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An Empirical Analysis of the Synergistic Effect of Urban Pilot Policies in China

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Abstract: The strengthening of urban innovation capacity has emerged as the main force behind the promotion of the high-quality development in China because it is a significant carrier of regional innovation. This work uses the multi-time point difference approach to study the synergistic effect, mechanism, and heterogeneity among the pilot policies of national innovation city, low-carbon city and smart city based on the panel data of 282 cities from 2001 to 2016. The findings demonstrate that (1) The national innovative city pilot policies, low-carbon city pilot policies, and smart city pilot policies have a significant effect on the improvement of urban innovation and show a synergistic effect. (2) With the help of government investment in science and technology and the construction of an innovation platform, the pilot policies of smart cities and innovative cities show a superposition effect; in addition, through the upgrading of industrial structure, the green technology innovation, public participation, low-carbon urban pilot policy, and the innovative city present the supplementary effect. (3) From the perspective of heterogeneity, the superposition and supplementary effects of lower administrative level cities are better. The effect of policy synergy overlay is the largest in the eastern region, whereas the effect of policy synergy supplement is stronger in the eastern and western regions than in the central region. The robustness test supports the conclusion of this paper. This paper analyzes the collaborative innovation effect of urban pilot policies, which can provide ideas for the combination design of policy tools.

Keywords: national innovative city pilot policy; low-carbon city pilot policy; smart city pilot policy; synergistic innovation

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1. Introduction

China currently faces dual restrictions on resources and the environment in addition to rising negative pressure on economic growth. To encourage new drivers of economic growth and ease resource and environmental constraints on economic growth, it is crucial to strengthen the strategy of innovation-driven development, accelerate the formation of a modern economic system and the mode of development dominated and supported by innovation, and promote industrial transformation and upgrading. To this end, while increasing investment in innovation and stimulating new vitality of enterprises and universities [1], China is constantly strengthening the construction of the innovation system, accelerating the construction of the innovation ecosystem, and improving the overall level of national innovation. In 2006, The State Council proposed to speed up the reform of the science and technology system and build a national innovation-oriented system. In 2012, with the release of the Opinions on Deepening the Reform of Science and Technology System and Speeding up the Construction of a National Innovation System, The State Council put forward a more prominent focus on science and technology reform (system and innovation system construction) and further deployment [2]. Since 2008, the Ministry of Science and Technology has gradually begun to build a new type of national city, hoping to enhance the city's innovation capacity and promote high-quality development by relying on innovation factors such as science, technology, and talents [3]. To actively respond to climate change and accelerate the transformation of the economic development model and economic restructuring, the state introduced the low-carbon city pilot policy in 2010 [4]. In addition, with the development of information and communication technology, the concept of the smart city has been realized. The change of smart cities to future society coincides with China's new development concept of innovation, coordination, green, open, and sharing. In 2012, China announced the first batch of smart pilot cities [5].

Innovation plays a vital role in the development of various sectors of the modern economy such as medicine, agriculture, security, national defense, and industry. As a kind of diversified policy system that focuses on stimulating the vitality of urban innovation and promoting high-quality urban development, the urban pilot policy focuses on its innovation effect [6]. For the government, the most direct approach is to increase investment in research and development and accelerate the growth rate of patents. In March 2021, Premier Li Keqiang announced China's goal of increasing R&D investment by seven percent per year between 2021 and 2025. This target affects an already large research and development base. China is now second only to the US in total spending on research and development, and even as a share of GDP (2.4 percent in 2020), it invests more than richer economies such as the EU or the UK [7]. The National Strategy for Innovation-driven Development also clearly sets out the goal of becoming a power in science and technology innovation by 2050. However, increasing investment in research and development does not guarantee success. Chen et al. show that many Chinese firms respond to R&D subsidies by rebranding non-R&D expenditures as R&D expenditures [8]. Zilibotti warned of the limitations of top-down innovation [9].

However, regional policy experiments, as experimental governance models responding to uncertainty, have gradually become a global trend [10]. As concrete manifestations of China's regional policy experiments, urban pilot policies can enable governments at all levels to accumulate experience, test effects, constantly revise and adjust policies, and, finally, find national policies that are suitable for replication and promotion. In addition, as important carriers of regional innovation, cities are increasingly rich in policy tools to promote their innovation ability, and the system is gradually improved. Each policy instrument is unique. Even if some policy tools are similar in the way they identify and address problems, there will always be significant differences, both in the specific details of how the tool is chosen and designed and in the overall social, political, economic, and organizational context in which it is applied. However, innovation policy instruments are often mixed, meaning that they are chosen with their complementary or synergistic effect on urban innovation in mind. However, Borras and Edquist pointed out that the combination of different policy tools would also produce a resource-grabbing effect [11]. However, the coordination of policy tools is a complex decision-making process, which requires the rational choice of tools and a combination of strategies [12].

So, does the urban pilot policy improve the level of urban innovation? What is the synergistic innovation effect between different policy instruments? Is it a synergistic additive effect or a synergistic complementary effect? Furthermore, what are their respective mechanisms of influence? Based on this, this paper constructs a quasi-natural experiment with the pilot policies of national innovation-oriented cities, low-carbon cities, and smart cities, investigating the impact of the pilot policies of three cities on urban innovation and the synergistic effect between the policies, which is conducive to testing the implementation effect of urban pilot policies, strengthening the understanding of the mechanism of urban innovation promoted by the pilot policies of cities, and improving the research on the synergy of policy tools.

The main marginal contributions of this paper include the following: (1) This paper focuses on the analysis of the urban innovation effect from the perspective of urban pilot policy coordination, which enriches the research system of the policy tool mix to a certain extent. (2) Constructing quasi-natural experiments with national pilot policies of innovative cities, low-carbon cities, and smart cities, making useful supplements to the relevant literature on policy implementation effects, and expanding the research content of urban pilot policy analysis. PSM-DID and other methods were used to solve the endogeneity problem to ensure the reliability of the research conclusions. (3) From the perspective of policy synergy, this paper analyzes the mechanism of promoting the urban innovation effect. From the aspects of government investment in science and technology and innovation platform construction, the internal mechanism of the synergistic superposition effect between smart city pilot policies and innovative city pilot policies is deeply revealed. In addition, from the perspectives of industrial structure upgrading, green technology innovation, and public participation, the internal mechanism of synergistic and complementary effects between pilot policies of low-carbon cities and innovative city policies is deeply revealed, and the research literature on policy synergy level is enriched. At the same time, this paper also analyzes the heterogeneity of urban administrative levels and urban locations to provide a reference for the relevant government departments to formulate urban pilot policy combination tools.

The remaining contents are arranged as follows: The second part includes a review of the literature and policy background, a theoretical analysis, and the hypotheses. The third part introduces the research design of this paper. The fourth part analyzes the empirical results of the data analysis and carries out the robust test. The fifth part examines the mechanism and heterogeneity of the collaborative innovation effect of urban pilot policies. The last part includes the conclusion and policy enlightenment.

2. Literature Review, Policy Background, and Mechanism Analysis

2.1. Literature Review

2.1.1. Government Behavior and Urban Innovation

The previous literature has extensively studied the effects of government participation and support in innovation activities, including government subsidies, industrial policies, and innovation environment construction, and mainly Developed two viewpoints, namely the promotion theory and the inhibition theory. As for the promotion theory, at the micro level, by analyzing the data of listed enterprises in China and small- and medium-sized enterprises in South Korea, Chen Chen, C. [13] and Doh [14] found that government support has a significant promoting effect on enterprise innovation. He, Y. et al. studied the influence of local industrial policies on enterprises' technological innovation and found that industrial policies in the form of local laws and regulations can effectively support enterprises' technological innovation activities by using subsidies and tax policies [15]. Wang, Y. and Feng, X. took the administrative approval policy as an example and found that the construction of the government system environment played an important role in enterprise innovation activities [16]. At the macro level, Yang, Z. and Qiu, G. revealed that deepening the reform of the fiscal decentralization system could mobilize the enthusiasm of local governments and further stimulate regional innovation output [17]. However, Zhang, L. and Ni, Z. argued that fiscal decentralization has a threshold effect on the concentration of scientific and technological talents and regional innovation efficiency, and when scientific and technological talents gather in an optimal range, the promotion effect on regional innovation efficiency is the largest [18]. In addition, Kleer found that government behavior would guide private investment, thus improving the innovation level of enterprises, industries, and cities [19]. In terms of the inhibition theory, Acemoglu et al. argued that government subsidies would crowd out enterprise innovation input and inhibit enterprise innovation development [20]. He, Y. et al. found that industrial policies in the form of local government regulations could not promote enterprise innovation [15].

2.1.2. Evaluation of the Effect of Urban Pilot Policies

The implementation of urban pilot policies is an important exploration for the Chinese government to participate in and support urban innovation activities. The evaluation of the effect after implementation enables the government to adjust the policies and measures in a timely and effective manner, which is more conducive to their effects. The existing literature on the effect evaluation of urban pilot policies is mainly divided into the following categories: First, the effect evaluation of national pilot policies for innovative cities. According to the national innovative city policy theme, scholars mainly focus on its effect on urban innovation. Li Zheng and Yang, S. analyzed the effect of innovation-oriented city policies and found that the effect presented an asymmetric "inverted V"-type change characteristic of first strengthening and then weakening [21]. Xu, C. and Jiang, S. [22] also pointed out that pilot policies of innovation-oriented cities have a weakening trend on urban innovation capacity year by year, and further studies on the spatial Dubin effect show that such policies have a spatial spillover effect and human capital crowding out effect. In addition, there is also research on green total factor productivity [23], green innovation efficiency [24], and enterprise innovation [25].

Second, low-carbon city pilot policies. Zhang Hua [26] found that low-carbon city construction can significantly curb carbon emissions by reducing electricity consumption and improving technological innovation levels, which is more significant in western cities and cities with local economic development levels. Hu, Q. and Ma, J. analyzed the impact of low-carbon city pilot policies on the two-stage green technology innovation efficiency from the perspective of the innovation value chain [27]. Lu Jin and Wang, X. conducted an analysis from the perspective of industrial institutions and pointed out that the positive intermediation of low-carbon city policies to promote industrial structure upgrading came from fiscal decentralization, technological innovation, and the green consumption concept, and had a positive spatial spillover effect [28]. Liu, P. and Ci, X. conducted an analysis and pointed out that pilot policies of low-carbon cities not only promote urban innovation through the upgrading of industrial institutions but also further promote urban innovation with the help of government financial support and the talent agglomeration effect.

Third, the smart city pilot policy [29]. Chu, E. believes that human capital agglomeration and smart industry cluster development are important driving forces for smart city construction to enhance urban innovation [30]. Yao, S. and Zhang, Y. argued that the smart city pilot policy could also improve the level of urban innovation by increasing the investment in urban science and technology and optimizing the information infrastructure, and the effect of the policy was gradually enhanced over time [31]. Jiang, X. and Wang, L. found three intermediary effects, namely, the positive innovation-driven effect, financial support effect, and foreign direct investment effect, in the process of studying industrial structure upgrading brought about by smart city policies [32]. Wu, L. analyzed the mechanism of the smart city policy from the perspective of green technology innovation [33]. Li Xia's study used a dual perspective of evolution characteristics and the conduction effect and found that smart city policies can promote urban technological innovation and generate positive spillover [34]. Shi, D. analyzed the effect of smart city policies from the perspective of environmental pollution.

Fourth, other urban policies [35]. Zhang, J. conducted an analysis and pointed out that the national IPR demonstration city policy significantly improved the level of urban innovation by strengthening government guidance and support, encouraging enterprise innovation, and optimizing the innovation environment [36]. On this basis, Li, S. and Rong, F. further revealed the conclusion that intellectual property governance can effectively improve the toughness of the industrial chain [37]. Some other scholars focus on the pilot policies of cultural consumption [38], the transformation of resource-exhausted cities [39], patent pilot policies [40], etc. Fifth, collaborative research of policy mix. Su, T. and Yu, Y. conducted an analysis and pointed out that the dual pilot policies of the low-carbon cities and the innovation-oriented cities could restrain carbon emissions by improving the level of green innovation and optimizing the industrial structure [41]. Compared with the single pilot, the double pilot policy has a stronger carbon emission reduction effect, but from the perspective of the dynamic effect, there is a certain time lag. Chen, C. and Li, P. found that the national innovation-oriented enterprise policy, high-tech enterprise policy, and innovation-oriented city policy showed synergistic innovation effects [13].

To sum up, as an important subject in the regional innovation system, the government's behavior can have a significant impact on regional innovation activities. The national pilot policies of innovation-oriented cities, low-carbon cities, and smart cities have a significant impact on the promotion of urban innovation. Scholars pay more attention to the economic effect of the national innovative city pilot policy and the smart city pilot policy, whereas the low-carbon city pilot policy focuses on the environmental effect. Some scholars have also analyzed the social effect [6,42]. The existing literature mainly analyzes the effect from a certain policy perspective, and seldom pays attention to the research on the impact of the combination design of urban policy tools on urban innovation, which leads to errors in the assessment of policy effectiveness. Therefore, based on the national innovative city pilot policy launched by the Ministry of Science and Technology in 2008, this paper explores whether the improvement of urban innovation capability is more significant from the perspective of policy coordination and their respective influencing mechanisms.

2.2. Policy Background

Thanks to the great victory of reform and opening up, China has made remarkable achievements in economic and social development. However, the lack of innovation capability is increasingly restricting economic and social development, and it is also overtaken by the scientific and technological advantages of developed countries. In the era of competition between the world's scientific and technological powers, China has put forward the important strategic task of building scientific and technological power and improving the overall efficiency of the national innovation system. Cities are not only important drivers of economic and social growth but also high grounds rich in innovation resources, playing an important role in building a national innovation system.

To fully implement the independent innovation strategy, China has carried out a series of "pilot promotion" policy experiments, including national innovation-oriented cities, low-carbon cities, and smart cities. The Ministry of Science and Technology established Shenzhen as the first national innovation pilot city in 2008. In 2009, 14 cities including Dalian and Qingdao were added to the pilot list. From 2010 to 2013, more than 40 pilot cities for innovation were approved. The national innovative city pilot policy aims to promote the transformation of urban economic development into an innovation-driven economy, improve the ability of independent innovation, and promote the process of building an innovative country. Specific measures can be refined into four points: first, to improve independent innovation and accelerate the adjustment and optimization of the industrial structure; second, to strengthen the supply of regional innovation factor resources; third, to encourage and support the development of public platforms and intermediaries for innovation; and fourth, to improve the environment for regional innovation.

In 2010, pilot low-carbon city policies were launched. The National Development and Reform Commission first launched pilot programs in five provinces, including Guangdong, and eight cities, including Shenzhen, and then published a list of the second batch of cities in 2012. The first batch of pilot programs began in 2010. The second batch of trials started in 2013, covering Hainan province and 28 other cities. This policy aimed to promote the low-carbon development of cities by adjusting the industrial structure, increasing the use of green renewable energy, improving energy efficiency, and developing a low-carbon transportation system [43]. Specific measures can be divided into the following points: first, adjusting the industrial structure; second, optimizing the energy mix; third, energy conservation and efficiency; and fourth, advocating for low-carbon and green lifestyles and consumption patterns.

In the process of economic development, environmental problems such as greenhouse gas emissions, haze, and marine pollution caused by urbanization have appeared one after another in the global scope, and it is increasingly urgent to solve them. This has not only attracted the attention of developed countries but has also received much attention from developing countries [44]. Adapa points out that the development of smart cities has become an important driving force for both economic growth and environmental protection [45]. In 2012, the Ministry of Housing and Urban-Rural Development published the first pilot list of 90 smart cities, which combines advanced concepts such as smart development with the specific process of new-type urbanization. Among them, there were 37 prefecture-level cities, 50 districts (counties), and 3 towns. In 2013, the Ministry of Housing and Urban-Rural Development identified 103 cities (districts, counties, and towns) as the second batch of smart city pilot projects. By 2015, the number of smart city pilot projects announced by the Ministry of Housing and Urban-Rural Development had reached 290.

2.3. Mechanism Analysis

2.3.1. Analysis of Policy Synergy Effect

Government policies are designed to solve public problems. Given the complex background environment and the transboundary nature of policy issues, the traditional unilateral policy decision-making mode has gradually declined, and the policy coordination derived from the synergy theory has become an emerging decision-making mode [46]. It has been pointed out that the government's participation will promote the improvement of urban innovation [29]. Therefore, the national pilot policy of innovative city and the pilot policy of smart city will be implemented for the same city at the same time. Due to the superposition of policies and measures, the transformation of innovation achievements will be accelerated through the construction of industry–university–research innovation interconnection platforms and the improvement of information infrastructure. It not only provides a more abundant capital reserve for urban innovation, continuously innovates information science and technology, and forms the incentive effect of urban innovation, but also releases a good signal of government support to the outside world under the implementation of dual policies. The effect of city reputation becomes prominent, resulting in the siphoning effect of human capital, and improves the level of human capital in quantity and quality. It is conducive to accelerating the knowledge spillover effect [47] and driving the improvement of urban innovation ability.

Hypothesis 1. *There is a synergistic innovation effect between the national innovative city pilot policy and the smart city pilot policy.*

The staggered implementation of the national pilot policies for innovative cities and low-carbon cities shows the country's determination and perseverance to achieve high-quality economic development and address climate change. Due to the synergy of the two policy objectives, the construction of innovative cities has the characteristics of innovation. The pilot policy of low-carbon cities focuses on the planning, construction, and governance of the urban economy and environment, and its core objective is the low-carbon and sustainable development of cities. Therefore, the pilot policy of innovative cities can provide powerful solutions and technical support for regional environmental protection and governance. This is the internal driving force for the economic development and transformation of all countries. Low-carbon city pilots can also promote the green transformation and upgrading of the urban economy from a policy-oriented perspective, promote urban innovation, and further enhance urban innovation with the help of government financial support and the talent agglomeration effect.

Hypothesis 2. *There is a synergistic innovation effect between the national innovative city pilot policy and the low-carbon city pilot policy.*

2.3.2. Analysis of Synergetic Effect Mechanism of Urban Pilot Policies

The synergistic effect mechanism should include two aspects: First, the synergistic effect superposition mechanism of urban pilot policies. The specific measures taken by the national innovation-oriented city pilot policy are to strengthen the supply of regional innovation factor resources, encourage and support the development of innovative public platforms and intermediary institutions, and improve the regional innovation environment. The core measures of the smart city pilot policy are the construction of information infrastructure and the development and application of information technology. Therefore, this paper analyzes the superposition mechanism of policy synergies from the path of policy core measures. Cities enjoy two similar policies at the same time, and the policy measures are superimposed. Not only do the central and local governments need to increase the innovation resources of pilot cities, but also under the dual policy certification, the city's reputation is prominent, resulting in the siphoning effect of human capital, thus forming the synergistic effect of urban pilot policies. First of all, cities benefit from dual pilot policies. Through government investment measures in science and technology, the supply of innovation resources is superimposed, and the spillover effect of innovation is enhanced. On the one hand, government investment in science and technology can ensure the supply of innovative activities with knowledge elements and provide resources [48]. On the other hand, sufficient government support provides an important institutional guarantee for talent, social capital, and industrial agglomeration [49]. Secondly, based on the signal transmission theory, under the dual pilot policy, the dual reputation effect can be formed, resulting in the talent capital agglomeration effect and knowledge spillover effect. The innovation-oriented city pilot policy relies on the urban innovation platform to carry out innovation activities, and by creating an effective institutional and cultural environment, it can encourage universities and research institutions to enhance innovation performance through scientific and technological research and the transformation of results and accelerate the knowledge spillover effect. As a high-tech-intensive activity, information infrastructure construction can not only improve the quantity of human capital and the quality of talent reserve in the field of cloud computing technology but also promote the rapid transformation and diffusion of industry–university–research achievements [50] and enhance the knowledge spillover effect.

Hypothesis 3. *Cities enjoy dual policy support with similar measures and form synergistic innovation effect superposition through government investment in science and technology and the establishment of innovation platforms.*

The second mechanism is the complementary mechanism of the synergistic effect of urban pilot policies. The pilot low-carbon city policy is a national policy exploration that deals with climate change, which requires mandatory intervention and constraint on ecological and environmental governance while taking into account social and economic benefits and is conducive to promoting high-quality urban development [51]. Specific measures include industrial structure optimization and upgrading, green technology innovation, advocating low-carbon life concepts, etc. The above measures promote the green transformation and upgrading of the urban economy and promote the sustainable development of the city.

This paper analyzes the complementary mechanism of policy synergies from the perspective of policy complementary measures. First of all, industrial structure optimization and upgrading measures can not only save production costs and improve resource utilization efficiency but also improve environmental quality and promote the development of the regional green economy. On the one hand, under the impact of pilot policies of low-carbon cities, enterprises will adjust their production structure under the pressure of local government environmental governance measures such as emission charges and environmental taxes to alleviate the impact of increased production costs on enterprise survival, promote the upgrading of the industrial structure of the whole industry [51], and then promote urban green development. On the other hand, the construction of low-carbon cities can promote the development process of emerging enterprises with low energy consumption, low pollution, and low emission through the market mechanism to achieve the sustainable economic development goal of optimizing and upgrading the traditional extensive industrial structure of cities.

Secondly, with the help of green technology innovation measures, pilot policies of low-carbon cities can not only directly promote green technology innovation at the city level, but also generate a knowledge spillover effect, thus indirectly promoting green technology development of industries or industries in cities. On the one hand, low-carbon city construction often encourages enterprises and other innovative subjects to carry out green technology research and development and application activities and guides them to purchase energy-saving, emission-reduction, and efficiency-enhancing technologies and production equipment, which improves the core competitiveness of enterprises and directly promotes the green technology innovation of the industry. On the other hand, green technology innovation can effectively balance economic growth and environmental governance [52], and the coordinated development of the two is the key force to achieving high-quality improvement of urban innovation. Finally, the pilot policy of low-carbon city can promote the green low-carbon transformation of the whole city and promote the high-quality development of the city by publicizing and advocating the concept of low-carbon life and consumption and calling on all people to participate in energy conservation and emission reduction activities. At the same time, it can also ensure the information advantage of citizens to supervise the effect of policy implementation.

Hypothesis 4. *Cities enjoy dual policy support under the consistency of policy objectives and form synergistic innovation effects with complementary measures through industrial structure upgrading, green technology innovation, and public participation.*

3. Study Design

3.1. Sample Selection and Data Source

Since 2008, 78 innovation-oriented city pilot projects have been set up in multiple batches. In 2010, low-carbon city pilot projects were set up in three batches. In 2012, smart city pilot projects were set up in multiple batches. By manually collecting several batches of pilot lists published by the Ministry of Science and Technology, the National Development and Reform Commission, and the Ministry of Housing and Urban-Rural Development, this paper selected the pilot list of innovative cities established in 2008–2013, the pilot list of low-carbon cities published in 2010 and 2012, and the pilot list of smart cities published in 2012–2014. Given the availability of data, data from 338 cities were selected as samples in this paper. In the process of selecting the experimental group and control group, the following treatments were carried out in this paper: (1) according to the practice of Shi, D. [35], only a county or district within the prefecture-level city was selected as the sample; (2) four municipalities directly under the Central Government and pilot cities with more data missing were excluded, and the missing values of individual samples were supplemented using the linear interpolation method; (3) excluding newly established prefecture-level cities due to the adjustment of administrative divisions from 2001 to 2016; (4) to reduce the influence of extreme values, this paper carried out tail reduction treatment on variables at 1% and 99% levels; and (5) selection of other prefecture-level cities in the province where pilot cities are established as the control group. This paper finally obtained the balance panel data of 282 cities from 2001 to 2016. The data processing software used was stata16, the city-related data was from the China City Statistical Yearbook, and the green technology innovation data was from the China Innovation Patent Research Database (CIRD). The descriptive statistical results of variables are shown in Table 1.

Table 1. Descriptive statistics of variables.

Variables	Obs.	Mean	Std. Dev.	Min.	Med.	Max.
In_innov	4512	−0.64	1.86	−5.36	−0.8	5.39
$Inno\_city$	4512	0.06	0.24	0	0	1
$Smart\_city$	4512	0.13	0.33	0	0	1
$Carbon\_city$	4512	15.7	1.1	9.28	15.71	19.09
$lnGDP$	4512	5.83	0.66	3.84	5.88	7.14
$lnps$	4512	11.2	2.01	4.01	11.32	15.61
$lnfdi$	4512	9.97	1.56	1.52	10.03	13.49
$lnhc$	4512	15.62	1.32	13.02	15.6	19.28
$lnfin$	4512	15.08	1.33	12.08	15.23	17.88
$lnil$	4512	0.15	0.08	0	0.17	0.3
$gsti$	4512	0.13	0.37	0	0.04	7.28
ip	4512	221.09	13.77	189.56	219.87	261.54
$indu\_str$	4512	85.3	275.63	0	10	2533
gti	4512	40.44	58.59	0.49	20.15	476
pp	4512	0.13	0.33	0	0	1

3.2. Model Specification

3.2.1. Policy Effect Model

In the real world, many policy pilot cities and times are not the same, and the number of individuals who accept the state of policy intervention is constantly changing. The difference in difference method is widely used in the field of policy evaluation because it can solve the endogeneity problem caused by missing variables and other factors. Because the pilot city and the pilot time of the urban pilot policy are different, the multi-time point difference method extends the implementation time of the traditional DID single policy to multiple periods, which can reduce the sample loss and make the results more general. In addition, some top-down policies tend to be one-size-fits-all and often ignore the conditions for the effectiveness of policy implementation. Therefore, a brief heterogeneity analysis is necessary.

Considering that urban pilot policies are set up in batches, the following regression model is constructed to scientifically evaluate the impact of urban innovation capability research:

$$In\_innov_{it} = \alpha_0 + \alpha_1 treated_{it} + \alpha_2 Control_{it} + \mu_i + \lambda_t + \xi_{it} \quad (1)$$

where In_innov_{it} is the city innovation index logarithm, $treated_{it}$ represents the policy processing variables, and $Control_{it}$ represents the control variables. μ_i represents the fixed effects, and for the city λ_t fixed effects for years and ξ_{it} as random perturbation terms. The estimated coefficient α_1 measures the effects of policy effect on urban innovation.

3.2.2. Mediation Effect Model

In recent years, the mediation effect model has been widely used in the social sciences to analyze mechanisms. Based on the practice of Wen, Z. and Ye, B. [53], this paper builds the following model combined with the model (1):

$$M_{it} = \beta_0 + \beta_1 treated_{it} + \sum_j \rho_j \times Control_{it} + \mu_i + \lambda_t + \xi_{it} \quad (2)$$

$$Innov_{it} = \delta_0 + \delta_1 treated_{it} + \delta_2 M_{it} + \sum_j \omega_j \times Control_{it} + \mu_i + \lambda_t + \xi_{it} \quad (3)$$

where M_{it} represents intermediary variables. It is necessary to test the joint significance of α_1, β_1, and δ_2; if it is significant, the mediation effect is established. Furthermore, if δ_1 is also significant and consistent with the $\beta_1 \times \delta_2$ symbols, it shows M_{it} the partial intermediary effect, and its contribution rate is $\beta_1 \times \delta_2 / (\beta_1 \times \delta_2 + \delta_1)$.

3.3. Variables Specification

3.3.1. Explained Variable

The explained variable is city innovation. As a core index reflecting the positive degree of innovation activities at the regional level, the number of urban patent applications is widely used to measure urban innovation [1,40,54]. The key to scientifically depicting the city's innovation activity is to obtain the patent value of each city. China's Urban and Industrial Innovation Report 2017 is regarded as a good data source [22]. Based on the authoritative data released by the State Intellectual Property Office, this data estimated the average value of patents at each age through the patent renewal model [55]. Therefore, this paper uses the urban innovation index as the explained variable, which is more powerful in measuring the level of urban innovation.

3.3.2. Core Explanatory Variable

Select innovative pilot city policy variables ($Inno\_city$), namely when i city in t established for the innovative pilot city, were set up after that year and the value is 1, otherwise the value is 0. The same set of low carbon city pilot policy variables ($Carbon\_city$) and smart city pilot policy variables ($Smart\_city$) were used.

3.3.3. Mediating Variable

This article selects the following mechanism test variables: government investment in science and technology ($gsti$), a measurement of government spending on science and technology as a proportion of total spending; innovation platform (ip), measured by the proportion of employment in information transmission, computer services, and software in the institutions of higher learning in cities and regions; upgrade of industrial structure effect ($indu\_str$), referencing Wang Wei [56], this paper uses the index of industrial structure upgrade, with the formula $indu\_str = \sum_{i=1}^{3} indu_i \times i(1 \leq i \leq 3)$ in which $indu_i$ represents the proportion of GDP in the first i industry; green technology innovation (gti), the adoption of green patent application numbers; and public participation (pp), using the internet broadband access users to represent the level of urban public participation. The higher the internet access rate, the more convenient it is for the government to publicize and advocate for low-carbon lifestyles and consumption projects. The public can receive more diverse information on green concepts, and more people can form a low-carbon green concept.

3.3.4. Control Variable

This article selects the level of economic development ($lnGDP$), measured by the logarithm of GDP; population size ($lnps$), the logarithmic measure of the population; level of foreign investment ($lnfdi$), the logarithmic measure of the actual foreign investment; level of human capital ($lnhc$), the logarithmic measure of the number of higher education students; financial development level ($lnfin$), the logarithmic measure of end loan balances of regional financial institutions [57]; and infrastructure level ($lnil$), the logarithmic measure of the total investment in fixed assets.

3.4. Parallel Trend Test

To ensure that the changing trend of innovation ability in the treatment group and the control group is the same before the implementation of the policy, a parallel trend test is needed. Based on the practice of Bai, J. [6], this paper conducted parallel trend tests on three kinds of urban pilot policies (Figure 1). The results showed that the relative time dummy variable coefficients before the policy occurred were not significant and the values were small, indicating that there was no significant difference between the experimental group and the control group in urban innovation ability before the policy occurred, indicating that both met the parallel trend test. In terms of dynamic effects, both innovation city pilot policies and smart city pilot policies are significantly improved after implementation, whereas the impact coefficient of low-carbon pilot policies is significantly positive and continuously improved after 2 years of implementation.

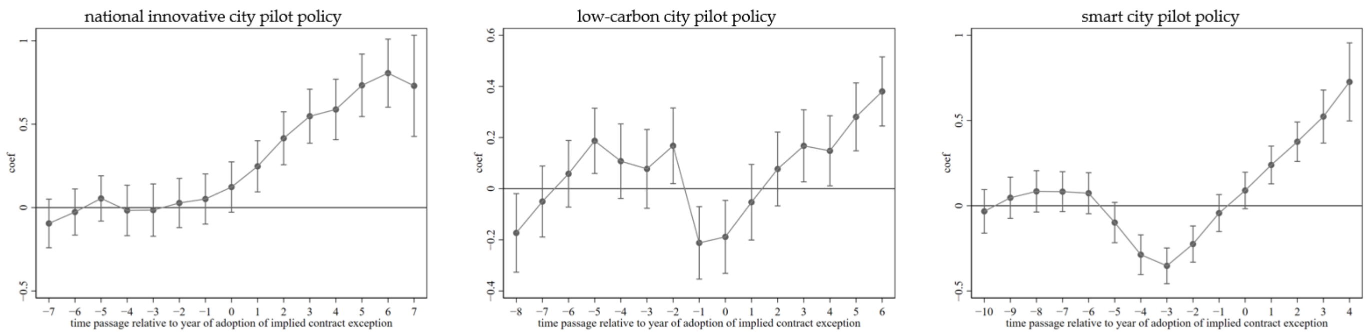

Figure 1. Parallel trend test and dynamic policy effect analysis.

4. Policy Effect Test

4.1. Testing the Effect of Policy Innovation

Table 2 reports the effects of national pilot policies for innovation-oriented cities, low-carbon cities, and smart cities on urban innovation capacity. The differential coefficient of 2.596 in column (1) is significantly positive at the 1% level, indicating that the national innovation-oriented city pilot policy has significantly improved the level of urban innovation. After the addition of control variables, the coefficient in column (2) becomes 0.528, which is less influential than the former. It may be interfered with by internal factors and the innovation ability may be weakened. The regression coefficient of columns (3) and (4) is positive at 1%, but the coefficient is the smallest, indicating that the low-carbon city pilot policy has a small effect on the improvement of urban innovation. The regression coefficients of columns (5) and (6) are positive at the 1% level, but their coefficients are smaller than those of the pilot policies of innovation-oriented cities, which may be due to the delay effect and weak innovation promotion effect due to the late establishment of the policies.

Table 2. Testing the effect of policy innovation.

Variables	**Dependent Variable: *In_innov***					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Inno_city	2.596 *** (26.44)	0.528 *** (12.12)				
Smart_city			1.935 *** (20.81)	0.112 *** (2.82)		
Carbon_city					2.189 *** (26.1)	0.42 *** (11.3)
Control variales	No	Yes	No	Yes	No	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4512	4512	4512	4512	4512	4512
R_squared	0.263	0.87	0.093	0.867	0.11	0.87

Notes: *** indicate significance at 1% levels.

4.2. Testing of Policy Synergies

Based on the practice of Su, T. and Yu, Y. [41], this paper analyzes the effect of two-way policy synergy by constructing dual pilot cities with policies, and the results are shown in Table 3. Table 3 illustrates the test results of the synergistic effect between the national pilot policies of innovative cities and smart cities and between the national pilot policies of innovative cities and low-carbon cities. The regression coefficients of columns (1) and (2) are 2.235 and 0.518, respectively, at the significance level of 1%. Compared with the coefficients of the pilot policies of a single innovation-oriented city, it is found that the implementation effect of the policy synergy effect is better than that of the single policy, indicating that the city enjoys double policy support and can enjoy a doubled supply of innovative resources. The city's reputation is significant in concentrating the effect of forming technology and the talent agglomeration effect, promoting city innovation, and Hypothesis 1 is verified. The regression coefficients of columns (3) and (4) are 2.539 and 0.559, respectively, at the 1% significance level. It was also found that the effect of synergies was better than that of a separate policy. In line with policy goals, green innovation and development can effectively collaborate to promote the quality of city development, positively guiding the promotion of urban innovation, and Hypothesis 2 is verified. After comparing the synergistic coefficient, it is found that the pilot policies of low-carbon cities have a better synergistic effect than the pilot policies of smart cities. This may be because pilot policies of low-carbon cities not only pay attention to ecological and environmental governance but also take into account social and economic benefits, which are more conducive to promoting high-quality urban development and improving urban innovation.

Table 3. Testing the synergistic innovation effect of policies.

Variables	**Dependent Variable: *In_innov***			
	(1)	**(2)**	**(3)**	**(4)**
$Inno\_city \times Smart\_city$	2.235 *** (12.93)	0.518 *** (9.07)		
$Inno\_city \times Carbon\_city$			2.539 *** (15.41)	0.559 *** (9.95)
Control variables	No	Yes	No	Yes
FE	Yes	Yes	Yes	Yes
Observations	4512	4512	4512	4512
R_squared	0.087	0.868	0.117	0.868

Notes: *** indicate significance at 1% levels.

4.3. Robust Test

This paper carries out a robust test from two aspects: (1) Changing the sample time interval. Because the first batch of low-carbon and smart pilot cities was set up late, the sample space was adjusted to 2006–2016. (2) PSM-DID. Because the urban pilot policy is not a natural experiment in the strictest sense, there is still a problem of bias in the selection of the treatment group and control group. Therefore, this paper conducts a robust test based on the multi-time point propensity matching differential method (PSM-DID). The results are shown in Table 4.

Table 4. Robust test.

Variables	**Dependent Variable: *In_innov***			
	Change Sample Interval		**PSM-DID**	
	(1)	**(2)**	**(3)**	**(4)**
$Inno\_city \times Smart\_city$	0.446 *** (7.23)		0.452 *** (2.71)	
$Inno\_city \times Carbon\_city$		0.409 *** (6.58)		0.591 *** (2.59)
Control variables	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Observations	3102	3102	876	492
R_squared	0.854	0.853	0.832	0.811

Notes: *** indicate significance at 1% levels.

5. Mechanism Analysis and Heterogeneity Analysis

5.1. Mechanism Analysis

Table 5 shows the spillover effect of the smart city pilot policy and the innovative city pilot policy on urban innovation due to the synergy of measures. Columns (1) and (2) report the mechanism of government science and technology input in policy innovation coordination, and the regression coefficient is significantly positive, indicating that the implementation of dual policies strengthens government science and technology input, provides a material guarantee for urban innovation, and promotes science and technology output. Furthermore, all three coefficients are significantly positive, indicating that government science and technology input have a partial mediating effect on urban innovation, and the contribution of this effect can be estimated to be about 10.56% by combining it with the regression coefficient, indicating that government science and technology input strengthens the urban science and technology foundation, broadens the supply of innovation resources, and contributes to the smooth development of urban innovation activities. Columns (3) and (4) report the action mechanism of the innovation platform for policy collaborative innovation, and the regression coefficients are both significantly positive, indicating that relying on the urban innovation platform, the reputation is significant, gathering a large number of innovative talents and social capital and accelerating the innovation performance and output; the mediating effect contribution of this part is about 17.03% by calculation. Above all, Hypothesis 3 is verified. According to the mediating effect ratio of the two, the reputation effect becomes prominent under policy coordination, thus generating the human capital agglomeration effect, accelerating the knowledge spillover effect, and significantly improving the innovation spillover effect.

Table 5. The superposition mechanism test of the synergistic effect of urban pilot policies.

Variables	**(1)** ***gsti***	**(2)** ***In_innov***	**(3)** ***ip***	**(4)** ***In_innov***
Inno_city × Smart_city	0.039 *** (6.71)	1.999 *** (11.56)	0.195 ** (2.08)	1.854 *** (10.16)
gsti		6.066 *** (21.4)		
ip				1.949 *** (12.41)
Control variables	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Observations	4512	4512	4512	4512
R_squared	0.006	0.158	0.048	0.229

Notes: **, *** indicate significance at 5%, 1% levels, respectively.

Table 6 reports the results of the collaborative innovation effect between national pilot policies of innovation-oriented cities and low-carbon cities. Columns (1) and (2) report the mechanism of industrial structure upgrading, and the coefficient is positive at the significance level of 1%, indicating that low-carbon policies optimize the energy structure and enhance urban innovation through the adjustment and upgrading of urban industrial structures. Columns (3) and (4) report the action mechanism of green technology innovation, and the coefficient is significant at the significance level of 5%, indicating that low-carbon policies improve the efficiency of energy utilization, promote the development of regional green economy, and improve the efficiency of innovative resources with the help of green technology innovation measures. Columns (5) and (6) show the mechanism of public participation, and the coefficient is positive at the significance level of 1%, indicating that low-carbon policies, by advocating for low-carbon green concepts, make the public widely participate in energy conservation and emission reduction activities, promote high-quality urban development, and thus promote the improvement of urban innovation. Above all, Hypothesis 4 is verified. Finally, by comparing the mediating effects of industrial structure upgrading, green technology innovation, and public participation, it is found that public participation is the main mediating variable, green technology innovation has a masking effect [53], and the mediating effect of industrial structure upgrading accounts for 20.68%.

Table 6. Complementary mechanism test of the synergies of urban pilot policies.

Variables	(1) *indu_str*	(2) *In_innov*	(3) *gti*	(4) *In_innov*	(5) *pp*	(6) *In_innov*
Inno_city × *Carbon_city*	6.794 *** (4.13)	2.014 *** (14.03)	836.139 ** (9.2)	−0.573 ** (−2.31)	126.825 *** (8.68)	−0.311 (−1.29)
indu_str		0.077 *** (39.89)				
gti				0.004 *** (21.18)		
pp						0.023 *** (23.46)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4512	4512	4512	4512	4512	4512
R_squared	0.119	0.408	0.225	0.355	0.186	0.529

Notes: **, *** indicate significance at 5%, 1% levels, respectively.

5.2. Heterogeneity Analysis

5.2.1. Administrative Rank Heterogeneity

Referring to the practice of Bai, J. [6], this paper sets virtual variables of administrative level for provincial capitals, cities separately listed in the plan, and cities in special economic zones and assigns them a value of 1, otherwise, it is 0. As can be seen from the results in Table 7, the regression coefficients are all positive at the significance level of 1%. Compared with the cities with higher administrative levels, the policy synergies of the cities with lower administrative levels are stronger. The reason for this may be that cities with low administrative levels have a poor supply of innovation resources and low innovation efficiency. With the support of coordinated policies, infrastructure construction has been gradually improved and the system and business environment have been continuously optimized, thus contributing to the rapid growth stage. However, cities with high administrative levels pay more attention to ecological governance through their excellent innovation foundation, which makes the difference between synergistic and complementary effects and superimposed effects greater than those of cities with low administrative levels.

Table 7. Testing the difference of policy synergy effect under the heterogeneity of administrative level.

Variables	Dependent Variable: *In_innov*			
	High Administrative Rank		Low Administrative Rank	
	(1)	(2)	(3)	(4)
Inno_city × *Smart_city*	0.363 *** (4.08)		0.585 *** (7.94)	
Inno_city × *Carbon_city*		0.453 *** (6.00)		0.602 *** (5.83)
Control variables	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Observations	544	544	3968	3968
R_squared	0.915	0.916	0.826	0.827

Notes: *** indicate significance at 1% levels.

5.2.2. Location Condition Heterogeneity

The eastern region has the unique advantages of coastal areas and convenient transportation, as well as the advantage of the national policy of continuously strengthening the opening-up of coastal areas, which make the green innovation development of the central and western regions lag behind this region. Therefore, from the perspective of policy interaction, regional differences are considered to test the innovation effect of policy coordination. Table 8 shows that the eastern region is superior to the central and western regions in terms of policy synergy and overlay effect because of its sound foundation of innovation, research and development, and its abundant resources. In terms of policy synergy and complementarity effect, the eastern and western regions are stronger than the central region. The reason for this is that the country continuously strengthens the policy dividend of ecological and environmental governance in the western region and continuously promotes the coordinated and sustainable development of the economy, society, and environment in the western region, so the policy synergy and complementarity effect is stronger than that in the central region.

Table 8. Testing the difference of policy synergy effect under the heterogeneity of location conditions.

Variables	Dependent Variable: *In_innov*					
	East		Middle		West	
	(1)	(2)	(3)	(4)	(5)	(6)
Inno_city × *Smart_city*	0.558 *** (7.04)		0.36 *** (4.50)		0.281 *** (3.15)	
Inno_city × *Carbon_city*		0.531 *** (8.07)		0.275 *** (2.6)		0.558 *** (3.86)
Control variales	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1552	1552	1600	1600	1360	1360
R_squared	0.884	0.884	0.861	0.86	0.831	0.832

Notes: *** indicate significance at 1% levels.

6. Conclusions and Policy Implications

In the context of rising global economic uncertainty, an in-depth analysis of the urban innovation effect from the perspective of policy coordination is of great significance for promoting high-quality urban development and then promoting high-quality economic development in China. By collating the balanced panel data of 282 prefecture-level cities from 2001 to 2016, this paper analyzes the innovative synergies between the national innovative city pilot policy and the smart city pilot policy and between the national innovative city pilot policy and the low-carbon city pilot policy from the perspective of policy coordination by constructing a multi-time point differential model. The mechanism and heterogeneity of policy coordination are further analyzed. The results show that (1) the national pilot policies of innovation-oriented cities, low-carbon cities, and smart cities all have positive effects on urban innovation, there is a synergistic innovation effect among policies, and the synergistic and complementary effect of policies is stronger than the superposition effect, indicating that the pilot policies of low-carbon cities have better synergistic effects on innovation-oriented cities than the pilot policies of smart cities. (2) The core functions of the national innovation-oriented city pilot policy and the smart city pilot policy are similar. The superposition of policies and measures expands the supply channels of innovation resources and forms the dual city reputation certification with the help of an innovation platform and information infrastructure construction. Finally, the superposition effect of policy coordination measures is formed, providing sufficient innovation resources for urban innovation. (3) The national innovative city pilot policy and low-carbon city pilot policy have the same policy objectives. Through industrial structure upgrading measures, energy structure is optimized, resource utilization efficiency is improved, economic growth and environmental governance are balanced by green technology innovation, and a low-carbon life concept and consumption concept are publicized and advocated for, which can promote the green and low-carbon transformation of the whole city. With the complementary mechanism of policy coordination measures, urban innovation ability is promoted. (4) The policy synergy effect of cities with lower administrative levels is stronger; among different regions, the synergistic effect of policies is the largest in the eastern region, and the synergistic effect of policies is stronger in the eastern and western regions than in the central region. The mechanism analysis of the collaborative innovation effect of urban pilot policies is shown in Figure 2.

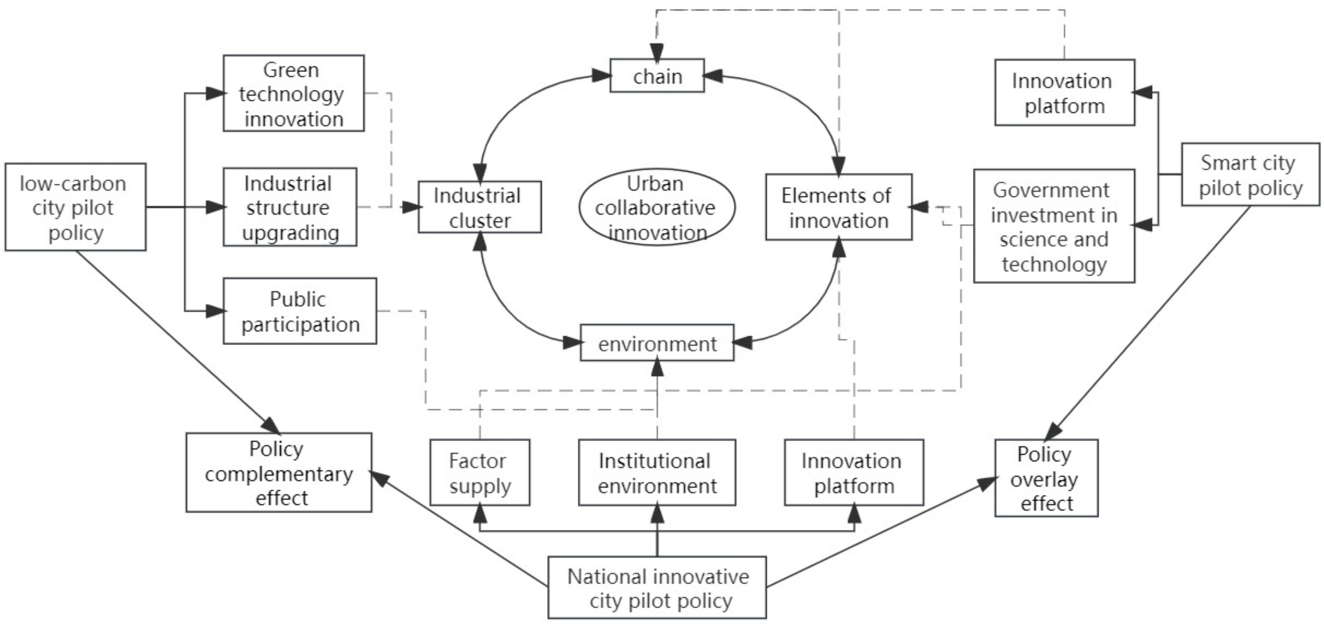

Figure 2. Analysis of synergistic innovation effect mechanism of urban pilot policies.

This article's research conclusion can provide the following policy implications: First, with regards to policy tool selection, attention should be paid to shifting from a single policy application to a differentiated combination of tools. To realize the continuous improvement of urban innovation, the power of policy combination tools can promote high-quality urban development in various aspects and form the incentive effect of multiple protection. However, attention should also be paid to the resource preemption effect of the combination of different policy instruments. Secondly, in terms of the implementation of specific measures, it is not only necessary to take the direct policy of element completeness as the leading factor, but also to pay attention to the improvement of the supply of innovation resources and the innovation platform, which can improve the guarantee for urban innovation under the dual reputation certification, supplemented by the implementation of social and environmental measures. Finally, in policy implementation, we should pay attention to the stage, fairness, and sustainability of policy synergies. For cities with different administrative levels and locations, the differences in resource endowment conditions and the phased characteristics of economic development should be taken into account, and the fairness of policies should be emphasized to promote coordinated development and achieve the goal of high-quality urban development. At the same time, we must consider how long the coordination of policies can last. On the one hand, we should avoid having insufficient policy capacity. On the other hand, we should avoid resource occupancy between policies.

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