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Impact of dual pilot policies for low-carbon and innovative cities on the high-quality development of urban economies

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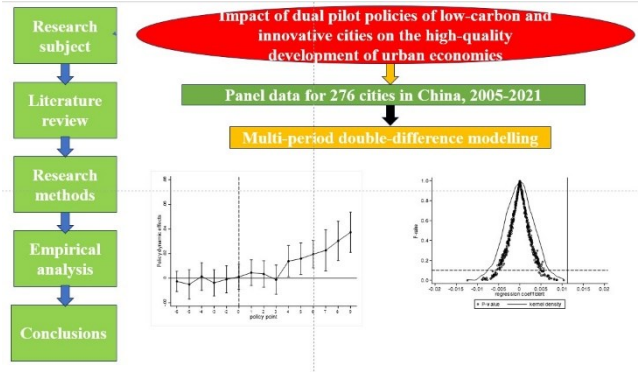
Graphical abstract



Abstract

A comprehensive and systematic assessment of the impact of the dual-pilot policy on the high-quality development of urban economies plays an important role in formulating scientific and effective urban development strategies and promoting green transformation and high-quality development of the economy. Based on the panel data of 276 cities in China from 2005 to 2021, the article used a multi-period double-difference model to explore the impact of the dual-pilot policy of low-carbon cities and innovative cities on the high-quality development of urban economy. The study found that: (1) the implementation of the dual-pilot policy significantly had significantly promoted the economic high-quality development of the pilot cities, and the dual-pilot policy had a more significant effect on the enhancement of urban economic high-quality development compared with the single-pilot. (2) The mechanism analysis showed that green technology innovation, industrial structure adjustment and entrepreneurial activity played a mediator role in the impact of the dual-pilot on the high-quality development of the urban economy. (3) The spatial effect showed that the dual-pilot policy not only promoted the high-quality economic development of the region, but also had a positive spillover effect on the high-quality economic development of the neighbouring regions. (4) The heterogeneity analysis showed that the dual-pilot policy promoted the high-quality economic development of the eastern cities, large-scale cities, and non-resource-based cities more strongly. Therefore, the Government should continue to promote and optimize the dual-pilot policy, give full play to policy synergies, and plan the policy layout scientifically and rationally in accordance with the characteristics of the city, so as to promote the high-quality development of the urban economy.

Keywords: Synergy effects, high-quality economic development, double-difference modeling, spatial spillovers

1. Introduction

Since the reform and opening up, China's economy has made brilliant achievements, but the traditional rough development model has also brought challenges to the environment and ecology that cannot be ignored. At present, China has jumped to the top of the global carbon emissions (Liu *et al.* 2017), and the serious environmental problems seriously threaten China's sustainable development (Feng *et al.* 2021). Therefore, it is urgent to change the traditional development model, promote green and low-carbon transformation, and achieve high-quality economic development. The report of the 20th CPC National Congress points out that high-quality development is the primary task of building a modern socialist country in an all-round way. Promoting the greening and low-carbonization of economic and social development is a key part of achieving high-quality development. Chinese President Jinping Xi further stressed at the National Conference on Ecological Environmental Protection that green development is an inevitable requirement for building a high-quality modernized economic system and a fundamental solution to the pollution problem. Green development not only contains huge development opportunities and potential, but will also force the economic and social system to comprehensively transform and upgrade, and thus promote the realization of high-quality development in which human beings and nature coexist harmoniously (Li *et al.* 2021).

The report of the Fifth Plenary Session of the 19th CPC Central Committee clearly pointed out that we must unswervingly implement the new development concept of

innovation, coordination, green, openness and sharing, take high-quality development as the core objective, deeply implement the innovation-driven development strategy, and promote economic transformation by innovation drive. The report of the 20th CPC National Congress, the assertion that "science and technology is the first productive force, talent is the first resource, and innovation is the first driving force" highlights the central position of innovation in promoting high-quality economic development. Innovation-driven can not only break the shackles of key core technologies subject to others, but also effectively solve the problem of unbalanced and insufficient development, give rise to new industries, cultivate new momentum, form new competitive advantages, and then lead and promote the economy to achieve high-quality development.

Cities, as the main gathering place for all kinds of resources and production factors, are important spatial carriers for practicing the concepts of green development and innovation drive, and are also the main focus point for high-quality economic development. In order to respond to the climate crisis and promote the high-quality development of the urban economy, China put forward a pilot policy for innovative cities in 2008, and has successively organized a number of innovative pilot cities, while in 2010 it began to gradually promote a pilot policy for low-carbon cities. The green development strategy and the innovation-driven strategy are the two pillars of China's economic development towards high quality (Guo *et al.* 2024), and the practice of low-carbon cities and innovative cities pilots is the best example of how these two strategies can be put into practice. The close implementation time and overlapping scope of the two pilot policies provide good quasi-natural experimental conditions for studying their impacts on the high-quality development of urban economy. An in-depth exploration of the impact of the dual-pilot policy on the high-quality development of urban economy and its mechanism can provide practical experience and theoretical support for the synergistic cooperation between the policies, and boost the practice of high-quality development of urban economy.

There are two main aspects of the literature that are closely related to the research of this paper. The first is the influencing factors of high-quality economic development. Scholars generally believe that factors such as environmental regulation (Chen *et al.* 2020), digital economy (Guo *et al.* 2023; Chen *et al.* 2023; Zhang *et al.* 2021), technological innovation (Peng *et al.* 2021; Wang *et al.* 2024; Liu *et al.* 2021), financial development (Yang *et al.* 2021), and opening up to the outside world (Kong *et al.* 2021) can effectively promote high-quality economic development. In addition, some studies have pointed out that new quality productivity promotes high-quality economic development by improving the quality of production factors, giving rise to new production organization forms and empowering innovation ecosystems (Du *et al.* 2023). The second is the respective implementation effects of pilot policies for low-carbon cities and pilot policies for innovative cities. In terms of low-carbon city construction, literature has shown that low-carbon pilot policies have achieved remarkable results in promoting air quality improvement (Wolff, 2014; Gehrsitz, 2017), promoting carbon emission reduction (Du *et al.* 2022; Yang *et al.* 2023; Zeng *et al.* 2023), enhancing urban entrepreneurial activity (Wang *et al.* 2023), and promoting regional coordinated development (Wang *et al.* 2024) through optimizing industrial structure, promoting clean energy use and strengthening carbon emission management. At the same time, the policy has stimulated the green innovation vitality of enterprises (Liu *et al.* 2023; Yin *et al.* 2023), promoted the research and development and application of green technology, and facilitated the high-quality development of enterprises (Wang *et al.* 2022). In terms of the construction of innovative cities, studies have focused on the role of innovative pilot policies in enhancing urban innovation (Gao and Yuan, 2022; Li *et al.* 2022), entrepreneurship (Bai and Li, 2022), industrial structure upgrading (Zhao and Toh, 2023) and carbon total factor productivity (Zhou *et al.* 2023). From the perspective of enterprises, the pilot policy has improved the innovation environment, promoted the market allocation of innovative talents, alleviated the financing constraints of enterprise innovation activities (Liu *et al.* 2024), and effectively driven the enterprise innovation "quality and quantity".

It can be seen from the above literature that, firstly, most of the existing studies focus on examining the drivers of high-quality economic development from the perspectives of the digital economy, scientific and technological innovation, and new-quality productivity, etc., and there are relatively few analyses from the perspective of government policies, which are unable to comprehensively assess the contribution of government policies to high-quality economic development. Secondly, most of the existing literature focuses on the effects of the implementation of a single pilot policy for low-carbon or innovative cities, and there is less literature on policy synergy. Finally, most of the studies do not analyze the spatial spillover effects of pilot policies, which may lead to a one-sided understanding of the effects of the policies and is not conducive to the coordinated development of the region. Based on this, this paper empirically analyzes the impact of dual-pilot policies on the high-quality development of urban economy from the perspective of synergy of pilot policies for low-carbon and innovative cities. The possible marginal contributions are: first, from the perspective of government policy, it examines focusing on whether the dual pilot policy of low-carbon and innovative cities can promote the high-quality development of urban economy, and provides new ideas for promoting the high-quality development of urban economy; second, based on the perspective of policy synergy, it explores the relationship between the dual-pilot policy and the high-quality development of urban economy, which enriches the research in related fields; third, it analyzes the spatial spillover effect of the dual-pilot policy on the high-quality development of the economy, and it further reveals the effect of the policy in the spatial

dimension and provides a basis for the formulation of a more scientific and effective urban development policy.

2. Theoretical analysis and research hypothesis

2.1. Dual-pilot policies and high-quality urban economic development

As the best practices of China's green development strategy and innovation-driven development strategy, the low-carbon pilot policy and innovative pilot policy have played an important role in promoting the high-quality development of urban economies. On the one hand, the low-carbon pilot policy is a powerful initiative of the state to actively respond to environmental challenges and realize sustainable development (Khanna, 2014), which encourages cities to move towards more environmentally friendly development, thus contributing to the maintenance of ecological balance and boosting the realization of high-quality development of the urban economy; at the same time, this policy has spawned the flourishing development of clean energy industry, green technology and environmental protection industry, which not only drives industrial upgrading (Zheng *et al.* 2021) and enhances the competitiveness and resilience of the city's economy, but also stimulates the innovation and vitality of green technology and environmental protection industry, and injects a steady stream of innovation power for the high-quality development of the urban economy. On the other hand, the innovative pilot policy promotes the innovation-driven development of the urban economy by encouraging and supporting innovative activities, which can enhance the core competitiveness of the urban economy and promote the development of urban industries in the direction of high-end, intelligent, and green; in addition, the innovative city actively cultivates and attracts human resources by optimizing the talent policy, giving full play to the talent agglomeration effect (Zhang and Wang, 2022), and providing the high-quality development of the regional economy with a solid human capital support.

Becoming a dual-pilot city will have a stronger impact on the high-quality development of a city's economy than a single-pilot low-carbon city or innovative city. For low-carbon pilot cities, becoming an innovative city will promote the vigorous development of urban innovation activities and the process of economic transformation and upgrading; for innovative pilot cities, becoming a low-carbon city will accelerate the development and expansion of low-carbon industries, promote the city's progress towards the goal of decarbonization, and achieve green and sustainable economic development, which will in turn promote the high-quality development of the city. Therefore, both low-carbon pilot and innovative pilot can help realize the high-quality development of urban economy, and there are policy synergies between them. Based on this, this paper puts forward the following hypotheses:

Hypothesis 1a: The dual-pilot policy of low-carbon and innovative cities has a significant positive impact on the high-quality development of urban economy.

Hypothesis 1b: Dual-pilot policies are a stronger driver of high-quality urban economic development than single-pilot policies.

2.2. Mechanisms of action of the dual-pilot policy to influence high-quality economic development

The mechanism by which the dual-pilot policy affects the high-quality development of urban economy is mainly reflected in three aspects, namely, green technological innovation, industrial restructuring and entrepreneurial activity. Firstly, in terms of green technology innovation, the low-carbon pilot policy encourages enterprises, research institutions and universities to strengthen the research and development and application of low-carbon technologies through clear policy guidance and financial support, so as to enhance the level of green technology innovation in cities and strengthen the comprehensive competitiveness of cities (Huang *et al.* 2021); Innovative cities stimulate the vitality of innovation in cities and promote the continuous advancement and application of green technologies by attracting and gathering innovative resources, including talents, information, knowledge and funds (Kong *et al.* 2023) and thus enhance the level of high-quality economic development. As a result, the low-carbon pilot policy clarifies the direction of green development, while the innovation pilot policy provides strong support for the research and development of new technologies, processes and materials, and the implementation of the dual-pilot policy promotes the innovation breakthroughs of green technologies, which contributes to the realization of the high-quality development of the city's economy.

In terms of industrial structure adjustment, the low-carbon pilot policy encourages enterprises to adopt cleaner production technologies and green manufacturing processes, and guides traditional industries to gradually get rid of the high-energy consumption and high-emission development mode, and transform and upgrade in the direction of being cleaner and lower-carbon (Zheng *et al.* 2021), thus improving the environmental protection level of the industries and the efficiency of resource utilization; by providing policy support and financial support, the innovative city pilot policy builds a good development platform for innovative enterprises, promotes the incubation and growth of new industries such as high-tech industries and modern service industries, and facilitates the in-depth upgrading and comprehensive optimization of industrial structure (Zhao and Toh, 2023). To sum up, the implementation of the dual pilot policy is not only conducive to enhancing the competitiveness and innovation capacity of the urban economy, but also helps to promote the transformation of the urban industrial structure in the direction of high-end and intelligentization. Under the guidance of the low-carbon pilot policy, the traditional industries take on new life; under the promotion of the innovation pilot policy, the emerging industries flourish. The two integrate and promote each other, providing a solid guarantee for the realization of high-quality economic development.

In terms of entrepreneurial activity, the governments of low-carbon pilot regions are bound to introduce new

industrial promotion policies under stricter environmental regulations, and increase scientific research funding and policy support for enterprises engaged in green innovation. The policy support and market demand jointly promote entrepreneurs to actively invest in the field of low-carbon technology and clean energy, and increase entrepreneurial activity (Xu and Qi, 2023), which in turn promotes the green transformation and high-quality development of the city's economy. The pilot policy of innovative cities can establish a more perfect innovation system and innovation network, stimulate the innovation vitality of entrepreneurs, attract more talents and capitals into the field of innovation, accelerate technological innovation and transformation of achievements (Zhang and Wang, 2022), promote the transformation of urban economy to knowledge-intensive and technology-driven, and realize the high-quality development of the urban economy. It can be seen that the implementation of the dual-pilot policy provides entrepreneurs with diversified support policies, including research funding, policy support, talent introduction, etc. These policy measures reduce the risk and uncertainty of entrepreneurship and enhance the confidence and motivation of entrepreneurs, thus promoting the vigorous development of innovation and entrepreneurial activities, and providing an important support and impetus for realizing the high-quality development of the economy.

Based on this, this paper puts forward the following hypotheses:

Hypothesis 2: Dual-pilot policies promote the realization of high-quality urban economic development through green technological innovation, industrial restructuring and entrepreneurial activity.

2.3. Spatial spillover effects of the dual pilot policy

While the dual-pilot policy of low-carbon and innovative cities has significantly improved the level of high-quality development of the economies of the pilot regions, its positive effects may also radiate to the surrounding areas, thus promoting the high-quality development of the economies of the region as a whole. First of all, the implementation of the dual-pilot policy has attracted a large amount of capital inflow, which not only meets the development needs of the pilot cities themselves, but also promotes the economic development of the neighboring cities through the capital flow. The optimal allocation of capital in the region enables the neighboring cities to obtain more investment, promote industrial upgrading and infrastructure construction, and then enhance their economic development level. Second, the dual-pilot policy promotes the agglomeration of innovation factors in the pilot region, and these innovation resources not only promote the technological progress and industrial upgrading of the pilot cities, but also drive the technological innovation and industrial upgrading of the neighboring cities through knowledge spillover and technology diffusion (Zhou *et al.* 2024). Finally, the successful practice of the dual-pilot policy provides valuable experience and inspiration for neighboring cities, which can learn from the policy framework and implementation path of the successful cities to accelerate their own transformation and upgrading, and thus promote the realization of high-quality economic development. Based on this, this paper puts forward the following hypotheses:

Hypothesis 3: The dual-pilot policy not only contributes to the high-quality development of the region's economy, but also has a positive spillover effect on the high-quality development of the neighboring regions' economies.

3. Model Construction and Data Sources

3.1. Modelling

In order to explore the impact of the dual-pilot policy of low-carbon cities and innovative cities on the high-quality development of urban economy, this paper adopts a multi-period double-difference model to compare the level of high-quality development of the economy of the pilot cities with that of non-pilot cities before and after the implementation of the dual-pilot policy, and constructs the benchmark model as follows:

$$hqd_{it} = \beta_0 + \beta_1 dualdid_{it} + \beta_2 X_{it} + \delta_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In Equation (1), hqd_{it}, is the explanatory variable, representing the level of high-quality economic development of city *i* in year *t*; $dualdid_{it}$ is the core explanatory variable, assigned a value of 1 if city *i* belongs to the dual-pilot city in year *t*, and 0 otherwise, β_1 is the core coefficient that is the focus of this paper, representing the effect of the dual-pilot policy on the high-quality development of the city's economy, X_{it} are the control variables, δ_i is the city fixed effect, λ_t is the year fixed effect, and ε_{it} is the random perturbation term.

In order to test the impact mechanism of the dual pilot policy of low-carbon cities and innovative cities on the high-quality development of urban economy, this paper refers to the studies of Jiang (2022), and constructs the following econometric model to test the mediation effect on the basis of the baseline regression equation (1):

$$media_{it} = \theta_0 + \theta_1 dualdid_{it} + \theta_2 X_{it} + \delta_i + \lambda_t + \varepsilon_{it} \quad (2)$$

In Equation (2), $media_{it}$, denotes the mediating variable, and θ_1 denotes the effect of the dual pilot policy on the mediating variable, and the meanings of the remaining variables are consistent with equation (1).

This paper constructs a spatial econometric model to extend the analysis of the impact of the dual-pilot policy on the high-quality economic development of the pilot cities and neighboring cities, as follows:

$$hqd_{it} = \alpha_0 + \alpha_1 Whqd_{it} + \alpha_2 dualdid_{it} + \alpha_3 Wdualdid_{it} + \alpha_4 X_{it} + \alpha_5 WX_{it} + \delta_i + \lambda_t + \varepsilon_{it} \quad (3)$$

In Equation (3), α_1 is the spatial autoregressive coefficient, α_3 is the elasticity coefficient of the spatial interaction term of the core explanatory variables, α_5 is the elasticity coefficients of the spatial interaction terms of the control variables, *W* is the spatial weight matrix, and the other variables have the same meaning as in equation (1).

3.2. Variable Description and Measurement

3.2.1. Explained variables

City economic high-quality development index (*hqd*). In constructing the evaluation index system for high-quality economic development, this paper draws on the research results of Zhao et al. (2020) and Guo et al. (2023), and takes into account the five core dimensions of industrial structure, inclusive total factor productivity (TFP), technological innovation, ecological environment, and living standards of residents. On this basis, the entropy weight method is used to measure the economic high-quality development index to ensure the objectivity and accuracy of the evaluation results (**Table 1**).

Table 1. System of indicators for evaluating the level of high-quality economic development

	Dimension	First-Order Index	Secondary Index	Indicator properties
High-quality economic development	industrial structure	Advanced industrial structure	Tertiary sector output/secondary sector output	+
		Rationalization of industrial structure	Thiel index	−
		Share of productive services	Number of employees in productive services/number of employees in urban units	+
	Inclusive TFP	Inclusive TFP index	Measured using the Hicks-Moorsteen index methodology	+
	technological innovation	innovation capacity	R&D expenditure/city GDP	+
			Number of patent applications for inventions	+
	ecological environment	Sulphur dioxide removal rate	(SO_2 generation - SO_2 emission)/SO_2 generation	+
		Integrated rate of industrial solid waste utilization	Comprehensive use of industrial solid waste/(industrial solid waste generation + comprehensive use of previous years' storage)	+
		$PM_{2.5}$	$PM_{2.5}$ Concentration	−
	Living standards for residents	GDP per capita	GDP/total population	+
		Per capita expenditure on education	Expenditure on education/total population	+
		Hospital beds per capita	Number of hospital beds/total population	+

3.2.2. Core explanatory variables

Dummy variable for dual-pilot policies for low-carbon cities and innovative cities (*dualdid*). In the year a city becomes a dual-pilot city and the following years, *dualdid* takes the value of 1, otherwise it takes the value of 0. Similarly, the dummy variables *lccpdid* and *innodid* for the low-carbon city pilot policy and the innovative city pilot policy in the following analysis take the value of 1 in the year a city becomes a pilot city and the following years, otherwise they take the value of 0. Among the three batches of low-carbon pilot cities, there is the phenomenon of provinces and cities crossing over, and they are grouped in the earlier batch of pilot list, and for low-carbon provinces, the provincial capital city is selected as the pilot city. There is the phenomenon of province and city crossover, which is categorized in the pilot list of the earlier batch, and for the low-carbon provinces, the provincial capital city is selected as the pilot city (Zhang and Huang, 2024). In addition, since the list of the second batch of low-carbon pilot cities was officially determined at the end of November 2012, considering the time lag of the policy, the second batch of the pilot policy is determined to be in 2013 (Feng *et al.* 2021).

3.2.2.1. Intermediate variables

(1) Green technology innovation (*pgpan*). Referring to the research of Sun (2023), this paper chooses the number of green patent applications per 10,000 people to measure the level of green technology innovation in each city.

(2) Industrial restructuring (*industry*). Referring to the research of Guo and Ma (2023), this paper uses the ratio of the output value of tertiary industry to that of secondary industry to measure the industrial structure adjustment. The larger the ratio is, the more reasonable the industrial structure is in the direction of service-oriented adjustment and upgrading, i.e., the more reasonable the industrial structure is.

(3) Entrepreneurial activity (*entre*). Drawing on the research of Zhao et al. (2020), this paper takes the city

population as a standardized base and the number of new start-ups per 100 people in the city as a measure of entrepreneurial activity.

3.2.2.2. Control variables

Drawing on the existing literature, this paper also controls for the following variables: (1) Human capital (*humcap)*, measured by the ratio of the number of students enrolled in higher education institutions to the total urban population (Zhang *et al.* 2022). (2) Degree of fiscal decentralization (*findec*), measured by the ratio of the general revenue of the government's finances to the general expenditures of the government's finances (Liu *et al.* 2023). (3) The level of economic development (*lnpgdp*), measured by the natural logarithm of GDP per capita (Chen *et al.* 2023). (4) The level of financial development (*finan*), measured by the ratio of year-end deposit and loan balances of financial institutions to regional GDP (Guo *et al.* 2023). (5) Population density (*popden*), measured by the number of people per unit of urban area (Guo *et al.* 2024).

3.3. Sample description and data sources

This paper selects the data of 276 cities from 2005 to 2021 as the research sample to empirically analyze the impact of the dual pilot policy of low-carbon and innovative cities on the high-quality development of urban economy. In order to ensure the continuity and comparability of the data, this paper excludes the cities with serious missing data as well as the four municipalities directly under the central government. In addition, continuous variables are all shrink-tailed by 1% before and after to minimize the impact of extreme values on the empirical results. Within the sample, there are 66 low-carbon cities, of which 43.9% are in the eastern region, 27.3% in the central region, and 28.8% in the western region. There are 71 innovative cities in the sample period, including 37 in the eastern region, 19 in the central region, and 15 in the western region. There are 37 dual-pilot cities in the sample, with the most concentrated distribution in the eastern region, accounting for 54.1%, followed by the western region and the least in the central region.

The list of pilot cities is manually organized based on the documents on the official websites of the two ministries and commissions, and the rest of the data is obtained from the China Urban Statistical Yearbook and the Wind database in previous years, and some missing values are filled in by linear interpolation. The descriptive statistics of the main variables are shown in **Table 2**.

Table 2. Descriptive statistics of the main variables

	Obs	Mean	Std. Dev.	Min	Max
hqd	4692	0.307	0.108	0.051	0.815
dualdid	4692	0.063	0.242	0.000	1.000
pgpan	4692	1.056	2.191	0.004	13.930
industry	4692	0.947	0.475	0.252	2.901
entre	4692	1.035	0.901	0.154	5.836
humcap	4692	0.018	0.023	0.000	0.119
findec	4692	0.465	0.223	0.089	1.027
lnpgdp	4692	10.420	0.745	8.604	11.980
finan	4692	2.256	1.044	0.869	6.275
popden	4692	5.723	0.890	2.848	7.138

Table 3. Benchmark regression results

	(1)	(2)	(3)	(4)	(5)
	non-lagging	non-lagging	1 period lag	Lag 2	3-phase lag
	hqd	*hqd*	*hqd*	*hqd*	*hqd*
dualdid	0.010***	0.011***	0.012***	0.011***	0.013***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
_cons	0.306***	0.275***	0.258***	0.249***	0.246***
	(0.000)	(0.040)	(0.041)	(0.043)	(0.043)
Controls	—	YES	YES	YES	YES
City	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES
Obs	4692	4692	4416	4140	3864
R^2	0.953	0.955	0.956	0.957	0.958

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

4. Results and discussion

4.1. Benchmark regression results

Table 3 presents the results of the baseline regression of the dual-pilot policy on the high-quality development of the urban economy. Among them, column (1) shows the regression results without adding any control variables and considering only city and year fixed effects. Columns (2)-(5) show the regression results with the core explanatory variables not lagged, lagged by 1 period, lagged by 2 periods, and lagged by 3 periods, respectively, with the addition of control variables controlling for city and year fixed effects. The results show that the coefficient of the dual-pilot policy is significantly positive regardless of whether control variables are introduced or not, and regardless of whether the core explanatory variables are lagged or not, and how many periods are lagged. It indicates that the implementation of the dual-pilot policy

has a significant positive impact on enhancing the level of high-quality economic development in the pilot cities. Hypothesis 1a is verified.

Table 4. PSM-DID test

	Matching year by year		mix-and-match	
	K-nearest neighbour matching	Nuclear matching	K-nearest neighbour matching	Nuclear matching
	hqd	***hqd***	***hqd***	***hqd***
dualdid	0.007**	0.009***	0.006**	0.008***
	(0.003)	(0.003)	(0.003)	(0.003)
_cons	0.310***	0.293***	0.341***	0.308***
	(0.052)	(0.047)	(0.049)	(0.044)
Controls	YES	YES	YES	YES
City	YES	YES	YES	YES
Year	YES	YES	YES	YES
Obs	2502	3059	2374	3553
R^2	0.958	0.956	0.959	0.954

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

Table 5. Other robustness tests

	(1)	(2)	(3)
	hqd	***hqd***	***hqd***
dualdid	0.014***	0.012***	0.009***
	(0.003)	(0.003)	(0.002)
_cons	0.278***	0.278***	0.321***
	(0.040)	(0.040)	(0.037)
Controls	YES	YES	YES
City	YES	YES	YES
Year	YES	YES	YES
Obs	4607	4692	4675
R^2	0.955	0.955	0.971

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

4.2. Parallel trend test

In applying the double difference model for empirical testing, the key prerequisite is to ensure that the parallel trend assumption holds. This means that before the implementation of the dual-pilot policy, cities should show similar trends in the dynamics of high-quality economic development among themselves. This paper draws on the research of McGavock (2021) to conduct the parallel trend test based on the event study method. The results are shown in *Figure 1*, and in order to avoid the problem of covariance, the paper takes the period before the implementation of the policy as the base period. The results show that none of the coefficients of *dualdid* pass the significance test before the implementation of the dual-pilot policy and satisfy the parallel trend assumption. In the three years after the implementation of the dual-pilot policy, the coefficients are still not significant, but from the fourth year onwards, the coefficients are all significantly positive and show a gradually increasing trend. This indicates that the implementation of the dual-pilot policy can significantly improve the level of high-quality economic development of the city, but there is a certain time lag.

4.3. Robustness Tests

4.3.1. Placebo test

In order to exclude the influence of other unobservable variables on the high-quality development of the city economy during the implementation of the dual-pilot policy, this paper conducts a placebo test on the baseline model by randomly constructing the treatment group and randomly generating the pilot time to ensure the robustness of the empirical results. This is done by randomly selecting 37 pseudo-dual-pilot cities out of 276 cities with the same number of real dual-pilot cities, and randomly matching the policy implementation time as well, on the basis of which the equation (1) is regressed. The above process is repeated 500 times and the kernel densities of the regression coefficients and their p-values for the 500 regressions are plotted in *Figure 2*. The result shows that the regression coefficients after the randomization process are basically distributed around the value of 0, most of them are not significant, and they are significantly lower than the actual benchmark regression coefficient of 0.011 in this paper, which indicates that the effect of the dual-pilot policy on the enhancement of the level of high-quality development of the city's economy is not interfered with by other non-observable factors, and the empirical results of this paper are relatively robust.

4.3.2. PSM-DID test

In the construction process of low-carbon cities and innovative cities, the state may consider the economic

conditions, population size, industrial structure, environmental conditions and other factors of the city and then make decisions, so there is a certain selective bias in the establishment of pilot cities. To solve this problem, this paper utilizes the PSM-DID model for further testing. In the current academic field, for the study of propensity score matching of panel data, scholars mainly tend to use the two major strategies of year-by-year matching and mixed matching, and the two ways have their own advantages and disadvantages, so this paper gives the results of the two test methods, as shown in **Table 4**. The results show that regardless of which way to match, the coefficient of the core explanatory variable *dualdid* is always significantly positive, indicating that the dual-pilot policy has a significant role in promoting the level of high-quality development of the urban economy, and the experimental results of this paper are robust.

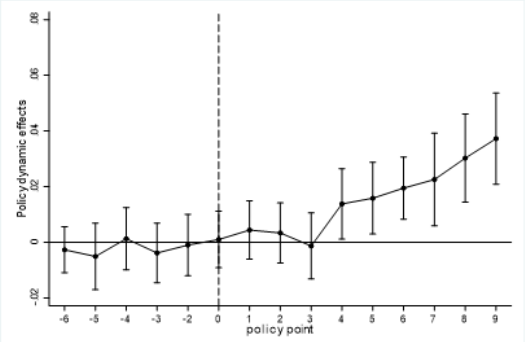


Figure 1. Parallel trend test

4.3.3. Other robustness tests

In addition to the above tests, this paper also conducts robustness tests in the following three aspects: first, changing the sample capacity. Confined to the problem of data acquisition, this paper selects the data of 276 prefecture-level and above cities from 2005 to 2021 as the research sample. Among them, there are five newly established dual-pilot cities in 2018, taking into account that the time lag in the implementation effect of the dual-pilot policy may cause bias in the empirical results. Therefore, this paper empirically tests the impact of the dual-pilot policy on the high-quality development of urban economy again by excluding the five newly established dual-pilot cities in 2018. Second, the impact of other policies is excluded. In addition to the pilot policy of low-carbon cities and the pilot policy of innovative cities, the pilot policy of smart cities may also have an impact on the level of high-quality development of the city's economy, which in turn causes bias in the empirical results. Therefore, this paper adds the dummy variable of smart city pilot policy (*smart*) to the benchmark model to re-regress. Third, the interaction terms of province and time are controlled. In the construction process of pilot cities, each province will combine its own conditions to implement the corresponding policies to promote the green low-carbon and innovative development of the region, the policy support and implementation of different strengths, and thus the impact on the high-quality development of the regional economy is also different. Therefore, this paper further improves the robustness of the baseline model by introducing the interaction terms of province and time.

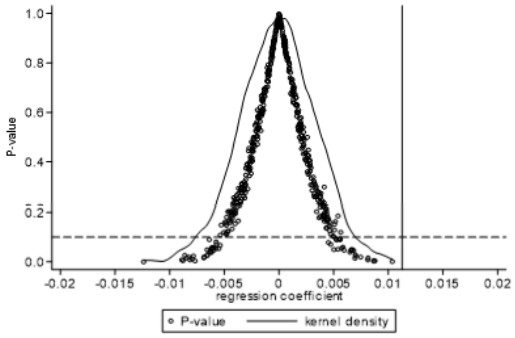


Figure 2. Placebo test

Table 5 presents the regression results of the other robustness tests. The results show that the coefficients of the core explanatory variable *dualdid* are all significantly positive at the 1% level, and the empirical results of this paper are again validated.

Table 6. Results of the mediation effect test

	(1)	(2)	(3)	(4)
	hqd	***pgpan***	***industry***	***entre***
dualdid	0.011***	3.009***	0.047***	0.613***
	(0.003)	(0.178)	(0.017)	(0.052)
_cons	0.275***	20.300***	3.145***	1.047
	(0.040)	(1.912)	(0.339)	(0.712)
Controls	YES	YES	YES	YES
City	YES	YES	YES	YES
Year	YES	YES	YES	YES
Obs	4692	4692	4692	4692
R^2	0.955	0.758	0.859	0.795

Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.

4.4. Impact mechanism test

The results of the mediation effect test are shown in **Table 6**. Column (1) shows the test results of the baseline regression model, and columns (2)-(4) show the regression results of the dual-pilot policy on the level of green technological innovation, industrial structure adjustment and entrepreneurial activity in cities, respectively. The results show that the regression coefficients of the dual-pilot policy on the mediator variables are all significantly positive at the 1% level, indicating that the dual-pilot policy can enhance the economic high-quality development of the pilot cities by promoting the level of green

technological innovation in the pilot cities, facilitating the adjustment of the industrial structure, and enhancing the entrepreneurial activity of the cities. Hypothesis 2 is verified.

4.5. Analysis of spatial spillover effects

4.5.1. Spatial autocorrelation analysis

Considering the combined effects of the city's economic development level and geographic location, this study adopts the economic-geographic distance nested weight matrix to analyze the global autocorrelation of the economic high-quality development level of the 276 prefecture-level cities from 2005 to 2021. The results in **Table 7** indicate that the levels of high-quality economic development are all significantly positive at least at the 5% level for the years 2005-2021, providing preliminary evidence of spatial correlation between the levels of high-quality economic development in the 276 prefectural cities.

Table 7. Global Moran Index values

Year	Moran's I	Z-value	P-value
2005	0.084	2.653	0.008
2006	0.088	2.771	0.006
2007	0.087	2.757	0.006
2008	0.078	2.462	0.014
2009	0.076	2.403	0.016
2010	0.088	2.794	0.005
2011	0.089	2.802	0.005
2012	0.091	2.877	0.004
2013	0.088	2.780	0.005
2014	0.094	2.963	0.003
2015	0.096	3.018	0.003
2016	0.082	2.599	0.009
2017	0.085	2.696	0.007
2018	0.097	3.059	0.002
2019	0.086	2.711	0.007
2020	0.093	2.916	0.004
2021	0.086	2.734	0.006

4.5.2. Analysis of spatial effects

Based on the above spatial autocorrelation test, this paper sequentially carried out the LM test, LR test, Wald test, Hausman test and SDM fixed effects test, etc., and finally determined that the spatial Durbin model with double fixed effects was the optimal choice. The test results are shown in **Table 8**, column (1) shows the overall regression results, which shows that the spatial autoregression coefficient is positive at 1% significance level, indicating that there is a significant spatial dependence on the level of high-quality development of the city's economy. The dummy variable of the dual pilot policy and its spatial interaction term are also significantly positive, indicating that the level of high-quality development of the city's economy will not only receive a positive influence from the pilot policy of this city, but also by the positively influenced by the pilot policies of neighboring regions. Columns (2)-(4) are the direct effect, indirect effect and total effect, respectively, of which the indirect effect is the key basis for judging whether there is a spatial spillover effect. The results show that the indirect effect is significantly positive at the 1% level, indicating that the dual-pilot policy has a significant positive spatial spillover effect on the high-quality development of the urban economy, i.e., the dual-pilot cities, while improving their own technological innovation capacity, promoting the transformation and upgrading of industrial structure and enhancing local entrepreneurial activity, will have a demonstrative role in leading the neighboring areas, which will lead to the enhancement of the innovation and entrepreneurial capacity of the neighboring cities and the optimization of industrial structure, and thus enhance the level of high-quality economic development of neighboring cities. Hypothesis 3 is verified.

Table 8. Spatial Durbin model and its effect decomposition

	(1)	(2)	(3)	(4)
	Main	**direct**	**Indirect**	**Total**
dualdid	0.007***	0.007***	0.014***	0.020***
	(0.002)	(0.002)	(0.005)	(0.005)
W×dualdid	0.012***			
	(0.005)			
W×hqd	0.077***			
	(0.027)			
sigma2_e	0.001***			
	(0.000)			
Controls	YES	YES	YES	YES
City	YES	YES	YES	YES
Year	YES	YES	YES	YES
Obs	4692	4692	4692	4692
R^2	0.059	0.059	0.059	0.059

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

5. Further discussion

5.1. Analysis of synergies of the dual pilot policy

In order to test the synergistic effect of the dual-pilot policy on the high-quality development of urban economy, this paper carries out the following processing: first, analyze the impact of the single-pilot policy of the low-carbon city pilot and the innovative city pilot on the high-quality development of urban economy. Specific operational steps are as follows: first, excluding the sample of low-carbon pilot cities, at which time the coefficient of *innodid* reflects the net effect of the impact of innovative city pilot policies on the high-quality development of urban economy. Similarly, excluding the sample of innovative pilot cities, the coefficient of *lccpdid* at this time reflects the net effect of the impact of low-carbon city pilot policies on the high-quality development of the urban economy. The results are shown in **Table 9**, the coefficients of *innodid* in columns (1)-(3) are always positive at 1% significance level, indicating that the single pilot of innovative cities can significantly improve the level of high-quality development of the pilot city's economy and the effect is more lasting. The coefficients of *lccpdid* in columns (4)-(5) are positive but not significant, and the coefficient of *lccpdid* in column (6) is positive and significant, indicating that the single pilot of low-carbon cities has a promoting effect on the level of

high-quality development of the city's economy, but with a certain time lag.

Table 9. Impact of single pilot on quality urban development

	(1)	(2)	(3)	(4)	(5)	(6)
	non-lagging	lag one phase	Two periods behind	non-lagging	lag one phase	Two periods behind
	hqd	*hqd*	*hqd*	*hqd*	*hqd*	*hqd*
innodid	0.006***	0.007***	0.007**			
	(0.002)	(0.002)	(0.003)			
lccpdid				0.002	0.003	0.004*
				(0.002)	(0.002)	(0.003)
_cons	0.221***	0.202***	0.197***	0.250***	0.241***	0.241***
	(0.043)	(0.044)	(0.047)	(0.037)	(0.038)	(0.039)
Controls	YES	YES	YES	YES	YES	YES
City	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
Obs	3570	3360	3150	3485	3280	3075
R^2	0.950	0.951	0.952	0.949	0.949	0.950

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

Table 10. Comparative Analysis of Dual Pilot and Single Pilot

	(1)	(2)	(3)
	non-lagging	lag one phase	Two periods behind
	hqd	*hqd*	*hqd*
dualdid	0.006**	0.007**	0.007**
	(0.003)	(0.003)	(0.003)
_cons	0.336***	0.323***	0.304***
	(0.063)	(0.065)	(0.068)
Controls	YES	YES	YES
City	YES	YES	YES
Year	YES	YES	YES
Obs	1700	1600	1500
R^2	0.960	0.962	0.963

Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.

Secondly, in order to further analyze the synergistic effect of dual-pilot policies, that is, to verify that dual-pilot policies are more significant than single-pilot policy in improving the level of high-quality economic development. The operation method is as follows: excluding the samples of non-dual-pilot policies from the total sample, and retain the samples that have become low-carbon cities or innovative cities, at which time the coefficient of *dualdid* indicates the net effect of single-pilot policies becoming dual-pilot policies on the impact of high-quality economic development. The test results are shown in **Table 10**, regardless of whether the explanatory variables are lagged, lagged by several periods of treatment, the coefficient of *dualdid* is significantly positive at the 5% level, indicating that the pilot policy of low-carbon cities and the pilot policy of innovative cities have produced policy synergy in promoting the high-quality development of the city's economy, and that the dual-pilot policy has a more significant effect on the promotion of high-quality development of the economy compared with the single-pilot policy. Hypothesis 1b is validated.

5.2. Heterogeneity analysis

5.2.1. Regional heterogeneity

Considering that differences in economic development across regions may lead to different implementation effects of the dual-pilot policy, this paper examines the regional heterogeneity of the impact of the dual-pilot policy on the high-quality development of the urban economy by dividing the cities into the east and the central and west according to their geographic locations. Drawing on the research of Han (2023), this paper first constructs the regional dummy variable (*area*), with the value of 1 assigned to the eastern region and 0 otherwise. Then, on the basis of model (1), we add the cross-multiplier term (*a_dual*) between the regional dummy variable (*area*) and the dummy variable of the dual-pilot policy (*dualdid*) to re-register the model. The results are shown in column (1) of **Table 11**, show that the coefficient of *a_dual* is significantly positive, indicating that the dual-pilot policy has a more significant effect on enhancing the level of high-quality development of the economy in the eastern cities than in the central and western cities. The possible reasons for this are: firstly, compared with the central and western regions, the eastern region has obvious resource advantages in economic development, scientific and technological innovation, talent concentration, etc. These resource advantages provide more development opportunities for the cities in the eastern region, which makes it easier for

them to benefit from the promotion of the dual-pilot policy. Secondly, the industrial structure of the eastern region is more diversified and rationalized, and after the implementation of the dual-pilot policy, the eastern region is able to carry out industrial upgrading and structural optimization more flexibly. Finally, the eastern region usually has a more active capital market and investment environment, which attracts more entrepreneurs to devote themselves to the innovative industries, and promotes increased entrepreneurial activity, and thus facilitates the high-quality development of the urban economy.

5.2.2. Urban scale heterogeneity

Cities of different sizes have huge differences in industrial structure, population density, and resource utilization efficiency, which will inevitably affect the effect of the dual-pilot policy on the high-quality development of the economy. In this paper, according to the Circular on Adjusting the Criteria for the Division of City Scale issued by the State Council in 2014, city scale is divided into large-scale cities and small-scale cities based on whether or not the resident population of a city reaches 5 million as the division criterion. The cross-multiplier term (*s_dual*) of the city scale dummy variable (*scale*, large-scale takes the value of 1, otherwise 0) and the dual-pilot policy dummy variable (*dualdid*) is introduced into the baseline regression model, and the regression results are shown in column (2) in **Table 11**. The results show that the coefficient of the cross-multiplier term is significantly positive at the 1% level, indicating that the dual-pilot policy is more significant in promoting high-quality economic development in large-scale cities. The possible reasons for this are, on the one hand, that large-scale cities have a more complete industrial chain and rich talent resources. The complete industrial chain helps to promote the innovation and development of green and low-carbon technologies and the transformation and upgrading of industrial structure, and rich talent resources further promote the transformation of scientific and technological achievements. On the other hand, large-scale cities tend to have more complete entrepreneurial ecosystems, including venture capital organizations, startup accelerators, etc., which provide more resources and support for entrepreneurs and boost entrepreneurial activities, thus promoting the high-quality development of the urban economy.

5.2.3. Heterogeneity of resource endowments

Given that resource endowment differences between cities also have an impact on the implementation effect of the dual-pilot policy, this paper refers to the National Sustainable Development Plan for Resource-based Cities (2013-2020) issued by the State Council in 2013 to divide cities into resource-based and non-resource-based cities. Column (3) in **Table 11** reports the results of the test for resource endowment heterogeneity, and it can be seen that the coefficient of the cross-multiplier term coefficient is significantly negative, indicating that the dual-pilot policy promotes the level of high-quality economic development of resource-based cities less than that of non-resource-based cities. The possible reasons for this are: firstly, resource-based cities rely on their own resource advantages and tend to rely on traditional resource industries. This dependence makes resource cities have a relatively low incentive to innovate, and the demand for and practice of green innovation is relatively insufficient. At the same time, the insufficient demand for green innovation leads to the relatively low level of entrepreneurial activity in the city, and the emergence and development of innovative enterprises are constrained to a certain extent. Lastly, the development mode and profit model of traditional resource industries are deeply rooted, and the industrial structure is relatively single, which makes it difficult to realize structural upgrading rapidly, and is not conducive to the improvement of the level of high-quality development of its economy.

Table 11. Heterogeneity test results

	(1)	(2)	(3)
	hqd	***hqd***	***hqd***
a_dual	0.045***		
	(0.005)		
s_dual		0.028***	
		(0.005)	
r_dual			-0.030***
			(0.007)
_cons	0.254***	0.286***	0.278***
	(0.041)	(0.040)	(0.040)
Controls	YES	YES	YES
City	YES	YES	YES
Year	YES	YES	YES
Obs	4692	4692	4692
R^2	0.956	0.955	0.955

*Note: * p < 0.1, ** p < 0.05, *** p < 0.01.The numbers in parentheses are robust standard errors.*

6. Conclusions and recommendations

6.1. Conclusions

Based on the panel data of 276 cities in China from 2005 to 2021, this paper uses a multi-period double-difference model to explore the impact of the dual-pilot policy of low-carbon cities and innovative cities on the high-quality development of urban economy, and draws the following conclusions: (1) The implementation of the dual-pilot policy significantly improves the high-quality development of the pilot city's economy, and compared with a single-pilot, the dual pilot has a more significant improvement in the high-quality development of economy. (2) Mechanism analysis reveals that the dual-pilot policy contributes to the realization of high-quality development of the city's economy by promoting the level of green technological innovation, industrial restructuring and entrepreneurial activity. (3) The dual-pilot policy not only promotes the high-quality development of the region's economy, but also has a positive spillover effect on the high-quality development of the neighbouring regions. (4) Heterogeneity analyses show that the dual-pilot policy has a stronger effect on the high-quality economic development of eastern cities, large-scale cities and non-resource cities.

6.2. Recommendations

This study's findings lead this paper to propose the following policy recommendations:

First, the Government should continue to implement the dual-pilot policy of low-carbon cities and innovative cities in an unswerving manner and expand the pilot scale in an orderly and reasonable manner. Pilot cities should give full play to their role as early demonstrators, actively summarize their experiences and promote them effectively, so as to lead other cities to follow suit and provide a reliable reference basis for the orderly expansion of the pilot scope. At the same time, when implementing the green development strategy and innovation-driven development strategy, the government should not only pay attention to the realization of a single policy goal, but also comprehensively consider the synergies between the policies, organically combining the two to form a policy stacking effect, and then maximize the promotion of high-quality development of the urban economy.

Second, the government should increase investment in green technology innovation, actively promote industrial restructuring and optimize the entrepreneurial environment. In terms of green technology innovation, the government can encourage enterprises, universities and scientific research institutions to carry out green technology research and development and application. In terms of industrial restructuring, the government should guide the transformation of the city's industrial structure into a green, low-carbon, technology-intensive and high value-added direction, eliminate backward production capacity and promote industrial upgrading. In terms of entrepreneurial activity, the government and enterprises should optimize the entrepreneurial environment, provide services such as entrepreneurial training, financing support and policy advice, and stimulate innovation and entrepreneurship in the whole society.

Third, interregional cooperation and exchanges should be actively strengthened to promote the sharing of policies, technologies, talents and other resources, and to promote economic interaction and cooperation between the pilot cities and the surrounding areas, so as to achieve win-win results in terms of high-quality economic development. In addition, a regionally integrated market system should be constructed, administrative barriers should be eliminated, the free flow and optimal allocation of factors of production should be promoted, and cities should be encouraged to set up a system of industrial collaboration and division of labor, so as to achieve complementarity of advantages and synergistic development.

Fourth, in formulating policies, the Government should take full account of the differences between pilot cities in terms of geographical location, city size and resource endowment, and plan the policy layout in a scientific and reasonable manner. For example, cities in central and western China can make use of the opportunity of the dual-pilot policy to actively attract capital, technology and talents from the developed regions in the east to promote local industrial upgrading and scientific and technological innovation, and at the same time, combine local resource endowments and market demand to cultivate and develop competitive featured industries and form unique industrial clusters. Small-scale cities should actively support the development of high-tech industries in order to stimulate the vitality of green technological innovation and promote the healthy and sustainable development of urban economy and society. While maintaining the advantages of traditional resource-based industries, resource-based cities should actively cultivate and develop new industries to reduce their dependence on a single resource, and also increase their investment in environmental protection and ecological restoration, so as to promote the transformation of resource-based cities towards green, low-carbon and circular development.

References

Bai, J., Li, W.M. (2022). Innovative city construction, business environment and urban entrepreneurship. Soft Science 36(09): 29-36.

Chen, L.M., Ye, W.Z., Huo, C.J., James, K. (2020). Environmental regulations, the industrial structure, and high-quality regional economic development: Evidence from China. – Land 9(12): 517.

Chen, W., Du, X.Y., Lan, W., Wu, W.L., Zhao, M.R. (2023). How can digital economy development empower high-quality economic development? – Technological and Economic Development of Economy 29(4): 1168-1194.

Du, C.Z., Shu, S., Li, Z.H. (2023). Mechanism and path of new quality productivity in promoting high-quality economic development. – Economic Review Journal (12): 20-28.

Du, M.Z., Feng, R.K., Chen, Z.F. (2022). Blue sky defense in low-carbon pilot cities: A spatial spillover perspective of carbon emission efficiency. Science of the Total Environment 846: 157509.

Feng, T., Lin, Z. G., Du, H. B., Qiu, Y. M., Zuo, J. (2021). Does low-carbon pilot city program reduce carbon intensity? Evidence from Chinese cities. – Research in International Business and Finance 58: 101450.

Feng, Y. C., Wang, X. H., Liang, Z. (2021). How does environmental information disclosure affect economic development and haze pollution in Chinese cities? The mediating role of green technology innovation. – Science of the total environment 775: 145811.

Gao, K., Yuan, Y. J. (2022). Government intervention, spillover effect and urban innovation performance: Empirical evidence from national innovative city pilot policy in China. – Technology in Society 70: 102035.

Gehrsitz M. (2017). The effect of low emission zones on air pollution and infant health. – Journal of Environmental Economics and Management (83):121-144.

Guo, B. N., Wang, Y., Zhang, H., Liang, C. Y., Feng, Y., Hu, F. (2023). Impact of the digital economy on high-quality urban economic development: Evidence from Chinese cities. – Economic Modelling 120: 106194.

Guo, Q. Q., Ma, X. Y. (2023). Study on the effect of pollution reduction of "Broadband China" strategy and low-carbon cities. – Industrial Economics Research (05): 129-142.

Guo, Y. Y., Xie, W. L., Yang, Y. (2024). Dual green innovation capability, environmental regulation intensity, and high-quality economic development in China: Can green and growth go together? – Finance Research Letters 63: 105275.

Han, G. G., Liu, T. G., Guo, X.J., Guo, S. Y. (2023). Can innovative city pilot policy effectively drive the digital transformation of enterprises? – Industrial Economics Research (05): 15-29+71.

Huang, J. C., Zhao, J., Cao, J. (2021). Environmental regulation and corporate RD investment-evidence from a quasi-natural experiment. – International Review of Economics and Finance (72): 154-174.

Jiang T. (2022). Mediating effects and moderating effects in causal inference. – China Industrial Economy (05): 100-120.

Khanna, N., Fridley, D., Hong, L. X. (2014). China's pilot low-carbon city initiative: A comparative assessment of national goals and local plans. – Sustainable Cities and Society 12: 110-121.

Kong, L. Q., Wang, M. L., Yu, S.H. (2023). Impact of innovation-driven policies on total factor energy efficiency: Based on the national innovation city pilot policy. – Resources Science 45(09): 1884-1898.

Kong, Q. X., Peng, D., Ni, Y. H., Jiang, X. Y., Wang, Z. Q. (2021). Trade openness and economic growth quality of China: Empirical analysis using ARDL model. – Finance Research Letters 38: 101488.

Li, C. G., Wan, J., Xu, Z. C., Lin, T. (2021). Impacts of green innovation, institutional constraints and their interactions on high-quality economic development across China.– Sustainability 13(9): 5277.

Li, L., Li, M. Q., Ma, S. J., Zheng, Y. L., Pan, C.Z. (2022). Does the construction of innovative cities promote urban green innovation? Journal of environmental management 318: 115605.

Liu, B., Gan, L., Huang, K., Hu, S. Y. (2023). The impact of low-carbon city pilot policy on corporate green innovation: Evidence from China. – Finance Research Letters 58: 104055.

Liu, B., Li, Y. F., Liu, J. P., Hou, Y. F. (2024). Does urban innovation policy accelerate the digital transformation of enterprises? Evidence based on the innovative City pilot policy. – China Economic Review 85: 102167.

Liu, L., Si, S. S., Li, J. (2023): Research on the effect of regional talent allocation on high-quality economic development—Based on the perspective of innovation-driven growth. – Sustainability 15(7): 6315.

Liu, M. D., Shadbegian, R., Zhang, B. (2017). Does environmental regulation affect labor demand in China? Evidence from the textile printing and dyeing industry. – Journal of Environmental Economics and Management 86: 277-294.

Liu, P. D., Zhu, B. Y., Yang, M. Y. (2021). Has marine technology innovation promoted the high-quality development of the marine economy?—Evidence from coastal regions in China. – Ocean & Coastal Management 209: 105695.

McGavock, T. (2021). Here waits the bride? The effect of Ethiopia's child marriage law. – Journal of Development Economics 149: 102580.

Peng, W. B., Yin, Y., Kuang, C. G., Wen, Z. Z., Kuang, J. S. (2021). Spatial spillover effect of green innovation on economic development quality in China: Evidence from a panel data of 270 prefecture-level and above cities. – Sustainable Cities and Society 69: 102863.

Sun, P. L. (2023). Research on innovation driven policies leading urban green , low carbon and high-quality development: Empirical evidence of innovative city pilot. – Journal of Technical Economics & Management (10): 37-42.

Wang, J. J., Ma, X. J., Fan, Y. J. (2024). Research on the synergy impact between digital economy and technological innovation on high-quality economic development. – Journal of Statistics and Information 39(04): 46-62.

Wang, J. T., Wang, H. R. (2024). Can low-carbon transition promote regional coordinated development? − Empirical evidence from "low-carbon city" construction. – Review of Economy and Management 40(03): 31-44.

Wang, Y. X., Wei, S. Y., He, X., Gu, H. L. (2023). Environmental regulation and entrepreneurial activity: Evidence from the low-carbon city pilot policy in China. – Sustainable Cities and Society 98: 104829.

Wang, Z. J., Wang, H. (2022). Low-carbon city pilot policy and high-quality development of enterprises: From the perspective of economic efficiency and social benefit. – Business and Management Journal 44(06): 43-62.

Xu, W. H., Qi, D. (2023). Research on the impact of low-carbon transformation on regional entrepreneurial activity: Empirical evidence from low-carbon city pilot projects. – East China Economic Management 37(11): 39-49.

Xu, Y. Z., Zhang, R. J., Dong, B. Y., Wang, J.J. (2023). Can the construction of low-carbon cities reduce haze pollution? – Journal of Environmental Planning and Management 66(3): 590-620.

Yang, S. B., Jahanger, A., Hossain, M. R. (2023). How effective has the low-carbon city pilot policy been as an environmental intervention in curbing pollution? – Evidence from Chinese industrial enterprises. Energy Economics 118: 106523.

Yang, Y. X., Su, X., Yao, S. L. (2021). Nexus between green finance, fintech, and high-quality economic development: Empirical evidence from China. – Resources Policy 74: 102445.

Yin, H. Y., Qian, Y. T., Zhang, B., Pérez, R. (2023). Urban construction and firm green innovation: Evidence from China's low-carbon pilot city initiative. – Pacific-Basin Finance Journal 80: 102070.

Zeng, S. B., Jin, G., Tan, K. Y., Liu, X. (2023). Can low-carbon city construction reduce carbon intensity? Empirical evidence from low-carbon city pilot policy in China. – Journal of Environmental Management 332: 117363.

Zhang, M., Huang, Y. L. (2024). Evaluation of the effectiveness of the dual pilot program for low-carbon cities and innovative cities-based on the green economy transition perspective. – Chinese Journal of Environmental Management 16(01): 73-81.

Zhang, S. P., Wang, X. H. (2022). Does innovative city construction improve the industry–university–research knowledge flow in urban China? – Technological Forecasting and Social Change 174: 121200.

Zhang, W., Zhao, S. Q., Wan, X. Y., Yao, Y. (2021). Study on the effect of digital economy on high-quality economic development in China. – PloS one 16(9): e0257365.

Zhang, Y. S., Zhang, S. P., Wang, X. H. (2022). The Impact of Low - Carbon City Construction on Urban High-Quality Development under the Double Carbon Goal: Based on a Quasi-Natural Experiment of the Pilot Policy for Low-Carbon Cities. – Journal of Xi'an Jiaotong University (Social Sciences) 42(05):39-48.

Zhao, T., Zhang, Z., Liang, S. K. (2020). Digital economy, entrepreneurship, and high-quality economic development: Empirical evidence from urban China. – Journal of Management World 36(10): 65-76.

Zhao, W. Q., Toh, M. Y. (2023). Impact of Innovative City Pilot Policy on Industrial Structure Upgrading in China. – Sustainability 15(9): 7377.

Zheng, J. J., Shao, X. F., Liu, W., Kong, J., Zuo, G. S. (2021). The impact of the pilot program on industrial structure upgrading in low-carbon cities. Journal of Cleaner Production 290: 125868.

Zhou, F., Zhao, Y., Liang, R., Zhu, S. W. (2024). Does the combination of low-carbon and innovative policies promote the high-quality development of enterprises?—A quasi-natural experiment based on the “dual pilot” of low carbon and innovation cities. Environment, Development and Sustainability:1-19.

Zhou, T., Huang, X. H., Zhang, N. (2023). The effect of innovation pilot on carbon total factor productivity: quasi-experimental evidence from China. – Energy Economics 125: 106895.