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Establishment of eco-industrial parks and urban carbon emissions

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Abstract: As a concrete practice form of green development concept in the industrial field, eco-industrial park is an important realization way to solve the problem of ecological environment deterioration and promote regional sustainable development. Using a quasi-natural experiment of eco-industrial parks approved nationwide, the impact of eco-industrial parks on carbon emissions in their cities is empirically examined using panel data of 283 prefecture-level cities nationwide. The empirical study found that: the policy of setting up eco-industrial parks can significantly enhance the carbon emission reduction effect of cities, and it shows the characteristics of accumulation and accumulation. Further research shows that the establishment of eco-industrial parks has an incentive effect on the achievement of carbon emission reduction targets in both local and neighboring cities. Therefore, we should further promote the construction of eco-industrial parks, and give full play to the positive effect of eco-industrial parks on the realization of the national "double carbon" target.

1. Introduction

Over the past 40 years of reform and opening up, an important engine to promote the rapid development of local economy is the industrial park. This has made it a new focus of regional development and even a new growth point of regional economy. At the micro level, enterprises can easily obtain production factors and infrastructure through the establishment and construction of industrial parks, and at the same time, enterprise managers are influenced by the preferential policies of industrial parks when deciding on their own location and production decisions. At the macro level, the establishment of industrial parks will encourage most manufacturing production sectors to form clustering effect in the region and provide sufficient development space for the formation of industrial clusters, thus realizing local economic growth[1]. In recent years, industrial parks in China have been booming. Since the first industrial park was established in 1979, various types of industrial parks have been developed rapidly in the following 40 years with the help of different industrial development policies, and as of 2018, there are 552 national-level development zones of various types in China, and the establishment of these parks has played the role of a booster for local economic development. The White Paper on Top 100 Research on the Development Competitiveness of China's National Industrial Parks shows that the GDP growth rate of development zones and eco-industrial parks at all levels in China is much higher than the national average for the same period [2]. However, the trend of declining urban environmental quality has been intensified under the influence of accelerating industrialization, and the concentration of "three high" enterprises in traditional industrial parks has easily caused massive consumption of resources and excessive emission of greenhouse gases, which has brought enormous pressure on local environmental quality and environmental management[3]. Especially in some areas, industrial parks have even become synonymous with high pollution and high energy consumption areas. Since the economy newly entered the new normal, China's economy has gradually shifted to the stage of high-quality development. At present, how to balance the relationship between economic development and ecological environmental protection has become one of the focuses of academic circles[4]. In the context of the new development concept and the goal of "double carbon", China urgently needs to explore a new industrialization path that is consistent with green economic growth, which can sustainably promote economic growth while achieving the goal of factor saving and environmental improvement as much as possible[5]. Eco-industrial parks, with the concept of green development as the goal, have certain advantages in reshaping the organizational model and have become one of the important paths to achieve high-quality development of urban economy. Compared with traditional industrial parks, eco-industrial parks add green, low-carbon and recycling requirements to the entry threshold, which can further improve the quality of regional economic development, organically combine economic growth and ecological protection, and ultimately achieve the green development goal of energy saving and emission reduction. Through literature combing, the articles develop that although there are more literature on the economic and social effects brought by the establishment of eco-industrial parks, there are more articles that take economic and technological development zones or high-tech industrial development zones at all levels as the research objects, and mainly carry out the discussion in terms of trade, industrial agglomeration, policy effect, entrepreneurship, factor market, spillover mechanism and economic performance assessment[6]. The few papers on eco-industrial parks also adopt qualitative analysis, and the conclusions obtained are limited to a certain extent[7]. As a representative of gathering new industries, eco-industrial parks, with the concept of green development, link different manufacturing enterprises and industrial sectors through institutional innovation, build an industrial symbiosis system by means of logistics, form a closed-loop cycle of factors, multi-level utilization and feedback of market information, and gradually improve the symbiotic organization form of resource sharing and mutual exchange of industrial by-products, aiming to achieve the double improvement of economic growth and environmental quality in the parks[8]. The aim is to achieve the double enhancement of economic growth and environmental quality improvement. It can be seen that the construction of eco-industrial parks can include more goals for environmental protection on the basis of economic development, which is in line with the goal of building a sustainable society in China [9]. Therefore, revealing whether the carbon environment improvement can be brought by the establishment of eco-industrial parks through quantitative research has certain reference value in promoting high-quality economic development and complementing the environmental effect effecteffect triggered by the establishment of new parks. In view of this, this paper empirically investigates the impact of eco-industrial parks on urban carbon emission reduction. Since eco-industrial parks are not approved in the same year and their establishment has temporal and spatial variability, this paper selects a double difference model to analyze the strength of this policy effect[10].

Compared with previous research results, the marginal contribution of this paper is mainly reflected in the following three aspects: First, this paper uses quantitative analysis methods and double difference models to evaluate the impact mechanism of eco-industrial park policies on urban carbon emissions[11]. At present, most of the literature on industrial parks focuses on development zones or eco-industrial parks, and the research results that analyze the contributions and effects brought by eco-industrial parks mostly adopt a qualitative perspective to discuss the situation and problems of the development of such parks themselves and the similarities and differences of different development models, while the few papers that adopt quantitative analysis methods mostly use DEA models to evaluate the economic and environmental performance of eco-industrial parks[12]. The few papers that use quantitative analysis methods mostly use DEA models to evaluate the economic and environmental performance of eco-industrial parks. Thus, this paper takes the establishment of eco-industrial parks as a quasi-natural experiment and adopts a double difference model to assess its impact on urban carbon emission reduction, which complements the study of environmental effects of eco-industrial park construction[13]. Secondly, this paper explores the mechanism of the relevant paths from three perspectives: energy efficiency, industrial structure and green technological innovation[14]. Thirdly, China's economy is in the stage of shifting from high-speed growth to high-quality development, and the green transformation of manufacturing industry has become the main governance task of most local governments, so the construction of eco-industrial parks with green development attributes has a certain driving effect on neighboring cities[14]. Thus, this paper integrates the double-difference spatial Durbin model to explore whether there is a spatial spillover effect.

2. Study design

2.1 Model setting

The DID method is often used in event studies, and the establishment of national eco-industrial parks is a major event in the change of industrial development mode and local economic development. In this paper, the benchmark regression model is set according to the principle of double difference method as follows.

$$CO2_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 \sum X_{it} + \delta_t + \gamma_i + \varepsilon_{it} \quad (1)$$

$CO2_{it}$ is the explanatory variable of this paper, representing the level of carbon emissions in cities, andDID_{it} is the dummy variable representing the establishment of national eco-industrial parks; the policy effect of the establishment of national eco-industrial parks isα_1 is a set of control variables.X_{it} is a set of control variables.δ_t is the dummy variable representing the level of urban carbon emissions; the policy effect of the establishment of national eco-industrial parks is denoted byγ_i is denoted as a series of control variables; the urban fixed effects are denoted asε_{it} then denotes the random disturbance term.

2.2 Variable setting and data description

Urban carbon emission level (CO2). In this paper, urban carbon emission is divided into two levels: one is total carbon emission; the other is urban carbon emission intensity. Thus, drawing on the idea of Yin-Yin Wu et al. (2021), urban carbon emissions are divided into total carbon emissions and carbon intensity, both of which are taken as logarithms. For the calculation of total carbon emissions at the prefectural level, this paper adopts the method provided by the international IPCC, which multiplies fossil energy consumption and carbon emission factors to obtain the total carbon emissions of cities by year.

Eco-industrial parks (DID). The number of eco-industrial parks owned by each city is not equal in the process of approval, i.e., multiple eco-industrial parks may exist in the same municipality at the same time. Therefore, in determining the establishment time variable of eco-industrial parks in different cities, cities with only one eco-industrial park are defined according to the establishment year, i.e., the value is 0 before the establishment and 1 after the establishment, and for cities with multiple eco-industrial parks, only the establishment year of the first eco-industrial park in the municipality is considered, i.e., the value is 0 before the establishment of the first eco-industrial park and 1 after the establishment. After that, the value is 1.

Mechanism variables. Industrial coordination effect (ind). The index of industrial structure rationalization is used as a proxy variable; green technology innovation (GI). The number of green patent applications by year in the city was used as a proxy variable; energy use efficiency (eff). Urban labor force (total employment in the city in calendar years), energy consumption (urban natural gas and electricity consumption) and capital stock were selected as input variables, urban GDP was used as desired output, and urban CO2 emissions in calendar years were used as non-desired output indicators, while the DSBM method was then used to obtain urban total factor energy efficiency in calendar years as a proxy variable.

Control variables. The control variables selected in this paper include: per capita GDP (lnpgdp); share of manufacturing industry (strind); share of total retail sales of social goods (strls); share of actual foreign capital utilization (strwz); population density (popden); share of private and individual employment (strsq); financial support (strpub); share of hydroelectric power generation (lnslfd).

3. Empirical Analysis

3.1 Baseline regression results

Table 1: Regression results of the establishment of eco-industrial parks on urban carbon emissions

	(1)	(2)	(3)	(4)
	lnCO2	lnCO2	lncogdp	lncogdp
DID	-0.053*** (0.016)	-0.069*** (0.016)	-0.087*** (0.025)	-0.097*** (0.029)
lnpgdp		-0.012** (0.004)		-0.218*** (0.066)
strind		-0.068*** (0.016)		0.039 (0.041)
strls		-0.297*** (0.074)		-0.141*** (0.044)
strwz		-0.067*** (0.012)		0.189 (1.155)
popden		-1.041*** (0.119)		-0.387*** (0.074)
strsq		-1.263*** (0.277)		2.206 (3.337)
strpub		-0.397*** (0.044)		0.388*** (0.049)
lnslfd		-0.894*** (0.298)		-0.901*** (0.301)
Constant term	-1.375*** (0.172)	-1.458*** (0.117)	-3.302*** (0.189)	-3.553*** (0.115)
Observations	3679	3679	3679	3679
Time fixed effects	No	Yes	No	Yes
Urban fixed effects	No	Yes	No	Yes
R2	0.5095	0.5383	0.5402	0.5113

Note: ***, **, and * denote statistically significant at the 1%, 5%, and 10% levels, respectively; all of the above regressions use robust standard errors with cities as the clustering variable. Same below.

Based on the previous analysis, in order to test the hypothesis H1 proposed in this paper, Table 1 shows the effects of the establishment of eco-industrial parks on urban carbon emissions. Columns (1) and (2) show the regression results without and with a series of control variables, respectively. The regression coefficients of DID variables in both columns are always significantly positive at the level of 1% or less. This indicates that the construction of eco-industrial parks significantly suppresses urban carbon emissions, which verifies the accuracy of hypothesis H1 in this paper.

3.2 Parallel trend test

Table 2 presents the results of the parallel trend hypothesis tests that include the full sample in this paper. According to the previous hypothesis, we conducted parallel trend tests on the experimental group sample (i.e., cities with eco-industrial parks) and the control group sample (cities that do not have them yet). The regression results are shown in Table 2. The coefficients of the interaction terms before 2011 are not significant, while the coefficients of the interaction terms afterwards show a gradual increase in the negative effect, indicating that the carbon reduction effect triggered by the policy implementation is more obvious and generally meets the requirements of the parallel trend test.

Table 2: Parallel trend assumption test results

Independent variable	lnCO2	lncogdp
Treat*year2009	0.007 (0.151)	0.013 (0.217)
Treat*year2010	0.015 (0.203)	0.029 (0.202)
Treat*year2011	-0.028*** (0.005)	0.033 (0.316)
Treat*year2012	-0.026** (0.009)	-0.039*** (0.008)
Treat*year2013	-0.029** (0.009)	-0.051*** (0.007)
Treat*year2014	-0.036*** (0.006)	-0.069*** (0.014)
Treat*year2015	-0.039*** (0.007)	-0.068*** (0.012)
Treat*year2016	-0.044** (0.014)	-0.077*** (0.013)
Treat*year2017	-0.056** (0.016)	-0.071*** (0.009)
Treat*year2018	-0.051*** (0.012)	-0.079*** (0.012)
Treat*year2019	-0.058** (0.018)	-0.073*** (0.015)
Treat*year2020	-0.067*** (0.015)	-0.077*** (0.012)
Control variables	Yes	Yes
Time fixed effects	Yes	Yes
Urban fixed effects	Yes	Yes
Observations	3679	3679
R2	0.5591	0.5624

3.3 Robustness test

PSM+DID test. This paper further draws on the idea of Dachian Shi et al. (2018), and in terms of methodology, in order to ensure the effective matching of two types of cities that have eco-industrial parks and those that do not yet have eco-industrial parks, this paper chooses the one-to-one nearest neighbor matching method and adds covariates (i.e., using control variables for characterization), so as to address the selectivity bias problem to a certain extent. Specifically, the logit method is applied to measure the policy dummy variables against the control variables, which in turn yields the scores after propensity matching, and samples with similar scores are affiliated with the same group, and subsequently it is also necessary to verify whether significant differences exist in the screened experimental and control groups. It can be seen that there are no more significant differences in the matched test results, indicating the validity of the PSM+DID method. Subsequently, the DID regression coefficients in column (1) of Table 3 are less different from those shown in Table 1, corroborating the scientific validity of the findings of this paper.

Instrumental variable method. Selecting appropriate instrumental variables for the core explanatory variables is the main method to avoid endogeneity from interfering with the regression results. In this paper, in terms of natural conditions, cities with a higher density of navigable rivers in their jurisdictions have lower transportation costs, which can easily contribute to the clustering of industrial enterprises, and higher-level environmental authorities will focus on monitoring these potentially polluting enterprises. To gain recognition from higher levels, local governments will propose clear environmental development goals. Moreover, river density is closely related to local natural conditions and will not be influenced by urban carbon emissions. Thus, this paper draws on Shi Lei et al. (2022) and selects urban river density (iv) as its instrumental variable. Columns (3) and (4) in Table 3 demonstrate the regression results of the instrumental variable method, showing that the coefficients are less different from the baseline regression results above and pass the instrumental variable test.

Table 3: Robustness test results

Robustness Approach	PSM+DID lnCO2	lncogdp	Instrumental Variables Method DID	lnCO2	lncogdp	Excluding other policy effects lnCO2 lncogdp	
			Phase I	Phase II			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DID	-0.067*** (0.014)	-0.086*** (0.019)		-0.066*** (0.013)	-0.089*** (0.014)	0.069*** (0.011)	0.082*** (0.010)
Iv			0.049*** (0.009)				
hdid						0.040*** (0.008)	0.038** (0.012)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Urban fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3614	3614	3679	3679	3679	3679	3679
R2	0.6662	0.6924	0.5023	0.5118	0.4874	0.4951	0.4577

Excluding the effects of other policies. In the baseline regression, does the "net effect" exist in the relationship between the establishment of national eco-industrial parks and urban carbon emission reduction? Is there any interference of urban carbon emissions by other related policies? By combing the environmental policy documents issued by the government after 2010, this paper selects the carbon emission trading pilot policy for further analysis. It is well documented that, controlling for a range of variables, the implementation of this policy can effectively reduce the level of urban carbon emissions and increase the incentive of industry to green transformation. In terms of the timing of the start of the carbon emissions trading pilot policy, seven provinces and cities were approved to carry out local pilot carbon emissions trading in 2011, so this paper establishes the corresponding policy dummy variable hdid (set to 1 for the year in which the pilot city was established and thereafter, and 0 for the rest of the years). From columns (6) and (7) in Table 3. It can be seen that the carbon trading pilot policy significantly reduces the total carbon emission and carbon emission intensity. And in this case, the regression coefficient of the policy dummy variable for the establishment of eco-industrial parks increased. This finding indicates that the pollution reduction effect of eco-industrial parks is more significant.

3.4 Heterogeneity test

The overall impact and transmission mechanism of the industrial support policy of eco-industrial park establishment on urban carbon emission has been analyzed above, but from the perspective of the economic base and development stages of different types of cities, the degree of effect of eco-industrial park establishment on alleviating carbon emission reduction in different types of cities may vary.

3.4.1 Resource-based and non-resource-based cities

Referring to the existing literature, the sample is divided into two categories (i.e., resource-based and non-resource-based cities) and the regressions are estimated separately. The regression results in Table 4 show that both types of cities are subject to the disincentive effect from the establishment of eco-industrial parks, and the environmental welfare effect brought by the establishment of eco-industrial parks is significantly higher in resource-based cities than in non-resource-based cities in terms of the degree of impact, which may be mainly due to the fact that resource-based cities have an industrial structure dominated by resource-dependent industries and face stronger pressure to reduce emissions, so resource-based cities are more willing to seek to reduce carbon emissions with the bonus of the policy of establishing eco-industrial parks. Therefore, resource-based cities are more willing to seek to reduce carbon emissions with the bonus of the policy of setting up eco-industrial parks.

Table 4: Results of heterogeneity analysis (1)

	Resource-based		Non-resource based	
Variables	lnCO2	lncogdp	lnCO2	lncogdp
DID	-0.076*** (0.015)	-0.079*** (0.007)	-0.064*** (0.014)	-0.068*** (0.009)
Observations	1508	1508	2505	2505
Time fixed effects	Yes	Yes	Yes	Yes
Urban fixed effects	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
R2	0.7402	0.7129	0.6221	0.6147

3.4.2 Heterogeneity test of the city's own characteristics

There are differences in the level of infrastructure and financial development in different types of cities. Since the green manufacturing industry belongs to a category of high-tech industries, its development is deeply integrated with the level of transportation infrastructure construction, so the different levels of transportation infrastructure construction may make the establishment and construction of high-tech zones have different effects on the level of urban carbon emissions. Secondly, according to the mean value of the infrastructure construction level (i.e., mileage per capita in cities) of the whole sample, cities are divided into two categories, above and below the mean value. At the same time, since the transformation of high-carbon industries depends to a large extent on the support of financial institutions, cities with a certain scale of financial markets have an advantage in terms of capital accumulation and can provide credit services to manufacturing enterprises that are willing to carry out green transformation. Thus, this paper divides the full sample of cities into two categories by the mean value of the degree of financial development (i.e., the share of total deposits and loans of financial institutions in the city's GDP). The regression results in Table 5 show that the establishment of eco-industrial parks can play a greater role in emission reduction in cities with a higher degree of urban infrastructure construction and a better level of financial development, which indicates that the emergence of the environmental welfare effect of eco-industrial park construction requires certain infrastructure investment and capital strength as an aid.

Table 5: Results of heterogeneity analysis (2)

			Infrastructure			
	Above average			Below average		
Variables	lnCO2	lncogdp	PM2.5	lnCO2	lncogdp	PM2.5
DID	-0.519*** (0.089)	-0.412*** (0.111)	-0.071*** (0.015)	-0.294*** (0.028)	-0.096*** (0.022)	-0.038*** (0.007)
Observations	2145	2145	2145	2100	2100	2100
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Urban fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.5149	0.5210	0.5311	0.5221	0.5047	0.5620
	Financial Development					
	Above average			Below average		
Variables	lnCO2	lncogdp	PM2.5	lnCO2	lncogdp	PM2.5
DID	-0.484*** (0.081)	-0.228*** (0.037)	-0.036*** (0.008)	-0.239*** (0.063)	-0.082*** (0.014)	-0.023*** (0.004)
Observations	2040	2040	2040	2205	2205	2205
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Urban fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.6129	0.6244	0.5759	0.6317	0.6027	0.6123

4. Research Conclusions and Policy Recommendations

4.1 Research findings

This paper analyzes the effect of the establishment of eco-industrial parks on the level of urban carbon emissions using panel data constructed from 283 prefecture-level cities across the country during 2008-2020, and the research methodology uses a multi-period double difference (multi-period DID) model. The results found that: first, in general, the establishment of eco-industrial parks can enhance the carbon emission reduction effect of cities across the country, and the conclusions consistently hold after dealing with the endogeneity issue and conducting a series of robustness tests. Second, the mechanism analysis shows that eco-industrial parks achieve urban carbon emission reduction by promoting industrial coordination, green technological innovation and energy efficiency. Third, eco-industrial parks have the strongest carbon emission reduction effect on cities with higher resource-based cities, infrastructure construction level and financial development.

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