econometric model is as follows:

$$ina_{i,t} = \alpha + \beta loca_i \times policy_{i,t} + \gamma control\_var_{i,t} + cityFE + yearFE + \varepsilon_{i,t} \quad (3)$$

The regression results are shown in Table 8, where the cross term between the policy dummy variable and the city location dummy variable is significantly positive at the 1% level, with a regression coefficient of 0.00985, indicating that the smart city pilot policy has a more pronounced effect on city policies in the northeast-oriented region. Thus, hypothesis H2 is verified.

### 5.4 Mechanism testing

Through the above research, it is confirmed that smart city pilot policies can improve the level of urban innovation activity, however, the mechanism of its influence still needs to be further explored. According to the mechanism analysis in the second part, talent concentration effect and industry concentration effect as well as innovation capital investment are the three important ways for smart city pilot policies to promote urban economic development and improve innovation activity level. In order to test their influence mechanisms, this paper draws on Xu Jia (2020) [43] 's method, the following triple difference model is constructed to test the mediating role of talent agglomeration, government capital investment, and industrial agglomeration.

$$ina_{i,t} = \alpha + \beta_1 M_{i,t} \times treat_{i,t} \times post_{i,t} + \beta_2 m_{i,t} + \gamma control\_var_{i,t} + cityFE + yearFE + \varepsilon_{i,t} \quad (4)$$

Among them, for  $M_{i,t}$  mediating variable, the four variables of talent, sci, edu, and industry are used as substitutes. The other variables are consistent with the previous section.

#### (1) Talent pooling effect

As mentioned earlier, talent is the key subject to enhance the city's innovation activity, and this paper measures the clustering effect of talent using the measure of the ratio of personnel engaged in subject matter activities to the number of employees in natural science research and technology development organizations above the county level. As shown in result, the coefficient of

talent\*treat\*post is significantly positive at the 10% level, indicating that the implementation of the Smart Pilot Cities policy has exerted the talent pooling effect. However, the coefficient of talent is not significant and the value is too small, indicating that talent has less impact on the enhancement of the city's innovation activity, in other words, the level of talent's innovation output in Shanxi Province is low. Thus, hypothesis H4 is verified.

## 6. Research findings and policy recommendations

### 6.1 Conclusions of the study

Based on the panel data of 11 prefecture-level cities in Shanxi Province, this paper measures the overall policy effect of the three phases of smart city pilot policies of the Interim Management Measures on National Smart City Pilot through a multi-temporal DID model, and then evaluates the construction of the innovation ecology in Shanxi Province; conducts robustness tests on the model through the PSM-DID test, the test of replacing the core variables, the split-sample regression test, the test of restricting the study time, and the placebo test; and further explores the heterogeneity of the impact of the policies on the innovation activity and the construction of the innovation ecology in Shanxi Province from two perspectives of city location and initial innovation level. The model is tested for robustness through PSM-DID test, sub-sample regression test, restricted research time test, placebo test, etc. The heterogeneity of policy effects on innovation activity in Shanxi Province and the construction of innovation ecology in Shanxi Province is further explored from the perspectives of the city's location and the initial level of innovation. Finally, we analyze the impact mechanism of policies on innovation activity through the DDD model. The study finds that:

(1) The introduction of the Interim Management Measures on National Smart City Pilots effectively promotes the enhancement of the city's innovation activity, and in the empirical test of the policy effect, the coefficients are positive at the significance level of 1% and 5%, which proves that the implementation of the policy is conducive to the construction of a good innovation ecological environment.

(2) The promotion of the implementation of the smart city pilot policy has a significant impact on the increase in the city's innovation activity, and this conclusion still holds after a series of robustness tests such as the PSM-DID test, the test of replacing the core variables, the split-sample regression test, the test of restricting the study time, and the placebo test.

(3) Heterogeneity exists in the impact of the Interim Management Measures on National Smart City Pilots on the innovation activity of cities: after the implementation of the policy, the impact effect is more significant for cities with higher initial innovation levels, making the difference in innovation levels between cities increase; its regional heterogeneity is also very obvious, compared with the southwest direction cities, the policy effect is more significant for the northeast direction cities close to the capital of the developed cities. The regional heterogeneity is also obvious.

(4) The mechanism test shows that the smart city pilot policy positively affects the city's innovation activity mainly through the talent pooling effect, government financial investment and industry clustering effect, and the impact of government financial investment is relatively large, while the impact of industry clustering is relatively small.

### 6.2 Policy recommendations

(1) Strengthening the "intellectual high ground" for scientific and technological development. Strengthen the role of basic research, emphasize the research and development and creation of basic scientific research, so as to lay a solid foundation for the top-level design and planning of scientific and technological innovation, and provide inexhaustible source power for urban innovation; understand that innovation is not a one-step process, and do a good job of long-term planning and long-term investment, and strengthen the awareness of independent innovative scientific research in colleges and universities, scientific research institutes and academies, so as to provide strong support for the construction of a scientific and technological innovation ecosystem. The government can

provide strong support for the construction of science and technology innovation ecology by establishing a corresponding regulatory mechanism. The government can avoid policy abuse and distortion of market competition by establishing appropriate regulatory mechanisms and enhancing transparency and fairness.

(2) Strengthening the "support point" of platforms and carriers. Strengthen the leading role of innovation carriers, highlight the planning leadership, guide the main body of innovation to a higher level of platform development, focusing on the research of innovation industry short board, technology reading point, to solve the problem of innovative technology neck, to establish a "gradient" reasonable layout of innovation carriers. Play a supporting role in science and technology innovation parks, relying only on universities to research and innovation is not enough to promote the overall development of innovation in Shanxi Province, to a variety of innovation carriers, such as industrial parks, science and technology parks, etc., centralized, and do a good job in the overall planning of the innovation program, not only the overall consideration of the strategy, but also to consider the details of the implementation of the specifics of the formation of a kind of innovation carriers of mutual cooperation, mutual cooperation, and a good state of affairs.

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