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Do Innovative Provincial Policies Promote the Optimization of Regional Innovation Ecosystems?

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Abstract: Innovative provinces are essential to innovative countries and robust support for constructing national and regional innovation systems. Based on the panel data of 28 provinces from 2016 to 2019, this paper builds a regional innovation ecosystem performance evaluation system from five dimensions: innovation subject, innovation environment, innovation resource, resource flow, and interaction intermediaries. The index weighting is carried out using the principal component analysis method, and the innovation ecosystem performance of various provinces is evaluated and analyzed to determine the regional distribution status of innovation ecosystem performance. Based on a multi-period difference-in-differences model, this paper empirically tests the impact of innovative provincial policies on the innovation ecosystem performance of each region in the former innovation development stage. The results show that innovative provincial policies significantly positively impact the regional innovation ecosystems, which are multi-dimensional, long-term, and stable. The three secondary indicators, including ecological composition, resource input, and circulation flow, show a positive impact. Further research reveals that the main pathways of the effects are promoting the expansion of innovation inputs and the increase of interaction intermediaries among innovation subjects. Finally, combining the contents and impact of the previous innovative provincial policies, this paper puts forward corresponding thoughts and suggestions for the next phase of regional pilot-type innovation policies.

Keywords: regional innovation ecosystem; innovative provincial policies; multi-period difference-in-differences model

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1. Introduction

The world is undergoing unprecedented changes, increasing uncertainty, and instability in the external environment. In this complex and ever-changing environment, innovation is critical for breaking through the siege, gaining an advantage, and winning the future. Innovation is widely regarded as the key driver for economic development at both national and regional levels. It is becoming essential for ensuring national sovereignty and security, narrowing the gap between developing and developed countries, and improving economic and social welfare [1]. With the continuous upgrading of industrial technology, the innovation paradigm has shifted from the linear paradigm (innovation paradigm 1.0) to the innovation system (innovation paradigm 2.0) and then to the innovation ecosystem (innovation paradigm 3.0), bringing significant changes to the innovation environment [2]. In 2004, the President's Council of Advisors on Science and Technology (PCAST) of the United States released "Sustaining the Nation's Innovation Ecosystems: Report on Information Technology Manufacturing and Competitiveness" and "Maintaining the Nation's Innovation Ecosystem: Preparing the United States for Global Leadership in Science and Engineering," pointing out that a dynamic and vibrant "innovation ecosystem" is essential to a country's technological and innovation leadership, and that the economic prosperity and global leadership of the United States depend on its innovation ecosystem. This is the first time an "innovation ecosystem" has been formally presented, which points out that innovation should not be viewed as a linear process but rather as an ecosystem of continuous interaction between research institutions and scientific talent, inventions, and the market, etc., involving a range of actors at all levels of government, academia, and industry. Through their interacting behaviors, the innovation ecosystem is influenced by legal and regulatory environments, determining a country's international innovation status. In 2005, the Industrial Structure Council of Japan proposed the "National Innovation Ecosystem" concept in the Innovation 25 Strategy, suggesting a shift in policy focus from technology policy to innovation policy based on the "ecosystem concept". In 2016, China proposed the goal of building an efficient and collaborative national innovation system in the "Thirteenth Five-Year" National Science and Technology Innovation Plan, which requires defining the functional positioning of various innovation entities, enhancing the innovative capacity and role of enterprises, giving full play to the backbone and leading part of national scientific research institutions, the foundation, and strength of higher education institutions, encouraging and guiding the development of new R&D institutions fully unleashing the role of science and technology social organizations, stimulating the vitality of various innovation, and systematically enhancing their capacity. Whether building a national innovation system or a national innovation ecosystem, the core emphasizes using systematic thinking to analyze the interaction between innovation entities such as a country's government, universities, and enterprises under the institutional environment. Today, countries worldwide are paying more attention to the importance of the innovation ecosystem in promoting innovation development. However, due to the concepts and methodologies, mainly concerning problems of scale and complexity, research on the national innovation ecosystem is challenging. Therefore, as the core building blocks of the national innovation ecosystem, the construction and development of the regional innovation ecosystems have become a critical path to optimize the allocation of innovation resources and enhance national competitiveness [3].

In recent years, China has implemented an in-depth innovation-driven development strategy to build an innovative country and a world technology power. Innovation has become a core element in China's modernization construction. The government's policy support for industrial R&D is expected to be crucial in fostering innovation. The structure of an innovative country and a world technology power requires reasonable government intervention in scientific and technological development [4]. As an institutional arrangement covering a wide range of R&D-related activities, innovation policy plays a crucial role in correcting market failures, building innovation networks, creating a fertile innovation environment, and improving overall innovation capacity [5]. China has proposed a series of innovation policies to promote innovation development and scientific and technological progress, including innovative provincial policies and a unique regional pilot innovation policy in response to the central government's overall plan for building an innovative country. Does the implementation of such policies have an impact on the development of regional innovation ecosystems?

Currently, the existing literature constructs the evaluation system of the regional innovation ecosystem from various perspectives when studying the regional innovation ecosystem. These include the regional innovation ecosystem's ecological niche fitness evaluation model, built using the grey prediction model based on ecological niche theory [2], The innovation ecosystem's R&D efficiency evaluation system is constructed from multiple dimensions based on participant-network theory [6] and the resilience evaluation of the innovation ecosystem from four dimensions: diversity, fluidity, cushioning, and evolution [7]. Some of the literature also analyzes the importance of the innovation ecosystem in development and finds that the regional innovation ecosystem plays a crucial role in strengthening technological innovation, promoting regional economic growth, and enhancing regional competitiveness [8]. In addition, the regional innovation ecosystem also has a spatial spillover effect on the digital economy. Each region can rely on the regional innovation ecosystem to build regional cooperation platforms [9].

Regarding the impact of innovative provincial policies, existing research is mainly focused on the ecological environment. It is found that innovative provincial policies can improve urban ecological efficiency [10], which contributes to reducing environmental pollution and carbon emissions significantly [11,12]. However, few studies have combined the regional innovation ecosystem with innovative provincial policies to explore their effect on each other. Therefore, further exploration is necessary to determine whether innovative provincial policies can optimize the regional innovation ecosystem and elucidate the mechanisms for such optimization. Examining the impact of China's unique innovative provincial guidelines on the regional innovation ecosystem can help comprehensively and deeply promote the optimization of the regional innovation ecosystem and the construction of an innovative country. Then, we can provide Chinese experience for constructing and developing the regional innovation ecosystem.

In this study, we select 28 provinces in China as the research objects. We employ the multi-period difference-in-differences method to empirically examine the impact of innovative provincial policies on the regional innovation ecosystem. The main contributions of this paper are the following: Firstly, this paper enhances research on regional innovation ecosystems by providing an index system for performance analysis from innovative provincial policies. Secondly, it validates the positive impact of these policies on the construction of the ecosystem and explores their impact mechanism. Based on the research conclusion, combining the central guidance on the construction of innovative provinces with the implementation plans of local government innovative province construction, this paper proposes policy recommendations, accordingly, aiming to improve the innovative province policies in the future.

2. Literature Review and Research Hypothesis

2.1. Literature Review

The literature related to this paper mainly revolves around two domains: innovation policies and innovation ecosystems.

Innovation policy refers to the sum of public policies adopted by countries or regions to promote scientific and technological innovation activities, with technology innovation policy as the core [13]. Depending on their research purposes, scholars have different categorizations of innovation policies: Rothwell and Zegveld categorize innovation policies into supply-side policies [14], demand-side policies, and environment-oriented policies based on policy tool theory; Ergas divides technology policies into mission-oriented technology policies and diffusion-oriented technology innovation policies according to their centralization or decentralization characteristics [15]; Howlett and Ramesh propose that innovation policies can be categorized into voluntary, mandatory, and mixed policies based on the government's degree of market participation [16].

Innovative provincial policies in China are unique regional pilot innovation policies that align with the central government's overall plan for building an innovative country. On 12 April 2016, the Ministry of Science and Technology of the People's Republic of China officially released the "Guidelines for Building Innovative Provinces." These guidelines emphasize the significant role of innovative provinces in building an innovative country, outlining eight requirements for these provinces. These requirements include creating a favorable business environment and emphasizing policy innovation; strengthening the main body of enterprises and accelerating industrial innovation; building high-end carriers and speeding up innovation leadership; consolidating the foundation of talent, and encouraging continuous innovation. The current research on innovative provinces primarily uses case analysis, focusing on implementing specific provinces' policies, analyzing the status of policy construction, and proposing corresponding policy recommendations. Wu et al. select two provinces from each of the eastern, central, and western regions of China, compare and analyze the differences in innovative province construction status among various regions in terms of overall objectives, construction measures, guarantee conditions, and overall characteristics, and propose policy suggestions [17]; Qian et al. select representative innovative provinces such as Zhejiang, Guangdong, and Jiangsu to analyze their development status and policy measures [18]. Shang et al. use the new Pasteur's Quadrant Model to systematically analyze Jiangsu's innovative province construction [19]. Some studies have also conducted empirical analyses of innovative provinces, focusing mainly on constructing evaluation indicator systems specific to innovative provinces. The analysis objects are often specific provinces or cities. For example, Li designs an evaluation indicator system for Guangdong's characteristic innovative province construction, combining Guangdong's technological work indicators, and proposes construction suggestions [20]. As for the policy effects, most existing research on the policy effects of regional innovation policies has predominantly focused on the micro-level. Research has found that regional innovation policies can promote firms' innovation behavior and efficiency. Specific mechanisms include facilitating patent output, encouraging firms to increase innovation input and expand investment, attracting additional investments, promoting collaboration among small and medium-sized enterprises, and enabling collaboration between enterprises and universities through intermediaries [21–24]. However, few studies analyze policy effectiveness by combining innovative provincial policies with innovation ecosystem theory at the provincial and national city levels.

In the following section, we review the literature related to the innovation ecosystem. The introduction of ecosystem theory in innovation management originally focused on the micro-enterprise level. Numerous scholars have defined the enterprise innovation ecosystem as an economic alliance comprising customers, suppliers, primary producers, investors, trading partners, and governments interacting [25–27]. In the innovation ecosystem, a common value proposition guides the participants, who dynamically coordinate and evolve through feedback loops with the external environment [28]. Focal companies must vertically integrate the innovation system components, as the future competition among enterprises will shift from single companies to ecosystems [29].

At the macro level of the innovation ecosystem, numerous scholars have researched its definition, construction, and characteristics. The macro-level innovation ecosystem consists of basic elements such as businesses, universities, research institutions, and governments, which are interconnected to form communities engaged in research, development, and application. These communities, along with the linkages between them and the innovation environment, create a symbiotic competitive system that is dynamic, complex, and open. This system is facilitated through the connection and transmission of material, energy, and information flows [30,31]. The innovation ecosystem has characteristics of dynamicity, growability, diversity, balance, openness, and self-organization [17,31,32].

Further studies have focused on the commercial ecosystem, innovation ecosystem, open innovation, and value creation, leveraging theories from neo-institutional economics, strategic management theory, and innovation management theory [29]. There have also been studies on the connotations, structure, and behavior of the innovation ecosystems at the macro (national and regional), meso (industrial), and micro (enterprise) levels [33,34]. Considering the significance of the innovation ecosystem in national innovation development, it has emerged as the fourth innovation-driving force outside of the market, government, and society. The innovation ecosystem promotes innovative activities through symbiosis, openness, dynamic interaction, and co-evolution, presenting numerous opportunities and challenges for China's innovation development. Furthermore, it is imperative to transform the national technology management model, shifting from a sole focus on technological importance to enhancing national industrial innovation capabilities and the efficiency of science and technology management, accomplished by cultivating more competitive innovation ecosystems [35]. To better achieve the strategic goal of building a world scientific and technological powerhouse, research and reflection on the innovation ecosystem should be combined with the actual situation of China's innovation development [4].

Numerous theories have been put forth by researchers to gauge the strength of regional innovation ecosystems, and many academics have developed indicator systems to assess regional innovation ecosystems in earlier research. For example, Zhou and Chen establish an evaluation system for China's regional technological innovation ecosystem suitability, which includes innovation groups, innovation resources, economic environment, and technological environment as measuring elements [36]. Li and Zhang establish a coexistence degree measurement model for the innovation ecosystem consisting of subsystems of symbiotic units, symbiotic substrates, symbiotic platforms, symbiotic networks, and symbiotic environment [37]. Xie and Liu constructed an evaluation system for ecological niche suitability based on two dimensions: species (innovation communities) and non-species (resource niche, habitat niche, and technological niche) [38].

2.2. Discussion

In summary, the research on innovation policies in China's innovative provinces mainly focuses on the policy release and implementation of specific provinces. It analyzes the status quo of policy construction and makes corresponding policy suggestions through case analysis. Most relevant empirical research focuses on building an assessment system for innovative provinces. The research on the innovation ecosystem has the characteristics of being introduced at the micro-enterprise level and extending to other levels, focusing on the four clusters of the commercial ecosystem, innovation ecosystem, open innovation, and value creation. Furthermore, current research is still primarily focused on the micro-level of enterprise strategy and innovation management. The national and regional innovation system level research mainly focuses on defining and evaluating the regional innovation ecosystem. It lacks an in-depth empirical analysis of the influencing factors on the regional innovation ecosystem. Therefore, what are the performances of the innovation ecosystem in various province-level regions of China? How did the innovative provincial policies released in the previous stage affect the development of the regional innovation ecosystem, and whether it achieves the expected optimization effect? In-depth research on these issues will be conducive to providing constructive policy recommendations for formulating and releasing innovation development policies. Based on an extensive review of the literature, we propose our method for dividing secondary and tertiary indicators and later test the differences in policy effects across dimensions based on the framework we established. Compared with previous studies, this paper makes three significant contributions. Firstly, we have enriched and supplemented the research on regional innovation ecosystems with an index system of regional innovation ecosystem performance from the perspective of innovative provincial policies. Secondly, we empirically validate the positive significance of innovative province policies on the construction of the regional innovation ecosystem and explore its impact mechanism, which opens up the "black box" of how innovative provincial policies promote the construction of the regional innovation ecosystem. Thirdly, this paper not only enriches the theoretical basis for constructing the regional innovation ecosystem but also provides empirical evidence, which provides Chinese experience for promoting the optimization of the regional innovation ecosystem.

2.3. Research Hypothesis

This paper starts by examining the field of innovation policy. It integrates previous theoretical research on the intervention of innovation policies to analyze and deduce the impact mechanism of these policies on the innovation ecosystem and further propose the research hypothesis. The theoretical research on the innovation intervention of innovation policies is relatively abundant, and its core is to eliminate innovation failures. The intervention mechanisms mainly include innovation policy intervention based on market failure, innovation policy intervention based on system failure, and innovation policy intervention based on evolutionary failure [39]. The evolutionary failure perspective supports adapting to differentiated potential development paths by diversifying policy and policy combinations, thereby meeting the needs of technology adjustment and system member adjustment [40].

Innovation policy intervention based on market failure refers to the situation where innovation input cannot spontaneously reach the market's optimal allocation without external intervention [41]. Corresponding innovation policies focus on innovation externalities. On the one hand, innovation has a spillover effect, which leads to insufficient autonomous research and development by innovation subjects. On the other hand, it includes the problems of negative effects caused by externalities and excessive research and development investment [42]. Innovation policy can influence the innovation behavior of entities, which in turn affects innovation investment and can mitigate market failures [43]. Some studies suggest the effect of regional innovation policies on firms' innovation performance is partially mediated by the impact of policy intensity and quantity on firms' R&D investment. Wang and Zhang argue that innovative city policies, high-tech zones, and economic and technological development zones primarily boost innovation output by increasing the innovation investment of the cities implementing the policies. Their impact increases over time as the policies are implemented [44]. In summary, innovation policies aim to optimize the innovation ecosystem by affecting regional innovation investment.

Based on system failure, innovation policy primarily emphasizes coordinating system member interactions as the primary regulatory mechanism. By encouraging connections among system participants, it seeks to improve innovation-related activities. The role of policymakers in the innovation system and related activities is becoming more organized. Klein et al. propose a policy framework based on system failure, which includes four aspects: interaction failure, capability failure, infrastructure failure, and institutional failure [45]. Previous studies have shown that government support, including financial investment, policy support, guidance, and direction, is a critical factor affecting the performance of industry-university-research cooperation [46,47]. It can significantly promote the coordinated development of regional industry-university-research innovation systems [48]. Zhou argues that the government can provide the necessary information and resources for industry-university-research cooperation to promote communication, reduce information asymmetry, establish trust mechanisms, and facilitate cooperation [49]. Policy and funding support at the government level can significantly improve the innovation performance of industry-university-research cooperation. Li et al. suggest that public policy can promote innovation by strengthening inter-species linkages [31]. Therefore, innovation policies may promote the flow of materials, information, and energy within the system by improving interactions and cooperation among members of the system and ultimately enhance the performance of the innovation ecosystem.

In an empirical study of policy innovation intervention in innovative provinces, Zeng and Wang collected data on 31 innovative provincial policies and corresponding launch dates between 2006 and 2013. The objective was to examine the impact of these policies on provincial innovation capabilities [50]. The results show no significant correlation between the implementation of innovation policies and improvements in provincial innovation capabilities. The authors attribute this to the absence of provincial innovation policy documents. Furthermore, they note that provincial policies formulated under macro-level strategic guidance from the central government always suffer from problems such as formalism, abstraction, and conformity, resulting in less effective implementation. However, this situation improved after establishing stage-based innovation strategic objectives in 2016 and releasing guidance documents for innovative provinces at the central level. As innovation theory has advanced to the ecological stage, the focus of guidance documents has shifted from isolated innovative behaviors of individuals to an ecological perspective that emphasizes the collaborative and interactive relationships among participants in the innovation ecosystem. Given the mechanism by which innovation policies affect the innovation ecosystem mentioned above, this paper aims to test the impact of innovative provincial policies on the regional innovation ecosystem. Based on this rationale, the following research hypothesis is proposed in this paper:

H1: *Innovative provincial policies have a significant positive impact on the performance of the regional innovation ecosystem.*

Regional innovation ecosystem performance depends on the subjects' performance at the micro level in the system. On the one hand, the quantity and quality of innovative subjects can somewhat reflect regional innovation's vitality. The more innovation subjects and higher their quality, the more favorable it is to form an active innovation environment, thus improving innovation performance. Innovation policies can increase the number of innovative subjects within the region. Firstly, favorable policies are usually given to eligible enterprises to promote innovation development within the region to attract them to settle down. Secondly, some regions also issue relevant policies to promote the construction of innovative subjects, such as research institutions, thereby increasing the number of innovative subjects within the region. On the other hand, individuals' behavior is also influenced by their surroundings, including economic development, cultural and educational levels, and market demand, which affect the number of innovation resources in the region and the motivation of innovation subjects to engage in innovative behavior. The research suggests a strong correlation between the innovation environment and innovation performance [51], and it can strengthen the positive impact of regional innovation policy on enterprise innovation performance [28]. Thus, the following hypothesis is proposed:

H2a: *Innovative provincial policies significantly positively impact the ecological composition, thereby improving regional innovation ecosystem performance*.

Innovation activities cannot be carried out without the resources input, especially innovation resources. Innovation resources mainly refer to research and development investments such as funding and talent investment for research and development activities. Innovation policies can affect the innovation behavior of subjects and then affect innovation input, thereby increasing innovation expenditure of enterprises and research institutions and improving regional innovation ecology [43]. Some studies have verified that the R&D investment of enterprises plays a mediating role in the promotion effect of regional innovation policies on enterprise innovation performance [28]. Wang and Zhang [44] pointed out that the three types of regional pilot policies: innovative cities, high-tech zones, and economic-technological development zones mainly promote the increase of innovative investment in pilot cities, leading to the improvement of innovation results and the longer the implementation time of pilot policies, the better the effect. Thus, the following hypotheses are proposed:

H2b: *Innovative provincial policies significantly positively impact the resource input, especially innovation resources, thereby improving regional innovation ecosystem performance*.

Many studies have verified that government support (including government funding, policy support, guidance, and promotion) is an important factor affecting the performance of industry-academia-research cooperation [46,47]. Moreover, such government support significantly promotes the coordinated development of the regional industry-academia-research innovation system [48]. On the one hand, Li et al. [31] believed that public policy could promote innovation by strengthening the connection between different entities. Zhou [49] pointed out that the government can provide necessary information and resources for industry-academia-research cooperation. Additionally, the government promotes communication and cooperation between the involved parties, reduces information asymmetry, establishes a trust mechanism, and facilitates smoother industry-academia-research cooperation, promoting resource flow among innovation subjects. On the other hand, policy support also promotes the increase of interactive intermediaries. For example, some regions provide subsidies and tax reduction policies for technology business incubators in university science and technology parks to promote the increase of interactive intermediaries and improve the transformation of scientific and technological achievements. The existence of interactive intermediaries can accelerate the resource flow within the system, thereby promoting the circulation flow of the entire innovation ecosystem. Therefore, the following hypotheses are proposed:

H2c: *Innovative provincial policies significantly positively impact the circulation flow within the ecosystem, thereby improving regional innovation ecosystem performance.*

The mechanism map is shown in Figure 1.

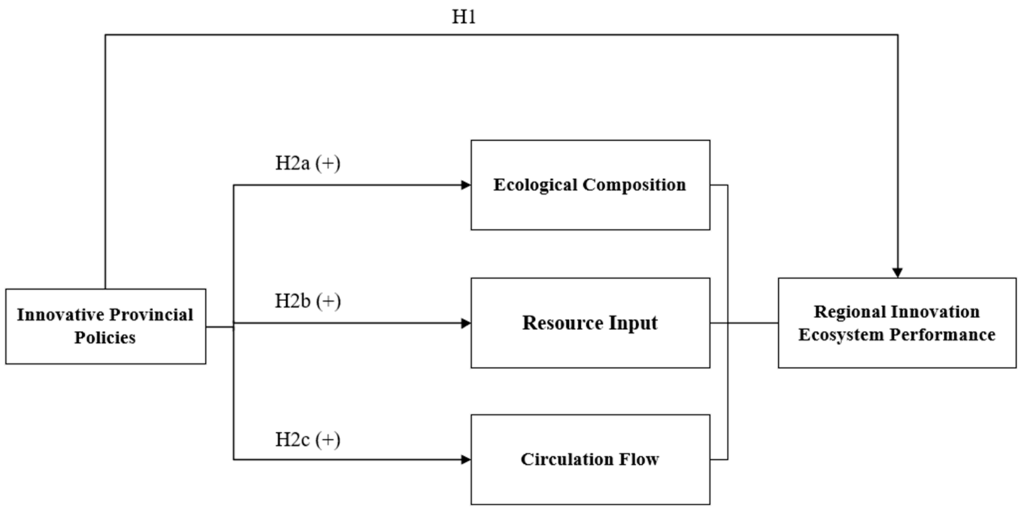

Figure 1. Mechanism map.

3. Research Design

3.1. Data Sources

The research data for this paper primarily originates from the National Bureau of Statistics and various statistical yearbooks, including the China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Torch Statistical Yearbook, and China Regional Statistical Yearbook. The independent variable, innovative provincial policies data, is sourced from the Peking University Law Database, excluding Hong Kong, Macao, and Taiwan region. Additionally, due to the lack of data for Tibet, Qinghai, and Ningxia, they were removed from the sample pool. Eventually, statistical data from 28 provinces in China, spanning 2016 and 2019, were selected as the research samples for analysis.

3.2. Variables Selection

The paper initially constructs a performance index system for the regional innovation ecosystem to measure the level of the innovation ecosystem in each region, which is the dependent variable. The independent variable is the publication of innovative provincial policies at the provincial level to examine the impact of innovation policies on the regional innovation ecosystem. Furthermore, five control variables are included to account for the fundamental condition of each province, including per capita GDP, urban population proportion, permanent resident population, resident consumption level, and the ratio of R&D expenditure to GDP. The definitions of the variables are shown in Table 1.

Table 1. Variable definition.

Type of Variable	Name of Variable	Definition	Variable
Dependent variable	Regional innovation ecosystem performance	Regional innovation ecosystem performance assessment values	Y_{it}
Independent variable	Innovative provincial policies	Dummy variable of Innovative provincial policies release ("1" indicates that an innovative provincial policy has been issued; "0" indicates that no innovative provincial policy has ever been issued in the current and previous years)	$policy_{it}$

Table 1. *Cont.*

Type of Variable	Name of Variable	Definition	Variable
Control variable	Per capita GDP	Regional real GDP per capita in logarithms	$lnpergdp_{it}$
	Permanent resident population	Regional year-end permanent resident population numbers in logarithms	$lnpop_{it}$
	Urban population proportion	Number of urban population/ Total population	$urban_{it}$
	Resident consumption level	Regional real population consumption level in logarithms	$lncsm_{it}$
	The ratio of R&D expenditure to GDP	Regional Internal Expenditure on R&D/Regional GDP	$R\&Dspending_{it}$

3.2.1. Independent Variables

The construction of the indicator system for evaluating innovation ecosystems in research exhibits consistency in selecting indicators. These metrics primarily concentrate on the input, subject, environment, and network of innovation. According to the literature review, "the innovation ecosystem is made up of connected organizations such as businesses, universities, research centers, and governments that collaborate on research, development, and application. The connections and transmissions of material, energy, and information flow between communities and the innovation environment, creating an open and complex system of symbiotic competition and dynamic evolution" [30,31]. Referring to Zhou and Chen [36], Li and Zhang [37], and Xie and Liu [38], this paper reorganized the indicators based on the above definition, selecting the ecological composition as a secondary indicator to measure the static composition of the innovation ecosystem, which includes the third-level indicators "innovation environment" and the basic element species analogous to ecology in the innovation ecology definition, namely "innovation subjects" (innovative enterprises, research institutions, universities). Considering the open nature of the innovation ecosystem, the secondary indicator, "resource input", is designed to evaluate the interaction between the external environment and the ecosystem. The secondary indicator, "circulation flow", measures the dynamic performance and symbiotic ability of the ecosystem by measuring the connections and transmissions of material, energy, and information flows in the innovation ecosystem, which includes tangible interaction intermediary platforms (interaction intermediaries) and intangible flow resources such as funds, technology, and talent. To ensure data availability, caliber consistency, and scientific measurement indicators, this study constructed a regional innovation ecosystem performance evaluation system composed of one first-level indicator, three second-level indicators, five third-level indicators, and 16 fourth-level indicators. The evaluation system evaluates the performance of the innovation ecosystem in various provinces from five major dimensions: innovation subjects, innovation environment, innovation resource, resource flow, and interaction intermediaries, as shown in Table 2.

Regarding index weighting, we refer to the weight determination method of previous innovation ecosystem index systems and ultimately adopt the principal component analysis (PCA) method [52]. This is because PCA can extract the typical characteristics of the innovation ecosystem in a centralized manner. Compared with other weighting methods, such as mean value weighting and entropy weighting, PCA can better solve the issue of collinearity that may exist in selecting innovation ecosystem indicators. The weights assigned to each component represent their contribution rate, reflecting the percentage of information contained in the original data of the component relative to the total information. This method eliminates the subjectivity associated with weighting based on previous experience or artificial weighting in some evaluation methods, resulting in a unique, more objective, and reasonable comprehensive evaluation outcome. After standardizing the raw data, the suitability of the research data for principal component analysis is tested. By conducting the KMO and Bartlett sphericity tests, the obtained KMO value is 0.851, exceeding 0.6, and the data pass the Bartlett sphericity test ($p < 0.05$), indicating that the research data are suitable for principal component analysis. The principal component analysis is performed on the original data using SPSS, and the first three eigenvalues of the principal components are greater than 1. The variance explained by these three principal components is 58.509%, 21.460%, and 7.114%, respectively, and the cumulative variance explained is 87.083% (see Table 3). Based on these results, a comprehensive evaluation function is constructed.

Table 2. Regional innovation ecosystem performance evaluation system.

Primary Indicator	Secondary Indicator	Tertiary Indicator	Quaternary Indicators	Unit	Meaning of Indicator
Innovation ecosystem performance	Ecological composition	Innovation subject	Number of R&D facilities	Unit	The size of the R&D cluster in the system
			Number of higher education institutions	Unit	The size of the university cluster in the system
			Number of enterprises of scale or above with innovation activities	Unit	The system's size of the cluster of firms with innovative activities
		Innovation environment	Per capita GDP	RMB	The economic background of the system
			Resident consumption level	RMB	The market performance of the system
			The average number of years of schooling for residents aged 15 and over	Year	The educational background of the system
			Public library collections	Million Copies	The cultural background of the system
			The contract value of technology introduction	Billion USD	The openness of the innovation environment within the system
	Resource input	Innovation resource	Full-time equivalents for research and development staff	Person-year	The amount of human resource input in the system
			Internal expenditure on research and experimental development funding	Million RMB	The amount of capital input in the system
	Circulation flow	Resource flow	The total turnover of technology contracts	Billion RMB	The technical flow between subjects within the reaction system
			Corporate funding in R&D investment in universities	Million RMB	Financial flows between subjects in the reaction system
			Corporate funding in institutional R&D investment	Million RMB	
		Interactive intermediaries	Number of business incubators	Unit	The cooperative mediation performance of subjects in the system
			Number of university science parks	Unit	
			The average output value of high-tech zones.	Million RMB	

Table 3. Variance explanation rate table.

Number	Principal Component Extraction		
	Characteristic Roots	Explanation of Variance %	Cumulative Value %
1	9.361	58.509	58.509
2	3.434	21.460	79.969
3	1.138	7.114	87.083

The relationship between the principal components and the 16 research items can be obtained through the component score coefficient matrix. Furthermore, the comprehensive scores of the innovation ecosystem performance of each region can be obtained by using the variance explanation rate of each principal component and the data from various indicators of 28 provinces. Regression analysis requires scores for each second and third-level indicator, but the weights for each fourth-level indicator are separately calculated. The cumulative contribution rate of the total from principal component analysis, eigenvalues, and component matrix determines the weights of various indicators. Specifically, the linear combination coefficient of each indicator is obtained by dividing its loading factor by the square root of the corresponding eigenvalue. The comprehensive score coefficient is then calculated by multiplying the linear combination coefficient with the explained variance, accumulating these values, and dividing by the cumulative explained variance. These coefficients are then normalized to obtain the weights of all fourth-level indicators. Finally, the weights for each indicator are obtained, as shown in Table 4.

Table 4. Component score coefficient matrix and indicator weights.

Name	Component			Weight
	Component 1	Component 2	Component 3	
The number of research and development institutions (units).	0.072	−0.097	0.465	0.053152
Number of higher education institutions (units)	0.054	0.173	0.406	0.083366
Number of enterprises above the scale of innovation activities (units)	0.075	0.198	0.008	0.090499
per capita GDP (RMB)	0.089	−0.059	−0.350	0.046732
Level of resident consumption (million RMB)	0.087	−0.086	−0.346	0.040124
Years of schooling for residents aged 15 and over (years)	0.067	−0.158	−0.202	0.017900
Public library collections (million items)	0.081	0.159	−0.146	0.083806
The contract value of technology introduction (billion USD)	0.084	0.042	−0.255	0.062869
The full-time equivalent of research and development staff (person-years)	0.088	0.157	0.008	0.093505
Internal expenditure on research and experimental development (million RMB)	0.099	0.102	0.033	0.093448
The total turnover of technology contracts (billion RMB)	0.087	−0.128	0.226	0.051728
Enterprise funding in R&D investment in universities (million RMB)	0.099	−0.052	0.055	0.068182
Corporate funding in institutional R&D investment (million RMB)	0.078	−0.153	0.266	0.042175
Number of business incubators (units)	0.073	0.189	−0.002	0.087323
Number of university science parks (units)	0.086	−0.063	−0.007	0.054797
The average output value of the High Tech Zone (million RMB)	0.078	−0.180	0.042	0.030392

The innovation ecosystem performance scores of 28 provinces are shown in Table 5. Since the original data for each indicator varies in nature, units, magnitude, and availability, directly analyzing and studying the characteristics and patterns of the research object is not feasible. Therefore, principal component analysis requires standardization of the original data before analysis, so it falls within a specific small range. Standardization is conducted by classifying data as positive if it is higher than the sample mean and negative if it is lower than the sample mean. Consequently, the weighted scores of each indicator may be positive or negative, resulting in some provinces achieving negative scores. As shown in Table 5, the regional innovation ecosystem performance score in some areas, such as Tianjin and Liaoning, shows a declining trend. The main reason is the poor performance of some indicators in these areas in some years. The average innovation ecosystem scores for 2016–2019 are −0.0895, −0.0312, 0.0187, and 0.1020, respectively, indicating a year-by-year upward trend. The provinces with innovation ecosystem performance scores higher than 0 are positioned above the average. In 2016–2017 Jiangsu Province demonstrated the best innovation ecosystem performance, while Guangdong Province achieved the best in 2018–2019. The number of provinces surpassing the average score fluctuated between 8–10, accounting for approximately 30% of all provinces.

Table 5. Performance scores of regional innovation ecosystems by province.

Province	2016	2017	2018	2019
Beijing	0.9871	1.1136	1.2975	1.5893
Tianjin	−0.3026	−0.3732	−0.3847	−0.3509
Hebei	−0.2400	−0.1893	−0.1360	−0.0788
Shanxi	−0.5144	−0.4876	−0.4587	−0.4625
Inner Mongolia	−0.6422	−0.6504	−0.6471	−0.6420
Liaoning	−0.0503	−0.0063	−0.0980	−0.0395
Jilin	−0.5335	−0.5307	−0.5155	−0.5091
Heilongjiang	−0.3269	−0.3230	−0.2880	−0.3322
Shanghai	0.4498	0.5147	0.5740	0.7367
Jiangsu	1.5792	1.6974	1.8312	2.1558
Zhejiang	0.5696	0.7266	0.8892	1.1401
Anhui	−0.1490	−0.0872	−0.0346	0.0447
Fujian	−0.1775	−0.1403	−0.0856	−0.0117
Jiangxi	−0.3933	−0.3449	−0.3064	−0.2421
Shandong	0.6360	0.7643	0.7913	0.7819
Henan	−0.0623	−0.0093	0.0398	0.1217
Hubei	0.0586	0.1654	0.2082	0.3355
Hunan	−0.1399	−0.0557	0.0023	0.0781
Guangdong	1.4122	1.6912	1.9996	2.3576
Guangxi	−0.5235	−0.4978	−0.4884	−0.4511
Hainan	−0.9405	−0.9311	−0.9232	−0.9140
Chongqing	−0.4670	−0.3862	−0.3476	−0.4212
Sichuan	0.0824	0.1484	0.2155	0.3403
Guizhou	−0.6312	−0.6057	−0.5806	−0.5578
Yunnan	−0.5338	−0.4945	−0.4820	−0.4508
Shaanxi	−0.2907	−0.2423	−0.2145	−0.0731
Gansu	−0.6364	−0.6235	−0.6196	−0.6100
Xinjiang	−0.7250	−0.7163	−0.7140	−0.6799
Average	−0.0895	−0.0312	0.0187	0.1020

According to the 2019 innovation ecosystem performance scores, the innovation ecosystem performance shows significant regional distribution differences. Regions with higher innovation ecosystem performance scores are mainly distributed in coastal cities. Provinces in the eastern regions have better innovation ecosystem performance than those in the western regions, with Guangdong and Jiangsu having outstanding performance. Shandong, Beijing, Zhejiang, and Shanghai also show a high level of innovation ecosystem performance. Provinces in the western and northern regions generally have lower scores, such as Xinjiang, Inner Mongolia, Jilin, and Gansu, with their innovation ecosystem performance not being ideal compared to other regions.

The eastern regions demonstrate better performance across various indicators than the western regions. It can be attributed to superior economic development and abundant innovation resources such as funds and talents. In addition, the government in the eastern regions places greater emphasis on innovation development due to its economic advantage. It fosters effective communication and interaction among industry, university, and research entities. However, many inland western regions lack basic innovation resources and have relatively weak economic development. Consequently, their provincial governments prioritize basic economic development over innovation, resulting in relatively poor innovation ecosystem performance. Besides inland, coastal provinces exhibit evident advantages in indicators such as the amount of technology introduction contracts and per capita GDP. This suggests that the geographical position of coastal provinces facilitates the introduction of advanced foreign technology, and their high level of economic development, to some extent, improves the regional innovation ecosystem performance.

K-means clustering is performed based on the innovation ecosystem performance scores of 28 provinces in China from 2016 to 2019. After six iterations, the clustering centers remained unchanged and converged to three centers, corresponding to innovation-leading, innovation-following, and innovation-lagging areas, with approximate scores of 1.60, 0.23, and −0.47, respectively. We can classify the innovation ecosystem performance data of 28 provinces in China from 2016–2019 into three levels: innovation-leading regions, innovation-following regions, and innovation-lagging regions.

Based on the clustering results (Table 6), we can see that innovation-leading provinces mainly include Beijing, Jiangsu, Guangdong, and Zhejiang in 2019. In contrast, the innovation-following areas encompass Liaoning, Shanghai, Sichuan, Shandong, Henan, Hubei, and intermittent years of Zhejiang, Anhui, Fujian, Hunan, Shaanxi, and Hebei. The remaining provinces are classified as innovation-lagging areas. Notably, six provinces made level leaps from 2016 to 2019, namely Zhejiang, Anhui, Fujian, Hunan, Shaanxi, and Hebei, all displaying an upward trend. Zhejiang, Shaanxi, and Hebei achieved level leaps in 2019. After comparison, it was found that five out of the six provinces that crossed the ranks issued policies related to innovation-type province keywords during 2016-2019.

Table 6. Regional innovation ecosystem performance clustering results.

Innovation-leading region	Beijing2016–2019, Jiangsu2016–2019, Guangdong2016–2019, Zhejiang2019
Innovation-following region	Liaoning2016–2019, Sichuan2016–2019, Shandong2016–2019, Shanghai2016–2019, Henan2016–2019, Hubei2016–2019, Zhejiang2016–2018, Anhui2017–2019, Fujian2018–2019, Hunan2017–2019, Shaanxi2019, Hebei2019
Innovation-lagging region	Tianjin2016–2019, Hebei2016–2018, Shanxi2016–2019, Inner Mongolia2016–2019, Jilin2016–2019, Heilongjiang2016–2019, Anhui2016, Fujian2016–2017, Jiangxi2016–2019, Hunan2016, Guangxi2016–2019, Hainan2016–2019, Chongqing2016–2019, Guizhou2016–2019, Yunan2016–2019, Shaanxi2016–2018, Gansu2016–2019, Xinjiang2016–2019

Among these level-leaping provinces, it can be seen that the provinces with significantly improved regional innovation ecosystems in recent years are predominantly concentrated in the eastern and coastal regions (Zhejiang, Hebei, Fujian). Only one province, Shaanxi, is located in the western region. The government must allocate more attention to the western regions, constantly expanding innovation resources and promoting the more balanced development of regional innovation ecosystems.

3.2.2. Dependent Variables

In 2006, Shandong Province took the lead in proposing the establishment of an innovative province and issued the "Decision of the CPC Shandong Provincial Committee and the People's Government of Shandong Province on Implementing the Science and Technology

Development Plan to Enhance Self-In Capacity and Build an Innovative Province". This was carried out to fully implement the "Decision of CPC Central Committee and the State Council on Implementing the Program for Enhancing Self-Innovation Capacity Science and Technology Planning". In 2016, the Ministry of Science and Technology officially issued the "Notice of the Ministry of Science and Technology on Printing and Distributing Guidelines for Building Innovative Pro". Subsequently, under the central guidance, provinces officially proposed the establishment of innovative provinces and issued relevant regulations. The Peking University Law Information Database includes all the central laws, local regulations, and other legal documents since 1949, assisting users in keeping up with the latest legal and regulatory developments. It is currently regarded as a mature, professional, and advanced legal and regulatory retrieval information system in China. Referring to previous studies on selecting policy variables related to innovation policies [50,51], we search for relevant policies within the scope of local regulations in the Peking University Law Database using "innovative provincial policy" as the keyword. We find that the peak period of the corresponding keyword policy occurred in 2016, while prior policies related to the keyword are sporadic and lack corresponding central work guidelines. The corresponding data is shown in Table 7. The "Year of release" indicates the total number of relevant policies released in the year, while the "Year of first release" represents the year when the relevant policies were first released in the province. Using the publication of innovative provincial policies after 2016 as the independent variable, we select the earliest corresponding local policy publication time to generate a dummy variable as the independent variable, and provinces that do not publish innovative provincial policies during the same period are used as the reference group.

Table 7. Status of policy release and Top 10 provinces with the earliest policies under the central work guidelines.

Year of release	2019	2018	2017	2016	2015	2014	2013	2011	2007	2006
Number of releases	9	5	8	27	12	9	3	2	1	1
Province of release	Jiangsu	Zhejiang	Anhui	Jiangxi	Hubei	Fujian	Shandong	Guangdong	Sichuan	Hunan
Year of the first release	2016	2016	2016	2016	2016	2017	2017	2017	2017	2018

3.2.3. Control Variables

Combined with previous studies on the factors affecting regional innovation capabilities and the selection of control variables, this paper adds control variables that may affect regional innovation capabilities to control the basic situation of each province. These variables include per capita GDP, urban population proportion, permanent resident population, resident consumption level, and the ratio of R&D expenditure to GDP [53,54].

3.2.4. Descriptive Statistical Analysis

The total sample in this paper is 112, which consists of balanced panel data from 28 provinces between 2016 and 2019. The basic characteristics of each variable are described in Table 8.

Table 8. Variable description statistics.

Definition	Variable	Observation	Min.	Max.	Mean	Std. Dev.
Innovation ecosystem performance	Y_{it}	112	−0.9405	2.3576	0.0000	0.7203
Urban population proportion	$urban_{it}$	112	0.4416	0.8830	0.6069	0.1112
The permanent resident population in logarithms	$lnpop_{it}$	112	6.8211	9.3519	8.3441	0.5820
Resident consumption level in logarithms	$lncsm_{it}$	112	9.4792	10.8896	9.9416	0.3385
Per capita GDP in logarithms	$lnpergdp_{it}$	112	10.2271	12.0089	10.9902	0.4099
The ratio of R&D expenditure to GDP	$R\&Dspending_{it}$	112	0.0047	0.0630	0.0185	0.0113

3.3. Research Model

Initially, this paper constructs a multi-dimensional evaluation index system to assess the performance of innovation ecosystems in various provinces in China. It analyzes and evaluates each province's scores and regional distribution of innovation ecosystem performance. Based on this, each region's annual innovation ecosystem performance indicators are used as the dependent variable to evaluate the impact of innovative provincial policies on regional innovation ecosystems.

To avoid the influence of unobservable variables such as time trends and individual differences on the estimation results, this paper uses the difference-in-differences (DID) method to compare the differences in regional innovation ecosystems before and after policy implementation between areas that have implemented innovative provincial policies and those that have not. After referring to relevant research, this paper finally uses the multiple-period difference-in-differences method to test the impact of innovative provincial policies on the regional innovation ecosystem.

We establish Model (1) as follows:

$$Y_{it} = \alpha_0 + \alpha_1 policy_{it} + \beta X_{it} + \lambda_i + v_t + \varepsilon_{it} \tag{1}$$

where Y_{it} denotes the regional innovation ecosystem performance of the i-th province or city in the t-th year. The focus of this study is on the dummy variable $policy_{it}$ defined as follows: for the i-th province, $policy_{it}$ = 1 in the years following the release of innovative provincial policies, and 0 otherwise. X_{it} is a set of province or city time-varying characteristics, including per capita GDP, urban population proportion, permanent resident population, resident consumption level, and the ratio of R&D expenditure to GDP. λ_i and v_t are regional and time dummy variables, respectively, and ε_{it} is a random error term.

4. Empirical Results

4.1. Parallel Trend Test

Analysis using the multi-period difference-in-differences model necessitates that data from each province adhere to the prerequisite of passing the parallel trend test. It requires that the trends in the regional innovation ecosystem performance of both treatment and control groups remain relatively consistent during the pre-intervention period of the innovative provincial policies. In this study, we conduct a parallel trend test by generating dummy variables for the pre-1 to pre-3 periods, the current period, and the post-1 to post-2 periods. These variables are determined by the year of implementation for each province's policy. The third pre-policy period is discarded as the base period, while the remaining periods are used as explanatory variables for regression analysis with the dependent variable, which is the performance of the regional innovation ecosystem. The figure of parallel trend test is shown in Figure 2.

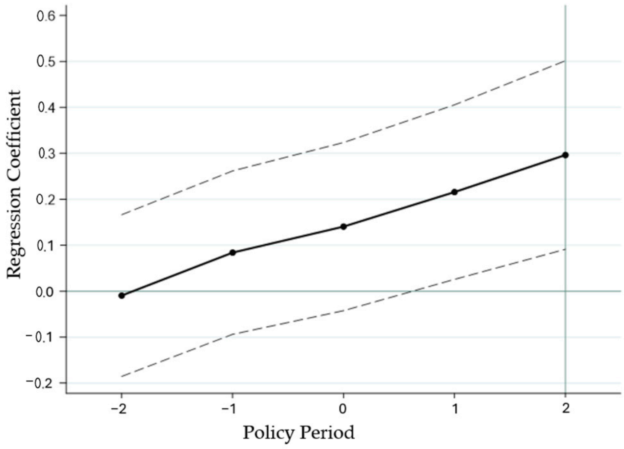

Figure 2. Parallel trend test.

As can be seen from Table 9, the results show that the coefficients of the policy regression in the current period and the pre-periods are not significant, indicating that there was no significant difference in the regional innovation ecosystem performance trends between the treatment group and control group before the implementation of the innovative provincial policies. After implementing the policies, both the regression coefficients in the table and the curve graph show a significant upward trend, suggesting that the innovative provincial policies have a significant positive impact on the regional innovation ecosystems, and this impact has a certain degree of long-term and stable effect.

Table 9. Parallel trend test results.

	(1)
*pre*2	−0.009
	(−0.105)
*pre*1	0.084
	(0.926)
current	0.141
	(1.506)
*post*1	0.216 **
	(2.226)
*post*2	0.296 ***
	(2.832)
urban	−4.233 **
	(−2.570)
laptop	0.606
	(0.830)
lnpergdp	−0.009
	(−0.070)
lncsm	−0.204 *
	(−1.707)
R&Dspending	27.550 ***
	(5.107)
_cons	−0.897
	(−0.159)
Individual fixed effect	YES
Time fixed effect	YES
N	112
Number of provinces	28
R-sq (within)	0.7322

Notes: z-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2. Baseline Regression and Hypothesis Testing Results

Based on the model constructed above, a multi-period difference-in-differences analysis is conducted to examine the impact of innovative provincial policies on the regional innovation ecosystem. The regression results are shown in Table 10, where column (1) presents the benchmark regression results without controlling for any control variables or time and individual fixed effects. Column (2) controls for individual and time-fixed effects on this basis but still does not include control variables. Column (3) adds control variables to column (1), and the coefficient of the policy virtual variable decreases, indicating that the addition of control variables effectively reduces the estimation error of the innovative provincial policy effect. Column (4) reports the multi-period difference-in-differences estimation results with all control variables, individual fixed effects, and time-fixed effects controlled. The core explanatory variable and the innovative provincial policies still have a statistically significant positive effect at the 1% level after excluding selection bias and time trend effects. It verifies assumption H1 and indicates that innovative provincial policies significantly positively impact regional innovation ecosystems' performance. The control variable, urban population proportion, shows a negative correlation at the 5% significance level when controlling for time and individual fixed effects. This finding is consistent with the research conclusions regarding the relationship between urbanization and innovation performance. It is speculated that there may be a "crowding-out effect" between the development of urbanization and the optimization of regional innovation ecosystems. As the development of urbanization requires a large amount of human and capital investment, it may affect the scale of innovation input in the limited resource context, negatively impacting the improvement of the regional innovation ecosystem level. Per capita, GDP does not significantly impact the regional innovation ecosystem performance. The level of resident consumption shows a negative correlation at the 10% significance level, presumed to be due to partial collinearity between resident consumption level and per capita GDP. The proportion of R&D expenditure to GDP has high regression coefficients and a significant level when controlling for and not for time and individual fixed effects, indicating that the proportion of R&D expenditure to GDP significantly impacts the regional innovation ecosystem performance.

Through calculating the scores of each second-level indicator using the previously solved weights and synthesizing the scores of third-level indicators for regression analysis, we find a significant impact of innovative provincial policies on regional innovation ecosystems on the dimensions of ecological composition, resource input, and circulation flow, which verifies the hypothesis H2a, H2b, and H2c. The results of second-level indicator regression are shown in Table 11. This finding highlights the multifaceted impact of innovative provincial policies on regional innovation ecosystems. Innovative provincial policies have a significant positive impact on the circulation flow within the regional innovation ecosystem. Innovative provincial policies can be deduced to strengthen collaboration and interaction among various innovation entities. This is accomplished by encouraging the development of diverse subject interaction intermediary platforms and facilitating the exchange of resources such as technology, talent, and funds among various entities. As a result, the regional innovation ecosystem's performance in various provinces is significantly improved. This paper goes on to perform regression analysis on the third-level indicators to confirm the specific pathways of its effects.

Table 10. Benchmark regression results.

	(1)	(2)	(3)	(4)
	Innovation ecosystem performance	Innovation ecosystem performance	Innovation ecosystem performance	Innovation ecosystem performance
$policy_{it}$	0.231 ***	0.136 ***	0.112 ***	0.109 ***
	(6.183)	(3.664)	(3.264)	(3.319)
$urban$			1.731 **	−3.938 **
			(2.298)	(−2.284)
$lnpop$			0.691 ***	0.777
			(6.576)	(1.013)
$lnpergdp$			0.180	0.067
			(1.415)	(0.489)
$lncsm$			−0.145	−0.227 *
			(−1.411)	(−1.788)
$R\&Dspending$			25.110 ***	27.744 ***
			(5.039)	(4.889)
_cons	−0.050	−0.235 ***	−7.836 ***	−3.056
	(−0.409)	(−4.762)	(−4.619)	(−0.516)
Individual fixed effect	NO	YES	NO	YES
Time fixed effect	NO	YES	NO	YES
N	112	112	112	112
Number of provinces	28	28	28	28
R-sq (within)	0.3075	0.4901	0.5704	0.6781

Notes: z-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 11. Second-level indicator regression results.

	(1)	(2)	(3)
	Ecological composition	Resource input	Circulation flow
$policy_{it}$	0.028 **	0.036 ***	0.043 ***
	(1.974)	(3.474)	(2.868)
$urban$	−1.444 *	−1.228 **	−2.437 ***
	(−1.905)	(−2.263)	(−3.115)
$lnpop$	0.240	0.305	0.116
	(0.712)	(1.264)	(0.334)
$lnpergdp$	0.139 **	0.022	−0.025
	(2.305)	(0.516)	(−0.405)
$lncsm$	0.033	−0.045	−0.151 ***
	(0.596)	(−1.116)	(−2.621)
$R\&Dspending$	8.460 ***	9.187 ***	13.262 ***
	(3.390)	(5.145)	(5.152)
_cons	−3.179	−1.785	2.148
	(−1.221)	(−0.959)	(0.800)
Individual fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
N	112	112	112
Number of provinces	28	28	28
R-sq (within)	0.5870	0.6414	0.6878

Notes: z-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

By regressing the scores of third-level indicators as dependent variables against policy dummy variables, we analyzed the specific ways the influence of innovative provincial policies on regional innovation ecosystems. The results of the regression analysis, presented in Table 12, indicate that the promotion of innovative provincial policies on regional innovation ecosystems mainly acts on two aspects: innovation input and interaction intermediaries. However, it does not exhibit a significant positive effect on the innovation environment, innovation subject, and resource flow. The regression results of innovation input are consistent with previous studies on innovation policy research and similar to the other three types of regional pilot policies: innovative cities, high-tech zones, and economic and technological development zones [44]. By setting innovation input as an assessment criterion, innovative provincial policies promote the increase of innovation input in pilot areas and drive the improvement of regional innovation ecosystems. Regarding interaction intermediaries, on the one hand, the policy guidance of the central government includes interaction intermediary-related indicators, such as the number of technology business incubators and maker spaces and high-tech industry development zones in the monitoring range. This inclusion aims to strengthen the attention of various provinces to such data. On the other hand, innovative provincial policies are a manifestation of government support (including government funding, policy support, and government guidance), which is an important factor affecting the effectiveness of industry-university-research cooperation [46,47], further promoting the increase of interaction intermediaries and ultimately optimizing regional innovation ecosystems. The innovation subject and resource flow do not exhibit a significant impact, which is speculated to be due to the insufficient involvement and emphasis of the corresponding dimensions in innovative provincial policies. Additionally, the evaluation indicator system does not include or includes data for this dimension, leading to limited content in local implementation plans. As for the innovation environment, compared to the dimensions that are easier to improve significantly in the short term, such as innovation input and interaction platform, the innovation environment has a certain inertia. This leads to a weak impact on government innovation policies on it and is difficult to achieve significant effects in the short term.

Table 12. Third-level indicator regression results.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Innovation subject	Innovation environment	Innovation resource	Resource flow	Interactive intermediaries
$policy_{it}$	0.011	0.017	0.036 ***	0.012	0.031 ***
	(1.269)	(1.526)	(3.474)	(1.229)	(3.495)
urban	0.191	−1.636 ***	−1.228 **	−2.176 ***	−0.262
	(0.406)	(−2.774)	(−2.263)	(−4.251)	(−0.566)
lnpop	0.296	−0.056	0.305	−0.115	0.231
	(1.416)	(−0.214)	(1.264)	(−0.504)	(1.124)
lnpergdp	0.025	0.114 **	0.022	0.020	−0.045
	(0.678)	(2.424)	(0.516)	(0.490)	(−1.229)
lncsm	−0.002	0.036	−0.045	−0.081 **	−0.070 **
	(−0.068)	(0.820)	(−1.116)	(−2.145)	(−2.062)
R&Dspending	3.135 **	5.326 ***	9.187 ***	8.369 ***	4.893 ***
	(2.025)	(2.745)	(5.145)	(4.969)	(3.220)
_cons	−2.922 *	−0.257	−1.785	2.761	−0.613
	(−1.810)	(−0.127)	(−0.959)	(1.572)	(−0.387)
Individual fixed effect	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES
N	112	112	112	112	112
Number of provinces	28	28	28	28	28
R-sq (within)	0.2570	0.4984	0.5149	0.5759	0.4315

Notes: z-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3. Robustness Tests

We conduct a placebo test in this paper to test the robustness of the model and examine whether the changes in the post-policy sample are due to other random factors besides the policy intervention. Since the policy periods in multi-period DID vary, we randomly generate a treatment group and randomly select a sample period for each sample object to obtain a pseudo-policy dummy variable. Based on this counterfactual sample, we conduct multi-period DID regression. Suppose the regression results for the estimated quantities remain significant under various fabricated scenarios. In that case, it suggests that the original estimates might be biased and that other policies or random factors could have influenced the changes in our dependent variable. We repeat this process 500 times, obtaining the coefficient estimation results of the random samples and drawing the kernel density distribution graph. The dotted line in the graph represents the estimated value of the DID coefficient mentioned above. As depicted in Figure 3, the true sample estimated coefficient, represented by the vertical dotted line, is significantly different from the mean of the kernel density distribution. This indicates a significant disparity between the estimated results of the random sample and the estimated results of the true sample, which means the placebo test is passed.

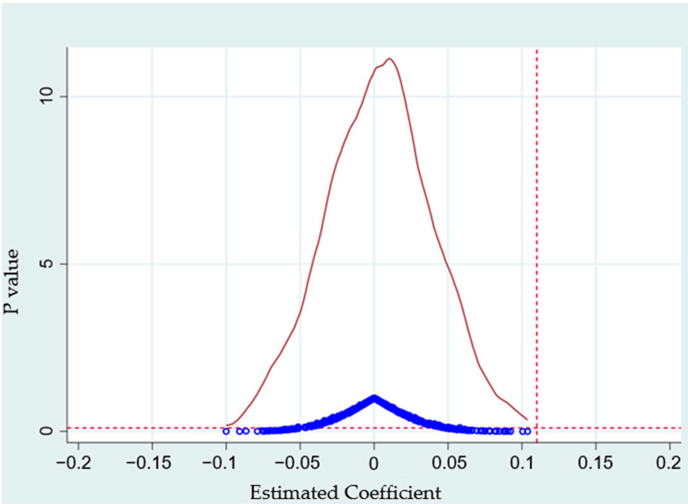

Figure 3. The kernel density distribution graph.

5. Conclusions and Suggestions

Innovation has emerged as a significant strategic resource for regional development, serving as the key driver for industrial transformation and overall competitiveness. It is crucial in promoting economic development, enhancing people's well-being, and pivotal in policy formulation and institutional arrangements. As a significant support for constructing an innovative country, innovative provincial policies significantly impact the construction of regional innovation ecosystems. This study uses panel data from 28 provinces in China from 2016 to 2019. It employs a multiple difference-in-differences method to empirically analyze and verify whether innovative provincial policies promote the improvement of the regional innovation ecosystem level. The conclusion drawn from this study includes: (1) Innovative provincial policies have a significant positive impact on the construction of regional innovation ecosystems and promote the strategic goal of building an innovative country in the macro sense; (2) Innovative provincial policies have significant promoting effects on the ecological composition, resource input, and circulation flow in the innovation ecosystem, thereby promoting the improvement of the innovation ecosystem level in multiple dimensions; (3) Further empirical results show that since 2016, the positive impact of innovative provincial policies on regional innovation ecosystems mainly relies on increasing the input of innovative resources (talent, funding), promoting various provinces to build diverse, innovative intermediary platforms, and promoting the exchange of diverse subjects. These actions ultimately optimize the performance of innovation ecosystems across the provinces.

Based on the research conclusion, this paper proposes the following suggestions, combining the central guidance on the construction of innovative provinces with the implementation plans of local government innovative province construction, aiming to improve the innovative province policies in the future:

First, the construction of innovative provinces must be promoted to facilitate the balanced development of regional innovation capabilities. China is leading in the Fourth Industrial Revolution, represented by new-generation information technologies such as AI, IoT, and big data. China needs to remain vigilant and continue strengthening its focus on innovation to maintain and gain greater advantages. Enhancing national innovative strength is inseparable from constructing and improving the innovation ecosystem at the provincial levels. Currently, the performance of the regional innovation ecosystem in China is unbalanced, leaving ample room for improvement. Therefore, efforts should be made to constantly facilitate the balanced development of the innovation ecosystem in all regions. While striving to strengthen the innovation capabilities of leading regions and build regions that lead the world in innovation, we should not underestimate the importance of building innovation capabilities in relatively less advanced areas. Diversified innovation policies such as regional pilot projects, innovation subsidies, and government procurement should be implemented to help accelerate the catch-up process in these relatively backward areas.

Second, the central guidance for constructing innovative provinces needs to be further optimized, and the evaluation index system for innovative provinces should be improved. Developed by the Ministry of Science and Technology in 2016, the evaluation index system for innovative provinces includes 30 evaluation indicators. This system provides construction guidance and task targets for provinces to build innovative provinces. The evaluation indicators primarily include a composite index of scientific and technological progress, the number of high-tech enterprises, the ratio of R&D expenses to the regional GDP, the decisions or opinions and supporting policies adopted by the party and government in promoting innovative development, and the presence of a science and technology management team with the ability to develop and manage innovation. The proportion of R&D expenditure to regional GDP is closely related to the secondary indicator "resource input" in the innovation ecosystem performance evaluation system constructed in this paper. This can explain the significant empirical result that innovative provincial policies positively impact resource input. The monitoring indicators consist of interrelated intermediate indicators such as the number of science and technology enterprise incubators, accelerators, and crowd innovation spaces, overall sales of national demonstration zones for independent innovation, high-tech industrial development zones, agricultural science and technology parks and sustainable development experimental zones, as well as innovation input indicators such as R&D personnel input and the proportion of public financial expenditure on scientific and technological public finance expenditure. These indicators are aligned with how innovative provincial policies affect innovation ecosystems, mainly through innovation input and interactive intermediaries. This suggests that the attached evaluation index system for innovative provinces in the innovative province guidelines is well-suited to guiding local policymaking.

In the next stage of policy formulation, we should further analyze the state of each dimension of the existing innovation ecosystem in China and refine the index system for innovative province construction. Suggestions can mainly be proposed from two perspectives. First, focus on the indicators in which innovative provincial policies do not demonstrate significant positive impacts, namely, innovation subjects, innovation environment, and flow resources. Additional indicators could be added to the innovation ecosystem, such as universities in flow resources and enterprise finance in research institutions, to promote better synergistic interaction between various ecological subjects, including industries and universities. Second, conduct a comprehensive study on the relationship between innovation ecosystem performance and innovation output. Analyze the performance of various third and fourth-level indicators on innovation output. Utilize this analysis to construct an evaluation index system for innovative provinces, considering the overall impact of each indicator. Select the indicators with greater impact as assessment indicators and those with relatively little impact as monitoring indicators to strengthen the corresponding indicator's performance.

Third, local governments must improve the specific construction and implementation plans for local innovative provinces based on the central guidelines, set clear goals, and properly assign tasks. The construction of local innovative provinces should follow the overall guidelines of central innovative provinces while avoiding conformity and superficiality. Identifying the relative weaknesses that restrict innovation development in each province's regional innovation ecosystem is recommended based on their unique circumstances. By referring to the targeted policies of the central government, a clearer and more comprehensive index system for the construction of innovative provinces can be proposed. This is aimed at guiding the improvement of the regional innovation ecology in each province and city. Clear multidimensional goals should be established, and more precise and quantitative language should describe key tasks. In addition, a reasonable division of responsibilities for each task should be allocated to avoid excessive overlapping of the same task among multiple departments and clarify the allocation of power and responsibility.

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