frontiers | Frontiers in Environmental Science

ORIGINAL RESEARCH
published: 19 May 2022
doi: 10.3389/fenvs.2022.910668

Can Industrial Relocation Reduce Air Pollution? Evidence From a Quasi-Natural Experiment in China

*Tao Ge[1,2], Xuchen Lv[1], Li Ma[1] and Xiaoyan Shen[1]**

[1]*School of Economics and Management, Nantong University, Nantong, China,* [2]*Jiangsu Yangtze River Economic Belt Research Institute, Nantong University, Nantong, China*

To reduce the increasingly severe air pollution caused by rapid industrialization, China has introduced a National Industrial Relocation Demonstration Zones (NIRDZs) policy. This paper takes the NIRDZs as a quasi-natural experiment and employs the difference-in-differences (DID) method to test the effects of industrial relocation on air pollution based on panel data of 285 prefecture-level cities from 2003 to 2018. Results show that the NIRDZs have an inhibitory effect on SO_2 emissions, although their local effect is significant in the first 5 years and their spillover effect only occurs within 50–100 km. Mechanism analysis reveals that the NIRDZs reduce air emissions by rationalizing and upgrading the industrial structure. Additionally, further discussions suggest that cities with moderate administrative areas and abundant natural resources should be prioritized as pilot cities, and industries including nonferrous metals, steel, automotive, new energy, new materials, and producer services should be designated as priority industries.

Keywords: industrial relocation, air pollution, difference-in-differences method, spillover effect, China

OPEN ACCESS

Edited by:
Haitao Wu,
Beijing Institute of Technology, China

Reviewed by:
Siyu Ren,
Nankai University, China
Munir Ahmad,
Zhejiang University, China

Correspondence:
Xiaoyan Shen
ntshenxy@sina.com

Specialty section:
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

Received: *01 April 2022*
Accepted: *19 April 2022*
Published: *19 May 2022*

Citation:
Ge T, Lv X, Ma L and Shen X (2022) Can Industrial Relocation Reduce Air Pollution? Evidence From a Quasi-Natural Experiment in China. Front. Environ. Sci. 10:910668. doi: 10.3389/fenvs.2022.910668

1 INTRODUCTION

Over the past decades, China has experienced rapid urbanization and industrialization, consuming more than 20% of the world's energy. However, although the extensive development has been beneficial to China's economy, it has also resulted in an industrial structure that is overwhelmingly labor-intensive and resource-intensive industries in some parts of the country, especially in the central and western regions. It has caused China to produce a large amount of air pollutants (Ahmad et al., 2020; Li et al., 2021) and even become the largest SO_2 emitter since 2005 (Wang et al., 2014). To reverse this situation, the 17th National Congress of the Communist Party of China called for "accelerating the transformation of economic development mode, promoting the optimization and upgradation of industrial structure, and taking a new path of industrialization with Chinese characteristics". In this context, reducing pollution emissions while optimizing industrial structure through industrial policies has become a common concern in China.

Industrial relocation is an important part of industrial policies and has attracted the attention of policymakers and researchers alike. Some scholars argue that traditional industrial policies are only aimed at promoting rapid economic growth in specific geographical regions (Luo et al., 2021), such as empowerment zones and enterprise zones in the United States, regional development aid in Europe, and special economic zones in China (Ham et al., 2011; Busso et al., 2013; Lu et al., 2019). Unlike the abovementioned policies, industrial relocation is designed to pursue high-quality development that takes the economy and the environment into account. In other words, industrial relocation seeks to simultaneously achieve industrial optimization and environmental improvement (Zhang et al., 2021). Obviously, this aligns more closely with the concept of sustainable development and therefore is gradually favored by policymakers. Actually, a group of policymakers has already implemented industrial relocation, the representative of which is the National Industrial Relocation Demonstration Zones (NIRDZs) initiated by the Chinese government in 2010.

Although a strand of literature has underlined that industrial relocation contributes to economic performance (Liu T. et al., 2020; Liu and Li, 2021), this is only one of its goals. A question worth discussing is whether industrial relocation has an impact on environmental performance. Meanwhile, some quantitative studies are controversial about the impact characteristics of industrial policy. For example, Song and Zhou (2021) find that its has a long-term effect but Luo et al. (2021) argue that its impact is only short-term. Therefore, what are the spatiotemporal characteristics of industrial relocation affecting air environment? More importantly, what is the influencing mechanism by which it affects air pollution? Additionally, it is also unclear whether the effects will vary across areas and how to better achieve emissions reduction, in view of regional differences (Liu and Qin, 2016), especially beside the usual factors, such as economic development and industrial base (Wang et al., 2015). The answers to these four questions are of great significance for the government to implement and improve industrial relocation based on actual conditions.

One popular hypothesis - the pollution haven hypothesis (PHH)–has been extensively and deeply discussed on the linkage between industrial relocation and pollution emissions (Wang et al., 2019). It suggests that the relocated pollution-intensive industries can alleviate the environmental pressure of transferring cities but may cause unexpected pollution (Zheng and Shi, 2017; Li T. et al., 2019), thereby increasing pollution emissions and harming the ecological environment. Nevertheless, the Porter hypothesis (PH) thinks that the opposite is true (Porter, 1991; Jaffe et al., 1995). It posits that reasonable environmental regulations can promote enterprise innovation, reduce the unit cost of pollution control, and ultimately lower pollutant emissions (Zeng and Zhao, 2009; Ge et al., 2020). Quantitative analysis has found evidence supporting the PH theory (Zhao and Yin, 2011; Rubashkina et al., 2015; Van Leeuwen and Mohnen, 2017) and PHH theory (Yin et al., 2016; Xu et al., 2017; Li K. et al., 2019), respectively. Several empirical studies have attempted to find the reasons for the debate. For example, Lan et al. (2012) hold that PHH or PH largely depends on the host country’s foreign direct investment (FDI). Candau and Dienesch (2017) and Tang (2015) found that the results could be reversed when FDI types and corruption were included in the model. Therefore, given that no consistent conclusion on the relationship between place-based industrial policies and pollution emissions is provided, it is necessary to summarize the theoretical and empirical basis of the conflict phenomenon and make more efforts to reveal the essence of the reality.

This paper attempts to construct a quasi-natural experiment based on the NIRDZs to answer the abovementioned questions. Panel data of 285 cities from 2003 to 2018 are used for empirical testing. We first investigate the impact of the NIRDZs policy on air pollution and then carry out a series of robustness tests, including a time trend test, PSM-DID estimation, placebo test, and concurrent test, to ensure the reliability of the estimated results. On this basis, we further study the spatiotemporal characteristics of policy effects. Meanwhile, we construct a mediating effect model to test whether the NIRDZs policy reduces air pollution through industrial structure optimization. In addition, we test the heterogeneity of policy effects in different cities and industries.

The five contributions of this research can be summarized as follows. First, the impact of the NIRDZs on air pollution is evaluated for the first time, which enriches the literature on industrial policies from the perspective of environmental economics. Second, it is challenging to eliminate endogenous problems by relying on metrology technology alone, but the quasi-natural experiment constituted by the NIRDZs provides such an opportunity (Lu et al., 2020), so the difference-in-differences (DID) approach is adopted to investigate policy effects. Third, this paper examines the impact of the NIRDZs policy on SO_2 emissions and analyzes its temporal and spatial heterogeneity. Compared with previous literature on policy effects, our results are more specific and in-depth. Fourth, to prevent slipping into a ”policy trap” from an environmental perspective, the mediating effect analyzes the impact mechanism, making our results more valuable for reference. Finally, given regional heterogeneity and industrial heterogeneity, this study discusses the selection of pilot cities and relocated industries, which provides a factual basis for optimizing industrial policies in the later stage.

The remainder of this paper is organized as follows. **Section 2** introduces the institutional background and hypotheses development. **Section 3** briefly interprets the methodology and data. **Section 4** presents the results and discussion. **Section 5** explores the selection of pilot cities and relocated industries. **Section 6** concludes.

2 INSTITUTIONAL BACKGROUND AND HYPOTHESES DEVELOPMENT

2.1 Institutional Background

Since the reform and opening up, the eastern region, with its unique geographical location and national policy support, has actively introduced foreign capital and undertaken international industries, which has promoted the vigorous development of labor-intensive and export-oriented manufacturing in the eastern region. However, with the excessive agglomeration of industrial factors, the crowding effect not only began to appear in the eastern region, but its environmental carrying capacity has also reached the upper limit. Notably, after the international financial crisis, the prices of production factors such as labor, land, and raw materials in the eastern region rose sharply, and its location advantages and cost advantages have been greatly offset. Consequently, the eastern region is eager to transfer labor-intensive and resource-intensive industries to provide sufficient space for high-tech and emerging industries. Meanwhile, the relative competitiveness of industrial development in the central and western regions has been significantly enhanced, thanks to abundant mineral resources, low factor costs, large market potential, and an increasingly perfect infrastructure. Under such circumstances, the central government has implemented the NIRDZs policy to promote industrial relocation from the eastern to the central and western regions.

Although the government has not explicitly formulated policy text related to environmental governance to guide the construction of the NIRDZs, it has put forward detailed environmental requirements in all guidance documents. In 2010, the "Guiding Opinions of the State Council on Industrial Relocation in the Central and Western Regions" clearly stated that resource carrying capacity and ecological environment capacity should be taken as an important basis for industrial relocation, and resource conservation and environmental protection should be strengthened to promote the coordination among economy, resources, and environment. Meanwhile, the "The Guidance Catalogue for Industrial Development and Transfer" issued in 2018 also requires all regions to firmly establish and practice the concept that green waters and green mountains are as valuable as mountains of gold and silver, strictly adhere to the bottom line of not destroying the ecological environment, and prevent cross-regional pollution transfer.

Obviously, the central government has clearly imposed stringent restrictions on resource utilization and air pollution in the NIRDZs. Pollution reduction is not only one of the original intentions of the central government to formulate the NIRDZs policy but also one of the inherent requirements for sustainable development, and it has been closely concerned by policymakers and researchers. Therefore, the practical effect of the NIRDZs policy on air pollution emissions should be systematically investigated to identify its environmental performance.

2.2 Hypotheses Development

2.2.1 Effect Analysis

Environmentally friendly development is an integral part of the expected objectives for NIRDZs policy as a special economic zone (Zheng et al., 2016; Alkon, 2018; Xi et al., 2021). To achieve this goal, pilot cities have introduced a series of pollution control measures. For example, they have raised environmental protection thresholds and industry selection standards to curb the entry of polluting industries (Wang and Luo, 2020). Meanwhile, they have implemented an environmental impact assessment system, which restrains corporate pollution behavior, raises public environmental awareness, and encourages local governments to strengthen pollution control (Zhang et al., 2016). Additionally, they have been required to implement cleaner production systems and cleaner production audits to force enterprises to apply advanced technologies, such as energy conservation, water conservation, material conservation, and environmental protection (Liao and Shi, 2018). Finally, pilot cities have introduced stricter total pollutant discharge control systems, and improved energy-saving and emission-reduction indicators and environmental monitoring and assessment systems, which have been proven to play an essential role in inhibiting air pollution (Zhu et al., 2014; Květoň and Horák, 2018; Miao et al., 2019). Therefore, Hypothesis 1 is proposed:

H1

The NIRDZs policy has a significant inhibitory effect on air pollution.

2.2.2 Heterogeneity Analysis

Place-based policies reveal strong heterogeneity over time and space (Faggio et al., 2017; Zheng et al., 2017). As China's economic system reforms deepen, the first-mover advantages and institutional rent in areas that implement the place-based policies will gradually decrease over time, and the subsidies provided by the central government will also be partially or fully capitalized into land rent (Krupka and Noonan, 2009). Therefore, the effects of place-based policies may diminish or even disappear with the time policies are implemented (Glaeser and Gottlieb, 2008). Some quantitative analysis supports this finding. For instance, O'Keefe (2004) found that California's enterprise zone increased the employment rate by 3% each year during the first 6 years, but it did not sustain an impact. Taking the enterprise free zone of the Paris region as an example, Gobillon et al. (2011) found that place-based policies can only temporarily stimulate employment.

According to the space economics theory, the core area where place-based policies are implemented will produce a siphon effect on the production factors in the surrounding areas, which results in a specific range of growth shadows (Cuberes et al., 2021). In other words, place-based policies may reduce economic growth and pollution emissions by inhibiting corporate production activities in the peripheral areas that are too close to the core area (Jia et al., 2020). When the spatial distance between areas reaches a specific range, the peripheral areas will not fall into the trap of growth shadows, and place-based policies will have a spillover effect to inhibit pollution emissions in the peripheral areas (Alder et al., 2016). However, as the spatial distance between areas further expands, the spillover effect of place-based policies will gradually decrease or even disappear, and its impact on the peripheral areas will no longer be significant (Cao, 2020). Much empirical evidence has supported this theory (Kline and Moretti, 2014; Briant et al., 2015; Faggio, 2019). Therefore, Hypothesis 2 is proposed:

H2

The NIRDZs policy only curbs air pollution in the short term and has a spillover effect within a specific spatial range.

2.2.3 Mechanism Analysis

Generally, enterprises in transferring areas possess more advanced production technologies and management concepts than those in undertaking areas (Tian et al., 2019). The NIRDZs policy will promote technology spillover and knowledge diffusion through formal and informal channels during the interaction between the two parties (Jindra et al., 2009). It helps to change the energy consumption structure by promoting renewable energy (Lin and Zhu, 2020) and reducing energy consumption and pollution emissions (Rasiah et al., 2014; Khan et al., 2020). More importantly, renewable energy may reduce production costs (Driessen et al., 2013), encouraging enterprises to consume renewable energy and ultimately forming a closed-loop benign feedback cycle mechanism for clean production (Li K. et al., 2019).

The NIRDZs policy will accelerate industry convergence between existing and relocated industries. Industry convergence can reduce the uncertainty of business operations, optimize the production structure and product quality, and then improve energy efficiency (Yang et al., 2020). Meanwhile, industrial convergence can reduce transaction costs, innovation costs, and transportation costs, as well as promote enterprises to share polluting facilities and technologies, resulting in energy conservation and emission reduction (Dou and Zhang, 2015). In addition, industry convergence can promote regional metabolism, which will improve the operating efficiency of traditional industries by popularizing low-energy and low-emission production patterns (Cao et al., 2020).

The construction of the NIRDZs is inseparable from the support of new-generation information technologies. The central government also tends to prioritize promoting and popularizing new-generation information technologies in pilot cities to play its exemplary role. New-generation information technology industry may drive modern service industries, such as information services, R&D and design, quality inspection, and business services, and create more potential economic growth points oriented by talents, technology, and knowledge (Yang et al., 2021). This will drive the rapid development of emerging industries characterized by high added value, high technology, and low energy consumption, improving regional resource utilization and reducing pollution emissions (McDowall et al., 2018). Notably, emerging industries can also provide experience and reference for industrial upgradation and clean production in traditional sectors (Ek and Soederholm, 2010). Therefore, Hypothesis 3 is proposed:

H3

The NIRDZs policy reduces air pollution by promoting industrial structure rationalization and industrial structure upgradation.

3 METHODOLOGY AND DATA

3.1 Econometric Methodology

The DID method can effectively evaluate the treatment effect by comparing the pre-treatment and post-treatment differences between the treatment group and the control group, so it is widely used in empirical research related to policy evaluation (Liu X. et al., 2020). In this study, the NIRDZs policy provides a quasi-natural experiment setting for investigating the effects of industrial relocation on air pollution. However, as reported in Supplementary Table A1, the NIRDZs policy is gradually implemented in different cities in different years (Li et al., 2016). Therefore, we employ a multi-period DID method to construct the model as follows:

$$AP_{it} = \alpha_0 + \alpha_1 did_{it} + \alpha X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (1)$$

where the subscript i and t denote the city and the year, respectively. AP_{it} is the air pollution of ith city in year t. did_{it} is the interaction term of the dummy variable of policy implementation and the dummy variable of the policy implementation period. If the city i belongs to the treatment group and the year t belongs to the policy implementation period, $did_{it} = 1$, otherwise, $did_{it} = 0$. α_1 is the interesting parameter that needs to be estimated, reflecting the actual effect of the NIRDZs policy on air pollution. X_{it} denotes control variables. ν_i and μ_t are the city and year fixed effect, respectively; ε_{it} is the error term.

Referring to Jacobson et al. (1993) and Li et al. (2016), we use the event study to identify whether DID method satisfies the parallel trend assumption and investigate the temporal heterogeneity of the NIRDZs policy on air pollution.

$$AP = \beta_0 + \prod_{k \geq -7, k \neq -1}^{8} \beta_k D_{it}^k + \beta X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (2)$$

where the dummy variable D_{it}^k represents the NIRDZs policy event. Assuming that the year of the city i participated in the NIRDZs policy is y_i and $k = t - y_i$. When $k \leq -7$, $D_{it}^{-7} = 1$, otherwise, $D_{it}^{-7} = 0$. Similarly, when $k = -6, -5, \cdots, 6, 7$, $D_{it}^k = 1$, otherwise, $D_{it}^k = 0$; when $k \geq 8$, $D_{it}^8 = 1$, otherwise, $D_{it}^7 = 0$. This study uses the first year before policy implementation as the base period in the specific regression analysis (i.e., $k = -1$), so the dummy variable D_{it}^{-1} is not included in the equation. The temporal heterogeneity can be tested according to the parameter β_k.

Next, we conduct the following model along the lines described by Cao (2020) to evaluate the spatial heterogeneity of the NIRDZs policy on air pollution.

$$AP = \lambda_0 + \sum_{s=50}^{500} \lambda_s N_{it}^s + \lambda X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (3)$$

where the parameter s ($s \geq 50$) represents the geographic distance between cities. Assuming that the NIRDZs policy is implemented within the spatial distance (s - 50, s] in the city i in year t, $N_{it}^s = 1$; otherwise $N_{it}^s = 0$. For example, N_{it}^{50} indicates whether the NIRDZs policy is implemented within 50 km of the city i in year t. In the regression analysis, this study uses 50 km as the basic unit and reports the estimated results when $s = 50, 100, \cdots, 450, 500$, respectively. The spatial heterogeneity effect can be tested according to the parameter λ_s.

Lastly, this paper employs the analytical framework adopted by Edwards and Lambert (2007) to analyze the impact mechanism of the NIRDZs policy on air pollution.

$$M_{it} = \varphi_0 + \varphi_1 did_{it} + \varphi X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (4)$$

$$AP_{it} = \gamma_0 + \gamma_1 did_{it} + \gamma_2 M_{it} + \gamma X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (5)$$

where M represents the mediating variables, and the other parameters are defined as above.

3.2 Variables Description

3.2.1 Explained Variable

As a major air pollutant, SO_2 has been closely monitored by various countries since the 1970s and has become the most commonly used indicator to measure the degree of air pollution (Yang et al., 2018). Xu et al. (2021) hold that compared to the absolute value of SO_2 emissions, per capita SO_2 emissions are a more scientific variable to reflect air pollution as it takes population factors into account. Thus, SO_2 emissions per 100 people (*SE*) are used to represent air pollution for empirical analysis.

3.2.2 Explanatory Variable

The core explanatory variable is did_{it}, which is the policy variable of the NIRDZs. Given that various cities may be affected diversely by the NIRDZs policy, pilot cities are classified according to administrative areas, resource endowments, and relocated industries to investigate the heterogeneity of policy effects and discuss how to improve the NIRDZs policy.

3.2.3 Control Variables

Referring to the existing literature, the following factors are introduced as control variables. 1) Gross regional product (GRP) per capita (*EG*) estimates the effect of economic growth on air pollution and should therefore be taken into consideration (Li et al., 2020; Hao et al., 2021). This index is adopted after adjustment, using 2003 as the base year. 2) Public transport per ten-thousand people (*PT*) is expected to reflect the infrastructure construction in urban areas (Zhou et al., 2019), and can be used to investigate the impact of public transportation (Yang et al., 2018). 3) The ratio of household registered population at the end of the year to the administrative area (*PD*) is employed to control the difference in pollution emissions caused by the local population (Yi et al., 2020). 4) Per capita power consumption (*PC*) captures the air pollution caused by the power industry with high pollution and high emissions (Yang et al., 2020). 5) The ratio of import and export volumes to gross regional product (*TO*) controls the trade openness effect, which can change the city's comparative advantage in favor of cleaner manufacturing and production (Ren et al., 2021; Ren et al., 2022a; Ren et al., 2022b).

3.2.4 Mediating Variables

Industrial structure rationalization (*ISR*) implies integration and coordination among industries, which reflects resource utilization efficiency (Zhang et al., 2020). Based on Zhu et al. (2019), this index is measured using the equation:

$$SO = \sum_{m=1}^{3} y_{i,m,t} \times lp_{i,m,t}, \quad m = 1, 2, 3 \tag{6}$$

where $y_{i,m,t}$ represents the ratio of the added value of the industry m to GRP in year t, $lp_{i,m,t}$ indicates the labor productivity of the industry m in year t.

Industrial structure upgradation (*ISU*) refers to transferring to the tertiary industry and is implicit in changes in industrial structure, which is reflected in the share of output value among different industries (Romano and Traù, 2017). Drawing on Wu et al. (2019) and Liu et al. (2021), this index is measured by the ratio of added value between the tertiary industry and the second industry.

3.3 Data Sources

Since the number of missing values for SO_2 emissions increased significantly after 2018 and the data for 12 cities were not available during the survey period, the sample consists of a panel dataset for 285 cities in mainland China covering the period from 2003 to 2018, leading to 4,560 observations. According to the difference that whether the selected cities have been included in the NIRDZs, 31 pilot cities (Xiangxi Tujia-Miao autonomous prefecture is excluded because the data for several variables were not available) are classified into the treatment group, and 254 cities are put into the control group.

The original data of this study comes from the CEIC China Economic Database and Chinese Research Data Services Platform, and the missing values are supplemented by interpolation. The descriptive statistics of all variables are presented in **Table 1**.

4 RESULTS AND DISCUSSION

4.1 Baseline Results

The estimated results are reported in **Table 2**. Column 1) shows the estimated coefficient of *did* is significantly negative without considering other variables. After adding control variables, Column 2) indicates the negative effect of the NIRDZs policy is also significant, and the estimated coefficient of *did* is -0.466. Column 3) considers the year fixed effect and city fixed effect; it is obvious that the results are still consistent with the above findings. The estimated coefficient of *did* is -0.494, indicating that the NIRDZs policy has reduced SO_2 emissions per 100 people by 0.494 units. Therefore, we argue that compared with the control group, the NIRDZs policy significantly abates air pollution in the treatment group, verifying H1. This is consistent with the findings of Li T. et al. (2019), who argue that the overall effect of industrial relocation is positive and can reduce energy consumption and pollution emissions.

4.2 Robustness Test

4.2.1 Time Trend Test

The prerequisite for adopting a multi-period DID method is that the sample satisfies the time trend hypothesis; that is, there is no significant difference in SO_2 emissions between pilot cities and non-pilot cities before the NIRDZs policy is implemented. We employ **Eq. 2** to test the time trend hypothesis. As shown in **Figure 1**, the parameter β_k is not statistically significant before the NIRDZs policy is implemented, indicating that air pollution in the treatment group and the control group have a common trend before policy implementation, thus verifying the parallel trend hypothesis.

4.2.2 PSM-DID Estimation

To address sample selection bias, we combine the DID method with propensity score matching (PSM). We first use the PSM to match them based on the systematic differences between pilot and non-pilot cities and adopt the policy dummy variable to conduct regression analysis on matching variables to get propensity scores. Referring to Du et al. (2021), per-capita

TABLE 1 | Summary statistics.

Variable	Definition	Unit	Mean	S.D.	Min	Max
AP	SO_2 emission per 100 people	ton	1.743	2.619	0.000	35.66
EG	Per capita GRP	10^4 CNY	3.090	2.958	0.189	24.86
PT	Per ten-thousand people public transport	bus	3.016	4.138	0.035	57.35
PD	Population per square kilometer	person	424.9	326.6	4.700	2587.4
PC	Per capita electricity consumption	KWh	2593	5,425	27.00	150,148
TO	Proportion of import-export volumes in GRP	%	20.13	35.56	0.020	351.4
ISR	Industrial structure rationalization	—	13.63	54.32	0.130	2251
ISU	Industrial structure upgradation	—	0.890	0.455	0.094	5.022

TABLE 2 | Baseline results of NIRDZs policy on SO2 emissions.

Variable	AP		
	(1)	(2)	(3)
did	–0.551** (0.246)	–0.466** (0.0019)	–0.494** (0.245)
_cons	1.771*** (0.142)	2.088*** (0.207)	1.567* (0.848)
Control variables	No	Yes	Yes
Year fixed effect	No	No	Yes
City fixed effect	No	No	Yes
Observations	4,560	4,560	4,560
R-squared	0.0021	0.2521	0.8431

*Note: ***, **, and * represent significance levels of 1, 5, and 10%, respectively; standard errors in parentheses. The same below.*

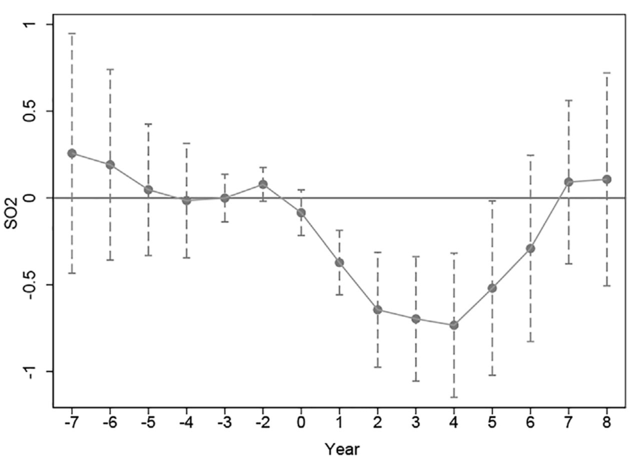

FIGURE 1 | Temporal heterogeneity.

GRP, public transport, industrial structure, and population density are used as matching variables. Next, we match pilot and non-pilot cities based on matching variables and propensity scores. In this study, the nearest neighbor matching method is used to conduct 1:1 pairing, and the successfully matched samples are finally retained to make the samples more in line with the prerequisites of DID approach that the treatment group and the control group satisfy the homogeneity hypothesis.

The estimated results using the PSM-DID method are reported in Column 1) of **Table 3**. As can be seen, the coefficient of did is negative and passes the 5% significance test, indicating that the NIRDZs policy still has a significant negative impact on air pollution in pilot cities, which is consistent with the baseline results.

4.2.3 Placebo Test

To further test the baseline results, we use the counterfactual analysis method to conduct a placebo test. Specifically, we assume that the policy is implemented 1 or 2 years in advance to construct the pseudo-implementation time of the NIRDZs policy. If the coefficient of *did* is not significant, it means that the NIRDZs policy does have an inhibitory effect on air pollution. Otherwise, it implies that the inhibitory effect is caused by other unobservable factors, and the abovementioned findings are unreliable (Yang et al., 2019; Pan and Tang, 2021).

The estimation results are shown in Columns 2) and 3) of **Table 3**. Regardless of whether the policy implementation time is advanced by 1 or 2 years, the coefficient of *did* is not significant, indicating that the NIRDZs policy has no significant impact on SO_2 emissions before the base year. Therefore, it is reasonable to believe that actual policy implementation plays an essential role in reducing air pollution, and our findings are robust.

4.2.4 Concurrent Event

In this study, the impact of the NIRDZs policy on air pollution will inevitably be disturbed by other events, so the estimates might be biased. To identify and address this problem, we search for other events that occurred in the years after the NIRDZs policy was implemented. After the new government came into being in 2013, it attached great importance to environmental protection and promulgated a series of environmental protection policies, laws, and regulations to solve the increasingly severe air pollution. Thus, we have reason to believe that the various environmental protection measures implemented by the new government have produced pollution reduction effects, which implies that the actual effect of the NIRDZs policy may be overestimated. Based on Zhang and Zhang (2020), we conduct a robustness check by excluding the 2013–2018 data from the benchmark model.

Column 4) of **Table 3** shows the results that the samples after 2012 are excluded. The coefficient of *did* is -0.258 and passes the 5% significance test, indicating that the results are consistent with **Table 1** except that the coefficient has declined. Therefore, although the inhibitory effect of the NIRDZs policy on SO_2 emissions is overestimated, there is indeed a statistically negative correlation between the two.

TABLE 3 | Robustness checks.

Variable	AP			
	(1)	(2)	(3)	(4)
did	−0.475** (0.236)	—	—	−0.258** (0.102)
did-advance 1	—	−0.360 (0.253)	—	—
did-advance 2	—	—	−0.390 (0.271)	—
_cons	−1.808* (1.039)	1.129 (0.854)	1.523* (0.860)	3.761*** (1.211)
Control variables	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes
Observations	3,419	4,560	4,560	2850
R-squared	0.838	0.839	0.843	0.9218

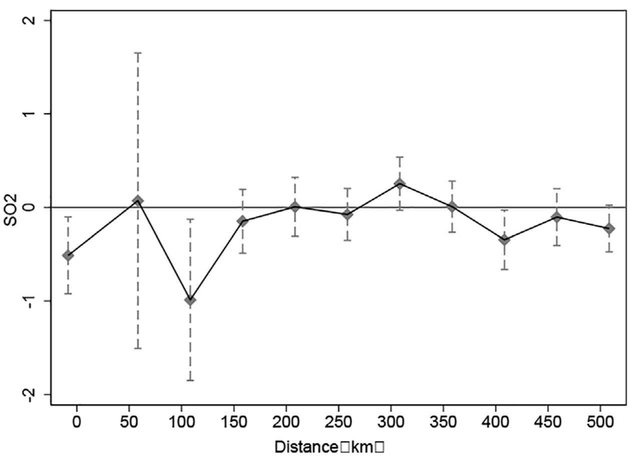

FIGURE 2 | Spatial heterogeneity.

4.3 Heterogeneity Test

To test the temporal heterogeneity of the NIRDZs policy on air pollution, **Figure 1** reports the changing trend of the parameter β_k in **Eq. 2** under the 95% confidence interval. With the increase of policy implementation years, the inhibitory effect of the NIRDZs policy on air pollution in pilot cities roughly experiences a process of first increasing, then decreasing, and finally disappearing. Specifically, from the first year to the fourth year after policy implementation, the inhibitory effect constantly increases and reaches the maximum in the fourth year. In the fifth year, the inhibitory effect gradually decreases. Starting from the sixth year, the impact of the NIRDZs policy on air pollution became insignificant. The results imply that the inhibitory effect of the NIRDZs policy on air pollution is temporally heterogeneous.

To investigate the spatial heterogeneity of the NIRDZs policy on air pollution, **Figure 2** describes the changing trend of the parameter λ_s in **Eq. 3** under the 95% confidence interval. As the geographical distance increases, the inhibitory effect of the NIRDZs policy on air pollution in surrounding cities first decreases, then increases, and finally decreases. Specifically, the growth shadow is within 50 km, which means that policy implementation in pilot cities may worsen air pollution in surrounding cities within 50 km. For surrounding cities within 50–100 km, the policy has a significant inhibitory effect on their SO_2 emissions. After the spatial distance exceeds 100 km, the policy on SO_2 emissions in surrounding cities becomes insignificant. Therefore, the inhibitory effect of the NIRDZs policy on air pollution in surrounding cities is spatially heterogeneous.

In summary, the NIRDZs policy has an inhibitory effect on SO_2 emissions, but its local effect is only significant in the first 5 years and its spillover effect only occurs within 50–100 km, which verifies H2. On the one hand, this finding is consistent with previous studies. For example, Wang and Qiu (2021) found that the pilot policy has only a short-term impact. The reason is that in the early stage of policy implementation, environmental governance is an important part of performance appraisal. However, local governments will take advantage of the central government's information asymmetry to relax environmental governance over time. On the other hand, this finding is consistent with agglomeration economic theory. If the non-pilot cities are too close to the pilot cities, the existence of agglomeration shadows may cause the pilot policy to have insignificant emission reduction effects on surrounding cities. As the geographic distance between cities expands, non-pilot cities can eliminate agglomeration shadows and gain a series of benefits from the pilot policy, such as technological spillovers and economic growth. However, when the spatial distance between cities is too large, the spillover effect of the pilot policy will gradually weaken and become insignificant.

4.4 Mechanism Test

This section investigates the impact mechanism of the NIRDZs policy, and the results are shown in **Table 4**. Columns 1) and 2) provide the industrial structure rationalization results as a mediating variable. The coefficients of *did* on *ISR* and *ISR* on *SE* are -10.610 and 0.001, respectively; both pass the significance test and are consistent with the sign of did on SO_2 emissions after considering a mediating variable. The results indicate a partial mediating effect, and the ratio of mediating effect to total effect is 2.15%. Columns 3) and (4), which use industrial structure upgradation as a mediating variable, indicate that the coefficients of *did* on *ISU* and *ISU* on *AP* are significantly positive and negative, respectively. Meanwhile, after adding the mediating variable, the coefficient of *ISU* on SO_2 emissions is statistically negative. Therefore, this result indicates that there is a

TABLE 4 | Impact mechanism of NIRDZs policy.

Variable	ISR	AP	ISU	AP
	(1)	(2)	(3)	(4)
did	–10.610** (4.160)	–0.488** (0.245)	0.008** (1.241)	–0.487** (0.242)
ISR	—	0.001* (0.000)	—	—
ISU	—	—	—	–0.932* (0.563)
_cons	1.619 (33.206)	1.566 (0.848)	0.873*** (0.089)	2.207** (0.960)
Control variables	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes
Observations	4,560	4,560	4,560	4,560
R-squared	0.283	0.843	0.294	0.814

TABLE 5 | Selection of pilot cities based on administrative areas.

Variable	AP				
	(1)	(2)	(3)	(4)	(5)
	A < 5,000	5,000 ≤ A < 10,000	10,000 ≤ A < 15,000	15,000 ≤ A < 20,000	A≥20,000
did	–0.818 (0.590)	–0.805 (0.980)	–0.597* (0.328)	0.090 (0.109)	–0.294 (0.508)
_cons	1.630* (0.838)	1.958** (0.813)	1.876** (0.826)	1.910** (0.825)	1.886** (0.822)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	4,112	4,144	4,240	4,128	4,192
R-squared	0.839	0.843	0.839	0.840	0.839

partial mediating effect. Based on these estimated coefficients, it can be calculated that the mediating effect accounts for 1.53% of the total effect.

In summary, the NIRDZs reduce air emissions by rationalizing and upgrading the industrial structure, verifying H3. Notably, comparing the coefficients of did after adding different mediating variables, we find that the change of did is more obvious when industrial structure rationalization is used as the transmission mechanism. This may be because the modern service industry is an endeavor that cannot be accomplished overnight, and then the impact of industrial structure upgradation on air pollution has a time lag.

5 FURTHER DISCUSSION: SELECTION OF PILOT CITIES AND RELOCATED INDUSTRIES

To give full play to the emission reduction effect of NIRDZs policy, it is necessary to identify its differences in various pilot cities and relocated industries. This section analyzes how to select pilot cities based on administrative areas and resource endowments and determine which industries should be relocated based on emission reductions.

5.1 Selection of Pilot Cities

According to the space economics theory, the optimal agglomeration economy is the result of the trade-off between external economy and external diseconomy; that is, the administrative area is too large or too small to be conducive to emission reduction. Taking 5,000 square kilometers as the basic unit, this study divides pilot cities into five types according to administrative areas: less than 5,000 square kilometers, 5,000 to 10,000 square kilometers, 10,000 to 15,000 square kilometers, 15,000 to 20,000 square kilometers, and more than 20,000 square kilometers.

Table 5 provides the estimated results. When the administrative area is less than 5,000 square kilometers, 5,000 to 10,000 square kilometers, and more than 20,000 square kilometers, the coefficient of *did* is negative but not statistically significant. When the administrative area is between 15,000 and 20,000 square kilometers, the coefficient of *did* is positive but still not statistically significant. When the administrative area is between 10,000 and 15,000 square kilometers, the coefficient of *did* is negative and passes the significance test. Therefore, in terms of reducing SO_2 emissions, the administrative area should be considered when selecting pilot cities for NIRDZs policy. Straightforwardly, cities with an administrative area of 10,000 to 15,000 square kilometers should be given priority.

According to the factor endowment theory, regions with abundant natural resources are more inclined to develop resource-based industries, which, in turn, accelerate local resource consumption and pollution emissions (Balsalobre-Lorente et al., 2018). To compare the differences in emission

TABLE 6 | Selection of pilot cities based on resource endowments.

Variable	AP					
	(1)	Resource-Based				
	Non-resource-based	(2)	(3)	(4)	(5)	(6)
		Full	Growing	Maturing	Declining	Renewing
did	–0.042 (0.141)	–0.863** (0.405)	–0.298*** (0.106)	–0.277 (0.345)	–3.473*** (0.812)	–0.758** (0.338)
_cons	1.868** (0.832)	1.902** (0.824)	1.903** (0.824)	1.867** (0.828)	1.951** (0.810)	1.833** (0.827)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,288	4,064	4,080	4,256	4,112	4,080
R-squared	0.838	0.839	0.839	0.839	0.848	0.839

reduction in pilot cities with different resource endowments, we conduct regression analysis according to the list and types of resource-based cities identified by the Chinese government in the "Issues on the National Plan for Sustainable Development of Resource-Based Cities of China (2013–2020)".

Table 6 summarizes the findings. In Columns 1) and 2), the coefficient of *did* is not significant in non-resource-based cities, while it is statistically negative in resource-based cities, indicating that it may be more appropriate to select resource-based cities as pilot cities from the perspective of emission reduction. This may be because resource-based cities will optimize the industrial structure dominated by resource-intensive industries through relocated industries. Columns 3) to 6) further report the results in different resource-based cities. The coefficients of *did* in growing, declining, and renewing resource-based cities are significantly negative, indicating that the NIRDZs policy is beneficial to reducing SO_2 emissions in these cities. The coefficient of *did* in maturing resource-based cities is not significant, meaning no emission reduction effect. Maturing resource-based cities have more abundant natural resources and lower energy costs, and production factors including labor and capital are mainly deployed in resource-based enterprises. The government will not immediately shut down its resource industries to maintain economic stability and reduce unnecessary frictional and structural unemployment.

5.2 Focus of Relocated Industry

According to the Catalogue for Guidance on Industrial Development and Transfer (2018) issued by China, the central government mainly supports pilot cities to relocate 19 industries: light industry (T1), textile (T2), food (T3), nonferrous metals (T4), steel (T5), building materials (T6), producer services (T7), electronic information (T8), chemical industry (T9), pharmaceutical (T10), machinery (T11), automotive (T12), rail transit (T13), ship and marine engineering equipment (T14), aerospace (T15), intelligent manufacturing equipment (T16), new energy (T17), new material (T18), and energy-saving and environmental protection industry (T19). We divide pilot cities into two types according to whether they have relocated a particular industry and then analyze their coefficients to determine whether the industry should be relocated. The results are shown in **Table 7**.

For nonferrous metals, steel, producer services, automotive, new energy, and new materials, the coefficients of *did* in pilot cities that relocate and do not relocate them are significantly negative and not significantly negative, respectively, indicating that the abovementioned industries contribute to reducing SO_2 emissions and local governments should actively relocate and develop them. Besides, it can be found that the absolute value of *did* in the new energy is the largest, suggesting that new energy has the strongest inhibitory effect on air pollution and should be given priority.

For light industry, electronic information, chemical industry, and aerospace, the coefficients of *did* in pilot cities that relocate and do not relocate them are negative but statistically insignificant. This implies that the abovementioned industries have no substantial impact on SO_2 emissions. In other words, although the abovementioned industries do not reduce pollution, they will not worsen the environment, and pilot cities can relocate these industries to pursue economic performance according to local conditions.

For other industries, including textile, food, building materials, pharmaceutical, machinery, rail transit, ship and marine engineering equipment, intelligent manufacturing equipment, and energy-saving and environmental protection industry, the coefficient of *did* in pilot cities relocating them does not pass the significance test, while the coefficient of *did* in pilot cities that do not relocate them is statistically negative, indicating that the abovementioned industries are not conducive to energy conservation and emission reduction, and local governments should be cautious in relocating them. Notably, the absolute value of *did* in the pharmaceutical industry is the largest, which implies that the industry has the strongest contribution to SO_2 emissions. China has a vast population, but pharmaceutical resources, an industry closely related to people's health, are relatively scarce. This makes the government more tolerant of non-low-carbon production and operation in pharmaceutical enterprises, resulting in high consumption, high emission, and high pollution in the pharmaceutical industry.

TABLE 7 | Focus of relocated industries based on air pollution.

Industry		did	_cons	Control variables/Fixed effects	Observations	R-squared
T1	Y	−0.319 (0.225)	1.634* (0.836)	Yes	4,464	0.838
	N	−1.389 (0.905)	1.860** (0.830)	Yes	4,144	0.845
T2	Y	−0.099 (0.178)	1.853** (0.832)	Yes	4,384	0.838
	N	−1.266** (0.631)	2.008** (0.795)	Yes	4,224	0.846
T3	Y	−0.464 (0.285)	1.806** (0.809)	Yes	4,480	0.843
	N	−0.651* (0.341)	1.648* (0.863)	Yes	4,144	0.838
T4	Y	−0.897** (0.400)	1.632* (0.857)	Yes	4,336	0.843
	N	−0.008 (0.150)	1.751** (0.830)	Yes	4,288	0.840
T5	Y	−0.840* (0.435)	1.991** (0.785)	Yes	4,256	0.850
	N	−0.264 (0.271)	1.483* (0.895)	Yes	4,368	0.839
T6	Y	−0.411 (0.297)	1.941** (0.807)	Yes	4,432	0.843
	N	−0.735** (0.364)	1.581* (0.844)	Yes	4,192	0.840
T7	Y	−0.885* (0.490)	1.611* (0.843)	Yes	4,272	0.844
	N	−0.196 (0.193)	1.925** (0.822)	Yes	4,352	0.839
T8	Y	−0.487 (0.295)	1.555* (0.848)	Yes	4,432	0.843
	N	−0.520 (0.363)	1.909** (0.827)	Yes	4,192	0.839
T9	Y	−0.470 (0.302)	1.558* (0.848)	Yes	4,432	0.843
	N	−0.566 (0.350)	1.902** (0.828)	Yes	4,192	0.839
T10	Y	−0.378 (0.270)	1.792** (0.806)	Yes	4,480	0.843
	N	−1.066** (0.472)	1.701** (0.857)	Yes	4,144	0.840
T11	Y	−0.088 (0.250)	1.819** (0.835)	Yes	4,272	0.838
	N	−0.823** (0.371)	1.752** (0.830)	Yes	4,352	0.845
T12	Y	−0.526* (0.311)	1.810** (0.806)	Yes	4,432	0,843
	N	−0.402 (0.265)	1.636* (0.869)	Yes	4,192	0.840
T13	Y	−0.377 (0.421)	1.609* (0.858)	Yes	4,272	0.843
	N	−0.578** (0.285)	1.836** (0.825)	Yes	4,352	0.839
T14	Y	−0.216 (0.180)	1.795** (0.817)	Yes	4,224	0.839
	N	−0.642* (0.353)	1.620* (0.866)	Yes	4,400	0.843
T15	Y	−0.667 (0.447)	1.909** (0.808)	Yes	4,288	0.843
	N	−0.340 (0.223)	1.519* (0.863)	Yes	4,336	0.839
T16	Y	−0.541 (0.500)	1.834** (0.809)	Yes	4,256	0.843
	N	−0.468* (0.252)	1.620* (0.872)	Yes	4,368	0.839
T17	Y	−1.022** (0.474)	1.894** (0.815)	Yes	4,272	0.843
	N	−0.088 (0.170)	1.480* (0.870)	Yes	4,352	0.840
T18	Y	−0.825** (0.392)	1.836** (0.818)	Yes	4,336	0.844
	N	−0.090 (0.205)	1.480* (0.867)	Yes	4,288	0.839
T19	Y	0.050 (0.158)	1.908** (0.823)	Yes	4,112	0.839
	N	−0.556** (0.269)	1.566* (0.848)	Yes	4,512	0.843

Note: Y and N indicate that pilot cities have relocated and have not relocated the industry, respectively.

6 CONCLUSIONS AND POLICY IMPLICATIONS

Air pollution has become one of the focus issues of public concern, and industrial relocation is an essential factor affecting pollution emissions. However, there is little literature to test the linkage between the two empirically. This study takes the NIRDZs policy as a quasi-natural experiment and uses a DID method to estimate the emission reduction effect by constructing panel data of 285 cities from 2003 to 2018. Results indicate that the NIRDZs policy has an inhibitory effect on air pollution. Compared with non-pilot cities, the SO_2 emissions per 100 people in pilot cities decreased by 0.49 units. However, the heterogeneity test shows that the NIRDZs policy only has an inhibitory effect in the first 5 years of policy implementation and has a spillover effect in surrounding cities within 50–100 km. The mechanism test reveals that the NIRDZs policy reduced air pollution through industrial structure rationalization and industrial structure upgradation. Further discussion suggests that the NIRDZs policy should be implemented in cities with moderate administrative areas and growing, declining, and renewing resource-based cities. Nonferrous metals, steel, automotive, new energy, new materials, and producer services can help reduce air pollution and should be listed as priority industries.

The findings provide some targeted policy implications for the government dedicated to emissions reduction. First, the NIRDZs policy has a unique advantage in promoting the local economy while simultaneously reducing air pollution. Therefore, the central government should expand the policy scope and improve the policy efficiency by rationally selecting pilot cities according to administrative areas and resource endowments. Second, considering industry heterogeneity, local governments should prioritize relocated industries that contribute to energy conservation and emission reduction, such as new energy, new materials, and production services. For sectors that may aggravate pollution emissions, local governments must raise environmental entry barriers and implement daily inspections on pollution control and emission reduction to eliminate new pollution sources. Third, local governments should play the role of gatekeepers. In the process of industrial development, local governments must clarify their role and positioning, avoid management offside, and let the market play a decisive role. Meanwhile, in fields that require government support, such as human, financial, and material resources, local governments should also prevent management absence and provide corresponding support without violating market discipline. Finally, local governments should explore stable collaborative mechanisms to stimulate potential added value in terms of industrial relocation and environmental governance. Most pilot cities located in the same zone are geographically adjacent. The regional collaborative mechanism between them can reduce transboundary pollution and avoid inefficient resource utilization caused by industry isomorphism (Xu and Wu, 2020).

This study adds new insights into industrial relocation, but much remains to be done. The first is that the impact of the rebound effect caused by technological progress on reducing air pollution needs to be examined (Pérez-Urdiales and Baerenklau, 2019). Meanwhile, whether the reduction in air pollution comes from the impact of other events still needs further investigation. Additionally, another line of research worth pursuing is the use of micro-enterprise data to recognize the environmental performance of the NIRDZs policy.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

TG: software, methodology, writing original draft, and project administration. XL: writing original draft. LM: data curation, writing—review and editing. XS: conceptualization, investigation, supervision.

FUNDING

This study was supported by the National Social Science Foundation of China (No. 21CJL016), and the Social Science Foundation of Nantong (No. 2021CNT002).

REFERENCES

Ahmad, M., Zhao, Z.-Y., Irfan, M., Mukeshimana, M. C., Rehman, A., Jabeen, G., et al. (2020). Modeling Heterogeneous Dynamic Interactions Among Energy Investment, SO_2 Emissions and Economic Performance in Regional China. *Environ. Sci. Pollut. Res.* 27, 2730–2744. doi:10.1007/s11356-019-07044-3

Alder, S., Shao, L., and Zilibotti, F. (2016). Economic Reforms and Industrial Policy in a Panel of Chinese Cities. *J. Econ. Growth* 21 (4), 305–349. doi:10.1007/s10887-016-9131-x

Alkon, M. (2018). Do special Economic Zones Induce Developmental Spillovers? Evidence from India's States. *World Dev.* 107, 396–409. doi:10.1016/j.worlddev.2018.02.028

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., and Farhani, S. (2018). How Economic Growth, Renewable Electricity and Natural Resources Contribute to CO_2 Emissions? *Energy Policy* 113, 356–367. doi:10.1016/j.enpol.2017.10.050

Briant, A., Lafourcade, M., and Schmutz, B. (2015). Can Tax Breaks Beat Geography? Lessons from the French Enterprise Zone Experience. *Am. Econ. J. Econ. Policy* 7 (2), 88–124. doi:10.1257/pol.20120137

Busso, M., Gregory, J., and Kline, P. (2013). Assessing the Incidence and Efficiency of a Prominent Place Based Policy. *Am. Econ. Rev.* 103 (2), 897–947. doi:10.1257/aer.103.2.897

Candau, F., and Dienesch, E. (2017). Pollution Haven and Corruption Paradise. *J. Environ. Econ. Manag.* 85, 171–192. doi:10.1016/j.jeem.2017.05.005

Cao, L., Li, L., Wu, Y., and Zeng, W. (2020). Does Industrial Convergence Promote Regional Metabolism? Evidence from China. *J. Clean. Prod.* 273, 123010. doi:10.1016/j.jclepro.2020.123010

Cao, Q. F. (2020). Driving Effects of National New Zone on Regional Economic Growth——Evidence from 70 Cities of China. *China Ind. Econ.* 7, 43–60. doi:10.19581/j.cnki.ciejournal.2020.07.014

Cuberes, D., Desmet, K., and Rappaport, J. (2021). Urban Growth Shadows. *J. Urban Econ.* 123, 103334. doi:10.1016/j.jue.2021.103334

Dou, J. M., and Zhang, K. (2015). Spatial Dependence, Economic Agglomeration and Urban Environmental Pollution. *Bus. Manag. J.* 36, 12–21. doi:10.19616/j.cnki.bmj.2015.10.004

Driessen, P. H., Hillebrand, B., Kok, R. A. W., and Verhallen, T. M. M. (2013). Green New Product Development: The Pivotal Role of Product Greenness. *IEEE Trans. Eng. Manage.* 60 (2), 315–326. doi:10.1109/tem.2013.2246792

Du, M., Liao, L., Wang, B., and Chen, Z. (2021). Evaluating the Effectiveness of the Water-Saving Society Construction in China: A Quasi-Natural Experiment. *J. Environ. Manag.* 277, 111394. doi:10.1016/j.jenvman.2020.111394

Edwards, J. R., and Lambert, L. S. (2007). Methods for Integrating Moderation and Mediation: A General Analytical Framework Using Moderated Path Analysis. *Psychol. Methods* 12 (1), 1–22. doi:10.1037/1082-989x.12.1.1

Ek, K., and Söderholm, P. (2010). The Devil is in the Details: Household Electricity Saving Behavior and the Role of Information. *Energy Policy* 38 (3), 1578–1587. doi:10.1016/j.enpol.2009.11.041

Edward L. Glaeser, E. L., and Joshua D. Gottlieb, J. D. (2008). The Economics of Place-Making Policies. *Brookings Pap. Econ. Activity* 2008 (1), 155–253. doi:10.1353/eca.0.0005

Faggio, G., Silva, O., and Strange, W. C. (2017). Heterogeneous Agglomeration. *Rev. Econ. Stat.* 99 (1), 80–94. doi:10.1162/rest_a_00604

Faggio, G. (2019). Relocation of Public Sector Workers: Evaluating a Place-Based Policy. *J. Urban Econ.* 111, 53–75. doi:10.1016/j.jue.2019.03.001

Ge, T., Li, J., Sha, R., and Hao, X. (2020). Environmental Regulations, Financial Constraints and Export Green-Sophistication: Evidence from China's Enterprises. *J. Clean. Prod.* 251, 119671. doi:10.1016/j.jclepro.2019.119671

Gobillon, L., Magnac, T., and Selod, H. (2011). The Effect of Location on Finding a Job in the Paris Region. *J. Appl. Econ.* 26 (7), 1079–1112. doi:10.1002/jae.1168

Ham, J. C., Swenson, C., İmrohoroğlu, A., and Song, H. (2011). Government programs can improve local labor markets: Evidence from State Enterprise Zones, Federal Empowerment Zones and Federal Enterprise Community. *J. Public Econ.* 95, 779–797. doi:10.1016/j.jpubeco.2010.11.027

Hao, Y., Gai, Z., Yan, G., Wu, H., and Irfan, M. (2021). The Spatial Spillover Effect and Nonlinear Relationship Analysis Between Environmental Decentralization, Government Corruption and Air Pollution: Evidence from China. *Sci. Total Environ.* 763, 144183. doi:10.1016/j.scitotenv.2020.144183

Jacobson, L. S., LaLonde, R. J., and Sullivan, D. G. (1993). Earnings Losses of Displaced Workers. *Am. Econ. Rev.* 83 (4), 685–709. Available at: https://www.jstor.org/stable/2117574.

Jaffe, A. B., Peterson, S. R., Portney, P. R., and Stavins, R. N. (1995). Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the

Evidence Tell Us? *J. Econ. Lit.* 33 (1), 132–163. Available at: https://www.jstor.org/stable/2728912.

Jia, J., Ma, G., Qin, C., and Wang, L. (2020). Place-Based Policies, State-Led Industrialisation, and Regional Development: Evidence from China's Great Western Development Programme. *Eur. Econ. Rev.* 123, 103398. doi:10.1016/j.euroecorev.2020.103398

Jindra, B., Giroud, A., and Scott-Kennel, J. (2009). Subsidiary Roles, Vertical Linkages and Economic Development: Lessons from Transition Economies. *J. World Bus.* 44 (2), 167–179. doi:10.1016/j.jwb.2008.05.006

Khan, A. N., En, X., Raza, M. Y., Khan, N. A., and Ali, A. (2020). Sectorial Study of Technological Progress and CO_2 Emission: Insights from a Developing Economy. *Technol. Forecast. Soc. Change* 151, 119862. doi:10.1016/j.techfore.2019.119862

Kline, P., and Moretti, E. (2014). People, Places, and Public Policy: Some Simple Welfare Economics of Local Economic Development Programs. *Annu. Rev. Econ.* 6, 629–662. doi:10.1146/annurev-economics-080213-041024

Krupka, D. J., and Noonan, D. S. (2009). Empowerment Zones, Neighborhood Change and Owner-Occupied Housing. *Reg. Sci. Urban Econ.* 39 (4), 386–396. doi:10.1016/j.regsciurbeco.2009.03.001

Květoň, V., and Horák, P. (2018). The Effect of Public R&D Subsidies on Firms' Competitiveness: Regional and Sectoral Specifics in Emerging Innovation Systems. *Appl. Geogr.* 94, 119–129. doi:10.1016/j.apgeog.2018.03.015

Lan, J., Kakinaka, M., and Huang, X. (2012). Foreign Direct Investment, Human Capital and Environmental Pollution in China. *Environ. Resour. Econ.* 51 (2), 255–275. doi:10.1007/s10640-011-9498-2

Li, P., Lu, Y., and Wang, J. (2016). Does Flattening Government Improve Economic Performance? Evidence from China. *J. Dev. Econ.* 123, 18–37. doi:10.1016/j.jdeveco.2016.07.002

Li, K., Fang, L., and He, L. (2019a). How Population and Energy Price Affect China's Environmental Pollution? *Energy Policy* 129, 386–396. doi:10.1016/j.enpol.2019.02.020

Li, T., Liu, Y., Wang, C., Olsson, G., Wang, Z., and Wang, H. (2019b). Decentralization of the Non-Capital Functions of Beijing: Industrial Relocation and Its Environmental Effects. *J. Clean. Prod.* 224, 545–556. doi:10.1016/j.jclepro.2019.03.247

Li, G., Fang, C., and He, S. (2020). The Influence of Environmental Efficiency on $PM_{2.5}$ Pollution: Evidence from 283 Chinese Prefecture-Level Cities. *Sci. Total Environ.* 748, 141549. doi:10.1016/j.scitotenv.2020.141549

Li, Z., Zou, F., and Mo, B. (2021). Does Mandatory CSR Disclosure Affect Enterprise Total Factor Productivity? *Econ. Res.-Ekon. Istraž.* doi:10.1080/1331677X.2021.2019596

Liao, X., and Shi, X. (2018). Public Appeal, Environmental Regulation and Green Investment: Evidence from China. *Energy Policy* 119, 554–562. doi:10.1016/j.enpol.2018.05.020

Lin, B., and Zhu, J. (2020). Chinese Electricity Demand and Electricity Consumption Efficiency: Do the Structural Changes Matter? *Appl. Energy* 262, 114505. doi:10.1016/j.apenergy.2020.114505

Liu, C., and Li, L. (2021). Place-Based Techno-Industrial Policy and Innovation: Government Responses to the Information Revolution in China. *China Econ. Rev.* 66, 101600. doi:10.1016/j.chieco.2021.101600

Liu, W., and Qin, B. (2016). Low-Carbon City Initiatives in China: A Review from the Policy Paradigm Perspective. *Cities* 51, 131–138. doi:10.1016/j.cities.2015.11.010

Liu, T., Pan, S., Hou, H., and Xu, H. (2020a). Analyzing the environmental and economic impact of industrial transfer based on an improved CGE model: Taking the Beijing-Tianjin-Hebei region as an example. *Environ. Impact Assess. Rev.* 83, 106386. doi:10.1016/j.eiar.2020.106386

Liu, X., Sun, X., Li, M., and Zhai, Y. (2020b). The Effects of Demonstration Projects on Electric Vehicle Diffusion: An Empirical Study in China. *Energy Policy* 139, 111322. doi:10.1016/j.enpol.2020.111322

Liu, S., Liu, C., and Yang, M. (2021). The Effects of National Environmental Information Disclosure Program on the Upgradation of Regional Industrial Structure: Evidence from 286 Prefecture-Level Cities in China. *Struct. Change Econ. Dyn.* 58, 552–561. doi:10.1016/j.strueco.2021.07.006

Lu, Y., Wang, J., and Zhu, L. (2019). Place-Based Policies, Creation, and Agglomeration Economies: Evidence from China's Economic Zone Program. *Am. Econ. J. Econ. Policy* 11 (3), 325–360. doi:10.1257/pol.20160272

Lu, X., Chen, D., Kuang, B., Zhang, C., and Cheng, C. (2020). Is High-Tech Zone a Policy Trap or a Growth Drive? Insights from the Perspective of Urban Land Use Efficiency. *Land Use Policy* 95, 104583. doi:10.1016/j.landusepol.2020.104583

Luo, J., Wang, Z., and Wu, M. (2021). Effect of Place-Based Policies on the Digital Economy: Evidence from the Smart City Program in China. *J. Asian Econ.* 77, 101402. doi:10.1016/j.asieco.2021.101402

McDowall, W., Solano Rodriguez, B., Usubiaga, A., and Acosta Fernández, J. (2018). Is the Optimal Decarbonization Pathway Influenced by Indirect Emissions? Incorporating Indirect Life-Cycle Carbon Dioxide Emissions into a European TIMES Model. *J. Clean. Prod.* 170, 260–268. doi:10.1016/j.jclepro.2017.09.132

Miao, Z., Chen, X., Baležentis, T., and Sun, C. (2019). Atmospheric Environmental Productivity Across the Provinces of China: Joint Decomposition of Range Adjusted Measure and Luenberger Productivity Indicator. *Energy Policy* 132 (9), 665–677. doi:10.1016/j.enpol.2019.06.019

O'Keefe, S. (2004). Job Creation in California's Enterprise Zones: A Comparison Using a Propensity Score Matching Model. *J. Urban Econ.* 55 (1), 131–150. doi:10.1016/j.jue.2003.08.002

Pan, D., and Tang, J. (2021). The Effects of Heterogeneous Environmental Regulations on Water Pollution Control: Quasi-Natural Experimental Evidence from China. *Sci. Total Environ.* 751, 141550. doi:10.1016/j.scitotenv.2020.141550

Pérez-Urdiales, M., and Baerenklau, K. A. (2019). Learning to Live Within Your (Water) Budget: Evidence from Allocation-Based Rates. *Resour. Energy Econ.* 57, 205–221. doi:10.1016/j.reseneeco.2019.06.002

Porter, M. E. (1991). America's Green Strategy. *Sci. Am.* 264 (4), 168. doi:10.1038/scientificamerican0491-168

Rasiah, R., Fei, Q., and Shen, L. J. (2014). The Clean Energy-Growth Nexus with CO_2 Emissions and Technological Innovation in Norway and New Zealand. *Energy Environ.* 25 (8), 1323–1344. doi:10.1260/0958-305X.25.8.1323

Ren, S., Hao, Y., and Wu, H. (2021). Government Corruption, Market Segmentation and Renewable Energy Technology Innovation: Evidence from China. *J. Environ. Manag.* 300, 113686. doi:10.1016/j.jenvman.2021.113686

Ren, S., Hao, Y., and Wu, H. (2022a). The Role of Outward Foreign Direct Investment (OFDI) on Green Total Factor Energy Efficiency: Does Institutional Quality Matters? Evidence from China. *Resour. Policy* 76, 102587. doi:10.1016/j.resourpol.2022.102587

Ren, S., Hao, Y., and Wu, H. (2022b). How Does Green Investment Affect Environmental Pollution? Evidence from China. *Environ. Resour. Econ.* 81, 25–51. doi:10.1007/s10640-021-00615-4

Romano, L., and Traù, F. (2017). The Nature of Industrial Development and the Speed of Structural Change. *Struct. Change Econ. Dyn.* 42, 26–37. doi:10.1016/j.strueco.2017.05.003

Rubashkina, Y., Galeotti, M., and Verdolini, E. (2015). Environmental Regulation and Competitiveness: Empirical Evidence on the Porter Hypothesis from European Manufacturing Sectors. *Energy Policy* 83 (35), 288–300. doi:10.1016/j.enpol.2015.02.014

Song, L., and Zhou, X. (2021). Does the Green Industry Policy Reduce Industrial Pollution Emissions? Evidence from China's National Eco-Industrial Park. *Sustainability* 13 (11), 6343. doi:10.3390/su13116343

Tang, J. (2015). Testing the Pollution Haven Effect: Does the Type of FDI Matter? *Environ. Resour. Econ.* 60, 549–578. doi:10.1007/s10640-014-9779-7

Tian, Y., Jiang, G., Zhou, D., Ding, K., Su, S., Zhou, T., et al. (2019). Regional Industrial Transfer in the Jingjinji Urban Agglomeration, China: An Analysis Based on a New "Transferring Area-Undertaking Area-Dynamic Process" Model. *J. Clean. Prod.* 235, 751–766. doi:10.1016/j.jclepro.2019.06.167

Van Leeuwen, G., and Mohnen, P. (2017). Revisiting the Porter Hypothesis: An Empirical Analysis of Green Innovation for the Netherlands. *Econ. Innov. New. Tech.* 26 (1-2), 63–77. doi:10.1080/10438599.2016.1202521

Wang, X., and Luo, Y. (2020). Has Technological Innovation Capability Addressed Environmental Pollution from the Dual Perspective of FDI Quantity and Quality? Evidence from China. *J. Clean. Prod.* 258, 120941. doi:10.1016/j.jclepro.2020.120941

Wang, Z., and Qiu, S. (2021). Can "Energy Saving And Emission Reduction" Demonstration City Selection Actually Contribute to Pollution Abatement in China? *Sustain. Prod. Consum.* 27, 1882–1902. doi:10.1016/j.spc.2021.04.030

Wang, L., Xu, J., and Qin, P. (2014). Will a driving restriction policy reduce car trips? The case study of Beijing, China. *Transp. Res. Part A Policy Pract.* 67, 279–290. doi:10.1016/j.tra.2014.07.014

Wang, Y., Song, Q., He, J., and Qi, Y. (2015). Developing Low-Carbon Cities Through Pilots. *Clim. Policy* 15 (S1), S81–S103. doi:10.1080/14693062.2015.1050347

Wang, Z., Chen, S., Cui, C., Liu, Q., and Deng, L. (2019). Industry Relocation or Emission Relocation? Visualizing and Decomposing the Dislocation Between China's Economy and Carbon Emissions. *J. Clean. Prod.* 208, 1109–1119. doi:10.1016/j.jclepro.2018.10.166

Wu, H., Hao, Y., and Weng, J.-H. (2019). How Does Energy Consumption Affect China's Urbanization? New Evidence from Dynamic Threshold Panel Models. *Energy Policy* 127, 24–38. doi:10.1016/j.enpol.2018.11.057

Xi, Q., Sun, R., and Mei, L. (2021). The Impact of Special Economic Zones on Producer Services Productivity: Evidence from China. *China Econ. Rev.* 65, 101558. doi:10.1016/j.chieco.2020.101558.

Xu, M., and Wu, J. (2020). Can Chinese-Style Environmental Collaboration Improve the Air Quality? A Quasi-Natural Experimental Study Across Chinese Cities. *Environ. Impact Assess. Rev.* 85, 106466. doi:10.1016/j.eiar.2020.106466

Xu, J., Zhang, M., Zhou, M., and Li, H. (2017). An Empirical Study on the Dynamic Effect of Regional Industrial Carbon Transfer in China. *Ecol. Indic.* 73, 1–10. doi:10.1016/j.ecolind.2016.09.002

Xu, C., Zhao, W., Zhang, M., and Cheng, B. (2021). Pollution Haven or Halo? The Role of the Energy Transition in the Impact of FDI on SO_2 Emissions. *Sci. Total Environ.* 763, 143002. doi:10.1016/j.scitotenv.2020.143002

Yang, M., Ma, T., and Sun, C. (2018). Evaluating the Impact of Urban Traffic Investment on SO_2 Emissions in China Cities. *Energy Policy* 113, 20–27. doi:10.1016/j.enpol.2017.10.039

Yang, X., Lin, S., Li, Y., and He, M. (2019). Can High-Speed Rail Reduce Environmental Pollution? Evidence from China. *J. Clean. Prod.* 239, 118–135. doi:10.1016/j.jclepro.2019.118135

Yang, F., Zhang, S., and Sun, C. (2020). Energy Infrastructure Investment and Regional Inequality: Evidence from China's Power Grid. *Sci. Total Environ.* 749, 142384. doi:10.1016/j.scitotenv.2020.142384

Yang, X., Zhang, J., Ren, S., and Ran, Q. (2021). Can the New Energy Demonstration City Policy Reduce Environmental Pollution? Evidence from a Quasi-Natural Experiment in China. *J. Clean. Prod.* 287, 125015. doi:10.1016/j.jclepro.2020.125015

Yi, F., Ye, H., Wu, X., Zhang, Y. Y., and Jiang, F. (2020). Self-Aggravation Effect of Air Pollution: Evidence from Residential Electricity Consumption in China. *Energy Econ.* 86, 104684. doi:10.1016/j.eneco.2020.104684

Yin, J., Zheng, M., and Li, X. (2016). Interregional Transfer of Polluting Industries: A Consumption Responsibility Perspective. *J. Clean. Prod.* 112, 4318–4328. doi:10.1016/j.jclepro.2015.07.103

Zeng, D.-Z., and Zhao, L. (2009). Pollution Havens and Industrial Agglomeration. *J. Environ. Econ. Manag.* 58 (2), 141–153. doi:10.1016/j.jeem.2008.09.003

Zhang, G., and Zhang, N. (2020). The Effect of China's Pilot Carbon Emissions Trading Schemes on Poverty Alleviation: A Quasi-Natural Experiment Approach. *J. Environ. Manag.* 271, 110973. doi:10.1016/j.jenvman.2020.110973

Zhang, L., Mol, A. P., and He, G. (2016). Transparency and Information Disclosure in China's Environmental Governance. *Curr. Opin. Environ. Sustain.* 18, 17–24. doi:10.1016/j.cosust.2015.03.009

Zhang, M., Sun, X., and Wang, W. (2020). Study on the Effect of Environmental Regulations and Industrial Structure on Haze Pollution in China from the Dual Perspective of Independence and Linkage. *J. Clean. Prod.* 256, 120748. doi:10.1016/j.jclepro.2020.120748

Zhang, Y., Li, X., Song, Y., and Jiang, F. (2021). Can Green Industrial Policy Improve Total Factor Productivity? Firm-Level Evidence from China. *Struct. Change Econ. Dyn.* 59, 51–62. doi:10.1016/j.strueco.2021.08.005

Zhao, X., and Yin, H. (2011). Industrial Relocation and Energy Consumption: Evidence from China. *Energy Policy* 39 (5), 2944–2956. doi:10.1016/j.enpol.2011.03.002

Zheng, D., and Shi, M. (2017). Multiple Environmental Policies and Pollution Haven Hypothesis: Evidence from China's Polluting Industries. *J. Clean. Prod.* 141, 295–304. doi:10.1016/j.jclepro.2016.09.091

Zheng, G., Barbieri, E., Di Tommaso, M. R., and Zhang, L. (2016). Development Zones and Local Economic Growth: Zooming in on the Chinese Case. *China Econ. Rev.* 38, 238–249. doi:10.1016/j.chieco.2016.01.001

Zheng, S., Sun, W., Wu, J., and Kahn, M. E. (2017). The Birth of Edge Cities in China: Measuring the Spillover Effects of Industrial Parks. *J. Urban Econ.* 100, 80–103. doi:10.1016/j.jue.2017.05.002

Zhou, Q., Zhang, X., Shao, Q., and Wang, X. (2019). The Non-Linear Effect of Environmental Regulation on Haze Pollution: Empirical Evidence for 277 Chinese Cities During 2002–2010. *J. Environ. Manag.* 248, 109274. doi:10.1016/j.jenvman.2019.109274

Zhu, S., He, C., and Liu, Y. (2014). Going Green or Going Away: Environmental Regulation, Economic Geography and Firms' Strategies in China's Pollution-Intensive Industries. *Geoforum* 55 (8), 53–65. doi:10.1016/j.geoforum.2014.05.004

Zhu, B., Zhang, M., Zhou, Y., Wang, P., Sheng, J., He, K., et al. (2019). Exploring the Effect of Industrial Structure Adjustment on Interprovincial Green Development Efficiency in China: A Novel Integrated Approach. *Energy Policy* 134, 110946. doi:10.1016/j.enpol.2019.110946

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.