Pol. J. Environ. Stud. Vol. 31, No. 5 (2022), 4745-4756
DOI: *10.15244/pjoes/150070* ONLINE PUBLICATION DATE: 2022-08-05

Original Research

Can the Urban Growth Boundary Reduce Urban Industrial Air Pollution in China? A Study from the Perspective of the Sustainability of Land Urbanization

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Received: 2 February 2022
Accepted: 16 May 2022

Abstract

Using the panel data on 93 prefecture-level cities in China from 2005 to 2018, this paper takes the UGB implementation in pilot cities as a quasi-natural experiment and uses the difference in difference model to empirically test the impact and mechanism of urban growth boundary (UGB) on urban industrial air pollution. The results show that the UGB policy has a significant role in reducing urban industrial air pollution. This conclusion remains valid after a series of robustness tests. Furthermore, we found that UGB reduces industrial air pollution through governance effects rather than spillover effects, and the negative impact is dynamic and sustainable. Hence, UGB contributes to the sustainable development of land urbanization in terms of reducing industrial air pollution. This research provides empirical evidence for the sustainable development of land urbanization and green development in China.

Keywords: urban growth boundary, industrial air pollution, land urbanization, spillover effect, governance effect

Introduction

Land urbanization refers to the transformation of land attributes from agricultural land to urban construction land, including industrial, residential, and commercial land. In western developed countries, their land urbanization process is led by the market due to the relatively perfect market environment. However, China's land system has special characteristics. Firstly, the land ownership system is dualistic (i.e., rural land) is collective-owned and urban land is state owned. Second, land use conversion is monopolized by the government, and the conversion of agricultural land to non-agricultural land is controlled by government approval and annual targets. Third, non-agricultural land is exclusively supplied by the government, and any unit or individual who needs land for construction can only apply to use state-owned land. Fourth, the value-added income from land is exclusively enjoyed

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by local governments. This characteristic land system arrangement makes the process of land urbanization in China dominated by local governments [1-3]. Influenced by the institutional arrangement of fiscal decentralization and political centralization, the main goal of local governments is to pursue regional development, and land urbanization has become an important tool to achieve development [4], as reflected in the following: controlling the supply of residential and commercial land, raising land and housing prices to ensure that the government obtains land growth revenues and provides a stable source of funds for urban development; enhancing the supply of industrial land to promote industrialization and boost economic growth. However, the early crude industrialization model of "pollution first, treatment later" and "high pollution, high energy consumption, low quality, low output", which is mainly based on heavy industry, has led to serious industrial pollution in cities. With the improvement of environmental quality requirements of cities, pollution-intensive enterprises have been relocated out of the cities and industrial land has been extended to the cities. Therefore, the traditional land urbanization has led to the disorderly spread of cities and the intensification of industrial pollution, which is not conducive to the sustainable development of land urbanization.

Urban growth boundary (UGB) is a spatial management tool used by countries worldwide as a way to control urban sprawl and achieve smart urban growth [5]. In recent years, the urban development policy of setting urban growth boundaries to reasonably utilize urban land space and enhance urban land efficiency has resonated with many scholars. Urban planning practices in western developed countries have shown that urban development boundaries go hand in hand with urban sprawl, and their function is not only to prevent urban sprawl, but more importantly, to provide reasonable diversion for potential future urban development. At the policy level in China, delineating urban growth boundaries has appeared several times in China's urbanization-related policies and regulations since 2006. In particular, in the "National Land Outline Plan (2016–2030)" and "Several Opinions on Delineating and Strictly Adhering to the Ecological Protection Red Line" triggered by the State Council in 2017, it is clearly stated that setting "survival line" "ecological line" "ecological protection red line" and "safeguard line", which are the flexible boundaries for urban growth. However, in practice, the Ministry of Housing and Urban–Rural Development and the Ministry of Land and Resources, which belong to the central government, did not determine the implementation of the UGB policy in 14 pilot cities until July 2014, and explicitly requested the use of the policy to promote the transformation of land urbanization development from an extensively expanding to an internally enhancing. In practice, can the implementation of UGB help to improve the industrial pollution problems, especially industrial air pollution, caused by the traditional land urbanization? What is the mechanism of its action? Can the UGB contribute to the sustainable development of land urbanization in terms of reducing industrial air pollution? Exploring these problems systematically has important theoretical and practical significance for the sustainable development of land urbanization and green development in China.

The rest of the paper is organized as follows: Section 2 provides a literature review, Section 3 introduces theoretical analysis and research hypothesis, Section 4 constructs indicators and designs the benchmarks of a regression model, Section 5 reports the basic regression results and performs model key hypothesis testing, Section 6 analyzes the sustainability, including spillover effect, governance effect, dynamic effects, and Section 7 concludes the paper.

Literature Review

With the development of urbanization, many cities have experienced the problem of urban sprawl [6], which has caused serious damage to the environment [7-10]. An UGB is one of the important tools used to manage urban growth; its purpose is not only to limit the urban sprawl but also to provide a reasonable plan for the future urban development. The role of the UGB has been examined in many pieces of research. The literature focuses on whether UGB can prevent urban sprawl and achieve compact urban development but has not reached a uniform conclusion [11-12]. UGB found influencing compaction has been explored in several studies. Fienup and Plantinga [13] showed that UGB increased the intensification rate by 16-21 percentage points, but Gennaio [14] pointed that UGB was only beneficial in promoting compaction within its boundary, its intended effect did not come to fruition outside the boundary. However, recent research recognized the critical role played by UGB only works in some areas [15], but in others it leaded to urban sprawl due to market pressures, institutional coordination and inadequate institutional environments [16-19]. Giovannoni [20] used Portland and Oregon as an example found that the city's UGB policy did not promote compaction compared to price mechanisms. Nevertheless, several studies have documented that the effectiveness of the policy largely depends on the population size, initial density level, organizational conditions of the region [21-22].

UGB policies may raise housing prices by limiting the supply of housing as they restrict the supply of land [23-25], the study has showed that Average land prices within and outside the boundary vary by $871 [26]. Furthermore, it's reported that when boundary is relaxed, the house prices fall [27]. Nevertheless, Jun [28] asserted that whether or not this effect occurs depends on the behavior patterns of developers, as if developers lack flexibility in responding to high land prices, then increased land prices will lead to higher house prices. However, if developers save on expensive land inputs, such as by higher-density multi-family units on small parcels of land rather than building single-family residential units, the effect on house prices may be small. Mathur [29] is also concerned that the effect of a UGB on house prices may depend on the elasticity of the demand and supply of housing. The idea is that if the demand for housing is highly elastic, a UGB may not raise house prices, as high supply elasticity can reduce price increases by increasing the new supply. Yet, a UGB policy may also affect housing prices through amenity effects, such as due to higher environmental quality of houses inside boundary, and with houses closer to the boundary having more open views, and therefore, higher prices [30-31].

Few studies have directly studied the impact of UGBs on environmental quality, and relevant studies have placed more emphasis on incorporating environmental protection into the delineation of UGBs, i.e., considering their governance of the environment from an ex- ante perspective, which can be divided into two main types of literature; the first type of literature directly delineates ecological control lines (including: ecological red lines, ecological buffers, farmland protection zones, etc.) while delineating UGB, dividing the area into ecological space and urban space [32-34], combining urban development with ecological constraints [35]. Gumber and Ghosh [36] further divided the ecological space into three levels (i.e., basic, intermediate, and optimal). Liu et al. [37] then divided the area into integrated evolution, basic farmland protection, construction land control, and priority for ecological protection to meet different needs. The second type of literature is more flexible and based on the assessment of the carrying capacity of urban areas, excluding areas with low land carrying capacity from the UGB, thus adjusting the delineation of the UGB [38]. Similarly, Liu et al. [39] proposed to adjust the delineation of UGB based on the assessment of ecological spatial quality to exclude areas with high ecological spatial quality from the UGB. It's suggested that this approach is more realistic and dynamic [40-41].

Compared with the existing literature, the marginal contribution and potential value of this paper may be as follows. First, although most studies have investigated the impact of UGB, few have considered the relationship between UGB and industrial pollution. In the context of Chinese context, the urban sprawl caused by extensively expanding land urbanization is characterized by heterogeneity in the choice of land types, thus requiring a focus on industrial pollution. Furthermore, the existing research mostly focuses on the UGB as a variable and uses quantitative analysis method to analyze it, or use the case study method to analyze. In terms of research methods, this paper regards UGB implementation in pilot cities as a quasi-natural experiment, and uses the difference in difference (DID) method, spatial DID method, Propensity Score Matching-DID(PSM-DID) method, and event study-DID method to evaluate the impact of the UGB on industrial pollution and excludes the other factors that potentially affect industrial pollution, providing more reliable empirical evidence for the sustainability of land urbanization. Finally, this paper explains the theoretical mechanism of the UGB policy to reduce industrial pollution from the perspective of governance effect and spillover effect, which fills the research gap of the policy.

Theoretical Analysis

As traditional rough land urbanization patterns run counter to the UGB policy, compact land urbanization patterns have become the inevitable choice. This development model was first proposed by Jenks et al. [42] and has since been practiced in several countries and cities. Although the understanding and practice of this model vary, it mainly comprises the following three parts: the compact development of urban space, industry and transportation. Among these, the compact development of urban transportation can be regarded as the precondition and support for the others, so when analyzing the impact of a UGB on urban industrial air pollution, this paper mainly analyzes the compact development of urban space and industry.

The compact development of urban space requires the spatially intensive distribution of each production factor within the city, which requires that the production factors be redistributed. In order to concentrate production to high-skilled and low-energy-consuming enterprises, a number of low-capacity, high-energy-consuming and high-polluting enterprises need to be eliminated, which may choose to close or migrate out of the city. However, due to the related migration costs, enterprises may migrate to neighboring cities based on the principle of proximity [43], and so there may be a spillover effect of UGB policies, leading to increased industrial air pollution in neighboring cities.

Compact development of urban industries cannot be achieved without industrial agglomeration and structural evolution. Therefore, a UGB may reduce industrial air pollution in a city via industrial structural evolution and agglomeration, and thus produce governance effects, which are analyzed as follows. From the viewpoint of industrial structural evolution, countries generally follow a pattern whereby the proportion of primary industry keeps decreasing, and the proportion of secondary industry increases first and then stabilizes, while the proportion of tertiary industry continues increasing. Compared with the industry-based secondary industry, the service-based tertiary industry emits less pollution, so the UGB can reduce industrial air pollution emissions by adjusting the industrial structure.

Industrial agglomeration can promote technological innovation via knowledge spillover and technological diffusion [44-45]. The main driving force of industrial pollution reduction in China lies in technological progress. On the one hand, technological renewal can help promote energy-saving technology. On the other hand, it also helps with research on clean energy sources, the adoption of which reduces the use of highly polluting fuel sources and thus reduces industrial air pollution from emissions. In this manner, a UGB can promote technological innovation to reduce industrial air pollution.

In summary, this paper puts forward the following hypotheses.

Hypothesis 1: If the governance effect of a UGB dominates, then the UGB reduces industrial air pollution in one city through technological innovation and adjustment of the industrial structure, whereas it has no significant effect on air pollution in neighboring cities.

Hypothesis 2: If the spillover effect of a UGB dominates, then the UGB reduces industrial air pollution in one city but enhances it in neighboring cities.

Hypothesis 3: If UGB reduces industrial air pollution through governance effects and the negative impact is dynamic and sustainable, UGB is conducive to sustainable land urbanization.

Material and Methods

Variable Setting

To examine the impact of a UGB on urban air pollution, this paper examines a series of data including atmospheric and urban-level data, gathered as follows.

First, atmospheric data are mainly obtained from the National Climatic Data Center (NCDC), collected from observation stations in China, including data on the temperature, pressure, dew point, wind direction, wind speed, and so on. In this paper, the average values of these indicators, obtained by year and city, are used to measure the average weather conditions at a city-year level; these provide the study's control variables.

Second, city-level data are mainly obtained from the China City Statistical Yearbook, for 2005-2018, and industrial SO_2 and dust emissions are used to measure industrial air pollution. Gross domestic product and foreign investment amounts are chosen as control variables.

We use the panel data on 93 prefecture-level cities in China from 2005 to 2018 limited by data availability. The data descriptions of the above variables, as well as related descriptive statistics, are shown in Table 1.

Model Construction

The question investigated in this paper is whether a UGB can reduce industrial air pollution. To address the possibly endogenous problem, this paper tests it using the DID method. The UGB policy has been implemented since 2014 and includes a total of 14 cities. Therefore, this paper uses the DID method to compare the average differences between the pilot cities and non-pilot cities before and after the implementation of the policy, to measure the effect of the policy. The specific model is set up as shown below:

$$Y_{\mathrm{ct}} = \alpha + \beta T\mathrm{reat}_{\mathrm{ct}} + \mathrm{X}'_{ct}\varphi + \delta_c + \gamma_t + \varepsilon_{ct}$$

where c denotes the city; t denotes the year; $\mathrm{Treat}_{\mathrm{ct}}$ = 1 means city c is a pilot city of the UGB in year t, $\mathrm{Treat}_{\mathrm{ct}}$ = 0 means city c is not a pilot city of the UGB in year t, and its coefficient β is the policy effect coefficient in this paper (if the coefficient is less than 0, it indicates that the UGB helps to mitigate industrial air pollution emissions); Y_{ct} is the level of air pollution, measured by the logarithm of industrial SO_2 emissions and industrial dust emissions; X'_{ct} includes urban control variables and atmospheric control variables; δ_c is the urban fixed effect, which measures urban characteristics that do not change with time; and γ_t is the time fixed effect, which measures temporal characteristics that do not change with the city.

Table 1. Descriptive statistics.

Variable	Mean	SD	p50	Min	Max
$\mathrm{lnindus\_so_2}$	10.43	1.260	10.65	4.520	14.24
lnindus_dust	9.720	1.240	9.880	4.280	15
lngdp	16.36	1.160	16.26	13.01	19.60
lnfdi	10.07	2.080	10.01	2.080	14.94
air_tem	153.0	55.74	161.8	-147	263.1
dew_point	67.05	291.1	93.96	-9999	222.2
sea_level	5800	7023	10,137	-9999	10,221
wind_speed	-140.9	391.4	18.91	-3044	53.59

Note: SD indicates standard deviation.

Table 2. Effect of urban growth boundary on industrial air pollution.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	lnindus_ SO_2	lnindus_ dust	lnindus_ SO_2	lnindus_ dust	lnindus_ SO_2	lnindus_ dust
$treat_{ct}$	-0.71***	-0.40***	-0.63***	-0.34***	-0.61***	-0.38***
	(-7.41)	(-3.73)	(-6.43)	(-3.04)	(-6.13)	(-3.36)
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Weather control variables	No	No	Yes	Yes	Yes	Yes
City control variables	No	No	No	No	Yes	Yes
N	1247.00	1249.00	1153.00	1155.00	1125.00	1127.00
R^2	0.57	0.25	0.61	0.25	0.61	0.25

Note: *** indicates significance at the 1% level.

Results and Discussion

This paper first reports the basic results of the regression using the DID method, followed by the effect of the UGB on air pollution and then performs relevant tests on the applicable assumptions of the DID method and assesses its robustness.

Empirical Results

The basic results of this paper are shown in Table 2. Columns (1) and (2) control only for city fixed effects and time fixed effects, columns (3) and (4) control for weather-related control variables on this basis and columns (5) and (6) further control for city-level control variables. This paper finds that all regression coefficients are negative and significant at the 1% level, and this result indicates that the implementation of a UGB significantly reduces industrial air pollution. Analysis using the results in columns (5) and (6) shows the implementation of UGBs resulted in a 61% decrease in industrial SO_2 emissions and a 38% decrease in industrial dust emissions in the pilot cities compared to the control group.

Hypothesis Test and Robustness Test

Test Based on PSM-DID Method

To overcome the systematic differences between the trends of the treatment group and control group, and thus reduce the bias of the DID method, this paper further conducts a robustness test using the PSM-DID method, which is a logit regression of the relevant control variables using a dummy variable based on whether or not the city is a pilot city implementing a UGB, with a propensity score then obtained. The city with the closest score matches as being the control group. This method can minimize the systematic differences in air pollution levels among different cities and, therefore, can reduce the bias caused by the DID method. Before applying the PSM-DID method, the common supporting test is required, to discover whether a difference exists between the mean values of the covariates of the treatment and control groups after matching. If there is no difference, the treatment and control groups are balanced after matching and can be tested using the PSM-DID method. The results of the common supporting test are shown in Tables 3 and 4, and the hypothesis that there is no significant difference

Table 3. Common supporting test based on lnindus_SO_2.

Weighted variable	Mean control	Mean treated	Diff.	|t|	p
lngdp	17.49	17.49	0.00	0.04	0.97
lnfdi	12.40	12.28	-0.12	0.57	0.57
air_tem	152.27	162.86	10.59	1.52	0.13
dew_point	82.25	89.29	7.04	0.75	0.45
sea_level	1089.50	482.05	-607.45	0.73	0.47
wind_speed	21.17	21.90	-0.73	0.13	0.90

Table 4. Common supporting test based on lnindus_dust.

Weighted variable	Mean control	Mean treated	Diff.	|t|	p
lngdp	17.47	17.47	0.00	0.00	0.99
lnfdi	12.37	12.25	-0.12	0.59	0.55
air_tem	152.77	162.61	9.84	1.44	0.15
dew_point	82.98	89.45	6.47	0.70	0.48
sea_level	1177.21	602.21	-574.00	0.69	0.49
wind_speed	20.84	21.93	1.09	0.19	0.85

cannot be rejected for each covariate after matching, thus justifying the use of the PSM-DID method in this paper.

Furthermore, this paper uses the kernel matching method for estimation, with the specific regression results shown in Table 5. The results estimated using the PSM-DID method demonstrate that a UGB reduces the industrial SO_2 emissions by 76% and industrial dust emissions by 51%. Compared with the results estimated by the DID, the emission reduction effect is found to be more significant, which lends further support to the empirical conclusion of this paper that a UGB has a significant reductive effect on industrial air pollution.

Placebo Test

To further test whether the results of this paper are influenced by other unobservable factors, this paper refers to Cai et al. [46] to conduct a placebo test by randomly assigning pilot cities. In this paper, firstly, 14 cities were randomly selected from 93 cities as the treatment group, assuming that these 14 cities piloted a UGB, and the other areas were used as the control group. The 14 cities were used as virtual pilot cities, and if effects on industrial air pollution are significant, then estimation in this paper has been biased; if the opposite is found, the results of this paper may have been less influenced by unobservable factors, to some extent.

In this paper, 1000-replicate sampling was conducted, and the model was regressed according to the initial regression. Fig. 1 presents the distribution of the virtual policy's estimated coefficients and the associated p-values, which are concentrated around zero, with most of the p-values greater than 0.1. This result indicates that the estimation results of this paper are less influenced by unobservable factors, and also proves the robustness of the results.

Mitigation of the Effects of Selection

One of the important premises of the DID method is that the policy occurs randomly, so the selection of pilot and non-pilot cities should be randomly chosen. However, in reality, the selection of pilot cities does not occur randomly and instead occurs following consideration of political and economic factors, to maximize the reform's benefit. Therefore, the selection of these cities may impact the final results over time. To address this issue, the paper draws on the study of Lu et al. [47], including possible baseline factors in the regression, with the interaction term as the linear trend over time. The regression equation is shown below:

$$Y_{\mathrm{ct}} = \alpha + \beta \mathrm{Treat}_{\mathrm{ct}} + \mathrm{X'}_{\mathrm{ct}}\varphi + Z'_{c} \times trend_{t} + \delta_{c} + \gamma_{\mathrm{t}} + \varepsilon_{\mathrm{ct}}$$

Z'_c is mainly measured by prerequisite factors such as whether it is a provincial capital city, special economic zone city, megacity, and so on. The regression results are shown in Table 6. After mitigating the bias caused by the non-random selection of pilot cities and non-pilot cities, the coefficient of the policy effect is still significantly negative, which indicates that the regression results of this paper are robust.

Table 5. Results of PSM-DID method.

	Before	After	Diff.	Before	After	Diff.
	lnindus_SO_2			lnindus_dust		
diff.	-0.21	-0.98	-0.77	-0.44	-0.96	-0.52
SD	0.17	0.30	0.35	0.16	0.26	0.31
|t|	-1.25	3.22	2.20	-2.76	3.59	1.67
p	0.21	0.00***	0.03**	0.01***	0.00***	0.10*

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively; PSM-DID indicate propensity score matching and difference – difference and difference

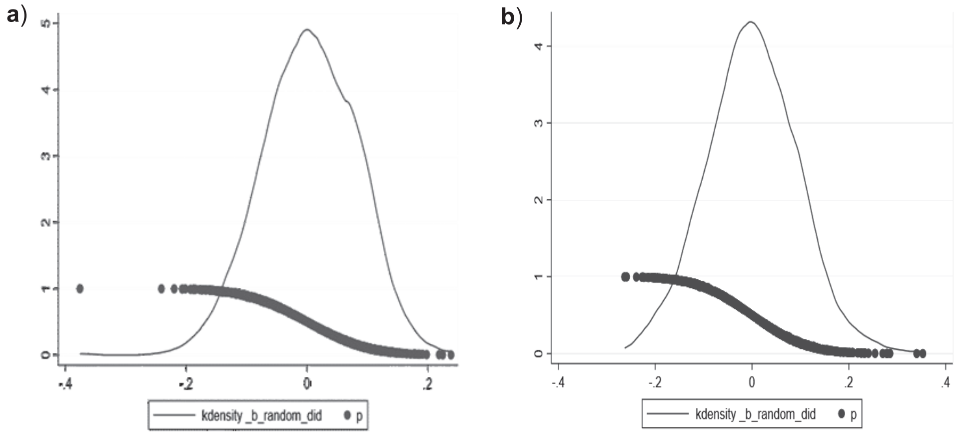

Fig. 1. Placebo test. a) the dependent variable is lnindus_SO_2; b) the dependent variable is lnindus_dust.

Other Environmental Policies

To further test whether the results of this paper are influenced by other environmental policies in the region, this paper adds dummy variables of related policies (2010 New Energy Policy, 2012 PM2.5 Monitoring Policy and 2013 Air Emission Limit Policy) to the regression equation, with the interaction term as the time linear trend, to control for the influence of related environmental policies. The results are shown in Table 7. The $treat_{ct}$ coefficients can be seen to be generally consistent with the basic regression results, indicating that the effects of other environmental policies do not bias the results.

Sustainability

Spillover Effect

To further test the spatial spillover effect of a UGB, to discover the possible impact on surrounding areas, this paper draws on the study of Chagas et al. [48] and uses the spatial DID method. The regression equation is shown below:

$$Y_{ct} = \alpha + (\beta + w\partial)Treat_{ct} + \rho w Y_{ct} + X'_{ct}\varphi + \delta_c + \gamma_t + \varepsilon_{ct}$$

$$\varepsilon_{ct} = \mu w \varepsilon_{ct} + b_{ct}$$

$w\partial Yreat_{ct}$ denotes the average indirect effect of the treatment group on the other areas, which can be further broken down into the effect of the treatment group on the treatment group and the effect of the treatment group on the control group. ρ is the spatial lag coefficient,

Table 6. Results when including baseline variables.

	(1)	(2)
Dependent variable	lnindus_SO_2	lnindus_dust
$treat_{ct}$	-0.46***	-0.26*
	(-3.93)	(-1.95)
city fixed effects	Yes	Yes
time fixed effects	Yes	Yes
weather control variables	Yes	Yes
city control variables	Yes	Yes
N	1125.00	1127.00
R2	0.62	0.26

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

Table 7. Results when including other environmental policies.

	(1)	(2)
Dependent variable	lnindus_SO_2	lnindus_dust
$treat_{ct}$	-0.61***	-0.38***
	(-6.13)	(-3.36)
Air emission limit policy	-0.13***	-0.05***
	(-12.59)	(-4.30)
PM2.5 monitoring policy	-0.10***	-0.02
	(-9.53)	(-1.24)
New energy policy	0.11***	-0.01
	(6.59)	(-0.27)
City fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Weather control variables	Yes	Yes
City control variables	Yes	Yes
N	1125.00	1127.00
R^2	0.61	0.25

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

μ is the spatial error coefficient and w is the spatial weight matrix (geographic adjacency matrix):

$$w = w_{TT} + w_{NTT}$$

The regression results are shown in Table 8. From the Lagrange Multiplier (LM) results, it can be seen that the p-values of LM-ERROR are all less than 0.05, while the p-values of LM-LAG are all greater than 0.05. So, it is more reasonable to analyze the scenario according to the DID-SEM and the DID-spatial Durbin models. In Table 8, Columns (1) and (3) are the regression results of the DID-SEM model and Columns (2) and (4) are the regression results of the DID-spatial Durbin model. From the results, it can be concluded that the UGB has no significant effect on industrial air pollution in the adjacent areas.

Governance Effect

From the previous empirical results, it can be deduced that a UGB can reduce urban air pollution and that there is no spillover effect. Based on the theoretical analysis, it can be ascertained that a UGB may have an effect on industrial air pollution via innovation and industrial restructuring. To verify this mechanism, this paper draws on the three-step method of Baron and Kenny [49] to verify the existence of this mechanism. First, $treat_{ct}$ is regressed on the mediating variables separately, and if the coefficients are significant, this indicates that a UGB has an effect on the mediating variables. Second, $treat_{ct}$ is regressed on the industrial air pollution, which is the basic regression result of this paper. Third, $treat_{ct}$ and mediating variables are regressed together on industrial air pollution, and if the coefficient becomes insignificant, or significant but with lower coefficients relative to the baseline regression, this indicates that a UGB has an effect on industrial air pollution via innovation and industrial restructuring. Urban innovation (*inno*) is measured using the urban innovation index from the Report on the Innovation Power of Chinese Cities and Industries, and the industrial structure (*third*) is measured using the proportion of tertiary industries' added value to the total added value in each city.

The regression results are shown in Tables 9 and 10. The results of the first regression show that a UGB promotes urban innovation and industrial restructuring, indicating that a UGB has a positive effect on the mediating variables. The results of the third regression indicate that the coefficient of $treat_{ct}$ becomes insignificant after adding the mediating variable, while the coefficient is significantly positive in the basic regression results. As mentioned in the previous section, this result proves the existence of the mediating effect.

Dynamic Effect

This paper draws on the two-step method of Greenstone and Hanna to verify the existence of dynamic effect [50]. The first stage uses the event study method to obtain the average level of industrial pollution during the event window, and then uses the results of

Table 8. Results of the spatial-DID method.

	(1)	(2)	(3)	(4)
Dependent variable	$lnindus\_SO_2$	$lnindus\_SO_2$	lnindus_dust	lnindus_dust
$treat_{ct}$	0.08	0.02	-0.25	-0.32
	(0.15)	(0.03)	(-0.51)	(-0.66)
$W_{TT}\times treat_{ct}$	-0.00	-0.00	0.00	0.00
	(-0.85)	(-0.68)	(0.02)	(0.24)
$W_{NTT}\times treat_{ct}$	-0.00	-0.00	-0.00	-0.00
	(-1.06)	(-0.87)	(-1.21)	(-1.00)
City fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Weather control variables	Yes	Yes	Yes	Yes
City control variables	Yes	Yes	Yes	Yes
LM-ERROR	0.00		0.00	
LM-LAG	0.81		0.81	
N	1274.00	1274.00	1274.00	1274.00
R^2	0.05	0.16	0.10	0.15

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

Table 9. Mechanism analysis I.

	(1)	(2)
	Inno	Third
$treat_{ct}$	162.86***	1.59***
	(17.62)	(2.79)
City fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Control variables	Yes	Yes
N	973.00	973.00
R^2	0.37	0.55

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

Table 10. Mechanism analysis II.

	(1)	(2)
	$lnindus\_SO_2$	lnindus_dust
$treat_{ct}$	-0.07	-0.21
	(-0.53)	(-1.36)
Mediating variable	Yes	Yes
City fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Control variables	Yes	Yes
N	956.00	958.00
R^2	0.41	0.20

the first stage to regress the policy, time trends, and policy variables×time trends, then we can obtain the impact of a policy one year after it has been in force as $\pi_1 + \pi_3$, two year after it after it has been in force as $\pi_1 + 2\pi_3$, three year after it after it has been in force as $\pi_1 + 3\pi_3$, four year after it after it has been in force as $\pi_1 + 4\pi_3$, the regression equation is shown below:

$$Y_{ct} = \alpha + \sum_{\tau} \sigma_\tau D_{\tau,ct} + X'_{ct}\varphi + \delta_c + \gamma_t + \varepsilon_{ct}$$

$$\hat{\sigma}_\tau = \pi_0 + \pi_1 1(Policy)_\tau + \pi_3(1(Policy)_\tau \times \tau) + \zeta_\tau$$

The regression results are shown in Tables 11. Columns (1) and (2) include policy variables, Columns (2) and (5) include policy variables and time trend, Columns (3) and (6) include policy variables policy, time trends, and policy variables*time trends. We report the estimated effect of the policy one year to four years. We can see that the effect of UGB on industrial dust was significantly negative from the fourth year, and on industrial SO_2 was significantly negative from the second year. This result proves the existence of the dynamic effect.

Discussion

This paper's analysis is related to at least two key economics questions. First, do the "Porter effect" or the "regulation haven effect" exist in land regulation like UGB? Second, why is the UGB policy effective in reducing industrial pollution? The paper's results provide new ideas for these problems.

Table 11. Dynamic effect.

	(1)	(2)	(3)	(4)	(5)	(6)
	lnindus_dust	lnindus_dust	lnindus_dust	$lnindus\_SO_2$	$lnindus\_SO_2$	$lnindus\_SO_2$
Time trend		-0.040 (0.393)	0.002 (0.265)		-0.033 (0.058)	0.032 (0.035)
Policy	-.174 (0.184)	0.109 (0.331)	0.707** (0.250)	-0.889*** (0.265)	-0.651 (0.493)	0.285 (0.336)
Policy*time trend			-0.299*** (0.070)			-0.468*** (0.094)
Lyear effct			0.409* (0.218)			-0.183 (0.294)
2 year effct			0.109 (0.207)			-0.651** (0.278)
3 year effct			-0.189 (0.218)			-1.119*** (0.294)
4 year effct			-0.488* (0.250)			-1.588*** (0.336)
N	14	14	14	14	14	14

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

There are two main views on the impact of environmental regulations on the choice of corporate locations, namely, the "Potter effect" and the "regulation haven effect". The former is of the view that appropriate environmental regulations can increase the competitiveness of firms by encouraging innovation and offsetting the costs of environmental compliance. Firms choose not to move [51]. The latter argues that strict environmental regulations will increase firms' production costs and make companies less competitive in the market, so firms will move to areas with relatively lax regulations, known as "regulation havens" [52]. The existence of the "Potter effect" and the "regulation havens effect" varies considerably across different types of environmental regulation. However, when comparing our findings to these, it is important to note that there is the "Porter effect" in land regulation but not the "regulation haven effect". Our discovery verifies that the technological progress that drive enterprise.

The effectiveness of environmental regulation depends on the size of the local governments' environmental administrative power. In terms of incentives of promotion, local governments, in accordance with their own environmental administrative power, have gradually relaxed supervision of large enterprises with high pollution levels, higher tax profits and employment, slowed the rate of upgrading of pollution control equipment and avoided raising the production costs of enterprises due to environmental regulation. UGB is implemented top-down by the central government, and the lower the environmental administrative power of local governments, the higher the policy effectiveness.

Conclusions

In this article, we apply a panel data of 93 prefecture-level cities in China from 2005 to 2018 to estimate the policy effect of UGB on industrial air pollution. A difference in difference (DID) methodology is used for estimation We find that the UGB policy significantly decreases the urban industrial air pollution. Our conclusion is robust after conducting a series of tests. Further, the mechanism analysis shows that the reduction of industrial air pollution is driven by promoting industrial restructuring and technological progress, and the spillover effect on surrounding cities is less significant. Third, the policy has few negative externalities, which is conducive to the sustainability of land urbanization.

Our study sheds some light on future policy implementation. First, our finding shows that there is a lag in the dynamic effect of UGB on industrial pollution, therefore, policy consistency is demanded. In addition, the compliance of the policy depends on local officials' motivation. For example, local officials might have short-sighted behavior due to tenure. Thus, a platform for government supervision involving non-State actors is needed.

Second, our finding provides another way of reducing urban industrial pollution. When exploring the factors influencing industrial pollution, the impact of land supply cannot be ignored. Land marketization helps reducing industrial pollution [53], so does the management of land. We can make full use of government and market forces to solve industrial pollution.

Third, our finding is based on UGB developed cities that have advanced technology, equipment and management experience, and higher innovation level. Application of the policy to less developed cities might be with caution since these cities generally have poor industrial structure and less innovation.

This article focuses simply on the effects of land urbanization on industrial air pollution. In the future, we would like to investigate whether the economic and population urbanization have an impact on air pollution or whether the impact is the same by economic and population urbanization. In addition, with more data available, we would like to explore the policy effect in longer period.

Acknowledgment

This research was funded by National Natural Science Foundation of China, grant number 71903129 and Shanghai Young Teachers Training Program grant number ZZLX21029.

Conflict of Interest

The authors declare no conflict of interest.

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