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The Early Effect of *Black Land Protection Plan in Northeast China* on Industrial Pollution Using Synthetic Control Method

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Abstract: This study used relevant industrial pollution emission data collected between 2004 and 2020 in northeastern China. It utilized the synthetic control method (SCM) and used entire county-level areas within the scope of the typical black land protection as the experimental group. Thirty regions in China (excluding Tibet, Hong Kong, Macao, and Taiwan), including the three non-black land areas of Liaoning, Jilin, Heilongjiang, and Inner Mongolia, and the other 26 entire provinces were taken as the control group. We studied whether the *Outline of Black Land Protection Plan in Northeast China (2017–2030)* (BLPP) has reduced local industrial pollution emissions since it was issued in 2017. The study found that implementation of the BLPP reduced industrial wastewater and sulfur dioxide emissions in black land areas significantly. Between 2017 and 2020, local industrial wastewater production decreased by 29.3% compared to the period without implementation of the outline, while industrial sulfur dioxide decreased by 12%. These results remained robust under the placebo and difference-in-difference (DID) tests. This once again showed that implementation of the outline had a significant effect on reducing industrial pollutant emissions in the black land area of northeastern China.

Keywords: black land area; industrial pollution emission; synthetic control method; policy impact evaluation

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1. Introduction

A valuable soil resource, black land is a type of high-quality arable land with good character and high fertility that is suitable for farming. The plains of northeastern China are among the world's three large black land areas and are an important Chinese commodity grain production base. The protection and sustainable utilization of cultivated land resources are related to the strategic need to ensure food security and social stability in the country. As the most fertile cultivated land resources in China, black land in northeast China is an anchor that guarantees Chinese food security and the supply of high-quality agricultural products. However, heavy industrial enterprises are the core of the social economy in northeast China and the main source of pollution. Industrial wastewater and sulfur dioxide emissions have substantial destructive effects on land resources [1–4]. Due to extended, highly intensive use of black land and a lack of scientific management and protection, cultivated land resources and agricultural ecological security in the black land region are severely challenged. There is an urgent need to take relevant, substantial measures to protect black land [5].

To strengthen the protection of black land, the Chinese government issued the *Outline of Black Land Protection Plan in Northeast China (2017–2030)* (the BLPP) in June of 2017 [6].

Has the BLPP effectively reduced industrial pollution in the black land area? The purpose of this study was to explore whether remedial policies like the BLPP have reduced industrial pollutant emissions in the black land area and the extent of reduction since its implementation in the black land of northeast China.

This research contributes to the empirical literature on the effect of land protection policy on land pollution. Previous studies focused on the evolution of remedial policies for black soil protection, but lacked empirical evaluations of remedial policies. By using SCM, as well as several robust checks, this paper provides rigorous evidence of the causal effect of the remedial policies for the black land area and the reduction of industrial pollution emissions.

The remainder of the paper is organized as follows. Section 2 presents the literature review. Section 3 describes the BLPP. Section 4 presents the data and methods used for the estimation of industrial emission reductions. Section 5 presents the results of the empirical analysis, as well as several robustness checks. Section 6 talks about the limitations of this study. Finally, Section 7 concludes.

2. Literature Review

Our literature review was focused mainly on two areas: the protection of black land in northeast China and an evaluation of the environmental effects of policies.

There are three main approaches to strengthen the protection of black land. The first is to make changes in farming methods. Traditional farming methods focus on improving the land utilization rate as much as possible and improving the yield per unit area of black land. Addressing cultivation-related methods of protecting black land, Yang [7], Yu et al. [8], and Wang et al. [9] respectively proposed that traditional cultivation methods should be modified and suggested innovative measures such as crop rotation, land fallowing, and optimization of planting structures to protect black land. The second approach is ecological environment construction. As the central link between the organic and inorganic worlds, soil has a close relationship with water and air pollution. Therefore, it has received increasing attention in environmental pollution research [10]. The third is the proposal and implementation of a black land protection policy. In recent years, policies and legislation that address black land have attracted increasing attention from government at all levels. Li et al. [11] proposed that the ecological protection and restoration of black land in northeast China must rise to the level of national law to highlight the seriousness and importance of such protection. Environmental control laws and regulations mainly remove human pollution sources that affect black land resources, especially in the northeast, where large industrial enterprises produce wastewater and discharge gas [12].

The other literature thread evaluated the impact of implementing relevant laws and policies that address resource protection. Zhang et al. [13] believed that the public goods attribute of environmental resources requires that control of high-pollution industrial enterprises not rely entirely on market mechanisms, but rather should be incorporated into the scope of government regulation in a timely manner. Zhang et al. [14] also believed that environmental resource policy, a type of social policy, contains certain institutional norms. He et al. [15] believed that local protection incentives and constraints, alongside promotion of structural reform within the environmental protection management system, are important institutional foundations for improving the Chinese environment and resources. However, Lin and Zheng [16] concluded that it is difficult to judge Chinese environmental and resource control policies consistently at the present stage because environmental problems involve the interests of all parties and demonstration of the extent and scope of the environmental impact is a long-term process. In addition, some scholars have pointed out that the implementation of environmental resource protection planning mechanisms in China, a large country in transition, is certain to be intertwined with other important reforms such as "central–local" governance [17]. Local government-based environmental resource protection behaviors are not only guided by the central government's policy but also lead to further adjustment of other local government strategies [18].

A review of relevant literature on the effects of Chinese environmental policies found that some policies failed to achieve the desired effect of reducing pollution. For example, Gamper-Rabindran [19] analyzed the Chinese Environmental Protection Agency's voluntary industrial toxics program and found that participants from several key industries did not reduce their health-index emissions of targeted chemicals more than nonparticipants. Lin [20] found that under specific pollution collection regulations in China, actual pollution from industrial plants sometimes increases as inspections increase. Thus, inspections by Chinese environmental authorities are effective in verifying self-reported pollution from factories, but not in reducing pollution. Wang et al. [21] took Chinese central environmental inspection as the research object and evaluated the effect of campaign-style law enforcement on promoting corporate environmental action. They found that central environmental inspections affect changes in environmental actions by enterprises. After implementation of central environmental inspections, the number of polluting enterprises decreased by 48% and the declines in small and micro enterprises were even greater. Some policies are also effective, based on panel data from 40 cities in the Yangtze River Economic Belt from 2004 to 2015, She et al. [22] explored the pollution situation of surface water using the difference-in-difference (DID) method, the River Chief Policy effectively improved the water quality of each tributary of the Yangtze River.

The related studies show that environmental policies cannot achieve all of the desired effects and sometimes counteract them. Thus, we need to evaluate the results and this study focused on evaluating the effect of the BLPP. We wanted to know whether the local authorities have taken measures to reduce industrial wastewater and exhaust gas discharges to protect the precious black land resources. In addition, because the government is the leading mechanism of ecological governance in China, legislation can improve local environmental quality only in areas where the government implements environmental protection strictly [23]. Existing black land research has focused on identifying the natural properties of black land and summarizing the research footprints of conservation methods [24,25]. Since there is little quantitative analysis of policy-driven improvement of local industrial waste discharge and its effect on black land conservation, this study examines the effect of the BLPP based on the synthetic control method (SCM).

3. Policy Context

Black land in northeast China, an important food base with regard to arable land, has been the subject of several protection policies in recent years. At the Chinese central governmental level, the "No. 1 Document" of the Central Government from 2015 to 2022 mentioned the protection of black land in northeast China for eight consecutive years.

In 2017, the Ministry of Agriculture, the Development and Reform Commission, the Ministry of Finance, the Ministry of Land and Resources, the Ministry of Environmental Protection, and the Ministry of Water Resources jointly issued the BLPP. The BLPP proposed to accelerate the establishment of a long-term mechanism for the protection of black land and sought to protect 250 million mu of black land by 2030. The BLPP covered the arable land in major black land-containing areas. In addition, the BLPP was intended to curb the trend of black land degradation and improve the quality of cultivated land in the northeast black land area by more than one grade on average. However, this outline policy was ambiguous and policy goals were defined, but specific implementation paths and means were not proposed. Instead, the central government hoped that local governments could explore operational policies that could meet local development conditions and could be replicated and promoted [6].

On March 30, 2018, the second meeting of the Standing Committee of the 13th People's Congress of Jilin Province adopted the *Regulations of Jilin Province on the Protection of Black Land* [26]. This was the first local law on the protection of black land in China. When the Jilin Province ecological and environmental protection conference proposed to build a beautiful "Jilin Pattern", it was clearly to make "blue sky, clear water, green mountains and black land" the most important purpose [26]. In 2020, the Ministry of Agriculture and

Rural Affairs and the Ministry of Finance issued the *Action Plan for Conservation Tillage of Black Land in Northeast China (2020–2025)*, which provided specific guidelines for the protection of black land [27]. In 2021, the policy of *Opinions of the CPC Central Committee and The State Council on comprehensively promoting rural revitalization and accelerating agricultural and rural modernization* proposed the implementation of a national black-land protection project [28]. In June of the same year, the Ministry of Agriculture and Rural Affairs and seven other departments jointly issued the *Implementation Plan of the National Black Land Protection Project (2021–2025)*. It proposed that the protection and utilization of 100 million mu of black land be completed during the 14th Five-Year Plan period from an engineering perspective and clarified the content and key points of the national black land protection project [29].

The strategies review suggests that the BLPP issued in 2017 is more comprehensive for the protection of black land in northeast China. Therefore, this study takes the year 2017 as the time point of the policy issued to test whether the implementation of the BLPP reduces industrial pollution emissions significantly.

4. Research Methodology and Data Sources

4.1. Research Outline

The promulgation and implementation of specific policies must be performed in specific government units. As an important basic economic region in China, the county-level region has a flexible economic development plan, but is easily affected by specific, strict policies. The BLPP issued in 2017 explicitly mentions the control of non-point-source pollution, with a focus on controlling emissions from industrial and mining enterprises and exogenous pollution such as urban garbage and sewage to reduce the pollution of black land. Therefore, local governments at all levels were required to take relevant measures to meet the policy requirements. The causal framework is shown in Figure 1.

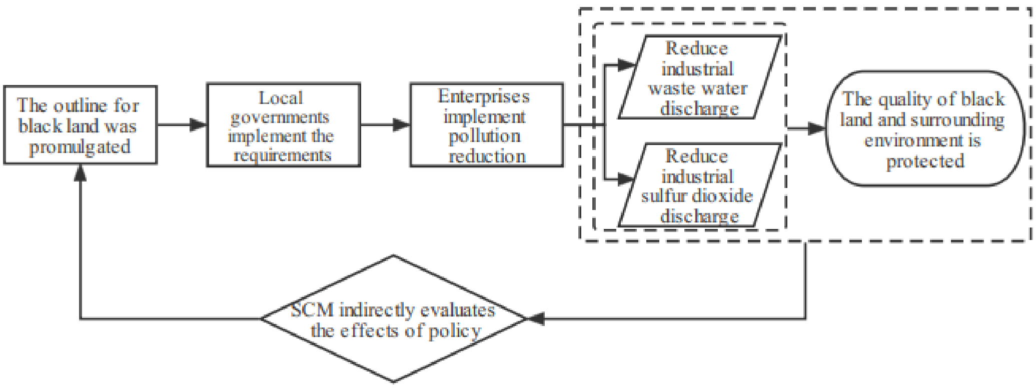

Figure 1. Evaluation of the effect of the BLPP.

Due to the vulnerability of the black land ecosystem, industrial wastewater discharge can directly affect the ecological environment of the soil and watershed. Pollutant enrichment effects are likely to damage the quality of local black land. Acid rain caused by industrial sulfur dioxide emissions has a broader impact on the ecological quality of regional black land. Therefore, this study uses the above two types of environmental pollutants to evaluate the results of the outlined policy.

4.2. Methodology

The SCM has been used widely as an advanced method of evaluating policy effects in academia [30–37]. Unlike the DID method, which focuses on subjective selection, the SCM control group is based on data selection results. The virtual control group that is most similar to the control group was constructed via data-driven selection. The choice of weights was also driven by data. This greatly reduced the error-free degree of subjective choice, solved the endogenous problem of policy to a certain extent, and ensured the reliability of the evaluation results [38]. It is feasible for one treatment group and on treatment time. This study has only one treatment group, which is the black land area of northeast China, and exactly one treatment timing, which is the year 2017. Thus, this study used the SCM method to evaluate the effect of the black land protection policy on industrial pollutant emission reduction in northeast China. The impact of the BLPP on industrial pollution emissions in the black land region was measured via a natural experiment. The typical black land region was taken as the experimental treatment group and 30 industrial pollution emission sequence data samples from other regions defined the control group.

The detailed SCM implementation steps were as follows: it was assumed that the relevant industrial pollution emission data for K + 1 regions was collected statistically in the period $t \in [1, T]$ and that region i (black land), which was the subject of environmental protection planning at $T_0(1 \leq T_0 \leq T)$, was the experimental group. The other K regions were the control group, which was composed of regions that did not adopt the protection mechanism. P_{it}^{Y} represents the pollution emissions from region i, which are affected by the planning outline mechanism, at time t. P_{it}^{N} represents the pollution emissions from region i, which is not affected by the relevant mechanism, at time t. Let $a_{it} = P_{it}^{Y} - P_{it}^{N}$ represent the change in pollution emissions from region i, which is subject to the protection plan, within time t. D_{it} is a dummy variable that indicates whether it is the region where the BLPP is implemented or not. The dummy variable equals 1 if region i implements the schema at time t and 0 otherwise. The pollution emission level of region i at time t is $P_{it} = P_{it}^{N} + D_{it}a_{it}$. Throughout this period, the control group is $P_{it} = P_{it}^{N}$. For the experimental group, $a_{it} = P_{it}^{Y} - P_{it}^{N} = P_{it} - P_{it}^{N}$. In this study, the change in industrial pollution emissions influenced by the policy mechanism is a_{it}. P_{it}^{Y} represents the known industrial pollution emissions affected by the BLPP. While P_{it}^{N} is unobtainable, it can be estimated using the factor model proposed by Abadie et al. [30]. The specific calculation formula is as follows:

$$P_{it}^{N} = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it} \tag{1}$$

where δ_t is the time fixed effect and Z_i is the observed r × 1 dimension control variable, which is not influenced by the implemented policy. In this study, the population, GDP, and industrial output of the black land region in 2005, 2010, and 2015 are selected as control variables. θ_t is the 1 × r dimension unknown parameter vector, λ_t is the common factor vector of the 1 × F dimension that cannot be observed, μ_i is the regional fixed effect of the F × 1 dimension, and ε_{it} is the short-term shock that cannot be predicted and has an average value of 0. Under general conditions, $\sum_{k=2}^{K+1} w_k P_{kt}$ can be used as an unbiased estimate of P_{it}^{N} if the period before the policy is longer than the period after policy implementation. Here, w_k represents the regional specific weight in the SCM. Finally, the estimated a_{1t} of the policy influence effect is calculated as follows:

$$\hat{a_{1t}} = P_{1t} - \sum_{k=2}^{K=1} w_k P_{kt}\ ,\ t \in [T_0 + 1, \ldots T] \tag{2}$$

Let Z_1 be a $k \times 1$ vector including the values of the pretreatment characteristics of the treated unit and Z_0 be the $k \times J$ matrix containing the values of the same characteristics for the donors. The optimal weights W^* minimizes:

$$\parallel Z_1 - Z_0 W \parallel = \sqrt{(Z_1 - Z_0 W)' V (Z_1 - Z_0 W)} \tag{3}$$

where V is a $k \times k$ symmetric and positive semi-definitive matrix, and V reflects the relative importance of each predictor.

In a study by Bertrand et al. [39], control groups were used successively as hypothetical experimental treatment areas. Then, the SCM was used to estimate the policy protection effect on each region. This test produced effect distributions that could be compared to the actual situation in the black land region. We also used the root mean square prediction error (RMSPE) to measure the difference between the region's real value and that of the synthetic control group. The calculation formula is as follows:

$$RMSPE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(P_{1t} - \sum_{k=2}^{K+1} w_k P_{kt}\right)^2} \quad (4)$$

where P_{1t} represents the true value of the experimental group, w_k represents the weight, P_{kt} represents the value of the control group, and T is the number of time periods in a specific year. When the early fit is good, the difference of the RMSPEs measured after and before policy implementation serves to measure the degree of influence of the BLPP policy.

4.3. Research Area and Data

The scope of black land in this study was the boundary line of typical black soil in northeast China drawn by Liu et al. [40] using the central gravity agglomeration method. The region starts from the Great Khingan Mountains in the north and reaches the southern part of Liaoning Province in the south, the mountainous edge of the Great Khingan Mountains in eastern Inner Mongolia in the west, and the Ussuri and Tumen Rivers in the east. It covers parts of Liaoning, Jilin, and Heilongjiang provinces, as well as the eastern part of Inner Mongolia. According to the second national land survey data and the county-level cultivated land quality survey evaluation results, approximately 278 million mu (a Chinese unit of area, equal to 1/15th of a hectare or 1/6th an acre) of typical black land have been cultivated in northeast China. This accounts for 1/4th of the country's arable land. Separately, Inner Mongolia accounts for 0.25 million mu, Liaoning province for 0.28 million mu, Jilin Province for 0.69 million mu, and Heilongjiang province for 156 million mu. At the same time, the black land in northeast China accounts for 1/4th of national grain output, 1/4th of commercial grain in the country, and 1/3rd of the total grain transfer volume nationally [1]. This zone included 73 county-level regions, which became part of the experimental group. The zone included 15 prefecture-level cities in three provinces. Thirty regions in other provinces (excluding Tibet, Hong Kong, Macao, and Taiwan) were used as the control group. The regions are shown in Figure 2.

The industrial pollution emission data used in this study were from the *China Statistical Yearbook on Environment (2005–2021)*, *China City Statistical Yearbook (2005–2021)* and related Chinese provincial statistical yearbooks, and the population and socio-economic indicator data at the county level were from the *China Statistical Yearbook (County-Level) (2005–2021)*[1]. However, small amounts of missing statistical data had to be added via multiple-item fitting to ensure data integrity. Then, it would be taken as the logarithm for these original data of industrial wastewater and sulfur dioxide emissions in the model.

Due to missing data in the available information on the county-level units in the black land area, it is difficult to obtain the economic and environmental data. For example, it is difficult to obtain the economic and environmental data of the counties in Inner Mongolia, which makes it difficult to use the industrial pollution emission estimation of the county-level administrative unit in this paper. Considering that the economic development level of each county-level unit in the black soil area is nearly the same, the proportion of population size represents the relative intensity of economic activities. Therefore, for some missing environmental data, the proportion of population size of each county in the municipal level and the industrial pollution emission of the municipal are introduced to estimate the industrial pollution emission of the county. The specific formula is as follows:

$$E_{i,c} = \frac{p_{i,\,c}}{P_c} \cdot e_c \quad (5)$$

where i represents a county-level region, c represents the prefecture-level city to which the county belongs, $p_{i,c}$ represents the population of the county-level region, P_c represents the total population of the prefecture-level city, e_c represents the total pollutant emission value of the prefecture-level city, and $E_{i,c}$ represents the calculated pollutant emission data for a specific county. This calculation method is also used for estimation of other missing data of a county-level region. Partial original industrial waste discharge data are shown in Table 1.

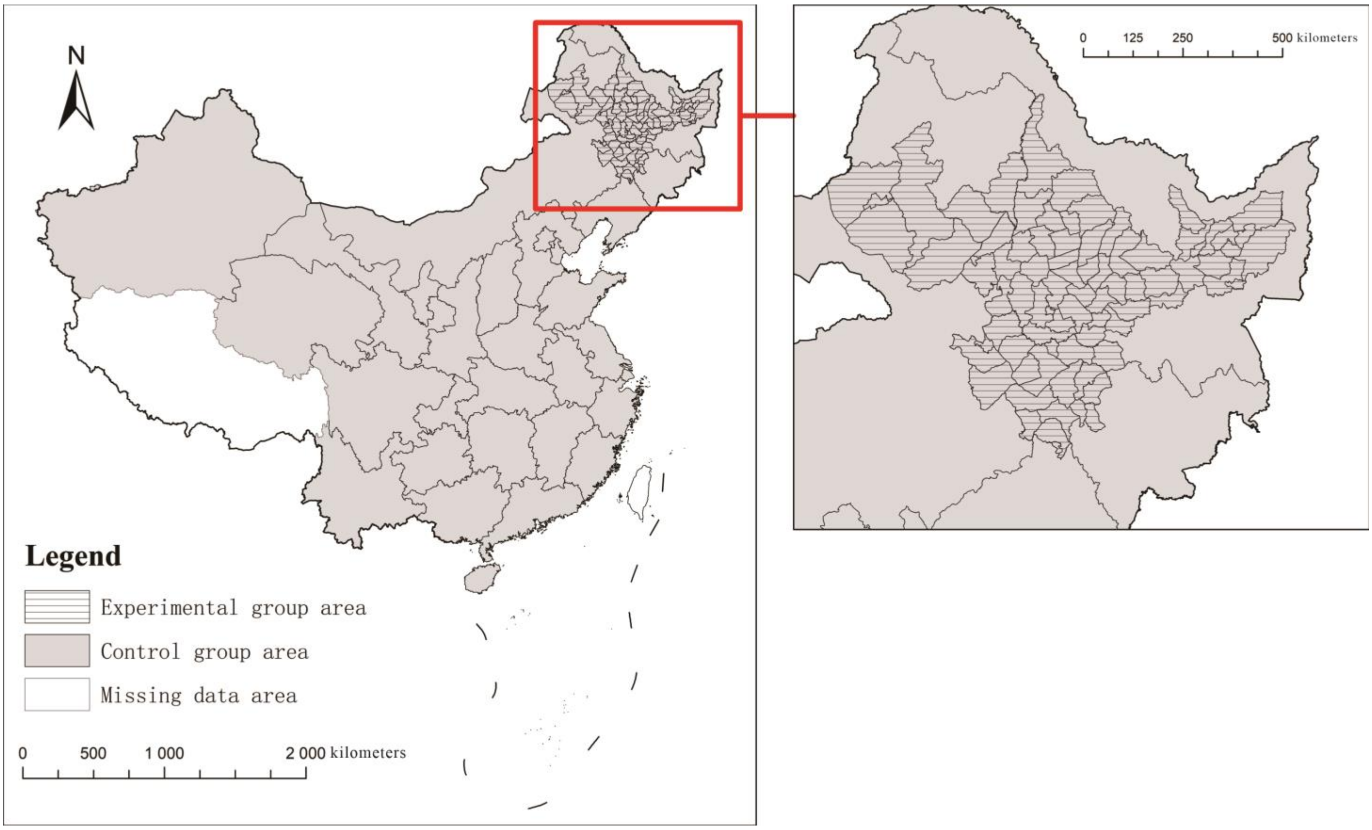

Figure 2. Typical black land county-level and national provincial regions.

Table 1. Industrial pollution emission data for northeast black land area and some provinces.

Area	Industrial Pollutants	2005	2010	2015	2020	Average
Black land area	wastewater (million tons)	243.44	263.21	291.79	96.90	234.64
	sulfur dioxide (ten thousand tons)	30.47	27.60	27.23	4.75	23.61
Jilin non-black land area	wastewater (million tons)	241.90	338.91	367.98	157.33	287.88
	sulfur dioxide (ten thousand tons)	14.09	16.23	17.00	3.60	14.69
Heilongjiang non-black land area	wastewater (million tons)	171.36	75.36	71.21	46.33	100.00
	sulfur dioxide (ten thousand tons)	6.63	10.95	3.91	1.99	6.91
Beijing	wastewater (million tons)	128.13	87.13	91.74	77.16	92.46
	sulfur dioxide (ten thousand tons)	10.50	5.99	4.03	1.01	5.47
Hebei	wastewater (million tons)	1245.33	1096.52	1065.50	395.12	1004.12
	sulfur dioxide (ten thousand tons)	128.10	104.29	104.24	22.45	96.56
Shanxi	wastewater (million tons)	320.99	394.31	492.62	315.80	402.19
	sulfur dioxide (ten thousand tons)	120.00	103.06	107.79	69.64	102.40
Anhui	wastewater (million tons)	634.87	733.99	695.80	655.24	690.17
	sulfur dioxide (ten thousand tons)	51.50	48.68	47.43	20.42	44.15
Shandong	wastewater (million tons)	1390.71	1545.72	1800.21	1015.79	1623.94
	sulfur dioxide (ten thousand tons)	171.50	115.26	135.89	73.35	134.96
Szechwan	wastewater (million tons)	1225.90	949.04	598.21	453.16	827.16
	sulfur dioxide (ten thousand tons)	114.10	85.68	65.71	34.13	76.92
Shaanxi	wastewater (million tons)	428.19	480.15	343.49	194.38	378.25
	sulfur dioxide (ten thousand tons)	80.00	77.74	57.59	12.43	59.97

Note: For brevity, only some representative data are listed.

5. Results

5.1. Baseline Results

The counterfactual results were synthesized by assigning weights to each region in the control group. The weights assigned to each region are shown in Table 2. According to Table 2, the weights of industrial wastewater discharge of non-black soil in Jilin, Heilongjiang, Inner Mongolia, Xinjiang, and other provinces and regions are 56.9% (the highest), 11.4%, 9.3%, 6.8%, and less than 5%, respectively. Similarly, the weights of industrial sulfur dioxide emissions of non-black soil areas in Jilin province, Inner Mongolia, and Xinjiang account for 68.3% (the highest), 28.4%, and 3.3%, respectively. The weight of the Jilin non-black land area accounts for the largest proportions in both groups because it has more similarity to the black land area.

Table 2. Weights of two groups of black land areas of synthetic industrial pollution emissions.

Synthetic Industrial Wastewater Emission Group (RMSEP = 0.0225)		**Synthetic Industrial Sulfur Dioxide Emission Group (RMSEP = 0.0317)**	
Province	**Weight**	**Province**	**Weight**
Jilin non-black land area	0.569	Jilin non-black land area	0.683
Heilongjiang non-black land area	0.114	Heilongjiang non-black land area	0.000
Inner Mongolia non-black land area	0.093	Inner Mongolia non-black land area	0.284
Xinjiang	0.068	Xinjiang	0.033
Fujian	0.047	Fujian	0.000
Hainan	0.030	Hainan	0.000
Qinghai	0.012	Qinghai	0.000
Ningxia	0.011	Ningxia	0.000

Note: The weights of other regions not listed are 0.

We took the population, GDP, and total output value of industries as control variables. It could display higher accuracy of the fitting results obtained via the SCM [41]. The fitted and real results for the selected control variables are shown in Table 3. There are small differences from the real data. The fitted result is satisfying for black land regions before 2017. Thus, we can take the synthetic data as the counterfactual results of the black land and use them to analyze the impacts of the BLPP issued in 2017.

Table 3. Comparison of the variable values of real and synthetic black land areas.

Predictive Control Variable	**Black Land Area**	**Synthetic Black Land Area ①**	**Synthetic Black Land Area ②**
2005 Population (10,000)	3001.74	3041.65	2624.26
2010 Population (10,000)	3004.24	3077.08	2670.55
2015 Population (10,000)	3249.57	3077.61	2685.72
2005 GDP (100 million yuan)	4394.39	4297.63	3696.80
2005 GDP (100 million yuan)	9987.68	9662.41	9502.81
2005 GDP (100 million yuan)	16,594.43	15,236.33	15,110.74
2005 Industrial output (100 million yuan)	4552.78	4368.25	3511.53
2010 Industrial output (100 million yuan)	12,420.93	13,651.48	12,962.24
2015 Industrial output (100 million yuan)	26,420.93	22,652.41	22,005.28

Note: ① using the weight of the industrial wastewater discharge, ② using the weight of the industrial sulfur dioxide discharge.

In Figure 3, the synthetic industrial wastewater discharge trend is quite consistent with that noted before implementation of the BLPP (before 2017). After 2017, the industrial wastewater discharges in the real black land area are lower than those in the synthetic black land area. This indicates that the policy effect is significant. Promulgation of the BLPP has a direct impact on industrial wastewater discharge, which is nearly 29.3% lower over the past four years (2017–2020) than that from the synthetic black land dataset.

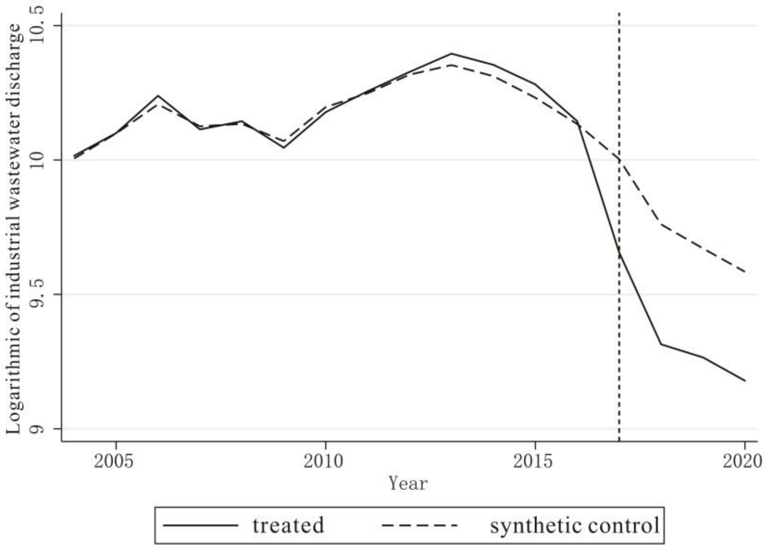

Figure 3. Industrial wastewater discharge in real and synthetic black land areas.

According to Figure 4, the industrial sulfur dioxide emission trends for the synthetic black land area also fit quite well with those in the real black land area before the BLPP issued in 2017. After implementation of the BLPP, the actual industrial sulfur dioxide emission is slightly lower than the synthetic data. This indicates that industrial sulfur dioxide emissions in the black land area may have been curtailed after promulgation of the BLPP, and that the policy has a significant impact. Quantitatively, the industrial sulfur dioxide emission in the black land area decreased by approximately 12% in 2020 compared with that in the synthetic black land area.

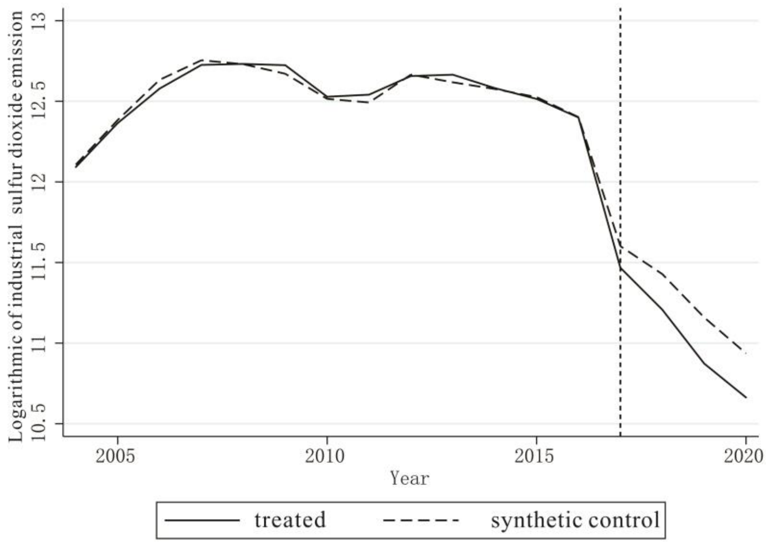

Figure 4. Industrial sulfur dioxide emission in real and synthetic black land areas.

5.2. Robustness Tests

We performed a placebo test to ensure the robustness of the results. The core idea of the placebo test is the creation of a fictitious treatment group or a fictitious policy timing. If the regression results produced by the estimators using different fictional methods remain significant, the original estimates are likely to be wrong and the changes in variables may be affected by other policy changes or random factors. Therefore, in this study, we used a fictitious treatment group to synthesize 30 control group regions sequentially.

The ratios of the post- to prior-intervention RMSPEs for the discharge of industrial wastewater and industrial sulfur dioxide emissions in the black land area and the 30 control group areas were calculated. However, to avoid problems caused by large errors and ensure the accuracy of the robustness test, we excluded provinces and regions in the control group whose prior-intervention RMSPE values were more than twice that of the experimental group by referring to the practice of Abadie et al. [38]. We took 2017 as the time node. A smaller prior-intervention RMSPE means a better fit, while larger post-intervention RMSPE indicates that the object is affected by the policy. Figures 5 and 6 show changes in industrial wastewater discharges and sulfur dioxide emissions, respectively, in the black land area and in the control regions after policy implementation. The bold orange line represents the treatment effect in the black land area and the remaining lines represent the placebo effects in the control regions.

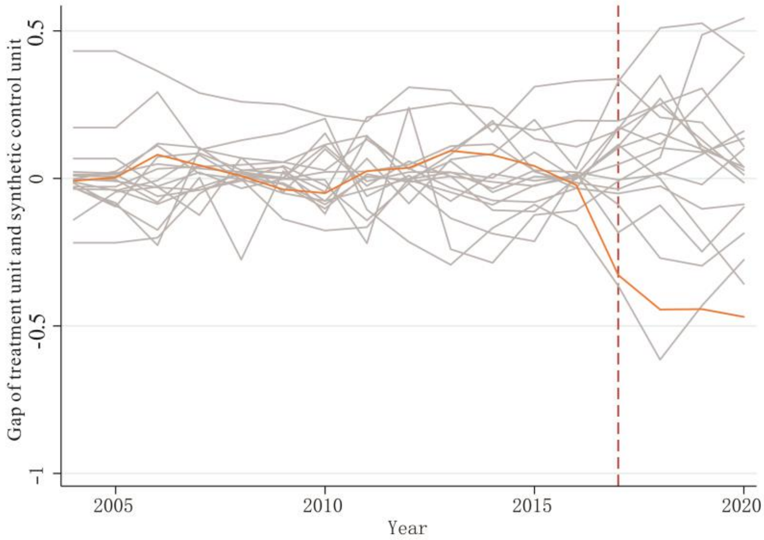

Figure 5. Industrial wastewater discharge gaps in the black land area and placebo gaps in the control regions.

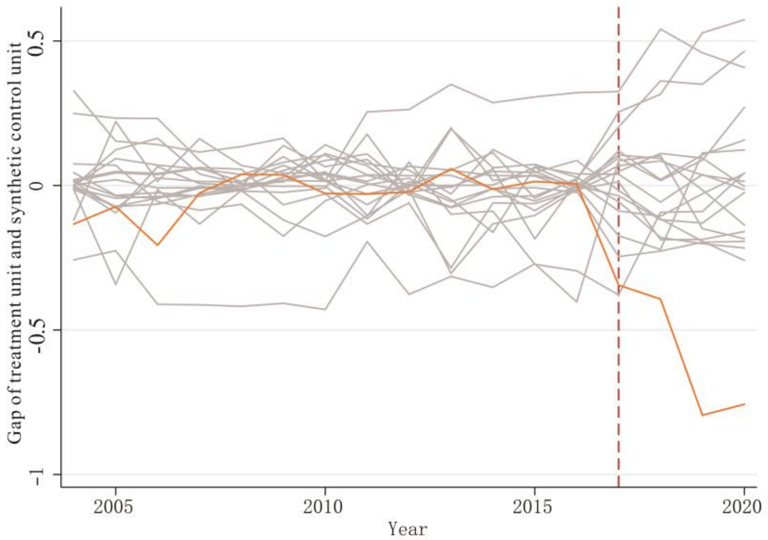

Figure 6. Industrial sulfur dioxide emission gaps in the black land area and placebo gaps in the control regions.

Table 4 shows the placebo test results, which include the RMSPE of the industrial wastewater discharge in the black land area and each control region. The small prior-intervention RMSPE in the black land area indicates that the fit is good before BLPP implementation. If the ratio is the largest, the area has the most significant change in industrial wastewater discharge upon the policy's implementation. After eliminating part of the control group, 19 regions remain. Figure 5 shows that since the year 2017, compared with other regions (grey lines), the black land area (orange line) has had more significant changes in industrial wastewater discharge. This means that there is a 1/20 or 5% probability of rejecting the significant result. Therefore, the placebo test demonstrates that the BLPP has a highly significant effect on industrial wastewater discharges in the black land area.

Table 4. Post/prior-RMSPE ratios for industrial wastewater discharges in the black land area and the control regions.

Area	Prior-Intervention RMSPE	Post-Intervention RMSPE	Ratio
Black land area	0.0238	0.3545	14.8611
Shanxi	0.0868	0.4909	5.6552
Liaoning	0.0847	0.3476	4.1026
Anhui	0.0681	0.2717	3.9947
Jilin non-black land area	0.0681	0.2324	3.4158
Tianjin	0.0433	0.1011	2.3349
Fujian	0.1659	0.3752	2.2481
Zhejiang	0.0589	0.1228	2.0853
Jiangxi	0.1038	0.1739	1.6752
Shandong	0.1468	0.1882	1.2821
Beijing	0.2634	0.2971	1.1281
Jiangsu	0.3059	0.2203	0.7202

Note: For brevity, only some representative data are listed.

The placebo test was also applied to obtain RMSPE values for industrial sulfur dioxide emissions in the black land area and other control regions. As shown in Table 5, the prior-RMSPE value in the black land area is small. This indicates that the fit is good. Based on the ratios of the post- to prior-intervention RMSPEs, the BLPP has an obvious impact on industrial sulfur dioxide emission reduction. After excluding unqualified control regions, the remaining 20 control regions were compared with the black land area. Figure 6 also displays that compared with other regions (grey lines), the black land area (orange line) has had a more significant change in industrial sulfur dioxide emissions since 2017. We conclude that the probability of industrial sulfur dioxide emission reduction in the black land area affected by the BLPP reaches more than 95%. Thus, it passes the placebo test.

Table 5. Post/prior-RMSPE ratios for industrial sulfur emissions in the black land area and the control regions.

Area	Prior-Intervention RMSPE	Post-Intervention RMSPE	Ratio
Black land area	0.1412	0.4451	3.1518
Anhui	0.0349	0.0982	2.8093
Shanxi	0.0605	0.1414	2.3366
Guangxi	0.0802	0.1755	2.1881
Henan	0.0471	0.1023	2.1707
Shandong	0.2394	0.4405	1.8397
Liaoning	0.1077	0.1713	1.5904
Hunan	0.0965	0.1451	1.503
Jiangsu	0.0577	0.6943	1.2029
Hubei	0.0684	0.0747	1.0921
Guangdong	0.0988	0.0771	0.7807
Tianjin	0.3494	0.0952	0.2723

Note: For brevity, only some representative data are listed.

In addition to the placebo test, we referred to the methods of Li et al. [42], who used the DID method. The specific DID method steps are as follows:

$$Y_{it} = \beta_0 + \beta_1 \cdot Treat_{it} \times Period_{it} + \sum_{k=1}^{3} \gamma_k Z_{it}^k + u_i + \tau_t + \varepsilon_{it} \tag{6}$$

where Y_{it} is the explained variable for the region i and time t, and both $Treat_{it}$ and $Period_{it}$ are dummy variables in region i and time t. The coefficient β_1 of the interaction term $Treat_{it} \times Period_{it}$ reflects the effect of the BLPP. In addition, $Z_{it}^k (k = 1, 2, 3)$ is the control variable, u_i is the individual fixed effect term, and τ_t is the time fixed effect term. We still use the black land area as the treatment group and the rest of the area as the reference group. The DID results are shown in Tables 6 and 7. Regardless of whether the control variables (population, GDP, and the value of industrial output) are added or not, the BLPP has an obvious significant effect on reducing industrial wastewater discharges and industrial sulfur dioxide emissions in the region with a dual time and region fixed effect (iii and vi). Thus, the robust effect of BLPP is verified further.

Table 6. DID estimation results of the BLPP effects (industrial wastewater discharge).

Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Treat × Period	−0.472 **	−0.459 *	−0.581 **	−0.818 ***	−0.487 **	−0.525 **
Variable control	NO	YES	NO	YES	YES	YES
Time fixed	NO	NO	YES	NO	YES	YES
Region fixed	NO	NO	YES	YES	NO	YES
Number of observations	510	510	510	510	510	510
R^2	0.09	0.13	0.27	0.29	0.28	0.25

Note: *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 7. DID estimation results of the BLPP effects (industrial sulfur dioxide emission).

Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Treat × Period	−1.026 **	−0.856 ***	−0.423 *	−0.758 ***	−0.623 *	−0.376 *
Variable control	NO	YES	NO	YES	YES	YES
Time fixed	NO	NO	YES	NO	YES	YES
Region fixed	NO	NO	YES	YES	NO	YES
Number of observations	510	510	510	510	510	510
R^2	0.17	0.23	0.29	0.28	0.21	0.36

Note: *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

6. Discussions

Under China's rapid urbanization and industrialization in recent decades, land pollution has become an unavoidable problem in the sustainable development of black land. Numerous remedial policies have been raised and implemented [7]. Such policies may face consistency and effectiveness problems [43]. Some studies have evaluated the effects of the remedial land protection policies, such as the arable land reduction effect [44], the positive economic impacts [45], etc., while there is little empirical evidence on how the remedial land protection policies affect the industrial pollution.

This study takes the implementation of the BLPP as a natural experiment to study the causal environmental impact of the BLPP. Our results find that after the implementation of the BLPP, the industrial wastewater discharges and sulfur dioxide emissions of the black land region were reduced significantly. This shows that the BLPP is crucial for protecting the black land region, which is also in accordance with the current research [7]. The results also show that the BLPP's effect is much greater for reducing industrial wastewater discharges than industrial sulfur dioxide emissions. A possible reason for this difference is that industrial wastewater discharges reduction is a more urgent factor in black land protection.

The results are also consistent with many other existing studies, which also found that land protection policies have effects on land protection, which includes arable land loss [44] and positive economic effects [45]. While the method employed to evaluate the effects of land protection policies varies, Zhong et al. [46] used the probit model and Sims et al. [45] used the fixed-effect model. With the SCM being widely used in the evaluation of policy impact, in this study, the SCM was applied to evaluate the environmental impact of the BLPP, and the results are more robust and convincing compared to the probit and fixed-effect models because of its natural-experiment setting. In this study, the pretreatment period is 2004 to 2016, which fulfills the requirement of the SCM. The characteristics of the synthetic control unit and treatment unit fit well in the pretreatment period, which tells us that the synthetic control is a better control for the causal effect of the BLPP. The causal inference method can be widely used in land research.

In addition, one may further question how industrial pollution reduction affects land quality and productivity, for what we really care about is how the BLPP improved the black land. Although it is well known that industrial pollution is one of the causes of harm to the black land [12], the impact of the industrial pollution on land quality may take more time to play a role and this also needs to be evaluated.

However, our research still needs to be furthered in three aspects. First, land contains other types of pollution that are not covered in our research, such as heavy metal pollution and solid waste pollution. Second, our research only provides an early-impact evaluation of the BLPP; the long-term effect should also be investigated. Third, the mechanism of how the BLPP affects the industrial pollution and the heterogeneity of the effect in different regions of black land are not discussed in this paper.

7. Conclusions

The typical black land area is an important soil resource in China, known as the northeast granary. In 2017, six departments jointly issued the BLPP to strengthen the protection of the black land. The discharge of large quantities of industrial waste into the black land regions was the most serious factor driving the destruction of the black land. Using SCM, we assessed whether the BLPP could effectively reduce industrial wastewater discharges and sulfur dioxide emissions in the black land area so that it could improve environmental quality and protect the overall external environment. The results show that industrial pollution emissions in the black land area did indeed decrease significantly after the BLPP was issued in 2017 compared with the previous situation. By 2020, industrial wastewater discharges in the black land area decreased by 29.3% compared to in the synthetic black land area, while industrial sulfur dioxide emissions decreased by 12%. Both of these effects passed robustness tests that involved placebo tests and other estimation methods.

This study shows that as a remedial policy to protect the quality of the black land in northeast China, the BLPP has achieved substantial results; the early impact of the BLPP on the reduction of industrial pollution is significant. This tell us that future designs should continue to be implemented.

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Note

[1] Chinese National Knowledge Infrastructure. Chinese Journal Full-text Database. https://www.cnki.net/, accessed on 18 January 2022.

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