Effectiveness of production reduction policy on improving air quality in Dongying

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Abstract. Emergency command-type production reduction policies have become an important tool for environmental management in China. However, there is currently little literature on systematic and rigorous identification of the effectiveness of corporate production reduction policies. By collecting data such as the air quality index during the implementation of the Dongying City's production reduction policy from 2017 to 2018, descriptive statistics and differential methods were applied to analyse the actual impact of the production reduction policy on the air quality index. After controlling other influencing factors, the study found that although the implementation of the enterprise's production reduction policy cannot effectively reduce the degree of air pollution, it can relatively slow the rate of further increase of air pollution.

1. Introduction

Emergency command-type production reduction is an important tool for environmental management in China. Over the past 30 years, China’s environmental management policy has gradually evolved and deepened. The status of this policy ranges from basic national policy to sustainable development strategy. It has gradually evolved from an orderly government-based command model in early 1980 to an environmental management policy system for command-and-control tools, market-incentive tools, and public-participating tools. However, due to the contingency and mandatory nature of command-based tools, the implementation cost is low, and local governments have higher preference for command-based tools than other environmental management policy tools. Generally speaking, the government considers two factors when implementing the command tool: one is the severity of the emission control standard (the amount of pollution allowed to be emitted); the other is the way to achieve the standard (how the polluting enterprise is allowed to meet the standard). In the latter case, regulators can stipulate the specific implementation of corporate compliance, and can also give enterprises the option to achieve their goals. At present, China's command-type tools mainly include: pollutant emission concentration control, total pollutant discharge control, centralized pollutant control, etc., but local governments prefer to use "one size fits all" pure command control means to totally discharge pollutants from pollution sources. At the same time as the quantitative control of the ratio, the company is forced to order production or stop production to achieve the purpose of controlling pollution. Practice has proved that the “one size fits all” command and control method can only temporarily relieve the environmental pollution warning. From the perspective of medium and long-
term environmental governance, the effects of emission reductions are minimal and they are highly damaging to economic entities.

The "blue sky under the policy of reducing production" has not fully appeared in reality. On the contrary, environmental pollution in some areas continues to deteriorate. The reason for this phenomenon has not formed a consensus conclusion. Some studies believe that this is a failure of the command-based policy. The emission reduction boundary is not determined according to the characteristics of different industries. On the contrary, some studies show that the policy has not failed, but only exists rebound effect, it is slowly working in a potential way.

This paper focuses on analysing the influence of Dongying’s air quality index (AQI) after government’s policy applied. The authors use historical air quality and relevant data (weather, season, etc.) during the implementation of the policy of Dongying City from 2017 to 2018. On the basis of this, the authors use descriptive statistics and difference method to study the actual changes in the AQI during the period. This will verify the effectiveness of the policy which is considered improve the air quality of Dongying City.

2. Literature review
Environmental management policy is a binding force for the purpose of environmental protection, individual or organization as the object, tangible system or intangible consciousness as the form of existence [1]. At present, there is no unified classification of environmental management policy tools, which can be divided into aspects such as government compulsory degree, government financial resources, and utilization of government resources. For example, Sterner (2003) collated the categories and examples of environmental management tools based on World Bank reports and divided them into four categories: First, the use of market mechanisms, including subsidy reduction, environmental taxes, user fees, deposit refund system. Second, create markets, including property rights and decentralization, tradable permits, and international compensation mechanisms. The third is environmental regulation, including standards, bans, permits and limits, zoning, responsibilities, etc. Fourth, public participation, including public participation in supervision, etc.[2]. McDonnell and others classify policy tools into order, incentive, capacity building, and system change according to the applicable purpose [3]. Howlett and others classify policy instruments into voluntary, mandatory, and hybrid types through government compulsory levels [4].

Command-type tools are one of the most commonly used methods in China's environmental management policies. Scholars have always paid more attention to the policies. In terms of its effects, some scholars believe that the command-based environmental management policy is conducive to corporate pollution control, and should increase the enforcement of orders, and some scholars have a skeptical attitude towards this. Mohamed H (2018) proposes that an order-based environmental management policy can control pollution emissions more quickly, but it is inefficient and not conducive to technological innovation [5]. Liang Q, Fan Y (2018) believe that the effect of command-based environmental management policies in the process of managing environmental problems, obtaining ecological benefits, and promoting the coordinated development of the environment and economic society will be immediate, but in the long run, the effect of improving corporate environmental awareness is not obvious [6]. Shuai W, Zhijun L (2014) believe that the impact of command-based environmental regulation on regional industrial green total factor productivity is U-shaped, and command-and-control regulatory tools lack the flexibility and incentives for long-term reduction [7].

3. Model
3.1. Variables
The AQI is a measure of air quality. Due the influencing factors of air pollution are very complicated, in order to eliminate the impact of other important factors on the air quality of Dongying City during the implementation of the production reduction policy, we first selected the air quality data of
Dongying City from October 2017 to March 2018. These include AQI and its synthetic air quality pollutant concentration index data, including fine particulate matter (PM$_{2.5}$), respirable particulates (PM$_{10}$), sulfur dioxide (SO$_2$), carbon monoxide (CO), and nitrogen dioxide (NO$_2$) and ozone (O$_3$). The reason for choosing variables from this time is that this interval includes not only the relatively low air quality winter heating period, but also the policy implementation from the first production cut on October 19, 2017 to the last production cut on March 28, 2018. The above data are derived from the historical daily data of Dongying City provided by the “China Air Quality Online Testing and Analysis Platform”. Secondly, due to rain and snow weather, temperature, wind and so on are also important factors affecting air quality, this paper also considers these daily meteorological data, and incorporates into the regression analysis, including the highest temperature (Temp_H), the lowest temperature (Temp_L), Rain, Snow, Wind, etc. The above weather historical data is from "2345 Weather Network". Thirdly, because the haze weather has obvious seasonal characteristics, according to the method of meteorology’s classification of seasons, the season is also included as a control variable in the regression equation. Finally, according to the analysis of the Ministry of Environmental Protection of China on the nine major air pollution prevention and control cities, the autos monthly output added value data is also included as a substitute variable of pollution source in the regression equation.

3.2. Model establishment

Based on the above analysis and existing research results, the following model is constructed:

$$Y_{it} = \beta_0 + \beta_1 Policy_t + \beta_2 Weather_t + \beta_3 Heat_t + \beta_4 Auto_t + \epsilon_t$$

(1)

As shown in equation (1), $Y_{it}$ represents the explanatory variable, $i$ represents data such as fine particulate matter (PM$_{2.5}$), respirable particles (PM$_{10}$), sulfur dioxide (SO$_2$), carbon monoxide (CO), nitrogen dioxide (NO$_2$), and ozone (O$_3$), $t$ represents the corresponding time node. The dummy variable $Policy_t$ indicates the production reduction policy. If this policy is implemented in Dongying City on the $t$ day, $Policy_t$ takes 1; otherwise, it takes 0. In addition, considering the impact of other major pollution sources on the effectiveness of the policy, we also selected a series of control variables such as weather and heating. Among them, $Weather_t$ include Temp_H, the Temp_L, the rain, the snow, the wind level, and the season. The authors use $Heat_t$ to indicate whether heating, $Auto_t$ means monthly increase in car volume. $\epsilon_t$ is a random disturbance term, indicating the combined effect of unobserved factors. The detailed data of each main variable is shown in Table 1.

Table 1. Descriptive statistics of major variables.

| Variable Name | Unit     | Mean    | Std. dev. | Minimum | Maximum |
|---------------|----------|---------|-----------|---------|---------|
| AQI           | Index    | 97.821  | 46.621    | 29      | 275     |
| PM$_{2.5}$    | $\mu g/m^3$ | 61.255  | 42.333    | 6       | 225     |
| PM$_{10}$     | $\mu g/m^3$ | 122.590 | 63.669    | 16      | 343     |
| SO$_2$        | $\mu g/m^3$ | 31.212  | 15.585    | 6       | 108     |
| NO$_2$        | $\mu g/m^3$ | 43.061  | 20.702    | 9       | 106     |
| CO            | $mg/m^3$  | 1.047   | 0.481     | 0.3     | 3.1     |
| O$_3$         | $\mu g/m^3$ | 85.623  | 45.813    | 9       | 253     |
| TEMP_H        | °C       | 11.660  | 8.761     | -4      | 30      |
| TEMP_L        | °C       | 0.879   | 6.951     | -11     | 19      |
| Rain          | Dumb variable | 0.077   | 0.267     | 0       | 1       |
| Snow          | Dumb variable | 0.027   | 0.164     | 0       | 1       |
| Wind          | Ordinal variable | 4.165   | 0.609     | 2       | 7       |
| Season        | Dumb variable | 0.495   | 0.501     | 0       | 1       |
| Heat          | Dumb variable | 0.571   | 0.496     | 0       | 1       |
| Policy        | Dumb variable | 0.170   | 0.377     | 0       | 1       |
| Auto          | Thousand  | 4.052   | 1.340     | 2.063   | 6.683   |

Note: Three significant digits are reserved after the decimal point, sample size 182.
3.3. Descriptive statistics
In order to study the overall effect of the Dongying City's production reduction policy on improving air quality, a descriptive statistical analysis is first conducted. Table 2 shows the air quality comparison data for the two periods of the policy. Table 3 shows the air quality comparison data of the three stages before, during and after the implementation of the production reduction policy. Table 2 shows that the AQI and various pollutant indicators (PM$_{2.5}$, PM$_{10}$, SO$_2$, CO, NO$_2$) after the implementation of the enterprise production reduction policy are significantly higher than the air quality indicators during the period when the production reduction policy is not implemented.

Table 2. Descriptive statistics on the implemented and unimplemented policy period.

| Variable Name | Unimplemented policy period | Implemented policy period |
|---------------|-----------------------------|---------------------------|
|               | Mean | Std. dev. | Mean | Std. dev. |
| AQI           | 89.740 | 39.619 | 145.000 | 56.350 |
| PM$_{2.5}$    | 53.403 | 35.575 | 107.097 | 49.673 |
| PM$_{10}$     | 111.939 | 56.886 | 184.774 | 66.446 |
| SO$_2$        | 30.116 | 15.374 | 37.613 | 15.515 |
| NO$_2$        | 0.963 | 0.402 | 1.539 | 0.606 |
| CO            | 41.028 | 20.404 | 54.935 | 18.596 |
| O$_3$         | 87.199 | 44.801 | 76.419 | 51.151 |

Sample size 181 31

Table 3. Descriptive statistics of air quality before and after implementation of the policy.

| Variable Name | Before the policy | During the policy | After the policy |
|---------------|-------------------|-------------------|-----------------|
|               | Mean | Std. dev. | Mean | Std. dev. | Mean | Std. dev. |
| AQI           | 69.389 | 31.408 | 99.702 | 49.052 | 92.278 | 29.449 |
| PM$_{2.5}$    | 42.778 | 31.657 | 65.919 | 45.212 | 42.889 | 26.101 |
| PM$_{10}$     | 77.889 | 45.081 | 125.584 | 65.418 | 130.000 | 59.920 |
| SO$_2$        | 18.889 | 6.144 | 34.180 | 16.109 | 21.278 | 9.473 |
| NO$_2$        | 0.978 | 0.449 | 1.121 | 0.490 | 0.650 | 0.326 |
| CO            | 34.222 | 16.661 | 46.205 | 21.296 | 31.389 | 15.236 |
| O$_3$         | 90.056 | 23.849 | 72.621 | 36.318 | 123.944 | 33.264 |

Sample size 18 161 18

Table 3 shows that the main indicators of air quality during the implementation of the production reduction policy are also significantly higher than the data before and after the implementation of the production reduction policy. If only from the data point of view, the air pollution situation during the policy will be more serious. In Figure 1, it gives the trend of AQI changes during the policy from October 2017 to March 2018.

Figure 1. Trend of AQI in Dongying City.
The weather conditions are only convenient for observation in the figure, and the position values in the figure are not practical. The “1” and “2” of the secondary axis represent the implementation of the 10% and 20% reduction policies, respectively. In Figure 1, we find that most of the AQI continue to rise during the implementation period. Taking the “20% reduction policy” from December 28 to 30, 2017 as an example, the AQI after the policy is changed by 47.1%, 39.8%, 25%, respectively. On October 21, the policy is not implemented, but the value is still reduced by 77.2%. If you look at the implementation of the longest-term (January 13-22, 2018) reduction policy, the AQI changes in the ten-day period are 44.3%, 7.9%, 19.5%, -22.4%, 102.6%, -10%, 27.9%, 3.4%, -28.7%, -79.6%, respectively. In fact, the sharp drop in the AQI on the last two days is caused by the snowfall of the day. Take the “20% reduction policy” without rain and snow weather period on December 28 and 29, 2017 as an example. Although the proportion of this reduction is large, the AQI increased by 66.7% and 23% respectively during this period. From the data graph, it is analyzed that the influence of rain and snow weather has a greater effect on the improvement of air quality in Dongying City. In fact, in the 17-day rain and snow historical weather of Dongying City of the period, a total of 8 days of AQI shows a weak growth of about 20, since the precipitation process is weak, and the time is short. The AQI of the remaining 9 days shows a downward change, on January 22, 2018, the AQI decreased by 159, which is 79.6% lower than the previous day. It can be seen that the effect of rain and snow on the elimination of air pollution is more obvious than the effect of the policy.

Figure 2. Trend of PM$_{2.5}$, PM$_{10}$ and CO in Dongying City.

Figure 3. Trend of SO$_2$, NO$_2$ and O$_3$ in Dongying City.

It is found from Figure 2 and 3 that the general trends of PM$_{2.5}$, PM$_{10}$, SO$_2$, CO, NO$_2$, and O$_3$ are basically similar to those of AQI. Therefore, from the results of descriptive statistical analysis, it can be concluded that the reduction policy of Dongying City has not improved the air quality.

3.4. Analysis of timeliness of production reduction policy

Considering that the dissipation of major pollutants in the atmosphere takes a certain time, the effect of the reduction policy will not be immediate, and there will be some differences in the effects of
weather, seasonal and other meteorological factors on different pollutants. To this end, after controlling other influencing factors, this paper conducts a stepwise regression analysis of the relevant data on the day of implementation of the policy and the previous day. The results are shown in Table 4.

Table 4. Impact of production reduction policy on AQI.

| The same day | AQI(1) | Previous day | AQI(2) | AQI(3) | AQI(4) | AQI(5) | AQI(6) |
|--------------|--------|--------------|--------|--------|--------|--------|--------|
| AQI(1)       | 60.346** | 70.791***    | 68.957*** | 57.378*** | 59.371*** | 58.758*** |
| (5.44a)      | (6.02a)  | (5.94a)      | (5.12a)  | (5.05a)  | (4.97a)  |
| 10% reduction policy |       |             |         |        |        |        |
| 20% reduction policy | 36.701** | 38.116**    | 37.967** | 27.116*  | 23.682  | 26.473* |
| (2.56a)      | (2.37a)  | (2.54a)      | (1.87a)  | (1.47a)  | (1.76a)  |
| Weather&Season NO | YES | YES | NO | YES | YES |
| Autos NO | NO | YES | NO | NO | YES |
| Sample size 182 | 182 | 182 | 181 | 181 | 181 |
| R² | 0.144 | 0.213 | 0.337 | 0.131 | 0.171 | 0.337 |

a. T statistics.
b. *, **, *** Separate indication 10%, 5%, 1% Typical Positivity Horizontal.

In the regression results table 4, the paper uses the relevant air quality data of the day and the previous day's production reduction as the explanatory variables, and studies the time trend of the production reduction effect. The models AQI(1) and AQI(4) mainly study the direct relationship between the policy and the AQI of Dongying City. Model AQI(2) and AQI(5) incorporate weather and seasonal factors into the regression model to control the effects of weather and seasonal factors on regression results. In AQI(3) and AQI(6), the monthly growth value of vehicles is included in the regression equation to determine the impact on the regression results of AQI.

The study found that when the 10% reduction policy is implemented, the regression values in the regression analysis of the day and the previous day's reduction data are significantly positive. When the 20% reduction policy is implemented, the data on the day of production reduction is still significantly positive. After one day of the 20% reduction policy, the results are significantly positive except for the regression results of weather and seasonal factors. After controlling the vehicle control variables, we can see from the regression results in Table 4 that in the 10% and 20% reduction policy models, the regression values are correspondingly reduced, which indicates that after controlling the weather, seasons and vehicle increments, the policy slows the increase of air pollution relatively.

If the data on the reduction of rain and snow weather is excluded from the sample data, calculate the changes in AQI during and after the period of production reduction. It can be found that the average daily growth rate of AQI during the policy is 6.85%, and without reduction is 11.22%. This shows that the Dongying City's production reduction policy has reduced the rate of increase in the AQI.

4. Discussion

The premise of the implementation of the “Emergency Plan for Heavy Pollution Weather” is that the air pollution situation in Dongying City has been quite serious. That is to say, the production reduction policy of Dongying City is implemented only when the air pollution is already serious. In fact, air pollution is the result of a combination of factors, and the causes of air pollution are very complicated. In terms of spatial distribution characteristics, Dongying City is located in the northern part of Shandong Province, China, where it is adjacent to the inland areas of the smog-prone areas of autumn and winter. In addition, air pollution is closely related to urban industry and pollution emissions [8]. But the three industries with the highest pollution index: electricity, gas and water production and supply are belong to the people's livelihood industry [9]. These industries are not within the scope of the policy. Therefore, the emissions from related companies are only part of the entire pollution source in Dongying City. Moreover, the dissipation of air pollutants requires a process. Short-term corporate
production reduction policies, especially in the case of air pollution in Dongying City, it is difficult to significantly improve air quality.

As one of the main sources of air pollutants, automobile exhaust has attracted more and more people's attention. The Chinese government has also adopted policies such as tail-limits for cities with high car ownership and high air pollution to control the degree of air pollution. In 2016, the number of vehicles in Dongying City is 674,000, which is only one tenth of Beijing [16]. Therefore, in Table 4, we can see that under the premise of controlling the weather, the season and the number of vehicles, the AQI is still significantly positive, but it is slightly lower than the weather and seasonal factors control alone. This shows that the impact of vehicle exhaust emissions on air quality in Dongying City is limited.

5. Conclusions
The previous application analysis method shows that after controlling the weather, the season and the factors affecting the vehicle increment, no matter what proportion of the production reduction policy is adopted, the effect of significantly improving the air quality of Dongying City has not been achieved. From the perspective of environmental protection, the production reduction policy is the main means to improve air quality. Although the AQI still maintain an upward trend during the policy implementation period, the air pollution growth rate slows down compared with the unimplemented policy period. It should be noted that while the production reduction policy plays an environmentally-friendly role, it will also have a negative impact on the social economy, because reducing production means lowering corporate income, and the current “one size fits all” reduction policy implemented by China has unfairness. Since this study can only collect relevant data from Dongying City, it does not represent the full effect of the implementation of the production reduction policy, but it can reflect the overall trend of the policy to a certain extent.

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