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Spatial Heterogeneity of China's Environmental Regulation on Industrial Pollution: Evidence from a Top–Down Environmental Enforcement Action

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To obtain precise information about enterprises' pollution control and take corresponding environmental protection measures is the key to preventing and controlling industrial pollution. Taking the lead–acid battery industry as an example, this paper employs data from the Environmental Enforcement Action to analyze the urban–rural and inter-provincial distributions of pollution-intensive enterprises and to quantitatively verify the spatial differences in China's environmental regulation on industrial pollution. The study finds that lead–acid battery manufacturing enterprises are mainly located in rural areas instead of urban areas; most pollution-intensive firms located in industrial parks, especially those approved by governments below the provincial level. The multivariate logistic model analysis finds that environmental regulation in urban districts is more strict than that in towns and villages, while the suburban areas are the laxest; environmental regulation in national-level development zones is more strict than that in provincial-level development zones, while zones below the provincial level are the laxest. In general, the environmental regulation is stricter in urban areas than in rural areas, and stricter in clustered space than in scattered space, while most inter-provincial environmental regulations have no significant differences. Local governments should effectively allocate conventional environmental law enforcement resources and shift the focus of law enforcement downwards to parks below the provincial level, and on suburbs and townships.

Keywords: Environmental regulation; environmental law enforcement; illegal pollutant discharge; industrial parks; industrial parks below the provincial level.

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1. Introduction

The report at the 19th National Congress of the Communist Party of China points out that "what we now face is the contradiction between unbalanced and inadequate development and the people's ever-growing needs for a better life". Solving this principal contradiction has put forward new requirements for ecological and environmental protection. Environmental regulation, as an important means of government intervention in externalities of pollution, plays an increasingly important role in ecological and environmental protection. Accurately grasping the pollution management status of enterprises and taking corresponding countermeasures for environmental protection hold the key to preventing and controlling industrial pollution, winning the battle against pollution and improving the government's ability to protect the environment.

Research on environmental regulation in China is usually limited to the national and provincial levels, which has largely come to a similar conclusion that the economically developed eastern regions have a higher degree of environmental regulation, while the pollution-intensive enterprises are attracted to regions with lax environmental regulations (Zhang *et al.*, 2009; Zhou and Zheng, 2015; Qu, 2019). While there are economic differences among the Eastern, Central and Western China, the urban and rural economic disparities are also significant. Then, how are pollution-intensive enterprises distributed between regions and between urban and rural areas? Does the degree of environmental regulation differ among different types of geographical spaces? Which geographical spaces have relatively weak environmental regulation? This paper aims to answer these questions which are highly relevant for the government to rationally allocate environmental protection resources.

This paper uses the data from enterprises in the lead–acid battery industry investigated in the Environmental Enforcement Action jointly carried out by the former Ministry of Environmental Protection of the People's Republic of China (MEP) and eight other ministries and government agencies as a sample, reveals the spatial distributions of pollution-intensive enterprises between urban and rural areas and between the provinces and quantitatively verifies the spatial differences in conventional environmental law enforcement. From 2003 to 2014, the former MEP for 12 consecutive years led the Environmental Enforcement Action for Straightening out Illegal Pollutant-discharging Enterprises and Safeguarding Public Health (hereinafter referred to as the Environmental Enforcement Action), a form of national environmental law enforcement implemented at the central level (Yang and Xiao, 2018). After 2015, in the course of air pollution control, the Environmental Enforcement Action was upgraded to Central Government environmental inspections, which have played an effective role in pollution control (Ge *et al.*, 2019; Wang *et al.*, 2019). Different from the daily local environmental law enforcement, which mainly covers key enterprises, the Environmental Enforcement Action takes an exhaustive investigation approach, covering all enterprises within a certain industry, which provides a sample for a comprehensive study of the spatial distribution of pollution-intensive enterprises and their compliance with environmental regulations.

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2. Literature Review

Environmental regulation is currently a hot topic of academic research, and it is closely related to economic variables such as industrial transfer, technological progress and economic growth.

In its literal sense, environmental regulation refers to the government intervention in the externalities of pollutant discharged by enterprises. The measures taken by enterprises to comply with one or certain environmental regulations are reflected in two indicators: first, the economic costs incurred by enterprises to reduce pollution, including investment and operating costs. The corresponding indicators for the pollution control costs of Chinese companies include: investment in compliance with the principle that protection facilities are designed, built and applied simultaneously with production facilities (the "three simultaneous" principle), investment in industrial pollution control and operating costs of facilities for wastewater, waste gas treatment, etc.; second, the reduction of pollutant discharges for pollution control, such as waste gas, wastewater and solid waste.

Methods of measuring the intensity of environmental regulations can be classified into three categories: qualitative descriptions, input-based or performance-based indicators and comprehensive index-based indicators (Li and Li, 2012; Cheng and Li, 2017). Some scholars believed that they can be divided based on pollution control input, pollutant emission, comprehensive indicators and natural tests (Wang and Li, 2015). Zhang and Zhang (2012) established an environmental regulation efficiency index. Zhao (2007) used the operating cost of wastewater and air pollution control facilities per unit of output value to measure the level of environmental regulation, while some studies used the amount of industrial pollution control per unit of output value (Zeng, 2010; Zhang *et al.*, 2010) or per capita pollution source control investment (Zhou and Zheng, 2015). Many studies used both pollution control input and pollutant discharge to measure environmental regulation. Tian *et al.* (2018) measured environmental regulation by environmental treatment inputs per unit of pollutant discharges, in which the environmental treatment inputs use the sum of environmental protection investments in compliance with the "three simultaneous" principle, industrial pollution source control investments and the operating costs of industrial waste gas and wastewater pollution control facilities. Some studies used a certain part of the pollution control investment to measure environmental regulation, such as the operating costs of industrial pollution control facilities per unit of pollution discharges (Li and Li, 2017). Some studies used the intensity of pollutant discharges to measure environmental regulation (Fu and Li, 2010). Due to the variety of methods and data scales, various problems arise in measuring environmental regulation, such as the multi-dimensionality and comparability of indicators (Wang and Li, 2015). The indicators have shortcomings including inconsistency, difficulty in obtaining, inaccuracy and endogeneity issues, which compromise the persuasiveness of empirical research results and their ability to verify and refute each other (Li and Li, 2012). In addition, the statistical scope of pollutant discharge data is often limited to key enterprises under investigation, and many enterprises produce and discharge in the nighttime to avoid environmental regulation (Feng *et al.*, 2019). Moreover, emissions from illegal pollutant-discharging enterprises are not included in the statistics (Li and Wang, 2019). Therefore, there is a certain deviation by using pollutant discharges to measure environmental regulation. The more the illegal pollutant discharges, the greater is the deviation.

In terms of the regional environmental regulation, Zhang *et al.* (2009) took into account the differences in the industrial structures of provinces and cities and used the ratio of actual emission intensity to theoretical emission intensity to measure environmental regulation, finding that the environmental regulations are stronger in eastern provinces represented by Beijing and Shanghai, while the environmental protection is weaker in central and western provinces. Qu (2019) measured the intensity of environmental regulations in various provinces in China and found that environmental regulations are most stringent in economically developed regions such as Guangdong, Beijing and Zhejiang. Gao (2016) reached similar conclusions. If there is a synchronous relationship between the level of economic development and environmental regulation, then the large gap of economic development in urban and rural areas implies that there are large urban–rural differences in environmental regulation. Zheng (2002) suggested that social transfer of environmental pollution occurs when there is a gap in economic levels between different regions, and this pollution transfer has a greater impact in a dualistic economic society. Since the implementation of China's environmental protection policies, urban areas have been given priority over rural areas, and this has been a consensus among academics. For example, Hong (2000) believed that urban areas are stronger in environmental protection than rural areas in terms of organization, system and public opinion control methods. During the period of traditional township enterprises, there were certain pollution problems because of the low level of technology and the fact that township enterprises were engaged in resource extraction and processing industries (Jiang and Li, 1994; Wei, 1994; Li *et al.*, 1999). China had conducted two relatively comprehensive surveys on the pollution of township enterprises in 1989 and 1995. From these surveys, the pollution control level of township enterprises was much lower than that of enterprises located in cities and towns. After the restructuring of township enterprises, there were still a large number of scattered enterprises and various industrial clusters in rural areas (Zhang and Ning, 2007; Qi *et al.*, 2010; Wang and Zhou, 2012; Wang *et al.*, 2014; Zhou and Zhang, 2014; Li, 2015a, 2017). In the course of upgrading the industrial structure of large cities, polluting enterprises retreat and relocate, meaning that urban industrial enterprises move outside the city (Li, 2018). Based on the specific geographic location of plants chosen by enterprises in the Beijing–Tianjin–Hebei region from 2005 to 2012, Xu and Liu (2020) found that within 50 km of Beijing's administrative boundary is a high sulfur dioxide emission zone, reflecting the fact that pollution-intensive enterprises are relocating to the outer urban areas. In addition, in response to the environmental problems of industrial parks, China has successively launched pilots such as national demonstration eco-industrial parks and green parks, which are mainly national-level development zones (Tian *et al.*, 2016; Zhao *et al.*, 2020).

In general, the existing studies on industrial environmental regulation have certain limitations. First, most of the environmental regulations are measured in provinces and cities, while ignoring the urban–rural differences within provinces and cities. Second, industrial parks have become an important form of enterprise spatial layout, but there are only few studies on the environmental regulation of different types of industrial parks. The

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policy concern is about national-level and provincial-level development zones, while ignoring the largest number of industrial parks below the provincial level. Finally, in terms of environmental regulation measurement methods, if the environmental law enforcement is lax and enterprises illegally discharge pollutants, the statistical pollutant emissions are often smaller than the actual emissions, and thus using indicators related to pollutant discharges to measure environmental regulation lacks accuracy.

The contributions of this paper are as shown in the following three aspects. First, enterprise-level data are used to reveal the spatial heterogeneity of environmental regulation. The current environmental regulation measurement uses national or provincial aggregate data, which conceals the spatial differences between urban and rural areas within the region. The use of enterprise data allows detailed observation of the spatial characteristics of enterprise locations, such as whether they are located in industrial clusters or whether they are dispersed in urban and rural areas. Second, the degree of environmental regulation in various industrial parks is compared. Industrial parks have become the main form and trend of industrial layout in China, but there is an absence of research on the environmental regulation of industrial parks. Thirdly, new methods for measuring environmental regulation differences are explored. The existing methods of measuring environmental regulations use conventional environmental data, which usually only cover key regions and key investigated enterprises. The thorough inspection of polluting enterprises in the top–down Environmental Enforcement Action makes up for the shortcomings of conventional law enforcement which cannot take into account non-key regions and non-key enterprises, and can reflect spatial differences in environmental regulations across all enterprises and regions, serving as an important extension of the existing methods.

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3. The Analytical Framework

Environmental regulation usually consists of two levels: the first is the textual level, including environmental laws and regulations, departmental regulations and industry standards; the second is the implementation level. A text that is not implemented is just a dead letter. At present, the differences in environmental regulation in China are mainly at the process of implementation.

3.1. *Conventional environmental law enforcement by local governments and the Environmental Enforcement Action by the Central Government*

China's environmental law enforcement can be divided into two categories: one is the conventional environmental law enforcement implemented by the local government, and the other is the top–down Environmental Enforcement Action implemented by the Central Government.

3.1.1. *Conventional environmental law enforcement*

Article 6 of the *Environmental Protection Law of the People's Republic of China* states that "Local people's governments at various levels shall be responsible for the environmental quality within areas under their jurisdiction". In other words, local governments are the main body of environmental law enforcement. Conventional environmental law enforcement is the daily enforcement by local environmental protection departments on the pollution discharge of enterprises in their jurisdiction, including inspection, spot check, monitoring and petition reception. Due to the limited human and material resources of local environmental protection departments, environmental supervision often only covers key regions with a limited area and a limited number of key enterprises, usually central urban areas and large- and medium-sized enterprises. It is difficult to ensure effective daily supervision on rural areas where the industrial enterprises are more scattered, small-scale enterprises and lower-level industrial parks. In addition, the technological level of Chinese enterprises varies, and a considerable number of enterprises have not yet reached the level of improving their competitiveness through environmental protection as suggested by the Porter Hypothesis (Porter and van der Linde, 1995). Without pollution control, enterprises can still maintain a meager profit, but once pollution control is carried out, many are on the verge of losing money. Local governments tend to be sympathetic to pollution-intensive enterprises and are lax in environmental regulation in order to maintain local revenue and employment.

3.1.2. *Top–down environmental enforcement action*

If the local government's daily environmental law enforcement is in place and the enterprises do not discharge pollutants illegally, then there is no need for special law enforcement by the Central Government. If not, the enterprises' illegal emissions will cause pollution to the surrounding environment, and even small enterprises will cause serious pollution due to long-term illegal discharge of pollutants. Environmental risks gradually increase as the pollution problems accumulate over time. Some environmental risks will erupt and develop into mass pollution incidents or regional pollution, arousing intense social concern. Eventually, the Central Government sends inspection teams to carry out inspection work at the local level. Yang and Xiao (2018) roughly divided the Environmental Enforcement Action into eight processes: occurrence of an incident → attention from the relevant authorities → establishment of a special governance leading group → mobilization and deployment meetings → formulating and issuing action plans → full implementation of action plans → inspection and feedback → summary and evaluation.

In the Environmental Enforcement Action, the enforcement body is usually the central ministries represented by the Ministry of Ecology and Environment (MEE). The Environmental Enforcement Action draws a lot of manpower and material resources from other positions to focus the limited enforcement resources on major pollution problems that have strong public reactions, and covers all polluting enterprises that are usually difficult to be detected by local governments or that are not thoroughly supervised. The Environmental Enforcement Action is often triggered by one or several pollution incidents, and the target is all enterprises in the industry where the pollution incident occurred. In the course of such campaign-style environmental law enforcement, polluting enterprises that would normally be difficult to be detected by the searchlights of routine enforcement are exposed and remedied. Since 2003, in response to the repeated illegal pollutant discharges of

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enterprises, the former MEP and eight other ministries and government agencies have organized the Environmental Enforcement Action for Straightening out Illegal Pollutant-discharging Enterprises and Safeguarding Public Health, focusing on a particular type of environmental pollution problems each year. The Environmental Enforcement Action serves to monitor and complement the conventional environmental law enforcement by local governments.

In short, conventional environmental law enforcement is a selective form of enforcement by local governments on a daily basis, highlighting urban areas and large and medium-sized enterprises, while neglecting the vast rural areas and small enterprises. The Environmental Enforcement Action, with its full coverage in space and enterprise size, can provide a cross-sectional picture of the extent to which enterprises of different sizes and geographic areas are subject to environmental regulation.

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3.2. *Extrapolating the intensity of environmental regulation from the results of the Environmental Enforcement Action*

The content of law enforcement of the Environmental Enforcement Action is similar to that of the conventional environmental law enforcement, i.e. to check whether the enterprises comply with environmental regulations and whether they discharge pollutants illegally, including whether the "three simultaneous" principle is strictly complied, whether the environmental impact assessment is conducted, whether the pollution control facilities are operating normally, etc. If an enterprise has violated the law, it will be subject to measures such as halting production for rectification; and if it has not violated the law, it can continue production. There is a relationship between the degree of enterprises' compliance with environmental regulations and the intensity of local governments' conventional environmental law enforcement. Generally speaking, the stricter the conventional environmental law enforcement and the wider the coverage, the higher the degree of enterprises' compliance with environmental regulations and the lower the probability of illegal pollutant discharges; the laxer the conventional environmental law enforcement and the smaller the coverage, the lower the degree of enterprises' compliance and the higher the probability of illegal pollutant discharges. In short, the actual degree of illegal pollutant discharges reflects the intensity of local conventional environmental regulation. Therefore, the intensity of conventional environmental regulation can be inferred from the results of the Environmental Enforcement Action.

In this paper, there is a logical relationship between the degree of enforcement of the Environmental Enforcement Action by the Central Government and the intensity of environmental regulation by local governments: the environmental regulation texts on which law enforcements by the Central Government and local governments are based, are the same. If local governments strictly enforce the environmental regulations, then the enterprises' illegal emissions will be detected and controlled in time, and the Central Government will not detect illegal emissions, and the proportion of remediation measures taken against the enterprises will be zero; if local governments do not carry out environmental law enforcement, and there is no daily supervision and monitoring of the enterprises' discharges, then the Central Government will detect all illegal pollutant discharges, and the proportion of remediation measures taken against the enterprises will be high. Therefore, the extent of conventional environmental law enforcement by local governments can be extrapolated from the results of the remediation measures taken by the Central Government in the Environmental Enforcement Action. The higher the proportion of remediation measures taken by the Central Government, the greater the number of regular illegal discharges, reflecting that the laxer the local governments' conventional environmental law enforcement, the lower the intensity of environmental regulation; the lower the proportion of remediation measures, the stricter the local governments' conventional environmental law enforcement, and the higher the intensity of environmental regulation. Of course, this relationship is only valid when the enterprises are homogeneous, so as to exclude the interference of industrial structure differences and ensure that environmental regulation texts are equally binding on enterprises.

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3.3. *Overview of the Environmental Enforcement Action in the lead–acid battery industry*

The lead–acid battery industry is a high pollution-intensive industry, including three sub-industries: plate production, battery assembly and recycling. The lead emissions in the air from the production and recycling processes will elevate blood lead levels. The lead–acid battery industry is a typical example of the rapid industrial growth in China in the last two decades (Li, 2016). Since 2002, China's automobile industry and electric bicycle production have surged, driving rapid growth in the upstream lead–acid battery manufacturing industry. Before the industry was regulated, China had become the world's largest producer of lead–acid batteries, accounting for more than a quarter of global lead–acid battery production (Wang *et al.*, 2011). However, as pollution control lagged behind, high growth also led to high pollution. A number of outbreaks of mass lead poisoning accidents caused by illegal discharges from lead–acid battery enterprises nationwide sparked strong calls for controlling pollution in the society. In 2011, nine ministries and agencies including the former MEP launched an Environmental Enforcement Action which carried out a thorough inspection of all lead–acid battery enterprises in China (MEP, 2011). After this inspection, the number of accidents of elevated blood lead levels caused by illegal pollutant discharges from the enterprises decreased sharply, with only one accident in 2012, and after 2013, there were almost no pollution accidents in lead–acid battery enterprises that aroused national responses.

4. Model Specification, Indicator Definition and Data Description

4.1. *Model*

In this paper, a multivariate discrete logistic model is used to simulate the relationship between the results of environmental remediation an enterprise is subject to and the spatial types and other variables. y represents the environmental remediation results of an enterprise, including banning, shutdown, halting production for rectification and continuation of production, which are indicated by the subscripts 1, 2, 3 and 4, respectively. $p(y)$ is the

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probability function of y. Taking continuation of production as the reference, the cumulative logistic model is expressed as

$$\ln\left[\frac{p(y_i)}{1-p(y_i)}\right] = \alpha_i + \sum_i^m \beta_i \,\text{type}_i + \gamma_1 \,\text{production1} + \gamma_2 \,\text{production2} + \sum_i^n \delta_i \,\text{province}_i + \varepsilon. \tag{4.1}$$

Among them, the intercept terms correspond to banning, shutdown and halting production for rectification, respectively; "type" denotes the geographical spatial type of the enterprise; "production_1" is the production scale of the plate manufacturing enterprise; "production_2" is the production scale of the battery assembly enterprise; and "province" denotes the province where the enterprise is located, so as to control inter-provincial differences. The larger the estimated value of β, which is the coefficient of "type", the higher the probability of being remediated and the lower the intensity of environmental regulation in that area; the smaller the estimated value of β, the higher the intensity of environmental regulation in that area.

4.2. *Indicator definition*

4.2.1. *Remediation results of the environmental enforcement action (y)*

The measures taken by the Environmental Enforcement Action against enterprises with illegal pollutant discharges are, in the descending order of strictness, as follows: banning, shutdown and halting production for rectification. Qualified enterprises can continue to produce.

(1) *Banning*: Enterprises with outdated production technologies and equipment that do not comply with national industrial policies should be eliminated.
(2) *Shutdown*: Enterprises that are poor in implementing the "three simultaneous" principle in environmental protection, safety facilities and occupational health.
(3) *Halting production for rectification*: Enterprises without environmental impact assessment or failing to meet the requirements of environmental impact assessment; enterprises without pollution control facilities, or their pollution control facilities are not operating normally; enterprises with excessive pollutant discharges, or failing to meet the protection distance requirements according to the law.

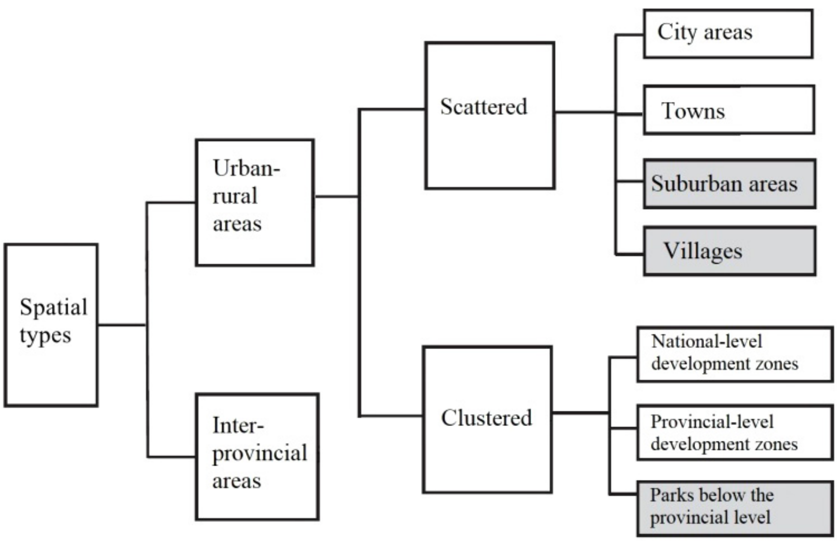
The proportion of remediation (Y) refers to the proportion of enterprises in a certain area that are subject to environmental remediation measures due to illegal pollutant discharges, i.e. the proportion of the number of enterprises that are banned, shut down and halted for remediation to the total number of enterprises.

4.2.2. *Geographical space (type)*

The geographical space in this paper refers to urban–rural and inter-provincial areas, with a focus on urban–rural areas. The spatial distribution of China's enterprises is very complex.

According to the current industrial layout requirements, new enterprises are generally located in industrial clusters, but there are still many enterprises scattered in the countryside. During the planned economy and the early years of reform and opening-up, China's industries were mainly located in cities. However, with the development of township enterprises, industry began to become an important pillar of the rural economy. Since the end of the 20th century, China has adopted a strategy of "concentrating enterprises in industrial parks", and various types of industrial clusters have emerged in the suburbs of cities and even in distant suburban counties. This has led to the coexistence of scattered and clustered industrial enterprises. There are two spatial types according to whether the enterprises are distributed in a contiguous area. The first type is scattered areas, such as city areas, towns, suburban areas and communities or villages in townships, where the enterprises are scattered; the second type is clustered areas such as industrial parks or industrial clusters, including national-level development zones (including high-tech zones and other industrial parks), provincial-level development zones and parks below the provincial level, where the enterprises appear in clusters and contiguous areas (see Fig. 1).

Based on the detailed production address of the enterprise and the *Administrative Division Codes and Urban-Rural Classification Codes for Statistical Purposes in 2011* published by the National Bureau of Statistics, this paper identifies the province, city, district, county, township, street and village (community) where the enterprise is located, and referring to Li (2015b), it divides the urban and rural areas in accordance with the 12-digit administrative division code. For the enterprises with unknown addresses, this paper searches for their detailed addresses based on their names, and thus determines their locations. Scattered areas are divided into four categories: city areas, towns, suburban areas and villages.



Note: The shaded areas indicate rural areas.

Fig. 1. Spatial types of enterprises.

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Clustered areas are divided into three categories: national-level development zones, provincial-level development zones and parks below the provincial level. National-level development zones and provincial-level development zones have formal names and the level of industrial park or development zone in which the enterprise is located can be determined from the *Catalogue of Approved Development Zones in China (2006 Version)*. Industrial clusters that are not listed in this catalog are considered parks below the provincial level.

Urban areas include city areas, towns, provincial-level development zones and national-level development zones, while rural areas include suburban areas, villages (villages under the administration of townships and towns) and parks below the provincial level. It should be noted that industrial parks below the provincial level are mainly located in towns, some near towns and most in villages under the administration of townships and towns. With the expansion of urban boundaries, national-level development zones and provincial-level development zones are gradually integrating with the main urban areas and becoming part of the urban areas. Industrial parks below the provincial level are far from the main urban areas and are difficult to develop into urban areas (Li, 2018). Thus, this paper classifies development zones at the provincial level and above as urban areas, and industrial parks below the provincial level as rural areas.

4.3. *Data specification*

As required by the Environmental Enforcement Action, the environmental protection departments of all provinces disclosed the remediation information of all lead–acid battery enterprises on their websites at the end of 2011, including the enterprise name, detailed production address, remediation status, production type, production capacity, etc. The data of enterprises used in this paper comes from the column of disclosure of environmental remediation information in key industries on the websites of the environmental protection departments of each province.

In 2011, a total of 1,962 lead–acid battery enterprises were investigated in the Environmental Enforcement Action, of which 1,848 (including 1,680 lead–acid battery manufacturing enterprises and 168 battery recycling enterprises) had production address information and remediation results. Battery recycling enterprises can cause serious lead pollution in the dismantling process, but due to the small number and the fact that they are largely located in rural areas, they will not be discussed in this paper.

The remediation information data of lead–acid battery enterprises has unique advantages in reflecting the level of environmental regulation. First, this set of data records the extent of enterprises' compliance with environmental regulations, the spatial location and production status of the enterprises, thus allowing the examination of the spatial characteristics of the intensity of environmental regulations, which is not available for other enterprise databases (such as the China Industry Business Performance Data); second, the data covers all enterprises in the lead–acid battery manufacturing industry, including a large number of samples that are not included in China Industry Business Performance Data and the statistics of pollutant discharges by key enterprises under investigation.

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Table 1. Meaning of variables and statistical characteristics.

Variable name	Variable meaning and assignment	Sample size	Mean	Standard deviation	Maximum	Minimum
Results of environmental remediation (y)	1 = banning, 2 = shutdown, 3 = halting production for rectification, 4 = continuation of production	1,680	2.2	1.1	4	1
Spatial types (type)	1 = urban areas, 2 = towns, 3 = suburban areas, 4 = villages, 5 = parks below the provincial level, 6 = provincial-level development zones, 7 = national-level development zones	1,680	3.9	1.5	7	1
Production capacity of plate ($production_1$)	10,000 kVAh	1,680	12.9	45.4	650	0
Production capacity of battery assembly ($production_2$)	10,000 kVAh	1,680	17.7	48.2	600	0

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In fact, China Industry Business Performance Data only records data on industrial enterprises above a designated size, and the statistics of waste gas and pollutant discharges by key industrial enterprises under investigation only include key enterprises under investigation,[2] with a large number of small- and micro-enterprises being excluded. Although the sales revenue of these small- and micro-enterprises is relatively small, their pollution level is no less than that of large enterprises if pollution control facilities are not installed. The influence of small enterprises cannot be ignored in industrial pollution control. This data provides a comprehensive picture of all enterprises in compliance with environmental regulations. In addition, the lead–acid battery industry is highly homogeneous, which avoids the interference of industrial structure with the comparability of environmental regulations.

The meaning and statistical characteristics of each variable are shown in Table 1.

5. Results and Discussion

5.1. *Distribution of lead–acid battery manufacturing enterprises*

In terms of urban and rural distribution, rural areas are the main distribution space for lead–acid battery manufacturing enterprises. As can be seen from Table 2, lead–acid battery manufacturing enterprises are distributed in all types of urban and rural areas with more enterprises in the rural areas. Before the special campaign, lead–acid battery manufacturing enterprises in suburban areas, villages and parks below the provincial level totaled 1,054, accounting for 62.74%, while those in the urban areas only accounted for 37.26%.

In terms of industrial parks, they are the main form and trend for the location of lead–acid battery manufacturing enterprises, and industrial parks below the provincial level are important spaces for these enterprises' location. Before the special campaign, there were 701 lead–acid battery manufacturing enterprises in industrial parks, accounting for 41.73% of the total; while after the remediation, the proportion increased to 67.89%. Among the industrial parks, the number of enterprises in the parks below the provincial level was the largest. Before the special campaign, there were 430 lead–acid battery manufacturing enterprises in the parks below the provincial level, accounting for 25.60% of the total; after the remediation, the proportion rose to 31.30%. The number of lead–acid battery manufacturing enterprises in national-level development zones is the smallest, with only 32 before the remediation; the number in provincial-level development zones is in the middle, with 239 before the remediation. As national-level and provincial-level development zones have specific industrial layout requirements, there are certain entry thresholds for the small-scale, pollution-intensive enterprises. In this case, parks below the provincial level have become the main choice for pollution-intensive enterprises.

[2] By matching with the database of key enterprises under investigation in 2011, it is found that only 323 enterprises in the lead–acid battery industry were recorded, which is less than 20% of the total number of enterprises identified in the Environmental Enforcement Action.

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Table 2. Urban and rural distributions of lead–acid battery manufacturing enterprises with different remediation results.

Types	Numbers					Proportions (%)			
	All enterprises	Banning	Shutdown	Halting production for rectification	Continuation of production	Banning	Shutdown	Halting production for rectification	Continuation of production
All enterprises	1,680	598	475	361	246	35.60	28.27	21.49	14.64
City areas	137	50	36	28	23	36.50	26.28	20.44	16.79
Towns	218	79	83	38	18	36.24	38.07	17.43	8.26
Suburban areas	248	128	54	48	18	51.61	21.77	19.35	7.26
Villages	376	170	116	70	20	45.21	30.85	18.62	5.32
Parks below the provincial level	430	115	123	115	77	26.74	28.60	26.74	17.91
National-level development zones	239	48	62	54	75	20.08	25.94	22.59	31.38
Provincial-level development zones	32	8	1	8	15	25	3.13	25	46.88
Urban areas	626	185	182	128	131	29.55	29.07	20.45	20.93
Rural areas	1,054	413	293	233	115	39.18	27.80	22.11	10.91

Source: The column of disclosure of environmental remediation information in key industries on the websites of the environmental protection departments of each province.

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As for regional distribution, lead–acid battery manufacturing enterprises are concentrated in the eastern region (see Table 3). Before the remediation, the number of enterprises in the eastern region accounted for 74.29% of the country's total. Among them, Jiangsu, Zhejiang, Guangdong and Shandong concentrated 59.64% of China's lead–acid battery manufacturing enterprises, accounting for more than half of the country's production capacity. After the remediation, the number of enterprises which can continue to produce in the eastern region accounted for 67.48%. And 47.97% of China's enterprises are located in Jiangsu, Zhejiang, Guangdong and Shandong. The eastern region still occupies a dominant position although its proportion has decreased. The distribution pattern of pollution-intensive enterprises basically reflects the economic strength of each region.

5.2. *Estimated results of spatial differences in industrial environmental regulation*

The estimation of Eq. (4.1) is shown in Table 4. It can be seen that the hypothesis that the overall coefficient is zero is rejected and the hypothesis that the coefficient of each variable is zero is also rejected, indicating that the selected variables have a significant effect on the dependent variable. Model 1 is the estimated result without the variable of production scale, while Model 2 and 3 include the variable of production scale to estimate the two processes of plate production and battery assembly, respectively. The city area is taken as a reference for the variable of urban–rural area type and Zhejiang is the reference for the variable of province. If the estimated coefficient is positive, the probability of an enterprise being remediated is relatively high, indicating that environmental regulations are relatively lax; the larger the coefficient, the laxer the environmental regulation. If the coefficient is negative, the probability of an enterprise being remediated is relatively low, indicating that the environmental regulations are relatively strict; the smaller the coefficient, the stricter the environmental regulation.

Among the scattered spatial type, the estimated coefficients for towns, suburban areas and villages are all positive, implying that these areas all have a higher probability of environmental remediation than urban areas. Urban areas have the most stringent environmental regulations, followed by towns; suburban areas and villages have a lower degree of environmental regulation, and suburban areas the laxest. Among the industrial zones, the estimated coefficients for all three types of industrial parks are significantly negative, indicating that all industrial clusters have stricter environmental regulations than urban areas. The estimated coefficient for national-level development zones is the smallest, indicating that they have the strictest environmental regulations, followed by provincial-level development zones, while parks below the provincial level have the laxest environmental regulations. There is an inverse relationship between the scale of an enterprise's production capacity and the degree of environmental regulation. The larger the enterprise's production capacity, the lower the probability of being subject to environmental regulation. This confirms the fact that large enterprises are usually subject to stricter environmental regulations. By region, taking Zhejiang as a reference, regions with significantly stricter environmental regulations than Zhejiang include Shanghai and Tianjin, while regions with significantly laxer environmental regulations than Zhejiang include Beijing, Jiangsu, Anhui

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Table 3. Urban and rural distributions of lead–acid battery manufacturing enterprises in various provinces.

Provinces	Numbers								Proportion of rural areas (%)	Proportion of remediation (%)
	City areas	Towns	Suburban areas	Villages	Parks below the provincial level	National-level development zones	Provincial-level development zones	Total		
Beijing	0	0	3	1	0	0	0	4	100	100
Tianjin	0	2	1	5	1	5	1	15	46.7	40
Hebei	16	7	5	50	10	13	0	101	64.4	89.1
Shanxi	1	0	0	4	1	0	0	6	83.3	100
Inner Mongolia	1	0	1	0	2	1	1	6	50	100
Liaoning	1	0	2	5	1	3	0	12	66.7	73.3
Jilin	0	1	1	0	0	1	3	6	16.7	100
Heilongjiang	2	0	0	0	0	0	0	2	0	50
Shanghai	4	4	4	2	1	1	0	16	43.8	18.8
Jiangsu	11	66	43	107	79	61	2	369	62.1	91.1
Zhejiang	6	30	76	80	86	38	1	317	76.3	94.3
Anhui	5	11	12	11	33	22	2	96	58.3	79.2
Fujian	1	11	3	20	47	10	3	95	73.7	88.4
Jiangxi	4	2	2	6	12	24	2	52	38.5	71.2
Shandong	15	32	23	9	21	27	1	128	41.4	77.3
Henan	18	11	13	23	11	4	0	80	58.8	90
Hubei	11	7	3	6	2	9	5	43	25.6	74.4
Hunan	9	5	4	9	4	1	2	34	50	82.4
Guangdong	12	21	27	13	93	13	9	188	70.7	79.8

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Table 3. (*Continued*)

Provinces	Numbers								Proportion of rural areas (%)	Proportion of remediation (%)
	City areas	Towns	Suburban areas	Villages	Parks below the provincial level	National-level development zones	Provincial-level development zones	Total		
Guangxi	2	2	3	0	4	0	0	11	63.6	72.7
Chongqing	6	3	19	2	5	4	0	39	66.7	74.4
Sichuan	3	3	1	21	14	1	0	43	83.7	93
Guizhou	2	0	0	0	0	0	0	2	0	100
Yunnan	2	0	1	2	3	0	0	8	75	100
Shaanxi	2	0	0	0	0	0	0	2	0	50
Gansu	2	0	1	0	0	0	0	3	33.3	66.7
Ningxia	1	0	0	0	0	1	0	2	0	50

Note: The proportion of rural areas indicates the proportion of the number of enterprises located in rural areas to the total number of enterprises; proportion of remediation indicates the proportion of the number of enterprises with remediation results including banning, shutdown and halting production for rectification to the total number of enterprises.
Source: Then column of disclosure of environmental remediation information in key industries on the websites of the environmental protection departments of each province.

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Table 4. Estimated results of multivariate logistic model.

		Model 1		Model 2		Model 3	
Explanatory variable	Variable interpretation	Estimated value	p-value	Estimated value	p-value	Estimated value	p-value
type (Reference = urban areas)	Towns	0.4044	0.0015	0.3194	0.0138	0.2819	0.0308
	Suburban areas	0.6322	< 0.0001	0.509	< 0.0001	0.4638	0.0004
	Villages	0.5705	< 0.0001	0.4708	< 0.0001	0.4452	< 0.0001
	Parks below the provincial level	−0.3488	0.0007	−0.3631	0.0005	−0.3728	0.0004
	Provincial-level development zones	−0.8276	< 0.0001	−0.6672	< 0.0001	−0.6604	< 0.0001
	National-level development zones	−1.0747	0.0002	−0.8052	0.0082	−0.7005	0.0207
$production_1$	Plate production			−0.017	< 0.0001		
$production_2$	Battery assembly					−0.016	< 0.0001
intercept 1	Banning	−1.5103	< 0.0001	−1.3408	¡0.0001	−1.2998	< 0.0001
intercept 2	Shutdown	−0.0468	0.7488	0.1795	0.2271	0.2251	0.1312
intercept 3	Halting production for rectification	1.393	< 0.0001	1.7251	< 0.0001	1.7686	< 0.0001
province (Reference = Zhejiang)	Anhui	0.4744	0.0376	0.6856	0.0034	0.593	0.0105
	Beijing	2.0809	0.0681	2.0248	0.0757	2.0732	0.0698
	Hebei	−0.3833	0.0876	−0.4288	0.0569	−0.225	0.3214
	Jiangsu	0.9458	< 0.0001	0.9715	< 0.0001	0.9531	< 0.0001
	Shanghai	−3.1738	< 0.0001	−3.3659	< 0.0001	−3.3845	< 0.0001
	Sichuan	1.5185	< 0.0001	1.5067	< 0.0001	1.5737	< 0.0001
	Tianjin	−1.2432	0.0129	−1.3786	0.0066	−1.4098	0.0054
N		1,680		1,680		1,680	
R^2		0.2551		0.3107		0.3128	

Note: Provinces with insignificant estimated coefficients are omitted.

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and Sichuan. The coefficients for other regions are not significant or the significance is not robust. In other words, the differences in environmental regulations between most provinces are not significant. On the whole, the degree of environmental regulation is generally lower in rural areas than in urban areas, and generally higher in clustered areas than in scattered areas, while most inter-provincial environmental regulations are not significantly different.

5.3. *Robustness analysis*

The signs of the estimated coefficients of the geographical spatial variable type remain consistent in Models 1–3, and they are all significantly not zero at the 5% level, indicating that the estimated results are robust. While in terms of inter-provincial variables, the differences in the degree of environmental regulation in most provincial areas are not significant. In order to test the extent of inter-provincial variation in industrial environmental regulation, the inter-provincial variables were retained in Models 1–3 by removing the geographical spatial variables. The results in Table 5 show that the estimated coefficients for most of the inter-provincial variables remain insignificant, which is largely consistent with the original estimation, except for Beijing, Jiangsu, Sichuan, Shanghai, Tianjin and Fujian, where the estimated coefficients are significant. This suggests that for pollution-intensive enterprises such as the lead–acid battery enterprise, the spatial differences in environmental regulation prior to the special remediation campaign were mainly urban–rural rather than inter-provincial.

This paper introduces income levels to further illustrate the urban–rural and inter-provincial spatial differences in environmental regulation. Since the income level of a country or region is highly correlated with the degree of environmental regulation (Dasgupta *et al.*, 2001), and in general, the environmental regulations in areas with high per capita income are often stricter, thus income levels have been used as a proxy variable to measure environmental regulation in some studies. The intensity of inter-provincial environmental regulation is measured by the proportion of remediation Y (see Table 3) targeting illegal pollutant-discharging enterprises in each province in the Environmental Enforcement Action; the higher the proportion of remediation, the lower the degree of environmental regulation. A regression analysis of the intensity of inter-provincial environmental regulation and per capita GDP (gdp), using OLS estimation, shows that the estimated coefficient of per capita GDP is not significant (see Table 6). In the linear function, the p-value of per capita GDP is 0.165, indicating that the estimated coefficient is not significant. In the quadratic function of one variable, the estimated values of both per capita GDP and the quadratic term of per capita GDP are not significant,

$$Y_i = \alpha + \beta_1\,\mathrm{gdp}_i + \beta_2\,\mathrm{gdp}_i^2 + \beta_3\,\mathrm{ratio}_i + \varepsilon_i. \tag{5.1}$$

If the proportion of rural enterprises "ratio" is added to the regression model of inter-provincial environmental regulation intensity and per capita GDP, the model fit and regression coefficients will change significantly. It can be seen from Table 6 that when the proportion of rural enterprises is added to Model 3, the model fit is improved over the previous two models, and the goodness of fit increases to 0.5530. The estimated value of

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Table 5. Estimated results of inter-provincial variables.

Explanatory variable	Variable interpretation	Model 1		Model 2		Model 3	
		Estimated value	p-value	Estimated value	p-value	Estimated value	p-value
intercept 1	Banning	−1.2467	< 0.0001	−1.1119	< 0.0001	−1.0724	< 0.0001
intercept 2	Shutdown	0.1443	0.296	0.3549	0.0117	0.4015	0.0044
intercept 3	Halting production for rectification	1.5078	< 0.0001	1.8512	< 0.0001	1.8996	< 0.0001
$production_1$	Plate production			−0.0198	< 0.0001		
$production_2$	Battery assembly					−0.0186	< 0.0001
province (Reference = Zhejiang)	Anhui	0.1589	0.4754	0.4313	0.0604	0.3432	0.1309
	Beijing	2.4411	0.0321	2.3001	0.0432	2.3196	0.0422
	Chongqing	−0.077	0.8026	−0.1388	0.6566	−0.0465	0.8815
	Fujian	−0.5571	0.0128	−0.6273	0.0058	−0.5986	0.0086
	Gansu	−0.3451	0.7319	−0.5584	0.5806	−0.5504	0.5862
	Guangdong	−0.1163	0.5296	−0.2227	0.2334	−0.0859	0.6458
	Guangxi	−0.1671	0.7562	0.0748	0.8969	−0.1835	0.7401
	Guizhou	0.5501	0.6574	0.3774	0.7615	0.5295	0.6702
	Hebei	−0.1998	0.3613	−0.2926	0.1847	−0.0863	0.6984
	Heilongjiang	−0.1242	0.9195	0.9169	0.4727	0.7944	0.5314
	Henan	0.3762	0.1122	0.1762	0.4598	0.1321	0.5796
	Hubei	−0.1922	0.5165	0.0992	0.7487	0.1385	0.6518
	Hunan	0.0154	0.9623	0.0328	0.9206	0.0661	0.8409
	Inner Mongolia	0.6662	0.3597	0.6711	0.3581	0.6602	0.3656
	Jiangsu	0.8551	< 0.0001	0.8854	< 0.0001	0.8524	< 0.0001
	Jiangxi	−0.2888	0.2942	−0.0807	0.7746	−0.2687	0.3392

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Table 5. (*Continued*)

Explanatory variable	Variable interpretation	Model 1		Model 2		Model 3	
		Estimated value	*p*-value	Estimated value	*p*-value	Estimated value	*p*-value
	Jilin	0.0698	0.9447	−0.1652	0.8702	0.0394	0.969
	Liaoning	−0.288	0.5369	−0.5145	0.2721	−0.5598	0.2322
	Ningxia	−1.0344	0.4078	−0.9767	0.4375	−1.0417	0.4073
	Shandong	−0.0179	0.9299	0.1346	0.5162	0.1206	0.5602
	Shanghai	−2.8205	< 0.0001	−3.0631	< 0.0001	−3.1125	< 0.0001
	Shaanxi	−1.0344	0.4078	−1.2933	0.3012	−1.3397	0.2843
	Shanxi	0.5501	0.4478	0.6436	0.3763	0.5298	0.4662
	Sichuan	1.5219	< 0.0001	1.4923	< 0.0001	1.5515	< 0.0001
	Tianjin	−1.4718	0.0025	−1.5388	0.002	−1.5878	0.0014
	Yunnan	−0.5495	0.3813	−0.8151	0.1958	−0.7894	0.2103

Table 6. Estimated results of the proportion of environmental protection remediation and income level.

	Model 1		Model 2		Model 3	
Explanatory variable	Estimated value	*p*-value	Estimated value	*p*-value	Estimated value	*p*-value
gdp	−0.0003	0.1648	0.0010	0.3847	0.0012	0.1315
gdp^2			−0	0.2494	−0	0.0560
ratio					0.6475	0.0001
N	27		27		27	
R^2	0.0757		0.1264		0.5530	

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the squared GDP per capita is significantly negative at the 10% level, but the coefficient is very small and almost negligible. The estimated value of the proportion of rural enterprises is significantly positive at the level of 1%, with each one percentage point increase in the proportion of rural enterprises leading to a 0.65 percentage point increase in the proportion of remediation. It can be seen that, at the provincial level, differences in income levels do not explain the differences in their degrees of environmental regulation, and that inter-provincial differences in the level of environmental regulation arise more from differences in the urban–rural distribution of enterprises within the province. The higher the proportion of rural enterprises, the lower the degree of environmental regulation. The differences of environmental regulation in rural areas determine the inter-provincial differences in environmental regulation. Overall, inter-provincial differences in the degree of environmental regulation are not significant in the period of this study, while significant differences exist in different types of urban–rural areas within the province, and this estimation is robust.

The analysis in this paper also shows that using income levels to measure environmental regulation requires attention to spatial scales. When using income levels to measure the degree of environmental regulation in a country or province, attention should be paid to the differences within these spatial scales. At a given point in time, even in provinces with higher levels of income, the level of environmental regulation is not necessarily more stringent, as there are significant differences in urban and rural income levels within the province. In the case of strict environmental regulations in urban areas, enterprises may choose suburban areas and villages around the city; the threshold for national-level development zones is high, so firms may choose parks below the provincial level with lower threshold. Taking Beijing as an example, Table 3 shows that there are no lead–acid battery manufacturing enterprises in the city areas and towns of Beijing, and all lead–acid battery enterprises are located in suburban areas and villages. Therefore, when measuring the degree of environmental regulation by income level, it is important to note the differences within the space, such as urban–rural differences and distribution differences of enterprises.

6. Conclusions and Policy Implications

This paper uses data from the enterprises surveyed in the Environmental Enforcement Action for the lead–acid battery industry as a sample to reveal the spatial distribution of

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pollution-intensive enterprises, and quantitatively verifies urban–rural and inter-provincial differences in China's environmental regulation on industrial pollution. The findings of the study are as follows.

First, rural areas are the main locations of lead–acid battery manufacturing enterprises, and industrial parks are the main form of enterprises' location. Before the Environmental Enforcement Action, lead–acid battery manufacturing enterprises in rural areas accounted for 62.74% of the total number, while those in urban areas accounted for only 8.15%. Those in industrial parks accounted for 41.73% of the total number, while parks below the provincial level accounted for 25.60%. These enterprises are concentrated in the eastern region, accounting for about 70% of the total enterprises in China.

Second, in terms of the intensity of environmental regulation in different spatial types, firstly, the intensity of environmental regulation is higher in urban than in rural areas, and that is generally higher in clustered areas such as industrial parks than in scattered areas. In terms of scattered areas, the environmental regulation in city areas is most stringent, followed by towns and villages, while the environmental regulation in suburban areas is the laxest. In terms of various industrial parks, the environmental regulation in national-level development zones is the most stringent, followed by provincial-level development zones, while parks below the provincial level have the laxest environmental regulations. Secondly, from an inter-provincial perspective, only a few provinces have differences in the degree of environmental regulations, while the differences in environmental regulations in most regions are not significant. Because of huge differences in income levels between urban and rural areas within the province, enterprises tend to be located in suburban areas and villages surrounding the city areas. The differences in environmental regulations between urban and rural areas are more significant than those between provinces.

Attention must be paid to the spatial differences between urban and rural areas when formulating environmental protection policies and allocating environmental law enforcement resources. Parks below the provincial level, suburban areas and villages are the weak links in environmental law enforcement for local governments. National-level and provincial-level development zones have certain entry thresholds for small, pollution-intensive enterprises, in which parks below the provincial level become the main choice for pollution-intensive enterprises, and thus attention must be paid to pollution prevention and control in lower-level industrial clusters.

With limited resources for environmental law enforcement, local governments should allocate enforcement resources rationally. Local governments tend to focus on large enterprises and urban areas for conventional environmental law enforcement, while ignoring rural areas and lower-level industrial clusters. This is prone to unfair punishment, while the sources of pollution, the real "foot-dragger", cannot be effectively monitored. Therefore, local governments should shore up the weak spots in the process of conventional environmental law enforcement, and shift enforcement resources to areas with weak environmental regulations to effectively supervise the sources of pollution. The focus of environmental law enforcement should be shifted downwards to areas with weak environmental regulations, such as parks below the provincial level, suburban areas and rural areas. Legislation should be enacted on the industrial layout of different functional areas in urban and rural areas to protect arable land and basic farmland from industrial pollution. Finally, the uncontrolled expansion of the number and size of industrial parks below the provincial level should be restricted, remaining true to the original aspiration of land conservation and intensive development of industrial parks.

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