Article

Can Chinese Central Government Inspection on Environmental Protection Improve Air Quality?

Ling-Yun He 1,2,* and Meng-Meng Geng 1

1 College of Economics, & Institute of Resource, Environment and Sustainable Development Research, Jinan University, Guangzhou 510632, China; hely_jnu@jnu.edu.cn
2 School of Business, Nanjing University of Information Science & Technology, Nanjing 210044, China
* Correspondence: lyhe@amss.ac.cn; Tel.: +86-20-181-4571-3770

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Abstract: Environmental pollution is one of the major sustainability problems in China. As a major institutional innovation to supervise local governments to implement environmental governance measures, the effect of central environmental protection inspection needs to be carefully investigated. In this paper, the environmental protection inspection in July 2016 was used as a quasi-natural experiment to estimate the effect of central environmental protection inspection on air quality by using the synthetic control method. The study found that not all regions under inspection have significantly reduced the Air Quality Index (AQI). For the four inspected regions, the AQI decreased in Inner Mongolia Autonomous Region and Jiangsu Province during the period of inspection. But the inspection does not affect Henan Province and Jiangxi Province. In terms of individual pollutants, for Inner Mongolia Autonomous Region and Jiangsu Province where AQI has declined, not all individual pollutant concentrations have decreased. The treatment of specific individual pollutants still needs to be concerned.

Keywords: central government inspection; environmental protection; air quality

1. Introduction

Environmental problems, especially air pollution, have become increasingly prominent in China with the development of the economy. According to statistics, in 2015, only 73 cities met the air quality standards among 338 prefecture-level cities, accounting for 21.6%, and 265 cities exceeded the standards, accounting for 78.4% (2015 Chinese Environmental Status Bulletin). The air quality standard means that the air quality index (AQI) is between 0 and 100. The greater the AQI value, the more serious the air pollution. According to international standards, less than 1% of cities met standards [1]. Environmental problems also have an impact on economic development and social welfare. Accounting report of Green GDP 2004, China, which is the first Green GDP accounting report in China, pointed out that the economic losses caused by air pollution reached 511.8 billion yuan in 2004. The average life expectancy of residents in northern China has been reduced by 5.5 years due to air pollution [2]. Therefore the environmental problem is one of the key problems that needs to be solved in the process of all-round development of China.

As one of the most serious problems, environmental pollution is attracting more attention. Because of non-competitiveness and non-exclusiveness of the environment, the market may become faulty in environmental governance. Therefore, the government’s role in environmental governance still allows no neglect. Since the 12th Five-Year Plan, the CPC Central Committee and the State Council have paid more attention to the environment and made a series of major decisions and arrangements. Under the Administrative Decentralization in China, the central government’s environmental supervision policy requires local government to implement. Local governments tend to neglect the environment for
the sake of local economic development. It is necessary to urge local governments to ensure the implementation of environmental policies to deal with severe environmental problems. The central environmental protection inspection (The 14th meeting of Central Leading Group for Comprehensively Continuing Reform proposed establishing a working mechanism for environmental protection supervision in 2015. From 2016 to 2017, the first round of central government inspection on environmental protection carried out inspections in 30 provinces (autonomous regions) in China in four batches) is an important institutional innovation of the CPC Central Committee and the State Council to supervise local governments in environmental governance.

The inspection is led by the Ministry of Environmental Protection, representing the CPC Central Committee and the State Council, which is supported by the state’s compulsion to supervise the party committees, governments, and relevant departments of all provinces (autonomous regions). This is a long-term institutional arrangement and new attempt by the central government to supervise the environmental governance of local governments. In order to improve efficiency, inspection methods need to be constantly revised and improved. It is a problem worthy of study whether the inspection has effectively improved the environmental conditions of the inspected regions. This paper mainly evaluates the effect of central environmental protection inspection from the perspective of air pollution and selects the first batch of inspected regions (In July 2016, the first batch of eight inspection teams successively stationed in Inner Mongolia Autonomous Region, Heilongjiang Province, Jiangsu Province, Jiangxi Province, Henan Province, Guangxi Autonomous Region, Yunnan Province, and Ningxia Autonomous Region to carry out one-month supervision) as the research objects to study whether the inspection has improved air quality in these regions. This study is conducive to clarifying the effect of environmental inspection in the inspected areas, and provides experience support for future environmental inspection. In addition, this study analyzed the difference in environmental inspection effect in each inspected area and discussed the possible influencing factors. This provides ideas for future inspection and is conducive to better supervising the environmental governance of local governments and improving environmental quality. This research has certain practical significance.

As an important institutional innovation, the central environmental protection inspection has gradually become a research hotspot. For example, scholars have studied the effect of environmental protection inspection from different perspectives. Some scholars believe that environmental protection inspection can improve environmental quality [3–6]. However, scholars have different opinions on this positive policy effect. Some scholars believe that this effect is only short term and unsustainable [3], while others believe that the effect will not gradually weaken after supervision [6]. In addition, some scholars have analyzed the effect of central environmental protection inspection from the perspectives of enterprise stock value [7], implementation of environmental regulations [8,9], and reaction of capital market [10]. From the existing literature, scholars began to study environmental inspection and tried to analyze the effect from different perspectives. However, there is no unified understanding of the effect of environmental inspection at present. Moreover, as an institutional innovation, the current research is relatively insufficient. Based on the research of scholars, this paper will analyze the impact of environmental protection inspection on the air quality of prefecture-level cities. This can enrich the research on the effect of environmental protection inspection, and has certain academic research significance.

The main purpose of this paper is tantamount to make use of the quasi-natural experiment formed by environmental protection inspection to estimate the effect of the inspection using a quantitative approach. As a quasi-natural experiment, the most common difference-in-difference method can be used to evaluate the inspection effect, with the inspected region as the treatment group and the unsupervised region as the control group. However, the choice of the group by the difference-in-difference method is subjective and less convincing. Moreover, in addition to satisfying the condition of being unsupervised when selecting a control group, it also must be satisfied that the treatment group and the control group have a collective trend before the inspection. Therefore, it is difficult to find a suitable control group once the universal tendency conditions are not satisfied.
point, the advantage of the synthetic control method is revealed. The method is built on data-driven to select the optimal control group weight, which reduces the subjectivity of the control group selection. The synthetic control method was first proposed by Abadie and Gardeazabal [11] to study the economic costs of terrorist activities in the Basque region of Spain. The basic idea is to use a linear combination of other parts of Spain to construct a synthetic region, and to make the economic characteristics of the synthetically controlled region as similar as possible to the Basque region before the outbreak of terrorist activity in the late 1960s, then compare the per capita GDP of the “synthetic Basque region” with the “real Basque region”. There are two points to note that when using the synthetic control method. Regions that are also covered by this policy should be removed when constructing potentially controlled regions and the number of periods before and after intervention needs to be large enough. This method has been widely used in recent years [12–16]. In this paper, the synthetic control method will also be selected as the main test method.

The objective of this paper is to evaluate the impact of the first environmental protection inspection on the air quality in the inspected regions. The synthetic control method will be adopted when evaluating the effectiveness of inspection. According to the basic principle of the method, the inspected region is treated as a treatment group, while the unsupervised regions are potential control groups. The synthetic group is constructed by a synthetic control method so that the air quality of the synthetic group and the treatment group before the inspection is as similar as possible. Then compare the differences between the treatment group and the synthetic control group to assess whether the central environmental protection inspection can improve local air quality. The main contribution of this paper is that in terms of research methods, this article utilizes the synthetic control method to evaluate the effect of inspection to overcome the subjectivity of common methods in selecting control groups.

The rest of the paper is organized as follows: Section 2 is a literature review, which has summarized the relevant literature. The Section 3 is the background, which mainly introduces central government inspection on environmental protection. Section 4 introduces methods, variables, and data separately. The Section 5 is the main results and discussion, which is the focus of this article. The Section 6 is the conclusions.

2. Literature Review

The government has formulated a series of policies to deal with environmental pollution, while scholars hold different views on the environmental governance effect of relevant policies. One is that environmental regulation can bring about environmental improvement. For example, Laplante and Ristolone [17] found that environmental regulation has a significant negative effect on pollution emissions from the research of Quebec’s pulp and paper industry. Panayotou [18] also found that the development of laws and regulations on environmental regulation could effectively reduce the emission of SO$_2$. Mori [19] evaluated a potential carbon tax in Washington State and found that a carbon tax can reduce GHG emissions. Miller and Vela [20] also demonstrate the effectiveness of environmental taxes in reducing emissions. However, some scholars hold the opposite view, that is, environmental regulation cannot improve environmental quality, or even increase environmental pollution due to the way of implementation and other reasons. For example, Davis [21] found that there is no evidence that the restrictions introduced by the government of Mexico City in 1989 have improved air quality. Cai et al. [22] found that the pollution reduction mandates has a smaller effect in the most downstream county of a province. Besides, some scholars hold that the effect of environmental policy is uncertain. Jin et al. [23] found that SO$_2$ has reduced due to the air pollution control policies, however, PM2.5 and O$_3$ were not affected. Through combing the existing literature, it is found that scholars have not formed a unified understanding of the environmental governance effect of environmental policies due to the differences in research perspectives and research methods and policy implementation.

As an important link in environmental protection, the implementation of environmental policy has a tremendous impact on the effect of the policy. Especially when the local government implements
the environmental policies of the central government. Local governments tend to promote economic growth and maximize tax revenue at the expense of environmental quality [24]. As a rule-maker, the central government should take action to adjust the existing central-local relations [25]. It is necessary to mobilize the enthusiasm of the local government to protect the environment and further promote policy implementation. Scholars have studied the policies and measures to supervise the local government’s environmental protection work. Liang and Langbein [26] studied the performance management system and found that the system only improved the air quality. Water pollution and emissions of soot were unaffected. With the institutionalization of public participation in environmental governance, scholars add public participation to the discussion of local government environmental governance. Dong et al. [27] found that citizens’ environmental complaints can provide valuable information for regulators to efficiently allocate inspection resources. Wu et al. [28] studied the effect of public participation on environmental performance and found that public participation has different effects on environmental performance. Li et al. [29] pointed out that environmental non-governmental organizations play a significantly positive role in China’s urban environmental governance.

The central environmental protection inspection is led by the Ministry of Environmental Protection to represent the central government’s high-level environmental protection deployment. It aims to transmit environmental protection pressure to the local government through supervision and achieve effective control of local environmental pollution. As a major reform measure and institutional arrangement of environmental supervision, some scholars have studied it. For example, Zhang et al. [30] evaluated the effectiveness of central environmental supervision, and found that the supervision significantly reduces industrial COD emissions by at least 26.8%. Chong and Sun [9] explored the emission reduction strategy of the environmental inspection system based on evolutionary game theory. Through combing the literature, we found that the existing literature is not enough for the research of the inspection, especially the empirical analysis. As the core system arrangement of the same responsibility of the party and government of ecological civilization, it is necessary to evaluate the effect of inspection in time and summarize the experience of inspection, to perfect the inspection system of environmental protection and promote the effective implementation of environmental protection. Based on the former research, the article takes the first batch of central environmental inspection as an example to analyze the impact of inspection on air quality.

3. Background: Central Government Inspection on Environmental Protection

To deal with the problems of inadequate implementation of policies and the difficult accountability of local governments in the process of environmental governance, China’s environmental regulatory system has been established and constantly improved. In 2002, the Ministry of environmental protection set up an organization in charge of environmental supervision in some cities. In 2008, six environmental protection supervision centers were established, covering 31 provinces (autonomous regions). At this stage, environmental supervision mainly focuses on “supervising enterprises” and supervising enterprises to abide by environmental protection laws and policies. However, this supervision model has certain limitations. Environmental regulation at the grass-roots level may not be enough to enable companies to implement environmental laws and policies. Local governments may help enterprises cope with environmental supervision for the sake of local interests. It is necessary to urge and restrain the local government to implement the responsibility of implementing environmental laws and policies.

In November 2012, the 18th National Congress of the Communist Party of China made the strategic decision of “strengthening the construction of ecological civilization”. Promoting ecological civilization is a long-term plan that concerns people’s wellbeing and China’s future. As an important aspect of promoting green development and improving the ecological environment, environmental management has an important impact on the construction of ecological civilization. The mode of inspection is also constantly improving. In July 2015, the “Environmental Protection Inspection Program (Trial)” was issued, which establish an environmental inspection
mechanism. After that, as an important part of environmental governance and a major measure to halt the environmental deterioration, “promoting environmental inspection and strict environmental law enforcement” was included in the 13th Five-Year Plan. The inspection is a major change in China’s environmental supervision model. On the one hand, the leading role has changed from the environmental protection department to the central government. It’s a high-level inspection. On the other hand, the inspection has changed from enterprise supervision to government supervision. Central government inspection on environmental protection mainly inspect the deployment of central environmental protection decisions by provincial party committees and governments, the processing circumstance of environmental issue, the improvement of environmental quality, and so on. The inspection also sinks to the prefecture-level city party committee and government. The results of the inspection will serve as an important basis for the assessment, evaluation, and appointment of leading cadres in the inspected regions.

At the end of December 2015, the central environmental protection inspection group entered Hebei Province for the first time and launched a one-month inspection. Hebei Province became the first pilot region to be inspected. During that period, the inspection group set up a special telephone and mailbox to accept the reports of the masses. Besides, it also used individual interviews, hearing reports, consulting correlative literature, and on-site investigations and otherwise. Meanwhile implementing the principle of inspection while handing over and rectification, timely solving the prominent environmental problems in the inspected region. After inspection, the inspection group will timely feedback on the specific situation to the inspected region. Within two years from 2016 to 2017, the inspection has covered more than 30 provinces (autonomous regions) (From July to August 2016, Inner Mongolia Autonomous Region, Heilongjiang Province, Jiangsu Province, Jiangxi Province, Henan Province, Guangxi Autonomous Region, Yunnan Province, and Ningxia Autonomous Region, were inspected; from November to December 2016, Beijing, Shanghai, Hubei Province, Guangdong Province, Chongqing, Shanxi Province and, Gansu Province were inspected; from April to May 2017, Tianjin, Shanxi Province, Liaoning Province, Anhui Province, Fujian Province, Hunan Province, and Guizhou Province were inspected; from August to September 2017, Jilin Province, Zhejiang Province, Shandong Province, Hainan Province, Sichuan Province, Xizang Autonomous Region, Qinghai Province, and Xinjiang Autonomous Region were inspected).

In July 2016, the central environmental protection inspection group officially started its work. Inner Mongolia Autonomous Region, Heilongjiang Province, Jiangsu Province, Jiangxi Province, Henan Province, Guangxi Autonomous Region, Yunnan Province, and Ningxia Autonomous Region became the first regions to be officially inspected. Since 12 July 2016, eight environmental protection inspection groups have been stationed in the above regions one after another for one month. Since November 12, the inspection groups have fed back the results to the inspected regions and asked these governments to publish rectification of environmental problems promptly. In the process of inspection, the supervisory groups focus on the prominent environmental problems and their treatment which are highly concerned by the central government, strongly reflected by the masses or have an odious social effect. The inspection also focuses on the environmental administrative omission of local party committees and governments and their relevant departments, and so on. During this period, eight inspection groups handed over 13316 environmental problems to the local government, of which 9722 cases were ordered rectification, 2906 cases were filed and punished, with a total fine of 225 million yuan. A total of 215 cases were filed and investigated in eight provinces, 327 persons were detained, 2275 persons were interviewed and 3492 persons were accountable.

In short, as an important measure of environmental protection, central government inspection on environmental protection is a long-term institutional arrangement to promote the construction of ecological civilization. It is unrealistic to improve the ecological environment through one or two inspections. In order to improve efficiency, inspection methods need to be constantly revised and improved. Taking these eight regions to be officially inspected firstly as examples, this paper discusses
the effect of central inspection on environmental protection, whether the inspection has improved the
air quality in the inspected regions and how to improve the environmental quality.

4. Method, Variables and Data

4.1. Method

In July 2016, environmental protection inspection groups were launched in Inner Mongolia
Autonomous Region, Heilongjiang Province, Jiangsu Province, Jiangxi Province, Henan Province,
Guangxi Autonomous Region, Yunnan Province, and Ningxia Autonomous Region. The change of
air quality brought by the inspection can be regarded as a quasi-natural experiment in the inspected
region. The most frequently used methods for policy evaluation include difference-in-difference,
regression discontinuity, propensity score matching, synthetic control method, and so on. Based on the
idea of the synthetic control method, this article chooses it to evaluate the effect of central environmental
protection inspection.

The synthetic control method was first proposed by Abadie and Gardeazabal [11] to study the
economic costs of terrorist activities in the Basque region of Spain. This method is adopted to study
the effect of the central environmental inspection on air quality in this article. The inspected region
is treated as a treatment group, and the unsupervised region is treated as a potential control group.
Here’s the basic idea: the synthetic control group is constructed by the appropriate combination of
these regions which have not been inspected, to make the air quality of the synthetic control group and
the treatment group as similar as possible before the inspection. The effect of environmental protection
inspection is evaluated by comparing the differences of air quality between the treatment group and
the synthetic control group after the inspection.

Suppose there are \( I + 1 \) regions, the first one was inspected, and the remaining \( I \) regions are
unsupervised regions which become potential control groups. The first region was inspected at time
\( T_0 \) (0 < \( T_0 \) < \( T \)). Let \( Q_i^N \) be the air quality that would be observed for region \( i \) at time \( t \) in the absence
of the inspection, for units \( i = 1, 2, \ldots, I + 1 \) and \( t = 1, 2, \ldots, T \). Let \( Q_i^1 \) be the air quality that would be
observed for region \( i \) at time \( t \) if unit \( i \) has been inspected. Let \( Q_{it} = Q_{it}^N + D_{it} \alpha_{it} \) be the air quality of
region \( i \) at time \( t \), and let \( D_{it} \) be an indicator that takes value one if region \( i \) was inspected at time \( t \),
and value zero otherwise.

For the first region, \( Q_{1t} = Q_{1t}^1 = Q_{1t}^N + \alpha_{1t}(T_0 < t < T) \) (1)

And the effect of environmental protection inspection is \( \alpha_{1t} \). This paper aims to estimate the size
of \( \alpha_{1t} \).

When \( T_0 < t < T \),

\[ \alpha_{1t} = Q_{1t}^1 - Q_{1t}^N = Q_{1t} - Q_{1t}^N \] (2)

\( Q_{1t} \) is the air quality of inspected region and can be observed. In order to estimate \( \alpha_{1t} \), we need
to estimate \( Q_{1t}^N \). We use a synthetic control method to construct a synthetic group by an appropriate
combination of potential control groups and compare it with the actual treatment group.

Suppose that the air quality of region \( i \) at time \( t \) is determined by the following model:

\[ Q_{it}^N = \delta_t + \beta_t Z_i + \gamma_t \mu_i + \epsilon_{it} \] (3)

where \( \delta_t \) is time fixed effect, \( Z_i \) is a \( (r \times 1) \) vector of observed variables that are not affected by central
environmental protection inspection, \( \beta_t \) is a \( (1 \times r) \) vector of unknown parameters, \( \gamma_t \) is a \( (1 \times F) \) vector
of unobserved common factors, \( \mu_i \) is a regional fixed effect that cannot be observed in the \( (F \times 1) \)
dimension. The error term \( \epsilon_{it} \) is a temporary impact that cannot be observed in each region, with an
average value of 0. Suppose there is a set of weight vectors \( W = (W_2 \ldots W_{I+1})' \), \( W_2 \) is the weight
of the second region in the synthesis of the first region, and so on, and satisfy for any \( i, W_i \geq 0, \)
\( W_2 + \cdots + W_{I+1} = 1 \). The first region of synthetic control can be written as:
The objective of this paper is to evaluate the impact of central environmental protection inspection on air quality, so air quality is an assessment variable. This paper uses AQI and six individual pollutant concentrations such as PM2.5, PM10, SO2, CO, NO2, and O3 to measure air quality. In this paper, absorbing the relevant research results, the factors affecting the evaluation variables are considered from meteorological, economy and society, which are called predictive variables, and mainly include temperature, humidity, wind scale, the proportion of secondary industry in GRP, population density, public recreational green space per capita, the green coverage rate of the built district, total electricity consumption and harmless treatment capacity. The units of variable and data sources are shown in Table 1. Besides, to improve fitting degree, this paper also considers AQI and six individual pollutant concentrations of January 2015, June 2015, October 2015, April 2016 and May 2016, and incorporated them into the influencing factors of the assessment variables, as a predictive variable.

Considering the difference of geographical span, climate conditions, air quality, economic development level, economic structure, and population density in the regions which were inspected (as shown in Table 2). Instead of mixing the first batch of inspected regions into a whole, this paper constructs a synthetic control region for each inspected region and separately analyses the influence of central environmental protection inspection in each region. Considering the requirements of the synthetic control method for the number of control groups, the prefecture-level city is selected as an analysis unit. As the synthetic control method can only analyze the individual treatment group, this paper chooses to evaluate multiple treatment groups and take the average value of prefecture-level cities to construct a new treatment group. The average values of each variable of prefecture-level cities under the jurisdiction of the eight inspected provinces are combined to form a new city, and the new city is named after the name of the capital (The following research mainly focuses on these new cities of Hohhot, Nanjing, Nanchang, Zhengzhou, Nanning, Kunming, and Yinchuan).
Table 1. Variables description.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQI index</td>
<td></td>
<td>[31]</td>
</tr>
<tr>
<td>PM2.5</td>
<td>µg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>PM10</td>
<td>µg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>SO₂</td>
<td>µg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>CO</td>
<td>mg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>NO₂</td>
<td>µg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>O₃</td>
<td>µg/m³</td>
<td>[31]</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>[31]</td>
</tr>
<tr>
<td>Humidity</td>
<td>%</td>
<td>[31]</td>
</tr>
<tr>
<td>Wind scale ordinal</td>
<td>ordinal</td>
<td>[31]</td>
</tr>
<tr>
<td>The proportion of secondary industry in GRP</td>
<td>%</td>
<td>[32,33]</td>
</tr>
<tr>
<td>Population density</td>
<td>person/sq.km</td>
<td>[32,33]</td>
</tr>
<tr>
<td>Public recreational green space per capita</td>
<td>sq.m</td>
<td>[34]</td>
</tr>
<tr>
<td>Green coverage rate of built district</td>
<td>%</td>
<td>[34]</td>
</tr>
<tr>
<td>Total electricity consumption</td>
<td>billion kWh</td>
<td>[33]</td>
</tr>
<tr>
<td>The value-added of secondary industry</td>
<td>billion</td>
<td>[33]</td>
</tr>
<tr>
<td>Harmless treatment capacity</td>
<td>ton/day</td>
<td>[34]</td>
</tr>
</tbody>
</table>

Table 2. The basic situation of the inspected regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Climate Types</th>
<th>GDP Ranking in 2015</th>
<th>The Proportion of Days when AQI Reaches the Standard in 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Mongolia</td>
<td>northeast, north northwest china, temperate continental climate, temperate monsoon climate</td>
<td>16</td>
<td>80.90%</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>northeast, temperate continental monsoon climate, transitional climate from warm temperate zone to subtropical zone</td>
<td>21</td>
<td>85.93%</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>eastern China, transitional climate from warm temperate zone to subtropical zone</td>
<td>2</td>
<td>66.80%</td>
</tr>
<tr>
<td>Henan</td>
<td>central China, subtropical zone humid climatic, temperate monsoon climate, subtropical monsoon climate</td>
<td>18</td>
<td>90.10%</td>
</tr>
<tr>
<td>Guangxi</td>
<td>south China, tropical monsoon climate, subtropical monsoon climate</td>
<td>17</td>
<td>87.90%</td>
</tr>
<tr>
<td>Yunnan</td>
<td>southwest, tropical monsoon climate, subtropical monsoon climate</td>
<td>23</td>
<td>97.29%</td>
</tr>
<tr>
<td>Ningxia</td>
<td>northwest, temperate continental climate</td>
<td>29</td>
<td>73.90%</td>
</tr>
</tbody>
</table>

This paper utilizes the monthly panel data for the period of January 2015 to March 2017 for a total of 27 months. From January 2015 to June 2016 for 18 months is the pre-inspection period, July 2016 to August 2016 is the period of inspection, and the period from September 2016 to March 2017 is the post-inspection period for a total of 7 months. Considering the period of the second batch of environmental protection inspection is November 2016 to December 2016, and the third batch is April 2017 to May 2017, to meet the demand of time of synthetic control method, the post-inspection period is selected to March 2017, and the second batch of inspected regions are removed from the control group. Besides, in January 2016 Hebei Province has been inspected as a pilot, thus removing the prefecture-level cities under the jurisdiction of Hebei Province from the control group. Therefore, the control group includes the cities that have not been inspected by the first batch of central environmental protection inspection, however, the second batch of cities under the jurisdiction of the inspected provinces and Hebei Province should be removed. At the same time, considering the seasonal differences between the north and the south, by the boundary of the Qinling Mountains-Huaihe River, if the city located in the north, then the northern cities are selected as the potential control group. For instance, if the treatment group is a prefecture-level city in Inner Mongolia Autonomous Region, and the corresponding potential control group includes the prefecture-level cities...
under the jurisdiction of Tianjin, Shanxi Province, Liaoning Province, Jilin Province, Shandong Province, Qinghai Province, Xinjiang Autonomous Region, and other northern regions.

Taking the Inner Mongolia Autonomous Region as an example, from 14 July to 14 August 2016, the first environmental protection inspection group stationed in Inner Mongolia Autonomous Region and carried out one-month inspection work. There are 12 prefecture-level cities. Considering the integrity of data, this paper makes use of the monthly panel data of six prefecture-level cities, such as Hohhot and Baotou to construct a new prefecture-level unit, which is named after Hohhot, the capital of Inner Mongolia Autonomous Region. The control group selected 38 prefecture-level cities in the northern provinces such as Tianjin, Shanxi Province and Liaoning Province (The 38 prefecture-level cities in the northern provinces include: Tianjin, Taiyuan, Shuozhou, Xinzhou, Lvliang, Jincheng, Changzhi, Linfen, Yuncheng, Shenyang, Dalian, Anshan, Benxi, Fuxin, Huludao, Changchun, Jilin, Siping, Liaoysin, Tonghua, Baishan, Baicheng, Songyuan, Jinan, Qingdao, Zibo, Zaozhuang, Dongying, Yantai, Weifang, Jining, Taian, Weihai, Rizhao, Dezhou, Linyi and Heze). Then the synthetic control method was used to evaluate the average impact of the first environmental protection inspection group on air quality of prefectural administrative units in the Inner Mongolia Autonomous Region. For inspected cities located in the south, such as those under the jurisdiction of Jiangsu Province, a new prefecture-level city was constructed in the same way as the treatment group. A total of 53 prefecture-level cities in Anhui Province, Hunan Province, and other southern provinces were selected as the control group (The 53 prefecture-level cities in the southern provinces include Hefei, Wuhu, Bengbu, Huainan, Ma’anshan, Huaibei, Tongling, Anqing, Huangshan, Fuyang, Suzhou, Chuzhou, Lu’an, Xuchang, Chizhou, Bozhou, Fuzhou, Xiamen, Zhangzhou, Quanzhou, Sanming, Putian, Longyan, Ningde, Changsha, Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Changde, Zhangjiajie, Yiyang, Loudi, Chenzhou, Yongzhou, Huaihua, Hangzhou, Ningbo, Wenzhou, Shaoshing, Huzhou, Jiaxing, Jinhua, Taizhou, Lishui, Zhoushan, Chengdu, Panzhihua, Deyang, Guangyuan, Neijiang). Then further analyze the effect of central environmental protection inspection.

5. Results and Discussion

5.1. The Impact of Central Environmental Protection Inspection on AQI

The impact of the environmental inspection is represented by the difference in air quality between inspected regions and corresponding synthetic regions. According to the basic principle of synthetic control method, the synthetic region is composed of unsupervised regions with different weights. The air quality of the synthetic region and the inspected region before the inspection is as similar as possible. If the inspected region is not inspected, the air quality of the synthetic region and inspected region will be similar as much as possible. But the fact is that the region is inspected. The difference of air quality between the synthetic region and the inspected region is caused by the inspection. The difference between them is the influence of inspection on air quality. Table 3 shows the weight of the synthetic control group corresponding to the treatment group. The first line is the treatment group, the first column on the left is the synthetic control group. The weight should minimize the mean square error of the gap between the AQI of the inspected region and the synthetic control region before the inspection.

<table>
<thead>
<tr>
<th></th>
<th>Hohhot</th>
<th>Nanjing</th>
<th>Nanchang</th>
<th>Zhengzhou</th>
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<tr>
<td>Anqing</td>
<td>-</td>
<td>0</td>
<td>0.197</td>
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<td>Baishan</td>
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<td>0.086</td>
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<td>Bengbu</td>
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<td>0.077</td>
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<td>-</td>
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<td>Changzhi</td>
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<td>-</td>
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<td>Chenzhou</td>
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<td>0.246</td>
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<tr>
<td>Chengdu</td>
<td>-</td>
<td>0.27</td>
<td>0</td>
<td>-</td>
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</tbody>
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Table 3. Cont.

<table>
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<tr>
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<tbody>
<tr>
<td>Dalian</td>
<td>0.154</td>
<td>-</td>
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<td>0</td>
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<tr>
<td>Dongying</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
<td>0</td>
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<tr>
<td>Fuxin</td>
<td>0.108</td>
<td>-</td>
<td>-</td>
<td>0</td>
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<tr>
<td>Hefei</td>
<td>-</td>
<td>0.163</td>
<td>0</td>
<td>-</td>
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<tr>
<td>Heze</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.562</td>
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<tr>
<td>Huludao</td>
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<td>-</td>
<td>-</td>
<td>0</td>
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<tr>
<td>Huzhou</td>
<td>-</td>
<td>0.035</td>
<td>0.06</td>
<td>-</td>
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<td>Huangshan</td>
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<td>0.012</td>
<td>-</td>
</tr>
<tr>
<td>Jiaxing</td>
<td>-</td>
<td>0.238</td>
<td>0</td>
<td>-</td>
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<tr>
<td>Linfen</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Lvliang</td>
<td>0.311</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Putian</td>
<td>-</td>
<td>0</td>
<td>0.232</td>
<td>-</td>
</tr>
<tr>
<td>Sanming</td>
<td>-</td>
<td>0</td>
<td>0.1</td>
<td>-</td>
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<tr>
<td>Shaoyang</td>
<td>-</td>
<td>-</td>
<td>0.041</td>
<td>-</td>
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<tr>
<td>Shenyang</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.031</td>
</tr>
<tr>
<td>Shuozhou</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Tongling</td>
<td>-</td>
<td>0</td>
<td>0.061</td>
<td>-</td>
</tr>
<tr>
<td>Weihai</td>
<td>0.119</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Suzhou</td>
<td>-</td>
<td>0.217</td>
<td>0</td>
<td>-</td>
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<tr>
<td>Xiangtan</td>
<td>-</td>
<td>-</td>
<td>0.001</td>
<td>-</td>
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<tr>
<td>Yantai</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.078</td>
</tr>
<tr>
<td>Yunbeng</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.073</td>
</tr>
<tr>
<td>Zhangzhou</td>
<td>-</td>
<td>-</td>
<td>0.003</td>
<td>-</td>
</tr>
<tr>
<td>Zaozhuang</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.034</td>
</tr>
<tr>
<td>Zoushan</td>
<td>-</td>
<td>0</td>
<td>0.049</td>
<td>-</td>
</tr>
</tbody>
</table>

“-” indicates that the city is not within the potential control group of the processing group city.

Taking Hohhot as an example, the synthetic Hohhot consists of 15.4% of Dalian, 11% of Dongying, 10.8% of Fuxin, 19.7% of Huludao, 31.1% of Lvliang and 11.9% of Weihai. Lvliang has the largest proportion. All other regions in the potential control group are assigned zero weights. The sum of the weights is one.

However, not all treatment groups can find a suitable synthesis control group. Among all of these inspected regions, the fitting effect before inspection of new cities which synthesized separately by the means of the prefecture-level cities under the jurisdiction of Heilongjiang Province, Ningxia Autonomous Region, Yunnan Province, and Guangxi Autonomous Region is not well. The synthetic control method does not apply to these regions. Take Heilongjiang Province as an example, as shown in Figure 1, before the second environmental protection inspection group stationed in Heilongjiang Province, that is, before July 2016, the fitting effect of AQI between Harbin and the synthetic control Harbin was not well, and there was a big gap between them. It may be that the suitable weight can’t be found among the 38 prefecture-level cities which were selected after considering various reasons to construct synthetic control Harbin, and it is also impossible to determine whether the gap of AQI between Harbin and synthetic control Harbin after July 2016 is caused by the fitting effect or the inspection effect. Therefore, these four regions will be excluded in the subsequent analysis, and mainly assessing the effect of environmental protection inspection in the Inner Mongolia Autonomous Region, Jiangsu Province, Jiangxi Province and Henan Province. The following will mainly analyze the new cities named after Hohhot, Nanjing, Nanchang, and Zhengzhou, which are separately synthesized by the prefecture-level cities under the jurisdiction of Inner Mongolia Autonomous Region, Jiangsu Province, Jiangxi Province and Henan Province.
Figure 1. Trends in AQI: Harbin and synthetic Harbin.

Tables 4 and 5 show the difference between the predicted variables between the actual value and the estimated value for each treatment group before inspection from January 2015 to July 2016. It can be seen that there is a small difference ratio between the actual value and the estimated value of the predicted variables. The difference ratio between the actual value and the estimated value of AQI in January 2015, June 2015, October 2015, April 2016 and May 2016 before the environmental protection inspection is also small. This indicates that the constructed synthetic control cities can be better fitting the treatment groups before the environmental protection inspection in July 2016.

Table 4. The actual value and the estimated value of predictive variables.

<table>
<thead>
<tr>
<th></th>
<th>Hohhot</th>
<th>Nanjing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual Value</td>
<td>Estimated Value</td>
</tr>
<tr>
<td>Ln (Temperature)</td>
<td>2.4513</td>
<td>2.4660</td>
</tr>
<tr>
<td>Ln (Humidity)</td>
<td>3.8306</td>
<td>3.9990</td>
</tr>
<tr>
<td>Wind scale</td>
<td>1.6117</td>
<td>1.5075</td>
</tr>
<tr>
<td>The proportion of secondary industry in GRP</td>
<td>48.0167</td>
<td>47.9697</td>
</tr>
<tr>
<td>Ln (Population density)</td>
<td>5.8088</td>
<td>6.1277</td>
</tr>
<tr>
<td>Ln (Public recreational green space per capita)</td>
<td>3.0393</td>
<td>2.7198</td>
</tr>
<tr>
<td>Green coverage rate of built district</td>
<td>41.1200</td>
<td>41.0891</td>
</tr>
<tr>
<td>Ln (Total electricity consumption)</td>
<td>2.8662</td>
<td>2.3936</td>
</tr>
<tr>
<td>Ln (The value-added of secondary industry)</td>
<td>4.0741</td>
<td>4.0695</td>
</tr>
<tr>
<td>Ln (Harmless treatment capacity)</td>
<td>7.1068</td>
<td>6.8705</td>
</tr>
<tr>
<td>Ln (AQI January 2015)</td>
<td>4.4923</td>
<td>4.5105</td>
</tr>
<tr>
<td>Ln (AQI June 2015)</td>
<td>4.4406</td>
<td>4.4306</td>
</tr>
<tr>
<td>Ln (AQI October 2015)</td>
<td>4.3085</td>
<td>4.2570</td>
</tr>
<tr>
<td>Ln (AQI April 2016)</td>
<td>4.4088</td>
<td>4.4041</td>
</tr>
<tr>
<td>Ln (AQI May 2016)</td>
<td>4.5451</td>
<td>4.4740</td>
</tr>
</tbody>
</table>

[Note:] difference ratio = (estimated value − actual value) / actual value.
Table 5. The actual value and the estimated value of predictive variables.

<table>
<thead>
<tr>
<th></th>
<th>Nanchang</th>
<th>Zhengzhou</th>
<th>Actual Value</th>
<th>Estimated Value</th>
<th>Difference</th>
<th>Ratio</th>
<th>Actual Value</th>
<th>Estimated Value</th>
<th>Difference</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln (Temperature)</td>
<td>2.7113</td>
<td>2.7167</td>
<td>0.002</td>
<td>2.4524</td>
<td>2.4500</td>
<td>−0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln (Humidity)</td>
<td>4.3511</td>
<td>4.3559</td>
<td>0.0011</td>
<td>4.1193</td>
<td>4.0985</td>
<td>−0.005</td>
<td></td>
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</tr>
<tr>
<td>Wind scale</td>
<td>1.0450</td>
<td>1.2612</td>
<td>0.2069</td>
<td>1.2267</td>
<td>1.2235</td>
<td>−0.0026</td>
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</tr>
<tr>
<td>The proportion of secondary industry in GRP</td>
<td>52.9033</td>
<td>52.9344</td>
<td>0.0006</td>
<td>51.3000</td>
<td>51.2170</td>
<td>−0.0016</td>
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<tr>
<td>Ln (Population density)</td>
<td>6.8940</td>
<td>6.4846</td>
<td>−0.0594</td>
<td>7.6808</td>
<td>6.9373</td>
<td>−0.0988</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ln (Public recreational green space per capita)</td>
<td>2.6980</td>
<td>2.5830</td>
<td>−0.0426</td>
<td>2.4377</td>
<td>2.5287</td>
<td>0.0373</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green coverage rate of built district</td>
<td>45.5733</td>
<td>44.0442</td>
<td>−0.0336</td>
<td>38.4533</td>
<td>40.5772</td>
<td>0.0552</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ln (Total electricity consumption)</td>
<td>2.1075</td>
<td>2.0999</td>
<td>−0.0036</td>
<td>2.6439</td>
<td>2.5781</td>
<td>−0.0249</td>
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</tr>
<tr>
<td>Ln (The value-added of secondary industry)</td>
<td>4.1426</td>
<td>4.2386</td>
<td>0.0231</td>
<td>4.4639</td>
<td>4.4680</td>
<td>0.0009</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ln (Harmless treatment capacity)</td>
<td>6.7006</td>
<td>6.6882</td>
<td>−0.0019</td>
<td>7.0371</td>
<td>7.0343</td>
<td>−0.0004</td>
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<td></td>
</tr>
<tr>
<td>Ln (AQI January 2015)</td>
<td>4.4732</td>
<td>4.4831</td>
<td>0.0022</td>
<td>5.0740</td>
<td>5.0359</td>
<td>−0.0075</td>
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</tr>
<tr>
<td>Ln (AQI June 2015)</td>
<td>2.9048</td>
<td>3.0962</td>
<td>−0.0022</td>
<td>4.6192</td>
<td>4.6192</td>
<td>0</td>
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<td></td>
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</tr>
<tr>
<td>Ln (AQI October 2015)</td>
<td>4.2868</td>
<td>4.2926</td>
<td>0.0014</td>
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<td>4.7108</td>
<td>0.0136</td>
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<tr>
<td>Ln (AQI April 2016)</td>
<td>4.1079</td>
<td>4.1168</td>
<td>0.0022</td>
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<td>4.7042</td>
<td>0.0085</td>
<td></td>
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</tr>
<tr>
<td>Ln (AQI May 2016)</td>
<td>4.1431</td>
<td>4.1512</td>
<td>0.0022</td>
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<td>4.5110</td>
<td>−0.0011</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

[Note:] difference ratio = (estimated value − actual value) ÷ actual value.

Figure 2 extends the period span to all sample intervals (January 2015 to March 2017) based on Tables 4 and 5. It shows the path of AQI of the treatment regions and synthetic control regions from January 2015 to March 2017. The red lines represent the path of AQI in treatment regions and the blue lines represent the path of AQI in synthetic control regions. Before the first batch of central environmental protection inspection in July 2016, AQI of treated regions and their synthetic control regions have similar paths, indicating that the synthetic control cities fitted each treated city well, and the fitting error was small. After the inspection in July 2016, the gaps of AQI between the treatment cities and their synthetic cities presented different forms. The effect of the inspection is determined by the path of the actual value after inspection. If the path of the actual value is below the estimated value, it indicates that the inspection is effective, and the greater the distance between them, the more obvious the effect is. Conversely, the inspection does not affect.

After the inspection in July 2016, the difference of AQI between the actual value and the estimated value in Hohhot and Nanjing appears, and the actual value is lower than the estimated value in general. The wider this gap is, the more obvious the effect of environmental protection inspection. Specifically, for Hohhot, the actual value of AQI is not lower than the estimated value at the beginning of July 2016, but after the inspection group has been stationed for a period, the actual value began to be lower than the estimated value, indicating that the effectiveness of the environmental inspection. There was a period of overlap in the AQI path of the actual value and the estimated value after inspection. As the inspection group only stays in the inspected region for one month. This may lead to laxity in the inspected region after inspection. After that, the actual value is significantly lower than the estimated value, which might be because the development of the second inspection and the first inspected regions realized the seriousness of the inspection. For Nanjing, since the beginning of the central environmental protection inspection in July 2016, the actual value of AQI starts below the estimated value. It indicates that the inspection has improved the air quality of Nanjing. For Hohhot and Nanjing, since March 2017, the distance between the actual value and the estimated value is gradually narrowing, indicating that the weak sustainability of the effect of inspection. For Nanchang and Zhengzhou, after the inspection in July 2016, the actual value of AQI is not lower than the estimated value. It indicates that environmental protection inspection has no effect on air quality in these two regions.
5.2. Validity Tests

Through the above analysis, we know that the first batch of central environmental protection inspection improved the air quality of Hohhot and Nanjing. To determine that this result is caused by central environmental protection inspection, a validity test is needed to support this conclusion. This paper adopts the permutation test, and the basic idea is that selecting a region at random in control groups, and assuming it was inspected in July 2016, then treated it as a treatment group. The synthetic control method was used to construct its synthetic control region, and further evaluate the effect of central environmental protection inspection and compare it with the real treatment group. If the difference is significant, it shows that the inspection has a significant impact on improving air quality. However, also note that if the fitting effect of a region in the control group before the environmental protection inspection is not ideal (the mean square error MSPE is very large), then after the inspection, the effect of the inspection may fluctuate greatly, and the credibility of the result is also low. Therefore, when conducting a validity test, selecting these regions that before the inspection the MSPE does not exceed 1.5 times the MSPE of Hohhot and Nanjing (There is no uniform standard for determining the multiple of MSPE. Abadie et al. [12] discard states with pre-Proposition 99 MSPE five times higher than California’s and retain 29 control states, they also discard states with pre-Proposition 99 MSPE two times higher than California’s and retain 19 control states. In this paper, the MSPE of Hohhot before the inspection is 45.47. In the control group, we remove the region where the MSPE is more than 1.5 times that of Hohhot and the number of these regions is 5. The MSPE of Nanjing before the inspection is 26.89. We also remove the region where the MSPE is more than 1.5 times that of Nanjing and the number of these cities is 9. The following figure shows the result).

Figure 3 displays the distribution of the gap between the actual value and the estimated value of the inspected regions in the permutation test. If the difference is negative, it means that the actual value is lower than the estimated value, that is, the inspection reduces AQI, otherwise, the inspection has no effect. The red lines represent the difference of AQI between the actual value and the estimated value in inspected regions. The gray lines represent the difference of AQI between the actual value and the
estimated value when the control regions are assumed to be inspected. As seen in Figure 3, for Hohhot, the gap of AQI between the actual value and the estimated value is positive at the beginning of July 2016 but shows a dropping trend. After the inspection group has been stationed for a period, the gap is negative and shows a dropping trend. There was a period of approximately overlap in AQI paths of the actual value and the estimated value after the end of the inspection. The gap is negative but shows a rising trend until the gap is zero. Then the gap begins to fall and the larger the negative value, the better the effect of inspection. In general, after inspection, the air quality of Hohhot has been improved, but the continuity of the effect size is not high. The gap is negative and shows a rising trend after the end of 2016 and indicates that the gap between the actual value and the estimated value is reduced gradually. Before the inspection in July 2016, the gap of AQI between the actual value and the estimated value between Hohhot and other regions was not significant. While after the inspection in July 2016, the gap was greater than most control regions. For Nanjing, the gap between the actual value of AQI and the estimated value is negative and shows a dropping trend at the beginning of July. The actual value of Nanjing has been below the estimated value, but the gap is changing. In summary, the air quality of Nanjing has been improved after inspection, but the continuity of the effect size is not high. The gap is negative and shows a rising trend from January 2017. The gap between Nanjing and other regions was not significant before inspection in July 2016. After the inspection in July 2016, the gap was greater than most control regions. It is a small probability event that a region obtained the effect of inspection as significant as that of Hohhot and Nanjing if the region was randomly selected. It indicates that the inspection has a certain influence on the air quality of Hohhot and Nanjing.

In addition, we also calculated the change in the ratio of the post-period MSPE and pre-period MSPE. Figure 4 shows the ratio of the post-period MSPE and pre-period MSPE of Hohhot, Nanjing and control regions (Post-Period MSPE represents the fitting difference after inspection; Pre-Period MSPE represents the fitting difference before inspection. We select these regions that before the inspection the MSPE does not exceed 1.5 times the MSPE of Hohhot and Nanjing). The white bars in the first column of each figure are the ratio of the post-period MSPE and pre-period MSPE of Hohhot, Nanjing. Blue bars are the ratio the post-period MSPE and pre-period MSPE of control regions. For Hohhot, the post-period MSPE is about 5.31 times the MSPE for pre-period. It is larger than the ratio of the control regions. This shows that the empirical results of Hohhot are effective, and further proves that the role of environmental inspection is significant. For Nanjing, the post-period MSPE is about 5.02 times the MSPE for pre-period, which is larger than the control regions. This also shows that the empirical results of Nanjing are effective, and further proves that the role of environmental inspection is significant.

Figure 3. Gap distribution in permutation test.
5.3. Robustness Tests

In order to test the sensitivity of the main results to weight changes, this section mainly learned from Abadie et al. [13] and conducted robustness tests. Recall from Table 3, these synthetic regions are estimated as a weighted average of these control regions. We iteratively re-estimate the baseline model to construct synthetic regions omitting in each iteration one of the unsupervised regions that received a positive weight in Table 3. By excluding regions with a positive weight, the goodness of fit is affected, but this test can evaluate the extent to which our results are affected by specific regions. In Hohhot, for example, the synthetic Hohhot is estimated as a weighted average of Lvliang, Huludao, Dalian, Weihai, Dongying, and Fuxin, with weights decreasing in this order. We iteratively re-estimate the baseline model to construct a new synthetic Hohhot, and in each iteration, one of the regions that received a positive weight is deleted. In Nanjing, the synthetic Nanjing is estimated as a weighted average of Chengdu, Jiaxing, Suzhou, Hefei, Bengbu, and Huzhou, with weights decreasing in this order. We construct a new synthetic Nanjing, in each iteration, one of the regions that received a positive weight is deleted. Through multiple iterations, we will test whether the effect of inspection on Hohhot and Nanjing are affected by the weight of synthetic regions and whether the absence of a region in the control group would lead to differences in results. Figure 5 displays the robustness tests of Hohhot, Nanjing, and reproduces Figure 2. The red lines represent the AQI of Hohhot and Nanjing. The blue lines represent AQI of synthetic Hohhot and synthetic Nanjing. The gray lines represent the leave-one-out estimates of synthetic Hohhot and synthetic Nanjing. The leave-one-out synthetic controls show a similar effect compared with the previous analysis. The robustness test found that the empirical results did not change with the control regions, which were consistent with the previous conclusions.
5.4. Discussion of Possible Causes

This paper estimates the environmental governance effect of this new mode of environmental inspection—central environmental protection inspection. As can be seen from the above results, not all regions under inspection have significantly reduced AQI. For the four inspected regions, AQI decreased in Inner Mongolia Autonomous Region and Jiangsu Province, but AQI in Henan Province and Jiangxi Province was not affected. Why the first batch of environmental protection inspection has different effects in these regions? The following will analyze the possible causes.

There are differences in geographical location, economic development level, industrial structure, urban layout, and air quality among the four inspected regions studied in this paper. To verify whether these differences can affect the effectiveness of the inspection, we mainly analyzed the level of economic development, industrial structure, population density, and other aspects. Among them, the index of economic development level is the GDP of prefecture-level cities, the index of industrial structure is the proportion of secondary industry in prefecture-level cities. The model is as follows:

$$AQI_{it} = \alpha_0 + \alpha_1 Inspection + \alpha_3 GDP + \alpha_4 Inspection \times GDP + \alpha_5 industry + \alpha_6 Inspection \times industry + \alpha_7 population + \alpha_8 Inspection \times population + \epsilon_{it} + \mu_{it}$$  \hspace{1cm} (6)

$AQI_{it}$ is the air quality for region $i$ at time $t$; $Inspection$ is a virtual variable, before July 2016, $Inspection = 0$, after July 2016, $Inspection = 1$; $\epsilon_{it}$ is control variable, mainly includes temperature, humidity, wind scale, public recreational green space per capita, green coverage rate of built district, total electricity consumption and harmless treatment capacity; $\mu_{it}$ is random error term.

As shown in Table 6, the influence of inspection on AQI is negative for the Inner Mongolia Autonomous Region and Jiangsu Province, while the effect is positive in Henan Province and Jiangxi Province. This further proves the above conclusion. For the Inner Mongolia Autonomous Region, the inspection has changed the direction of the effects of GDP, industrial structure, and population density on AQI. There was a certain negative correlation between GDP and AQI, industrial structure, and population density are positively correlated with AQI. The interaction with inspection and GDP is significantly and positively correlated with AQI, the interaction with inspection and industrial structure is negatively correlated with AQI, the interaction with inspection and population density is significantly and negatively correlated with AQI. This shows that the inspection made the Inner Mongolia Autonomous Region improve the air quality by adjusting the industrial structure and optimizing the population density. For Jiangsu Province, the inspection has changed the direction of the effects of GDP and population density on AQI. The interaction with inspection and GDP is positively correlated with AQI, the interaction with inspection and population density is significantly and positively correlated with AQI. This shows that based on the level of economic development, the optimization of urban population density in Jiangsu Province also has a positive effect on the improvement of air quality. For Henan Province and Jiangxi Province, the inspection hasn’t changed the direction of the effects of GDP and industrial structure on AQI. There was a certain positive correlation between GDP and AQI, the interaction with inspection and GDP is also positively correlated with AQI. This shows that the economic development level of the two regions is still relatively low, the effect of adjusting industrial structure and population density on air quality is weaker than that of economic development. For Jiangxi Province, the industrial structure is significantly and negatively correlated with AQI. But its effect is far less than that of GDP. To summarise, the differences in economic development level, industrial structure, population density, and other aspects of the above four regions make the inspection shows different effects.
Table 6. Cause validation.

<table>
<thead>
<tr>
<th>AQI</th>
<th>Inner Mongolia</th>
<th>Jiangsu</th>
<th>Henan</th>
<th>Jiangxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td>$-15.7295$</td>
<td>$-68.0129^{**}$</td>
<td>$6.0694$</td>
<td>$1.8269$</td>
</tr>
<tr>
<td>Ln(GDP)</td>
<td>$-19.4163^{**}$</td>
<td>$-12.4005$</td>
<td>$2.05507$</td>
<td>$38.9600^{***}$</td>
</tr>
<tr>
<td>Inspection * Ln(GDP)</td>
<td>$11.0283^{***}$</td>
<td>$0.7906$</td>
<td>$2.8991$</td>
<td>$3.1079^{**}$</td>
</tr>
<tr>
<td>industry</td>
<td>$0.3758$</td>
<td>$0.6829$</td>
<td>$0.5000$</td>
<td>$-0.7781^{***}$</td>
</tr>
<tr>
<td>Inspection * industry</td>
<td>$-0.2002$</td>
<td>$0.1475$</td>
<td>$0.2438$</td>
<td>$-0.1289$</td>
</tr>
<tr>
<td>Ln(population)</td>
<td>$25.4572^{***}$</td>
<td>$-34.7327$</td>
<td>$4.9241^{***}$</td>
<td>$1.1523$</td>
</tr>
<tr>
<td>Inspection * Ln(population)</td>
<td>$-5.9069^{**}$</td>
<td>$8.3220^{***}$</td>
<td>$-4.9768$</td>
<td>$-2.9196$</td>
</tr>
<tr>
<td>Control</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Obs 101 348 444 297
R-squared 0.7037 0.7194 0.7313 0.7236

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, $p$ value in parentheses.

5.5. Further Analysis

As discussed above, the first batch of central environmental protection inspection has different effects on air quality in the inspected regions. Since the AQI is calculated from six kinds of individual pollutants (PM2.5, PM10, SO$_2$, CO, NO$_2$, O$_3$). It is necessary to clarify which pollutants mainly caused the changes in AQI and the main role of environmental inspection for the individual pollutant. Therefore, the impact of the first batch of central environmental protection inspection on the six kinds of individual pollutants will be further analyzed below. The following figures show the result.

Figures 6–8 display the paths of the actual value and the estimated value of the six individual pollutants over time in Hohhot and Nanjing. As seen in these figures, for Hohhot, the actual value of PM10 concentration after the inspection is lower than the estimated value, which indicates that the environmental protection inspection reduces the PM10 concentration. The remaining five individual pollutants were not affected by the environmental protection inspection. The actual values and the estimated values were almost the same after inspection. The difference is that the concentration of PM2.5, SO$_2$, and NO$_2$ will be lower than the estimated value over time, indicating that the concentration of pollutants was fall. For Nanjing, the paths of the actual value for NO$_2$ concentration and O$_3$ concentration are almost the same as the estimated value after the inspection. Except that the actual value at the beginning of July 2016 is lower than the estimated value, but not obvious. It indicates that the effect of the inspection on NO$_2$ concentration and O$_3$ concentration is not significant. The remaining four individual pollutants were affected by the inspection, the actual value began to be lower than the estimated value, indicating that the inspection decreased the concentration of PM2.5, PM10, SO$_2$, and CO. But for PM2.5, PM10, and CO, the continuity of the effect size is not high. At about February 2017, the actual value begins to coincide with the estimated value. For individual pollutants that were influenced by inspection in Hohhot and Nanjing, the sustainability of the effect is poorer.
Figure 6. Individual pollutants in treatment regions and synthetic regions.

Figure 7. Individual pollutants in treatment regions and synthetic regions.
Figure 8. Individual pollutants in treatment regions and synthetic regions.

It can be observed from the preceding analysis that the inspection didn’t improve air quality in Zhengzhou and Nanchang. In terms of individual pollutants, besides SO$_2$, the remaining individual pollutants in Zhengzhou and Nanchang were not affected by the environmental protection inspection (Figures 9–11). The actual values and the estimated values were almost the same after inspection. After the inspection, the actual value of SO$_2$ was lower than the estimated value in Zhengzhou, but the gap was small. In Nanchang, the actual value of SO$_2$ after the inspection was lower than the estimated value, but from the end of 2016, the actual values and the estimated values were almost the same.

In conclusion, for Hohhot and Nanjing where the AQI has declined, not all the individual pollutants that makeup AQI are influenced by the inspection. The first batch of central environmental protection inspection improved the air quality of Hohhot mainly by reducing the concentration of PM10, and the improvement of air quality in Nanjing was mainly reflected in the decrease of the concentration of PM2.5, PM10, SO$_2$ and CO. One explanation could be that in response to environmental inspection, local governments may choose to treat pollutants that can see noticeable results in a fairly short time frame. A significant decrease in the concentration of one or more pollutants may be comprehensively reflected in the change of AQI. For Zhengzhou and Nanchang where the AQI didn’t influence by the inspection, besides SO$_2$, the remaining individual pollutants were not affected by the environmental protection inspection. However, SO$_2$ less affected by the inspection in Zhengzhou and Nanchang. The gap between the actual value and the estimated value was small. Its decline does not bring about the change of AQI.
Figure 9. Individual pollutants in treatment regions and synthetic regions.

Figure 10. Individual pollutants in treatment regions and synthetic regions.
6. Conclusions

This paper mainly analyzes the effect of the first batch of central environmental protection inspection on air quality in the Inner Mongolia Autonomous Region, Jiangsu Province, Henan Province, and Jiangxi Province. The study found that the inspection has improved the air quality of the Inner Mongolia Autonomous Region and Jiangsu Province, however, there was no effect for Henan Province and Jiangxi Province. The differences in economic development level, industrial structure, population density, and other aspects of the above four regions may lead to different effects of this inspection. For Inner Mongolia Autonomous Region and Jiangsu Province, after the end of the inspection, the sustainability of the inspection effect is poor. The long-term effectiveness of environmental protection inspection needs more attention. In terms of individual pollutants, for inspected regions where the AQI has declined, not all the individual pollutants that makeup AQI are influenced by the inspection. The inspection reduced the concentration of PM10 in the Inner Mongolia Autonomous Region, but the remaining five individual pollutants were not affected by the environmental protection inspection. For Jiangsu Province, the inspection has no effect on NO2 concentration and O3 concentration, but the remaining four individual pollutants were influenced by the inspection. The treatment of specific individual pollutants still needs to be concerned.

Author Contributions: The authors contribute equally in the project. L.-Y.H. conceived the whole project and acquired funding supports for it. M.-M.G. calculated the results under L.-Y.H.’s supervision. L.-Y.H. and M.-M.G. analyzed the data, discussed the results, and co-wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare that there are no conflict of interest involved.
References


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