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RESEARCH ARTICLE

The impact of eco-industrial parks on urban haze pollution: evidence from China

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Abstract
With the green, circular, and low-carbon concept, eco-industrial parks are regarded as key drivers for maximizing environmental and economic benefits. Based on the panel data of 276 cities in China from 2007 to 2018, this paper regards the establishment of eco-industrial parks as a quasi-natural experiment, and employs the difference-in-differences method to test the impact of eco-industrial parks on urban haze pollution. We find that eco-industrial parks significantly reduce urban haze pollution and the conclusion holds with robustness tests. Heterogeneity analysis shows that the effect of eco-industrial parks on haze pollution is more pronounced in eastern and resource-based cities. Finally, mechanism analysis indicates that eco-industrial parks reduce urban haze pollution mainly by promoting technological innovation, upgrading industrial structure, and strengthening urban environmental regulations.

Keywords: industrial parks; eco-industrial parks; haze pollution; difference-in-differences

JEL classification: L16; L52; Q53

1. Introduction

Severe haze pollution is a major public concern in some developing countries with high economic growth such as China. In order to solve the environmental problems, China has put forward requirements of scientific, law-based, and systematic pollution control in 'The 14th Five-Year Plan for the National Economic and Social Development and the Outline of Long-Term Goals for 2035'. However, China's air pollution is still very serious. According to the Report on the State of the Ecology and Environment in China 2019, 53.4 per cent of the 337 cities at the prefecture level and above fail to meet national air quality standards, and the days with PM2.5 as the primary pollutant comprise 78.8 per cent of the days under heavy or very heavy pollution. Severe air pollution jeopardizes people's health (Khomenko *et al*., 2021; Chen *et al*., 2023*a*), increases healthcare expenditures (Zhang *et al*., 2023), and adversely affects economic development.

China has been devoted to exploring how to optimize economic organization and remedy the environmental degeneration caused by rapid industrialization. During the past years, industrial parks such as development zones and high-tech zones have been widely established in China. These industrial parks which are conducive to gathering economic resources and driving the agglomeration development of related industries are considered to provide environmental benefits (Lu *et al.*, 2019). However, some researchers believe that industrial agglomeration aggravates environmental pollution (Wu *et al.*, 2023). Moreover, they point out that industrial parks do not pay enough attention to building a circular economy and managing exhaust gas emissions. Recently, several studies suggested that these traditional industrial parks can be transformed into Eco-industrial Parks (EIPs), which are more beneficial to improving energy efficiency and pollution prevention (Mathews *et al.*, 2018).

In countries such as Denmark, the United States, and Canada, the EIP program has been implemented for over a decade. They apply the concept of green, recycling, low-carbon, and environmental protection to the infrastructure construction and enterprise development of parks. In China, the government initiated the construction of EIPs in 2000. By 2020, the number of EIPs had increased to roughly 55. Meanwhile, a lot of EIPs were under construction. However, is this new type of industrial park conducive to solving the problems of high energy consumption and high pollution in traditional industrial parks? Is it a form of economic organization that contributes to alleviating haze pollution? What is the mechanism by which it affects haze pollution? Answering these questions is significant to understanding how the country promotes the industrial parks' green transformation and improves environmental quality.

Based on the panel data of 276 prefecture-level cities in China from 2007 to 2018, this paper regards the construction of the EIPs as a policy shock and evaluates the impact of EIPs on urban haze pollution. The result shows that the construction of EIPs reduces haze pollution significantly. Heterogeneity analysis shows that the effect of EIPs on haze pollution is more pronounced in eastern and resource-based cities. In addition, we find that the key mechanisms through which EIPs affect urban haze pollution are promoting technological innovation, upgrading industrial structure, and strengthening urban environmental regulations.

This paper contributes to the existing studies in two ways. First, a strand of literature has regarded traditional industrial parks as an industrial agglomeration area (Xiong *et al.*, 2022; Lu *et al.*, 2023*b*), and investigated the impact of industrial agglomeration in the park on environmental pollution. Some researchers believe that traditional industrial parks are conducive to reducing environmental pollution (Lu *et al.*, 2023*b*). But more researchers hold different views on this and they proposed that traditional industrial parks can exacerbate haze pollution (Hou *et al.*, 2019; Lu *et al.*, 2019; Wu *et al.*, 2023). Therefore, the present study tries to fill the gap by examining the impact of EIPs in China on haze pollution. Moreover, this paper addresses the problem of estimation bias caused by reverse causality and the non-randomness of policy. In the past, industrial parks have been considered as the gathering place and refuge for polluting enterprises (Schwarze, 1996; Hou *et al.*, 2019). The conclusion of this paper shows that the new type of industrial park represented by EIPs has numerous environmental benefits, and provides inspiration for promoting the green and recycling transformation of traditional industrial parks.

Second, most of the current studies on EIPs mainly focus on defining what EIPs are and how they develop. For example, Geng *et al.* (2007) analyzed the advantages and challenges of investing in EIPs. Fang *et al.* (2007) investigated the establishment of China's

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EIPs and stated that the development of EIPs is still in its infancy. Zeng *et al.* (2021) systematically analyzed China's EIPs, and found that EIP interventions have improved both environmental and competitiveness performances. However, there is an apparent lack of empirical research regarding the assessment of the policy effects and environmental benefits. This paper fills the gap by evaluating the impact of EIPs on haze pollution in China. In addition, based on the establishment principle and indicators of China's EIPs, we comprehensively analyze the mechanism by which EIPs affect haze pollution from the perspectives of technological innovation, industrial upgrading and environmental regulations. This research can inform policymakers on how to optimize the construction of EIPs, and promote EIPs' contribution to reducing environmental pollution and achieving sustainable development.

2. Institutional background and theoretical analysis

2.1 Institutional background

As a catalyst for industrial development, traditional industrial parks have made important contributions to China's economic development, but they have caused serious pollution to the environment (Lu *et al.*, 2019; Wu *et al.*, 2023). This issue is proposed to be addressed through their transformation into EIPs which follow the green development concept and seek to achieve the win-win balance between economic growth and environmental protection. Enterprises within EIPs are required to achieve green and low-carbon transformation and development, and control pollution emission load within a permissible range. EIPs have gradually established an infinitely reusable, recyclable, and renewable industrial ecosystem, and the air pollutants and emissions in EIPs have been significantly reduced (Chertow, 2000; Qian *et al.*, 2022).

What is more, enterprises in EIPs can reduce haze pollution by applying cleaner production technologies, optimizing energy structure, and taking other emission reduction measures. On the one hand, EIPs provide green technical support to enterprises in the parks by introducing high-level talent and teams. On the other hand, strict environmental regulation implemented in EIPs forces enterprises to increase R&D expenditures for clean energy technologies (Wu *et al.*, 2023), thus reducing air pollutant emissions. Moreover, EIPs promote green technological progress by encouraging enterprises to optimize energy structure and use non-fossil and renewable energy, which is conducive to reducing haze pollution (Qian *et al.*, 2022). Besides, high technology and low pollutant emissions enterprises attracted by EIPs can also promote the green transformation of traditional enterprises, which is conducive to achieving industrial structure upgrading and emission reduction. Detailed operational aspects of the EIPs are described in the online appendix of this paper.

Figure A1 in the online appendix shows the number of newly added EIPs every year in China up to 2016. During the sample period of this paper, in 2008, the former State Environmental Protection Administration named Suzhou Industrial Park, Suzhou National Hi-Tech District and Tianjin Economic-Technological Development Area for the first time as the National Eco-industrial Demonstration Parks. Since then, the construction of EIPs has been in full swing. By 2016, 48 EIPs had been approved for operating, and 45 EIPs had been approved to start construction.

The geographic distribution of EIPs in China is shown in figure 1. There are 31, 11, and 6 EIPs in eastern, central and western China, respectively. Because the number of EIPs in the eastern region significantly exceeds that of other regions, one may be concerned that the location of EIPs may be endogenous. To alleviate the endogeneity caused

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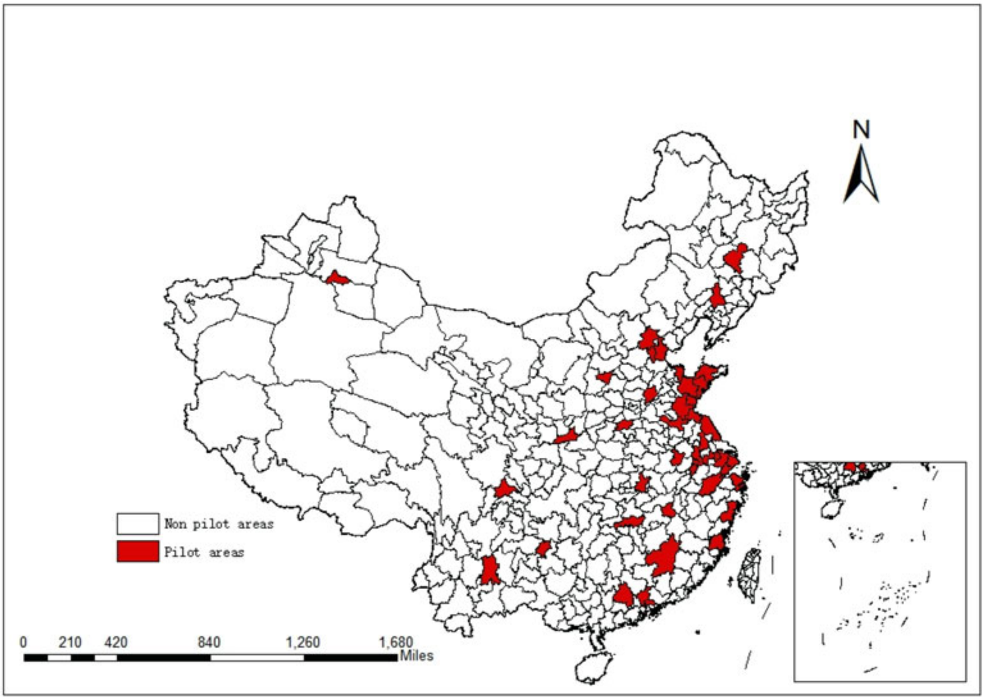

Figure 1. Distribution of EIPs in China.

by the location of EIPs, we employ the propensity score matching (PSM) method and instrument variable (IV) strategy to strengthen causal inference.

2.2 Theoretical analysis

EIP policy aims to promote regional eco-industrial development, and it offers an innovative pathway to realizing energy saving, emission reduction and environmental protection. Under the rigorous and standardized requirements, the EIPs effectively drive technological innovation, industrial structure upgrading, and environmental regulation, which in turn affects haze pollution. The influence mechanisms through which EIPs affect haze pollution are shown in figure A2 in the online appendix.

First, the construction of EIPs reduces haze pollution through technological innovation in two main ways. (1) EIP projects have accelerated technological innovation. According to the National Eco-Industrial Demonstration Park Management Measures, the government must offer abundant financial and fiscal support for EIPs to introduce advanced innovation talents and cleaner technologies, which can help EIPs improve their technological innovation level and reduce air pollutant emissions. Meanwhile, after being certified as EIPs, the parks introduce many favorable policies to encourage the development of high-tech enterprises, thus attracting a tremendous amount of well-established high-tech companies at home and abroad. For example, there are about 500 production-oriented enterprises and most of them are high-polluting enterprises in Nanchang National High-tech Industrial Development Zone (NNHIDZ). With the construction of environmental protection platforms and advanced environmental protection technologies, NNHIDZ significantly improves local air quality. According to the above analysis, we believe that EIPs can reduce haze pollution through promoting technological innovation. In addition, according to the existing literature, location-oriented policies such as EIPs can significantly improve the innovation level. For example, Wu *et al*. (2023) regard EIPs as a quasi-natural experiment and used a difference in differences (DID) model to examine the impact of EIPs on urban green innovation. They found that the establishment of EIPs significantly increases the number of green patent applications.

And (2), green technological innovation is conducive to reducing environmental pollution. The specific manifestations are front-end prevention and back-end governance. In terms of front-end prevention, green technological innovation drives the emergence of digital environmental protection projects such as intelligent pollutant monitoring systems and early environment warning systems, which effectively prevent and control pollution sources. Moreover, the continuous development and application of production, energy-saving and environmental protection technology enables enterprises to substantially improve energy efficiency and reduce pollutant emissions (Chen *et al*., 2022). In terms of back-end governance, green technological innovation promotes the improvement of pollution control facilities and strengthens the reuse of pollutants, thereby improving environmental quality. For example, Tianjin municipality launched a special fund of $100 million to support green development in the Tianjin Economic-Technological Development Area. The fund provided subsidies for appropriate green innovation projects including the comprehensive utilization of resources, the construction of distributed photovoltaic power stations, cleaner production, and the construction and operation of hydrogen refueling stations. This measure effectively incentivizes enterprises in parks to promote technological innovation in the production process, increase capital investment in pollution control and reduce greenhouse gas emissions.[1]

Second, the construction of EIPs reduces haze pollution through industrial structure upgrading, again in two main ways. (1) EIPs have positively contributed to industrial transformation and upgrading. In EIPs, there are two ways to promote industrial upgrading, namely, supporting the green transformation of energy-intensive industries and developing emerging green industries. The green transformation of traditional high-polluting and energy-intensive industries is a gradual process that is likely to span a decade or more. In this process, the negative impacts of green transformation on haze pollution can come into effect within a short period of time, and they will increase significantly as time goes on (Tong *et al*., 2020). What is more, EIPs introduce favorable policies for high-tech industries with green technological innovation, encouraging the green and low-carbon transformation of traditional pollution-intensive industries (Li *et al*., 2015). Therefore, EIPs can reduce haze pollution within two years through industrial upgrading. (2) The industrial upgrading promotes pollution prevention and control (Grossman and Krueger, 1995). The secondary industry is considered as the major contributor to environmental pollution. Therefore, it is bound to reduce pollutant emissions when the proportion of the secondary industry drops and the proportion of the emerging industry rises (Cole *et al*., 2005; Li and Li, 2022). Moreover, compared with polluting industries, the development model of emerging industries is sustainable and can produce a demonstration effect, forcing the polluting industries to reduce pollutant emissions.

[1] See https://www.teda.gov.cn/contents/3952/225761.html for more information.

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Third, the construction of EIPs reduces haze pollution through environmental regulation for two reasons. (1) The establishment of EIPs can strengthen urban environmental regulations. Compared with traditional industrial parks, EIPs are required to meet many compulsory indicators, including elastic coefficient of comprehensive energy consumption, application ratio of renewable energy and so on. This means that EIPs impose higher requirements for cleaner production and environmental protection. (Zeng *et al*, 2021; Qian *et al.*, 2022; Wu *et al.*, 2023). Therefore, EIPs can produce a strong demonstration effect on the local area and improve the level of environmental regulations. (2) The strict environmental regulation is conducive to reducing haze pollution. EIPs have stricter environmental regulations, and set the performance indicators such as industrial technology level, resource and energy utilization efficiency, pollutant emissions, and economic benefits. The enterprises in the parks are required to meet these environmental goals. EIPs also implement compulsory audits of cleaner production, improving clean production levels of enterprises. What is more, in EIPs, there are specific standards for the total discharge quota of key pollutants. In addition, EIPs require enterprises to disclose environmental information, including waste, by-products and residual energy, which may be useful for other enterprises' production. During this process, other enterprises can recycle and reuse the production materials and products as long as possible, thus promoting the establishment of a circular economy model and reducing haze pollution.

Based on the above theoretical analysis, this paper proposes the following hypotheses:

Hypothesis 1 (H1): The construction of EIPs can reduce urban haze pollution.

Hypothesis 2 (H2): The construction of EIPs reduces haze pollution through technological innovation, industrial upgrading, and environmental regulations.

3. Research design and data

3.1 Model

Based on the panel data of 276 prefecture-level cities in China from 2007 to 2018, this paper regards the establishment of EIPs as a quasi-natural experiment. Because the start-up time of EIPs is not the same, with reference to Bertrand *et al.* (2004), a DID model is constructed as follows:

$$\ln PM2.5_{it} = \alpha_0 + \alpha_1 EIP_{it} + \sum \gamma_j X_{it} + \mu_i + \nu_t + \varepsilon_{it}, \quad (1)$$

where i and t denote city and year, respectively. The dependent variable is the natural logarithm of annual PM2.5. EIP_{it} is a dummy variable, and if city i started the construction of the EIP in year t, then EIP_{it} equals 1 since year t, and otherwise it equals 0. α_1 is the coefficient that we focus on to test whether EIPs have a reduction effect on annual PM2.5 concentrations. X_{it} is a set of control variables. μ_i and ν_t refer to the city and year fixed effects respectively. ε_{it} is the error term.

3.2 Variables and data sources

(1) Dependent variable. The dependent variable is urban haze pollution levels measured as PM2.5 concentrations. PM2.5, as one of the primary air pollutants, is believed to reflect the overall level of haze pollution effectively (Burkhardt *et al.*, 2019; Heyes and Zhu, 2019; Chen *et al.*, 2023*b*). The existing literature mainly obtains the annual average PM2.5 concentration data from Columbia University (Lin *et al.*, 2014;

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Fu *et al.*, 2015). Instead of this data set, the data used in this paper come from the Atmospheric Composition Analysis Group at Dalhousie University in Halifax. ArcGIS software is used to extract and transform the data from the global data set published by this institution, and then we obtain the urban annual average PM2.5 concentration for China. Although the data from both Columbia University and Dalhousie University are collected with ground-based tracking stations and National Aeronautics and Space Administration satellites, the data set used in this paper has the following advantages. First, the data set published by Dalhousie University is available for a much longer time period than data released by Columbia University. Second, the data set in the paper achieves higher accuracy. The reason is that, before 2014, the data set produced by Columbia University only contains three-year average PM2.5 concentrations rather than annual average observations.

(2) Independent variable. The independent variable is EIP policy, an indicator to reveal whether the EIPs have been approved for establishment in the city. EIP equals 1 if the city was approved for the park construction, or one of the industrial parks in the city is approved for an EIP officially; EIP equals 0 otherwise. The list of EIPs comes from the website of the Ministry of Ecology and Environment of the People's Republic of China. It is worth noting that both the operational parks and the parks under construction are included in the treatment group. In further analysis, we investigate heterogeneity in treatment effects across the two groups of parks. Because our sample period is from 2007 to 2018, we exclude the cities whose establishment year of EIP is 2001 and 2003. Furthermore, some cities have more than one EIP which were established in different years; in this case, we take the year when the first EIP was established as the year that the EIP policy came into effect. Finally, there are a total of 276 cities, including 48 in the treatment group and 228 in the control group.

(3) Control variables. To ensure that the results are not driven by omitted variables, we control some factors that may influence haze pollution and use lag-one period as controls. Specifically, the control variables are defined as follows. The level of economic development, ED, is measured by GDP per capita. Population size, PS, is measured as the total population of the city at the end of the year. Industrial structure, IS, is measured as the proportion of the output value of the tertiary industry to GDP. The level of secondary industry development, SD, is measured as the proportion of the output value of the secondary industry to GDP. The level of infrastructure development, ID, is defined as the length of road construction. The level of opening-up to the outside world, OP, is measured by the ratio of FDI and GDP.[2]

3.3 Descriptive statistics

The sample of this paper consists of 2007–2018 data on 276 prefecture-level cities in China. The descriptive statistics of each variable are presented in table 1.

4. Empirical results

4.1 Parallel trend test

The prerequisite for the DID is to meet the parallel trend test, that is, the haze pollution levels in the treatment group and the control group should have the same changing trend before the implementation of EIP policy. Referring to Beck *et al.* (2010), this paper tests

[2]The data are obtained from the China Research Database Services.

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Table 1. Descriptive statistics

	Variables	N	Mean	Min	Max
Dependent variable	lnPM2.5	3,300	3.650	1.280	4.702
Independent variable	EIP	3,312	0.095	0	1
Mediating variables	Technology innovation (TI)	3,285	2.547	0	11.052
	Industrial structure upgrading (AIS)	3,305	0.910	0.006	5.340
	Industrial structure upgrading (RIS)	3,310	0.876	0.527	0.997
	Environmental regulation (ER)	3,213	0.057	0	0.170
Control variables	The level of economic development (ED)	3,299	10.46	4.595	13.06
	Population size (PS)	3,307	5.869	2.898	8.131
	Industrial structure (IS)	3,230	0.391	0.182	0.696
	The level of secondary industry development (SD)	3,235	0.489	0.190	0.770
	The level of infrastructure development (ID)	3,293	12.93	5.466	17.76
	The level of opening-up to the outside world (OP)	3,307	0.003	0	0.115

the parallel trend based on equation (2),

$$\ln PM2.5_{it} = \beta_0 + \beta_k \sum_{k=-7}^{7} EIP_{it}^{k} + \sum \gamma_j X_{it} + \mu_i + \nu_t + \varepsilon_{it}, \tag{2}$$

where $\ln PM2.5_{it}$ represents the haze pollution level of city i in year t. k denotes the k-th year of the establishment of the EIPs. EIP_{it}^{k} represents a series of dummy variables for the relative time of establishment of EIPs (7 to 2 years before the EIPs were established, in the year when the EIPs are established, and 1 to 7 years after the EIPs are established). In particular, we define EIP_{it}^{-7} as equal to 1 if the establishment year is for 7 or more years before the establishment of the EIP, otherwise 0. EIP_{it}^{7} is equal to 1 if the observation is for seven or more years after the establishment of the EIP, otherwise 0. The coefficient β_k captures the differential effect of the construction of EIPs on urban haze pollution. Other parameters and variables are defined in accordance with model (1).

The test results are presented in figure 2. It shows no significant difference between the haze pollution levels of the treatment group and the control group before the construction of EIPs, which provides evidence for satisfying the parallel trend assumption and the effectiveness of the DID model. The effect of haze pollution reduction follows parallel trends until one year after the establishment of EIPs (time '1' on the horizontal axis); thus, there is a lagged effect of EIPs on air quality improvement. The reason is that

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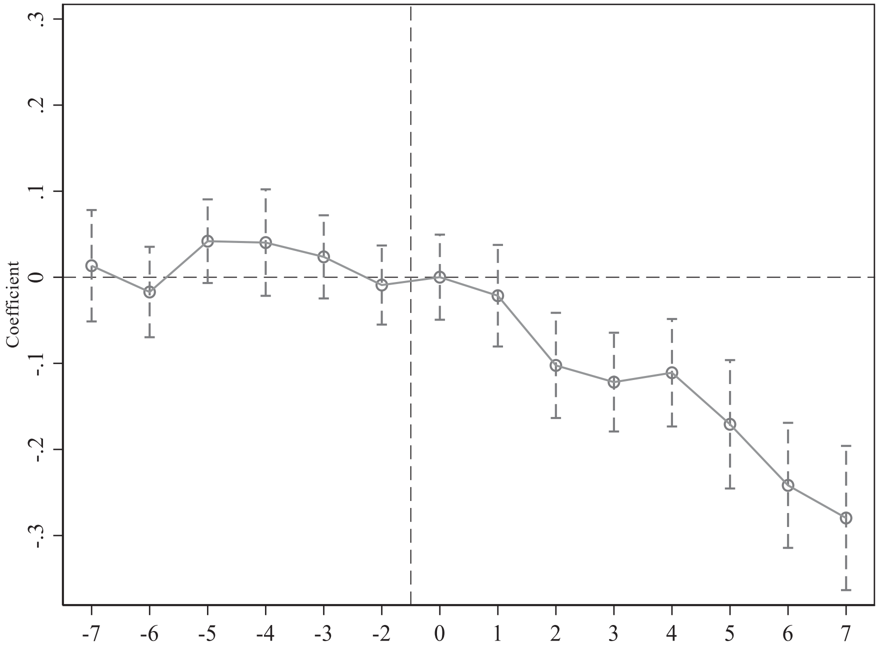

Figure 2. Parallel test.
Notes: All effects are relative to the one year before the policy went into effect.

the traditional business philosophy that prioritizes production over environmental protection is still rooted at the beginning of policy implementation. In addition, it takes time for EIPs to affect urban haze pollution. In the second year after their establishment, the EIPs exert the effect of decreasing haze pollution levels gradually and the effect remains stable until the fourth year. In the following years, the policy effect gradually strengthens, illustrating that the effect of EIPs on haze pollution in the long run is still significant.

4.2 Baseline results

After confirming that the parallel trend hypothesis is satisfied, the paper adopts the DID approach to evaluate the effect of the establishment of EIPs on haze pollution based on the two-way fixed effects model. Table 2 presents the results. We control the city and time fixed effects in all columns. Column (1) does not include any control variables and the estimated coefficient is significantly negative at the 1 per cent level. Columns (2)–(7) gradually cover the full set of control variables. Almost all of the estimates are still significant at the 1 per cent level, indicating that the construction of EIPs can effectively reduce haze pollution and improve urban air quality. The main reason is that the EIPs, which are designed with the principle of reducing, reusing and recycling, improve the urban air quality.

4.3 Instrumental variable

Another potential pitfall is the non-randomness of the distribution of EIPs across cities. We tested for the common trends in the DID estimation to rule out the possibility that

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Table 2. The effect of establishing EIPs on haze pollution

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	lnPM2.5	lnPM2.5	lnPM2.5	lnPM2.5	lnPM2.5	lnPM2.5	lnPM2.5
EIP	−0.161 (0.019)	−0.057 (0.021)	−0.043 (0.021)	−0.043 (0.016)	−0.043 (0.016)	−0.043 (0.015)	−0.042 (0.015)
ED		−0.171 (0.011)	−0.162 (0.012)	−0.161 (0.007)	−0.161 (0.007)	−0.051 (0.012)	−0.052 (0.012)
PS			−0.278 (0.102)	−0.279 (0.059)	−0.279 (0.059)	−0.198 (0.059)	−0.196 (0.059)
IS				−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
SD					0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
ID						−0.087 (0.008)	−0.087 (0.008)
OP							1.021 (0.958)
Time FE	YES	YES	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES	YES	YES
Constant	3.666 (0.002)	5.447 (0.118)	6.979 (0.544)	6.981 (0.336)	6.977 (0.336)	6.478 (0.332)	6.475 (0.332)
Observations	3,300	3,287	3,283	3,282	3,282	3,264	3,264
R^2 within	0.032	0.185	0.190	0.192	0.193	0.228	0.228

Notes: The level of economic development (ED), measured by GDP per capita (logarithm). Population size (PS), measured as the total population of the city at the end of the year (logarithm). Industrial structure (IS), measured by the proportion of the output value of the tertiary industry to GDP. The level of secondary industry development (SD), measured by the proportion of the output value of the secondary industry to GDP. The level of infrastructure development (ID), defined as the length of road construction (logarithm). The level of opening-up to the outside world (OP), measured by the ratio of FDI and GDP. All control variables are lagged by one period. Standard errors in parentheses.

confounding events might bias our estimates, and this section provides additional support using an IV approach. We use predicted EIPs as the IV for real establishment of EIPs. Specifically, first, following the forecasting method proposed by Lipscomb *et al.* (2013), we predicted the likelihood of the placement of EIPs based on predetermined local geographic attributes over each of the five-year periods (see online appendix table A1). Second, referring to Lu *et al.* (2023*a*), we further adopted a jackknife method and estimated the probability of having an EIP. This 'leave-out'estimate partly alleviates the concern about a weak instrument problem as it is less likely to violate the exclusion restriction criterion. Then, we ranked the cities based on the estimated probability, as was done by Duflo and Pande (2007), and generated a 0/1 variable on the predicted EIP, for the top N_j cities if the province launched N_j EIPs during that period. The predicted EIP serves as an IV for the actual EIP. Table 3 shows the results of IV estimation based on the two-stage least square (2SLS) strategy. Column (1) shows the first-stage result, which indicates the IV is a very strong positive predictor of establishing EIPs with a Cragg-Donald Wald F-statistic larger than 10, eliminating the problem of weak IVs. The second-stage result is shown in column (2); although the absolute estimation is

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Table 3. IV estimation

	(1)	(2)
	First-stage estimates	Second-stage estimates
	EIP	lnPM2.5
IV	0.075 (0.000)	
EIP		−0.228 (0.125)
Cragg-Donald Wald *F*-statistic	31.518	
Control variables	YES	YES
Observations	3,170	3,170

Notes: Standard errors in parentheses.

much larger than those in the traditional DID estimation, the 2SLS estimate confirms the negative relationship of EIPs and haze pollution.

5. Extensive analysis

5.1 Robustness test

5.1.1 PSM-DID

Cities with EIPs tend to invest more in environmental protection and the public may have stronger environmental awareness to embrace a better ecological environment. For this reason, referring to Heckman *et al.* (1998), this paper uses the PSM method to match the treatment group and the control group cities within a common value range, and then estimate the model with the DID method. Our matching approach begins with selecting matching variables. The variables include the level of economic development, population size, industrial structure, level of secondary industry development, level of infrastructure development, and level of opening-up to the outside world. Next, we use the logit model parameter estimation to obtain the propensity score. Finally, the observations sharing a similar propensity score are matched. This paper adopts three approaches to find a matched control city for each of the treatment cities, namely, nearest neighbor matching, radius matching and kernel matching. We then perform DID estimation after matching.[3] The results are reported in table 4, and indicate that EIPs have significantly improved urban air quality.

5.1.2 Placebo test

In order to ensure the robustness of the conclusions of this research, and to further examine the influence of EIPs on haze pollution without the interference of other unobservable factors, this paper performs a placebo test (Li *et al.*, 2016). Specifically, the data are first grouped according to cities. One year was randomly selected from the year variable in each city as its policy time to construct the policy dummy variable, and then model

[3]It should be noted that after matching and before estimating the coefficients, balance tests should be further conducted. The results are not presented here due to space limitation. The absolute values of the standard deviations of each variable are greatly reduced after matching. The *t*-test of each variable does not reject the null hypothesis that the two sets of data are not significantly different, indicating that PSM has a better matching effect on the sample cities.

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Table 4. PSM-DID estimation results

	(1)	(2)	(3)
	Nearest neighbor matching	Radius matching	Kernel matching
Variable	lnPM2.5	lnPM2.5	lnPM2.5
EIP	−0.070 (0.015)	−0.121 (0.016)	−0.119 (0.016)
Control variables	YES	YES	YES
Time FE	YES	YES	YES
City FE	YES	YES	YES
Constant	5.713 (0.363)	7.010 (0.374)	7.159 (0.351)
Observations	2,511	2,795	3,242
R^2 within	0.228	0.071	0.066

Notes: Standard errors in parentheses.

(1) was used for regressions. We repeated the above process 1000 times, and figure A3 (online appendix) plots the *p*-value and the distribution of regression coefficient kernel density. In figure A3, the influence coefficient of EIP on haze pollution in the baseline regression is marked with dashed lines. It can be seen that the coefficients of EIP policy under the placebo test are mostly concentrated around 0, which is obviously different from the actual estimated parameters, which proves that the influence effect of EIP on haze pollution does not result from unobservable factors, and thus indicates that the results of the baseline regression are robust.

5.1.3 Additional robustness checks

We present a set of additional robustness checks of our baseline regression results to buttress the causal interpretation of our results. First, following Wu *et al.* (2023), we assume the year in which each city first constructs an EIP is the policy year. However, one concern is the expectation effects. Specifically, industrial parks may take environment protection measures to meet the requirement of the environment commitment statement before submitting the development plan and thus increase the possibility of being approved for EIP construction. To further verify that the establishment of the EIPs is an exogenous shock, we examine the expectation effects by constructing a dummy variable Before1. Before1 equals one if the observation year is for one year before the EIP construction and zero otherwise. Then, we include the dummy in our baseline regression along with our control variables. The result in column (1) of table A2 in the online appendix shows that the coefficient of Before1 is not significant, indicating that the establishment of the EIPs cannot be predicted by the environment protection measures taken in advance, which further alleviates the endogeneity concern about the expectation effects.

Second, we prune the baseline sample in two ways to ensure that cities/provinces with specific characteristics are not driving the results. (1) We exclude the centrally administered municipalities. The administrative level of centrally administered municipality is the same as a province, which gives them advantages in urban pattern, economic level and policy preferences over an ordinary prefecture-level city. (2) We exclude provinces without EIPs. The research objects are 276 prefecture-level cities in China, and it is worth

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noting that the EIPs are mainly established in economically developed provinces. In order to improve the comparability between the treatment group and the control group, this paper excludes provinces without EIPs. (3) We exclude the observation of the EIPs under construction. An EIP under construction is not accepted and named officially, which may bias estimates of EIPs on local air quality. The results reported in columns (2)–(4) of table A2 in the online appendix suggest that our baseline result is robust to sample selection bias.

Third, any other events during the sample period that affected haze pollution may bias our estimates. We consider three contemporary policies to alleviate the confounding effects. (1) The new environmental protection law. China's new Environmental Protection Law, implemented on January 1, 2015, is the nation's first attempt to harmonize economic and social development with environmental protection. It improves environmental regulation and details harsher penalties for environmental offences, which may have a positive impact on air quality. (2) The low-carbon city (LCC) pilot project. In 2010, the Chinese government announced the first batch of cities and provinces to carry out the LCC project. Subsequently, the list of the second and third batches of pilots was released in 2012 and 2017, respectively. The implementation of LCC projects has effectively accelerated low-carbon technological innovation and reduced carbon emissions (Yang *et al*., 2023). (3) The Carbon Emission Rights Trading Pilot (CERTP) policy. The National Development and Reform Commission has organized several clusters of CERTPs, in 2011, 2013 and 2016. The goal of CERTP policy is reducing greenhouse gas emissions at a much lower cost and upgrading industrial structure. In this regard, CERTP policy has a positive effect on reducing haze pollution. The results presented in table A3 in the online appendix show that, after controlling for the enactment of environmental laws, low carbon city policy, and emission trading pilot policy, the coefficients of EIP continue to be significantly negative, supporting our main hypothesis.

Fourth, to investigate whether our baseline result is robust to the measurement of variables, we consider the alternative proxy. The paper employs the number of EIPs in prefecture-level cities as a substitute independent variable and the results are shown in column (1) of table A4 in the online appendix. We further employ the SO_2 emissions as proxies for haze pollution. The regression results shown in columns (2)–(3) of table A4 indicate that the construction of EIPs reduces urban SO_2 emissions, which is consistent with our main result.

5.2 Heterogeneous analysis

5.2.1 Heterogeneity of resource endowments

Differently from non-resource-based cities, the economic development of resource-based cities depends on the exploitation and processing of natural resources, leading to severe resource exhaustion and environmental deterioration (Yu *et al*., 2022). Therefore, we test the difference of EIPs on the haze pollution of cities with different resource endowments. We classify the sample cities based on their resource endowments according to the Plan of Sustainable Development for Resource-based cities in China (2013–2020) issued by the State Council. Specifically, 111 prefecture-level cities are defined as resource-based cities, while another 165 cities are defined as non-resource-based cities. The results are presented in columns (1)–(2) of table A5 in the online appendix. We find that the establishment of an EIP can not only promote the improvement in air quality in resource-based cities, but also in the non-resource-based city. What is more, the empirical P-value used to test the significance of the differences between

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the coefficients is 0.000, suggesting that the difference is significant. The results clearly illustrate that for resource-based cities, the effect of EIPs on haze pollution is more pronounced. The reason may be that resource-based cities often rely on heavy industry for development and may suffer from resource-exhaustion and serious pollution in the long term. EIPs promote the formation of an industry symbiosis of sharing resources and exchanging by-products. This can help resource-based cities escape the curse of natural resources.

5.2.2 Geographic heterogeneity

The eastern coastal region of China has the rational industrial structure high marketization level and favorable conditions for innovation, which are helpful in exerting the reduction effect of EIPs on haze pollution (Yang *et al.*, 2023). Compared with the eastern region, China's central region and western regions are landlocked. The economic development of landlocked regions heavily relies on the resource-based industries with high pollution and high energy consumption; therefore, these regions do not lay a solid foundation for the development of 'high-tech' industries (Yu and Zhang, 2022). These characteristics make it difficult to exert the reduction effect of EIPs. According to figure 1, the number of EIPs in western China is also significantly less than that in the eastern and central regions. According to the above analysis, we try to examine the heterogeneous effects of different regions. Cities are divided into three groups according to their location, namely Eastern China, Central China, and Western China. Table A5 in the online appendix presents the impact of the EIPs on haze pollution in different regions. The coefficient is negative at the 1 per cent level of significance in column (3), whereas it does not pass the significance test in columns (4) and (5). Meanwhile, the empirical P-value between the eastern and central, eastern and western, central and western are 0.000, 0.000 and 0.050, respectively. The results suggest that the difference is significant, meaning that compared with central and western cities, the air quality in eastern cities has been greatly improved due to the EIPs.

5.3 Mechanism analysis

In this section, we examine intrinsic influence mechanisms through which the EIP affects urban haze pollution. We check the connection between EIP and green technological innovation (GTI), industrial structure upgrading (ISU) and environmental regulation (ER). The specific regression model is as follows:

$$M_{it} = \lambda_0 + \lambda_1 EIP_{it} + \sum \theta_j X_{it} + \mu_i + \nu_t + \varpi_{it}, \tag{3}$$

where M represents the mechanism variable The other variables are consistent with equation (1). First, we use the number of patents of the city as a measure of technology innovation. Second, referring to Gan *et al.* (2011), we use two measures to calculate the industrial structure upgrading: rationalization of industrial structure (RIS) and advancement of industrial structure (AIS). We obtain industrial structure using equations (4) and (5) where $Y_{i,t}/Y_t$ is a ratio with $Y_{i,t}$ being output of industrial sector i and Y_t being total output. $L_{i,t}/L_t$ refers to the ratio of employment in the industrial sectors i to all sectors. Third, referring to Dong *et al.* (2020) and Hou *et al.* (2023), this paper measures the intensity of environmental regulations by calculating the composite pollution index of gaseous emissions, including industrial wastewater, soot, and sulfur dioxide emissions. Specifically, we first calculate the emission intensity of each pollutant and normalize it.

Table 5. Influence mechanisms

	(1)	(2)	(3)	(4)
Variable	GTI	AIS	RIS	ER
EIP	0.405 (0.056)	0.158 (0.027)	0.018 (0.005)	0.013 (0.006)
Control variable	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Constant	0.065 (0.399)	−1.376 (0.162)	0.289 (0.027)	−0.181 (0.027)
Observations	2,739	1,796	1,799	3,088
R^2 within	0.673	0.202	0.088	0.087

Notes: GTI represents green technology innovation, measured by the number of green patents of the city. AIS represents advancement of industrial structure. RIS represents rationalization of industrial structure. ER represents environmental regulation. Standard errors in parentheses.

Then, we use the adjustment weight, the ratio of each pollutant emission intensity to its average emission intensity, to reflect the difference in pollution among the samples. Last, we calculate the environmental regulation intensity of each city in the panel data by summing up the product of adjustment weight and each pollutant emission intensity.

$$RIS_{i,t} = 1 - \frac{1}{3}\sum_{i=1}^{3}\left|\frac{Y_{i,t}}{Y_t} - \frac{L_{i,t}}{L_t}\right| \tag{4}$$

$$AIS_{i,t} = \frac{Y_{3,t}}{Y_{2,t}} \tag{5}$$

The regression results are reported in table 5. The result in column (1) shows the coefficient of EIP is positive and significant at the 5 per cent level, which indicates that the establishment of EIPs can improve urban green technological innovation. Columns (2)–(3) show that the regression coefficient of EIP is significantly positive, implying that the establishment of EIPs can also promote industrial structure upgrading. From the result in column (4) of table 5, we find that the construction of EIPs has a significant positive effect on improving the level of urban environmental regulation. In sum, the above results confirm that the implementation of EIP policy is driving air quality improvement by promoting technological innovation, upgrading industrial structure and strengthening urban environmental regulation.

6. Conclusions and policy implications

This paper uses the exogenous shock of the implementation of the EIP policy in China to construct a quasi-natural experiment, systematically assessing the effect of the establishment of EIPs on urban haze pollution through the DID method. The empirical results show that, first, the construction of EIPs will significantly improve urban air quality. Second, the effect of EIPs on haze pollution is more pronounced in eastern and resource-based cities. Third, the EIPs have decreased urban environmental pollution by promoting technological innovation, upgrading industrial structure and strengthening urban environmental regulations.

Based on the main conclusions of this paper, the following policy recommendations are put forward. First, China should vigorously promote the construction of EIPs nationwide. However, the coverage of cities where EIPs are set up is still relatively narrow, which shows that the construction of EIPs has a huge potential for reducing haze pollution and has yet to be tapped. At this stage, efforts should be taken to provide preferential policies for EIPs – such as financial incentives, industrial upgrading, environmental governance, and green innovation – and support environmental infrastructure construction so that traditional industrial parks can be transformed into EIPs.

Second, the government should implement differentiated development strategies of EIPs based on local conditions and promote the balanced development of EIPs across different regions in China. For western and central cities, they should develop various types of EIPs with different construction focuses, so as to achieve enhanced environmental, economic and social performance. For non-resource-based cities, they should increase subsidies to stimulate the cities' enthusiasm for EIP construction and incentivize their motivation to learn advanced management experience. In addition, the developing cities should learn good experiences from pilot regions, strengthen their awareness of environmental responsibilities and change the traditional business philosophy that prioritizes production over environmental protection to enable the policy to play a full role in these areas.

Third, the government should explore the path of emissions reduction from different perspectives. On the one hand, they should increase high-tech and high-skill human capital investment, improve the ability and quality of independent innovation, and promote the rational and effective allocation of resources. On the other hand, they need to set strict standards to promote the upgrading of traditional industries, strengthen environmental management system certification and environmental information disclosure. In addition, government regulation, market regulation and social public regulations should also be put forward and emphasized to ensure that EIPs reduce haze pollution in the green production of cities.

7. Limitations and future research

Like the previous literature, this paper has some limitations, which provide directions and suggestions for future research. First, this paper puts forward a way to evaluate the impact of EIPs on the environment in China. Due to data limitations, however, the research can only examine the short-term effect of EIPs on haze pollution rather than the results in the long term. Second, in the selection of indicators, EIPs may also reduce water pollution, soil pollution and other environmental problems in addition to haze pollution; therefore, follow-up studies are needed on these topics. Third, this study mainly focuses on the emission reduction effect brought about by EIPs, without examining its economic effect, which cannot directly answer the question of how to trade off between economic development and environmental protection. Despite these limitations, it is still undeniable that not only does our paper provide evidence for the relationship between EIPs and haze pollution and extend the research of industrial parks and environmental performance, it also shows reference value for the government to reduce haze pollution.

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Competing interest. The authors declare none.

References

Beck T, Levine R and Levkov A (2010) Big bad banks? The winners and losers from bank deregulation in the United States. *The Journal of Finance* **65**, 1637–1667.

Bertrand M, Duflo E and Mullainathan S (2004) How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics* **119**, 249–275.

Burkhardt J, Bayham J, Wilson A, Carter E, Jesse D, O'Dell K, Ford B, Fischer E and Pierce J (2019) The effect of pollution on crime: evidence from data on particulate matter and ozone. *Journal of Environmental Economics and Management* **98**, 102267.

Chen Z, Paudel P and Zheng R (2022) Pollution halo or pollution haven: assessing the role of foreign direct investment on energy conservation and emission reduction. *Journal of Environmental Planning and Management* **65**, 311–336.

Chen F, Zhang X and Chen Z (2023*a*) Air pollution and mental health: evidence from China health and nutrition survey. *Journal of Asian Economics* **86**, 101611.

Chen X, Chen L, Xie W, Mueller N and Davis S (2023*b*) Flight delays due to air pollution in China. *Journal of Environmental Economics and Management* **119**, 102810.

Chertow M (2000) Industrial symbiosis: literature and taxonomy. *Annual Review of Energy and the Environment* **25**, 313–337.

Cole MA, Elliott RJR and Shimamoto K (2005) Industrial characteristics, environmental regulations and air pollution: an analysis of the UK manufacturing sector. *Journal of Environmental Economics and Management* **50**, 121–143.

Dong Z, He Y, Wang H and Wang L (2020) Is there a ripple effect in environmental regulation in China? Evidence from the local-neighborhood green technology innovation perspective. *Ecological Indicators* **118**, 106773.

Duflo E and Pande R (2007) Dams. *The Quarterly Journal of Economics* **122**, 601–646.

Fang Y, Côté P and Qin R (2007) Industrial sustainability in China: practice and prospects for eco-industrial development. *Journal of Environmental Management* **83**, 315–328.

Fu J, Jiang D, Lin G, Liu K and Wang Q (2015) An ecological analysis of PM2.5 concentrations and lung cancer mortality rates in China. *BMJ Open* **5**, 009452.

Gan C, Zheng R and Yu D (2011) An empirical study on the effects of industrial structure on economic growth and fluctuation in China. *Economic Research Journal* **46**, 4–16.

Geng Y, Zhu Q and Haight M (2007) Planning for integrated solid waste management at the industrial park level: a case of Tianjin, China. *Waste Management* **27**, 141–150.

Grossman GM and Krueger AB (1995) Economic growth and the environment. *The Quarterly Journal of Economics* **110**, 353–337.

Heckman JJ, Ichimura H and Todd P (1998) Matching as an econometric evaluation estimator. *Review of Economic Studies* **65**, 261–294.

Heyes A and Zhu M (2019) Air pollution as a cause of sleeplessness: social media evidence from a panel of Chinese cities. *Journal of Environmental Economics and Management* **98**, 102247.

Hou D, Li G, Chen D, Zhu B and Hu S (2019) Evaluation and analysis on the green development of China's industrial parks using the long-tail effect model. *Journal of Environmental Management* **248**, 109288.

Hou S, Yu K and Fei R (2023) How does environmental regulation affect carbon productivity? The role of green technology progress and pollution transfer. *Journal of Environmental Management* **345**, 118587.

Khomenko S, Cirach M, Pereira-Barboza E, Mueller N, Barrera-Gómez J and Rojas-Rueda D (2021) Premature mortality due to air pollution in European cities: a health impact assessment. *The Lancet Planetary Health* **5**, 121–134.

Li Z and Li C (2022) How industrial upgrading can improve China's air quality: empirical analysis based on multilevel growth model. *Environmental Science and Pollution Research* **29**, 54456–54466.

Li J, Pan S, Kim H, Linn J and Chiang P (2015) Building green supply chains in eco-industrial parks towards a green economy: barriers and strategies. *Journal of Environmental Management* **162**, 158–170.

Li P, Lu Y and Wang J (2016) Does flattening government improve economic performance? Evidence from China. *Journal of Development Economics* **123**, 18–37.

Lin G, Fu J, Jiang D, Hu W, Dong D, Huang Y and Zhao M (2014) Spatio-temporal variation of PM2.5 concentrations and their relationship with geographic and socioeconomic factors in China. *International Journal of Environmental Research and Public Health* **11**, 173–186.

Lipscomb M, Mobarak AM and Barham T (2013) Development effects of electrification: evidence from the topographic placement of hydropower plants in Brazil. *American Economic Journal: Applied Economics* **5**, 200–231.

Lu Y, Wang J and Zhu L (2019) Place-based policies, creation, and agglomeration economies: evidence from China's economic zone program. *American Economic Journal: Economic Policy* **11**, 325–360.

Lu FW, Sun WZ and Wu JF (2023*a*) Special economic zones and human capital investment: 30 years of evidence from China. *American* Economic *Journal: Economic Policy* **15**, 35–64.

Lu J, Zhou Q, Qi W, Qu S and Bi J (2023*b*) The heterogeneous effects of Chinese industrial parks on environmental pollution. *Science of The Total Environment* **896**, 165279.

Mathews J, Tan H and Hu M (2018) Moving to a circular economy in China: transforming industrial parks into eco-industrial parks. *California Management Review* **60**, 157–181.

Qian L, Xu X, Sun Y and Zhou Y (2022) Carbon emission reduction effects of eco-industrial park policy in China. *Energy* **261**, 125315.

Schwarze R (1996) The role of common law in environmental policy: comment. *Public Choice* **89**, 201–205.

Tong HF, Wang Y and Xu JJ (2020) Green transformation in China: structures of endowment, investment, and employment. *Structural Change and Economic Dynamics* **54**, 173–185.

Wu J, Nie X, Wang H and Li W (2023) Eco-industrial parks and green technological progress: evidence from Chinese cities. *Technological Forecasting and Social Change* **189**, 122360.

Xiong L, Ning J, Dong Y and Dai M (2022) Simulation of the pollution abatement behavior of regional metal-related enterprises based on the interactive perspective of industrial agglomerations and emission reduction effects. *Environmental Geochemistry and Health* **44**, 1081–1098.

Yang S, Jahanger A and Hossain MR (2023) Does China's low-carbon city pilot intervention limit electricity consumption? An analysis of industrial energy efficiency using time-varying DID model. *Energy Economics* **121**, 106636.

Yu Y and Zhang N (2022) Does industrial transfer policy mitigate carbon emissions? Evidence from a quasi-natural experiment in China. *Journal of Environmental Management* **307**, 114526.

Yu W, Peng Y and Yao X (2022) The effects of China's supporting policy for resource-exhausted cities on local energy efficiency: an empirical study based on 284 cities in China. *Energy Economics* **112**, 106165.

Zeng Z, Cheng L, Shi L and Luetkenhorst W (2021) China's green transformation through eco-industrial parks. *World Development* **140**, 105249.

Zhang X, Zhang X, Liu Y, Zhao X and Chen X (2023) The morbidity costs of air pollution through the lens of health spending in China. *Journal of Population Economics* **36**, 1269–1292.

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