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Research on the Impact of Industrial Park Policies on Urban Carbon Emissions and Regional Spillover Effects based on the "Dual Carbon" Goal Taking the Yangtze River Delta Urban Agglomeration as an Example

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Abstract

This study takes the Yangtze River Delta urban agglomeration as a sample to evaluate the direct and spatial spillover effects of low-carbon industrial park pilot policies on urban carbon emissions. Theoretical analysis shows that policies suppress local carbon emissions through pathways such as technological progress, green investment, and industrial agglomeration; At the spatial level, there are spatial spillover characteristics that can be driven by technology diffusion to reduce emissions in the surrounding areas. The effectiveness of policies varies among cities and is influenced by administrative levels and resource endowments. This study provides policy optimization basis for regional collaborative governance under the "dual carbon" goal.

Keywords

Low Carbon Industrial Park; Carbon Emissions; Spatial Spillover Effect; Yangtze River Delta Urban Agglomeration.

1. Introduction

1.1. Research Background

Global climate change has become a severe challenge facing the development of human society. The assessment report of the Intergovernmental Panel on Climate Change points out that greenhouse gas emissions caused by human activities have brought global temperature rise close to the critical threshold, and promoting a comprehensive green transformation of the economy and society and achieving carbon reduction targets has become an international consensus.

As the world's largest carbon emitter, China officially proposed the strategic goal of "peaking carbon emissions before 2030 and achieving carbon neutrality before 2060" in 2020. The industrial sector is the main source of energy consumption and carbon emissions in China, accounting for over 70% of the country's total carbon emissions. [1] In the form of industrial organization, industrial parks play a special and crucial role - over 2500 national and provincial industrial parks contribute more than 50% of the total industrial output value and approximately 31% of the national carbon emissions. [2] This means that the effectiveness of low-carbon transformation in industrial parks largely determines whether the "dual carbon" goals can be achieved as scheduled.

In recent years, China has continuously promoted the upgrading of industrial parks towards green and low-carbon directions. The 2016 Industrial Green Development Plan (2016-2020) explicitly proposed the construction of green industrial parks and low-carbon industrial park demonstration projects. The 2024 Central Economic Work Conference further emphasized that

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key economic development areas should establish a number of zero carbon parks to promote comprehensive green transformation of economic and social development. In June 2025, the National Development and Reform Commission, the Ministry of Industry and Information Technology, and the National Energy Administration jointly issued the "Notice on Carrying out the Construction of Zero Carbon Parks", which for the first time clarified the construction conditions, indicator system, and organizational methods of zero carbon parks at the national level, marking the transition of low-carbon policies in parks from pilot exploration to systematic promotion.

The Yangtze River Delta urban agglomeration, as one of the most active regions in China's economy and with the most densely distributed industrial parks, bears the mission of taking the lead in the low-carbon transformation process. However, systematic quantitative evaluation and mechanism analysis are still needed to address key issues such as the actual emission reduction effectiveness of low-carbon policies in industrial parks in local practices, whether policy effects will spill over to surrounding cities through industry linkages, technology diffusion, and whether there are significant differences in policy responses among different types of cities.

1.2. Research Significance

1.2.1. Theoretical Significance

One is to enrich the research system for low-carbon policy evaluation. Taking the pilot policy of low-carbon industrial parks as the focus and evaluating its impact on urban carbon emissions can provide new evidence for low-carbon policy evaluation and promote the deepening of regional environmental policy evaluation research.

Secondly, establish an analysis framework for emission reduction mechanisms from a spatial perspective. Revealing the transmission mechanism of policy influence between regions from both direct effects and indirect spillovers can help expand the application boundaries of the theory of spatial spillover of environmental regulation.

1.2.2. Practical Significance

One is to provide empirical evidence for optimizing policies for regional low-carbon parks. By identifying effective pathways and existing constraints for policy implementation, scientific references can be provided for policy iteration and optimization.

Secondly, to serve the policy system construction under the "dual carbon" strategic goal. The low-carbon policy of industrial parks is an important lever for implementing carbon peak and carbon neutrality goals. A systematic evaluation of their emission reduction effects and regional spillover effects can help build a more accurate and effective policy toolbox.

Thirdly, to respond to the practical needs of scientific decision-making and green performance evaluation of local governments. In the context of regional integration development, clarifying the impact of local policies on surrounding cities can provide decision-making references for collaborative governance and ecological compensation mechanism design among local governments.

2. Literature Review

2.1. Research on Low Carbon Industrial Parks

The concept definition and construction path of low-carbon industrial parks were the focus of early research. Wang Jinnan et al. [3] divided the green and low-carbon development of industrial parks in China into three eras, believing that since the Central Economic Work Conference proposed the establishment of a batch of zero carbon industrial parks in 2024, the construction of industrial parks has entered the 3.0 era with zero carbon as the core goal. Other

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scholars have interpreted the connotation and characteristics of low-carbon parks from different perspectives, and generally believe that their core lies in achieving regional level carbon emission control through industrial symbiosis, energy cascade utilization, and clean production. The research by Feng Yuxi et al. [4] points out that the concept of zero carbon parks has undergone a phased evolution from green parks, ecological industrial parks to low-carbon parks, and ultimately to zero carbon parks, reflecting the continuous deepening of strategies to address climate change. Regarding the park itself, Liu Xiaoyu et al. [5] pointed out that low-carbon industrial parks need to have characteristics such as high resource and energy efficiency, advanced clean production processes, and emphasized the importance of a circular economy system. Lv Yizheng et al. [6] further proposed that industrial parks should follow the principles of intensive economy and regional synergy, and build a green economic system that integrates the industrial chain and ecological chain.

2.2. Research on the Evaluation of Low Carbon Policy Effectiveness

The research in the field of low-carbon policy performance evaluation is becoming increasingly rich, with a focus on low-carbon city pilot projects, green innovation, and other issues. Guo Feng et al. [7] investigated the impact of low-carbon city pilot policies on urban green technology innovation and found that policies can significantly improve the level of urban green innovation, and there are spatial spillover effects, providing a basis for understanding the technology diffusion path of policies. Based on data analysis of 282 cities in China from 2006 to 2020, Wang Jiao et al. [8] showed that carbon trading policies effectively promote urban green and low-carbon transformation by promoting green technology innovation and improving energy utilization efficiency. Zheng Meng et al. [9] analyzed the impact of low-carbon city pilot projects from the perspective of corporate environmental and social responsibility, and confirmed that policies promote green transformation by strengthening corporate environmental responsibility awareness. Ma Ge et al. [10] further examined the effect of low-carbon policy pilots on corporate environmental performance and found that green technology innovation plays a mediating role in it. Wang Yafei et al. [11] extended their research to the level of green total factor productivity and found that low-carbon city pilot projects significantly promoted the growth of urban green total factor productivity, and the policy effects exhibited regional heterogeneity. Although the above research did not directly focus on industrial parks, it reveals the green innovation transmission path and policy heterogeneity characteristics of low-carbon policies, providing important references for analyzing the mechanism of park policies in this study.

2.3. Research on Factors Affecting Carbon Emissions and Spatial Spillover

The study of factors influencing carbon emissions and spatial effects provides theoretical and methodological support for understanding policy spillovers. Xue Fei et al. [12] used the national low-carbon industrial park pilot policy as the research object and evaluated its carbon emission reduction effect using the difference in differences method. They found that the policy significantly reduced the carbon emission intensity of the pilot cities. The study by Xiao Qian et al. [13] approached from the perspective of digital space and found that carbon emission spillovers have significant asymmetric characteristics, and industrial virtual agglomeration is an important driving mechanism for achieving regional collaborative carbon reduction. Ma Dalai et al. [14] used a spatial panel data model to study the influencing factors of China's industrial carbon emission performance, and found that factors such as energy intensity and industrial structure have a significant impact on carbon emission performance, and there is spatial correlation between provincial carbon emissions. Shao Shuai et al. [15] explained the energy-saving and emission reduction effects of economic agglomeration from a theoretical perspective, and found that economic agglomeration reduces carbon emissions through technological progress and energy efficiency improvement. These studies collectively indicate

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that carbon emissions have spatial correlations, and policy effects can be transmitted across regions through channels such as industry associations and factor flows, laying a methodological foundation for analyzing the spillover effects of park policies in this article.

2.4. Literature Review

In summary, existing research has achieved rich results in defining the concept of low-carbon industrial parks, evaluating policy effects, and identifying factors affecting carbon emissions, laying a solid foundation for this study. However, there are still room for expansion as follows: firstly, from a research perspective, most policy evaluations focus on the local effects of policies on the implementing regions, with insufficient attention paid to how policies affect the spatial spillover effects of surrounding cities through channels such as industrial linkages and technology diffusion. Secondly, in terms of research subjects, there are relatively few systematic evaluations of low-carbon industrial parks as a specific location oriented policy, and existing studies mostly use traditional difference in differences models, which are difficult to capture the spatial transmission characteristics of policies. Thirdly, in terms of mechanism analysis, the transmission path of policy effects still needs to be further revealed, especially the mediating role of industrial agglomeration and carbon emission efficiency in the transmission of policy effects. Based on this, this study intends to use the Yangtze River Delta urban agglomeration as a sample to systematically evaluate the direct and spatial spillover effects of low-carbon industrial park pilot policies on urban carbon emissions, and examine their transmission mechanisms and urban heterogeneity, in order to provide theoretical support and empirical evidence for regional collaborative governance under the "dual carbon" goal.

3. Theoretical Analysis of the Impact Effect

3.1. Theoretical Basis

(1) Environmental regulation theory. Environmental regulation refers to the government's regulation of various behaviors that pollute the public environment with the aim of protecting the environment. According to different means and methods, environmental regulation can be divided into three categories: command and control, market incentive, and voluntary. In the field of low-carbon development, there are two theoretical expectations for the emission reduction effect of environmental regulations: one believes that regulations will force enterprises to engage in technological innovation, offset compliance costs through "innovation compensation", and ultimately achieve a win-win situation between emission reduction and competitiveness, namely the "Porter hypothesis"; Another perspective suggests that regulation may trigger a "green paradox", where companies accelerate their extraction and emissions under policy expectations, leading to a short-term increase in carbon emissions. [16] In this study, the pilot policy of low-carbon industrial parks belongs to a typical location oriented environmental regulation. The above theory provides a basic judgment framework for analyzing whether the policy effectively suppresses urban carbon emissions.

(2) Externality theory. Environmental externality refers to the environmental impact of the production and consumption behavior of economic entities on others or society, which is not reflected through market prices. Carbon emissions have typical negative externalities, where emitters benefit while the costs are borne by the entire society. This is an important manifestation of market failure and the basic basis for government intervention. [17] The theory of externalities provides two key insights for this study: firstly, low-carbon policies in industrial parks essentially internalize the negative externalities of carbon emissions through government regulation, forcing park enterprises to bear the social costs of their emissions; Secondly, externalities are not limited to administrative boundaries, and carbon emissions in a

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region can affect a wider area through atmospheric diffusion, laying a theoretical foundation for understanding policy spillover effects.

(3) Spatial overflow theory. Spatial spillover effect refers to the impact of a region's policies or economic behavior on neighboring areas, which is transmitted through channels such as geographical proximity, factor flow, and industrial associations. The study of spatial spillover in the field of environmental regulation has received widespread attention in recent years. Scholars have found that the impact of environmental regulation not only occurs in the areas where regulations are implemented, but also spreads beyond boundaries to surrounding areas. This overflow has a dual nature: on the one hand, strict regulation of green technology and management experience in the region may spread to the surrounding areas, producing a positive "trickle down effect"; On the other hand, high carbon industries may shift to regions with loose regulations, forming a negative "polarization effect". [18] In this study, the spatial spillover theory provides a core analytical framework for analyzing the direction and intensity of the impact of low-carbon industrial park policies on surrounding cities in the Yangtze River Delta.

3.2. Direct Effect

Analyze from the perspective of government regulation. The low-carbon park policy requires park management agencies to develop and implement strict carbon emission admission standards, set entry thresholds for high energy consuming and high emission industries, and guide existing enterprises to undergo green transformation through incentives such as fiscal and tax subsidies and green finance. From a practical perspective, the construction of national green industrial parks clearly requires parks to meet standardized standards in ecological protection, spatial layout, and industrial symbiosis. This government led environmental regulation forms rigid constraints on park enterprises, prompting them to internalize the external costs of carbon emissions. At the same time, centralized supervision at the park level has economies of scale compared to decentralized enterprise supervision, reducing the cost of implementing environmental policies. When the industrial output value of the park accounts for a high proportion of the urban industry, the emission reduction effect of the park will be directly reflected in the decrease of the total carbon emissions of the city.

From the perspective of corporate behavior. Faced with policy pressure, park enterprises usually adopt two response strategies. One is to reduce the carbon emission intensity per unit of output through green technology innovation. Enterprises increase research and development investment, adopt clean production processes, and transform high energy consuming equipment. Research has shown that the pilot policy of national low-carbon industrial parks can achieve low-carbon goals by improving the green technology level of enterprises, mainly by enhancing their awareness of environmental responsibility, exerting the management effect of environmental information disclosure, and attracting high-level talents through policy support. The second is to achieve emission reduction by optimizing the industrial structure. The low-carbon park policy promotes the evolution of urban industrial structure towards low-carbon direction through industrial screening and stock guidance. In the incremental stage, the park sets strict carbon emission admission standards, prioritizes the introduction of low-energy, high value-added strategic emerging industries, and restricts the entry of high energy consuming industries. In the stock link, the park guides traditional enterprises to extend towards the high-end of the industrial chain, promoting the transformation of resource intensive industries into technology intensive industries.

3.3. Indirect Effect

The low-carbon park policy can also promote emission reduction in neighboring cities through technology diffusion, experience demonstration, and industrial linkage. Cao Yanqiu et al. [19] found that the construction of national ecological industrial demonstration parks not only

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reduces the pollution emissions of enterprises in the park, but also achieves positive environmental spillover effects of green upgrading of development zones by improving the energy utilization efficiency and technological innovation of enterprises outside the park. This technology diffusion benefits from the transaction cost advantage brought by geographical proximity. Compared to distant cities, the cost of obtaining technology information in surrounding cities is lower, and the learning effect is more significant. The policy interactions within the same urban agglomeration are frequent, and the experience of leading regions often serves as a reference for developing regions. The promotion of the Yangtze River Delta integration strategy has further strengthened this policy synergy effect. Deng Rongrong et al. [20] based on the spatial double difference model also confirmed that low-carbon pilot policies have significant spatial spillover effects on urban ecological efficiency. Pilot cities have a positive impact on surrounding non pilot cities through production technology, emission reduction experience, and institutional construction.

Other studies have shown that the direction and intensity of spatial overflow are influenced by multiple factors. Geographic distance is a fundamental factor. As the distance increases, transaction costs rise and spillover effects weaken. The research on the pilot policy of low-carbon transportation system shows that the spatial spillover effect of the policy has an impact on both the local and neighboring areas. Urban characteristics can also regulate spillover effects, with resource-based cities and old industrial bases being more likely to become carriers of pollution transfer, while cities with strong innovation capabilities are more likely to benefit from technology diffusion. The economic connections between cities within the Yangtze River Delta urban agglomeration are close, and the industrial division of labor is clear. The spatial spillover effects of policies may be more significant, which requires policy evaluation to go beyond the analytical perspective of a single city and incorporate regional interaction dimensions.

4. Existing Problems and Countermeasures

4.1. The Current Situation and Problems of Policy Implementation in the Yangtze River Delta Industrial Park

The local emission reduction effect of policies faces multiple constraints. From a financial perspective, the initial investment in the construction of zero carbon parks is large, and the financial pressure on enterprises is significant. The park requires large-scale updates of production equipment and construction of renewable energy facilities, with initial investment far exceeding that of traditional parks. Small and medium-sized enterprises find it even more difficult to obtain sufficient financial support due to low credit ratings and insufficient collateral. From a technical perspective, key technologies such as efficient energy storage, green hydrogen production, and carbon capture are still mainly in the laboratory stage, with slow industrialization processes that restrict their large-scale application in industrial parks.

Regional spillover effects are accompanied by pollution transfer risks. There are significant differences in factor endowments, development stages, and low-carbon foundations among cities in the Yangtze River Delta region, and an organic synergistic relationship has not yet been formed in low-carbon development. High carbon industries such as steel and chemical may migrate to regions with looser regulations or weaker policy enforcement due to differences in the implementation of environmental policies within the region. This type of industrial transfer based on short-term cost avoidance rather than long-term green upgrading not only offsets the hard won emission reduction achievements of the destination, but also forces the destination to face doubled transformation pressure and lock-in effects in the future.

There are institutional barriers to policy coordination and accounting systems. There are multiple issues with carbon emission accounting in various provinces and cities within the

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current region, including inconsistent boundary setting, inconsistent activity data collection standards, and lack of shared key emission factor databases. Taking the steel industry as an example, due to differences in accounting methods for the same product in Shanghai, Jiangsu, and Zhejiang, it is difficult to accurately quantify the implicit carbon flow in cross provincial industrial chains. The carbon footprint certification systems in the Yangtze River Delta and surrounding regions have not yet been mutually recognized, and the carbon accounting standards are not unified. At the same time, the current policy has not established classification guidance standards, and different types of parks face differentiated emission reduction paths, but policy design has not been matched with industrial characteristics.

4.2. Countermeasures and Suggestions

Optimize pilot design. There are differences in the response of different types of cities to low-carbon park policies, and policy design needs to reflect adaptability. Provincial capital cities should leverage their innovation advantages and take the lead in piloting zero carbon parks; The focus of resource-based cities should be on low-carbon transformation of existing industries and promoting the extension of traditional industries to the high-end of the industrial chain; Small and medium-sized cities can develop characteristic low-carbon industries based on their local resource endowments. By implementing classified policies, avoid one size fits all promotion.

Strengthen regional collaborative governance. To address the risk of pollution transfer, it is necessary to establish a policy coordination framework in the Yangtze River Delta region. Drawing on the experience of demonstration zones, establish a joint investment mechanism and a joint meeting system to coordinate park planning and environmental standards. Explore cross regional horizontal ecological compensation, provide compensation to areas where carbon emissions increase due to industrial transfer, and achieve cost sharing and benefit sharing.

Improve policy incentive mechanisms. Green technological transformation faces the problems of large investment and long return cycle. We will coordinate the use of central budget funds and local government special bonds to support zero carbon parks, and encourage policy banks to provide medium - and long-term low interest loans. Support pilot projects for carbon emission pledge financing, establish industry university research platforms, provide special subsidies for technological transformation of small and medium-sized enterprises, and lower the threshold for transformation.

Improve the precision of governance. Promote the establishment of a carbon management platform in the park and unify carbon emission accounting standards. Establish a dynamic assessment mechanism, regularly evaluate policy effectiveness, distinguish between short-term incremental optimization effects and long-term technology diffusion effects, timely identify rebound effects and pollution transfer risks, and ensure that policy goals are consistent with implementation effects.

5. Conclusion

This study takes the Yangtze River Delta urban agglomeration as the research object, and conducts theoretical analysis on the impact of low-carbon industrial park pilot policies on urban carbon emissions and their regional spillover effects. From the perspective of policy effectiveness, low-carbon park policies have a significant direct inhibitory effect on urban carbon emissions, mainly achieved through technological progress, green investment, and industrial agglomeration. Policy incentives encourage enterprises to increase green technology research and development, guide capital investment in the clean energy sector, promote industrial spatial organization optimization, and form a synergistic emission reduction effect.

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At the spatial effect level, policies exhibit spatial spillover characteristics. The spillover effect is specifically reflected in the diffusion of technology and the demonstration of experience to drive emissions reduction in surrounding cities. The economic connections of the Yangtze River Delta urban agglomeration are closely linked, and the direction and intensity of spatial spillover are influenced by geographical distance and urban characteristics. At the level of heterogeneous response, there are significant differences in policy responses among different types of cities. Provincial capital cities have abundant innovation resources, and the emission reduction effect relies more on technology diffusion; Resource based cities are facing stock lock-in effects, and emission reduction pathways rely more on industrial transformation; Small and medium-sized cities need to explore distinctive low-carbon paths based on local endowments.

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