Grid management and air quality of Xi'an city

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Abstract. Xi’an was the first city which came up with grid management. Since the implementation of grid management, the air quality of Xi’an has improved quite obviously. But, factors influencing air quality are so many. Thus, we should further launch an empirical research to obtain the grid management impact on air quality. This paper explores it in the way setting policy dummy variable, and the research result manifests that grid management improves the air quality obviously, especially, in the aspect of NO2, SO2. In a nutshell, grid management can provide “Xi’an Model” in the perspective of Haze Management.

1. Introduction
Xi’an city carried out grid management officially in 2014, and there were 3748 atmospheric grids in the whole Xi’an city, which eliminated dead zones in haze management. Grid management had become an innovative approach to govern haze. There was a grid member in every atmospheric grid, searching sources of pollution by their senses and achieving control of them. If grid member’s dissuasion is invalid, they will report this situation to “Smart Platform” which will exert accountability.

Since the implementation of grid management, the air quality of Xi’an has gradually raised among 74 important cities from the first quarter in 2013 to that in 2015. Especially, the number of high quality weather of Xi’an raised by 53%, the number of heavy pollution went down by 43%, and the number of severe contamination reduced by 82% in 2014. Its decreasing amplitude ranked first. But at the same time of improvement of air quality, the phenomenon of extreme weather still exists. The number of high quality were respectively 138, 211, 251, 192 and 180 days from 2013 to 2017, and especially in 2015. But, there was a gradual decreasing after that. And there were just 188 days of high quality weather in 2018, which manifested that effect of haze management had gradually decreased.

Ministry of Environment Protection criticized that grid management had some issues about grid and accurate management.

There are many factors of influencing air quality, such as geography, weather and economical activities. Thus, we cannot judge the relationship between grid management and improvement of air quality directly, and we should further launch an empirical research to gain the accurate conclusion.

There are also abundant researches about the relationship between environmental regulation policy and improvement of air quality, such as vehicle limitation policy[1,2] (Viard, 2015, Yi Lan et al., 2018), energy substitution policy[3] (Tang Yun, Liang Ruo-bing, 2018), central environmental protection...
Inspection\cite{4}(Zhangli Liu, Jiannan Wu, 2019), city rail transit and BRT\cite{5,6}(Shen Ren-jun et al. , 2018, Gao Ming et al. , 2018).

Grid management has implemented many years, but there are few researches about it, let alone the empirical researches. So this paper, exploring the relationship between grid management and air quality, has policy meaning.

The research approach of this paper is single difference which is used by Zhao Xiao-guang et al. (2010) to research the relationship between Beijing vehicle limitation policy and air quality\cite{7}. On the one hand, this approach can simplify the select of index of grid management. On the other hand, it can efficiently avoid multicollinearity which easily appears in time series analysis.

2. Econometric model and data declaration

For researching the relationship between grid management and air quality, and at the same time, considering weather factor and economic activities impact on air quality, this paper terminally sets below econometric model:

\[ \text{aqi}_t = \alpha_0 + \alpha_1 \text{coverage}_t + \alpha_2 \text{industry}_t + \alpha_3 \text{vehicle}_t + \sum_{i=1}^{5} \gamma_i Z_{it} + \eta_t + \xi + \sum_{i=1}^{11} \varphi_{it} + \epsilon_t \]  

\( \text{aqi}_t \), air quality index(AQI) in every day. Subscript \( t \) are dates from 10th October, 2013 to 31st December, 2017. \( Z_{it} \), weather variable, including day highest temperature, day lowest temperature, day wind speed and weather dummy variable(rain and snow). For air quality distribution has obvious time distribution feature, and thus, we have to separate time effect from AQI to gain accurate result of the grid management influence on air quality. \( \eta_t \) manifests the time effect of national holiday, \( \xi_t \) manifests the time effect of weekend, \( \varphi_{it} \) manifests the time effect of month from January to November.

Explained variable-AQI is sorted from www.tianqihoubao.com. Due to differences of measure level from different websites, all weather variables are also sorted from the same website. Although weather variables can reverse to 1st January, 2011, while AQI can just reverse to 28th October, 2013. Thus, the start time series is 28th October, 2013. Another issue is that there are 5 days data miss(23rd January, 2014, 24th March, 2014, 8th August, 2014, 22nd August, 2014, 4th October 2017, respectively), so we select www.aqistudy.cn/historydata data to replenish the time series.

Wind scale, control variable from tianqihoubao, is converted to wind speed by using the table of transformation between wind scale and wind speed. National holiday and weekend dummy variable are sorted from the notification of partial holiday arrangement released by the State Council.

\( \text{coverage}_t \), the most favored variable, is set to policy dummy variable, which means implementing grid management is “1”, and otherwise is “0”. By the way, we also consider other variables influencing AQI, such as industrial value added from enterprise above designated size and the number of social vehicles value added, because they both can pollute the air quality.

The detailed data declaration can be seen in Table 1.

3. Analysis of regression

3.1. Regress of whole sample

We launch a regression based on equation (1), and regression report is Table 2. As we can see first 3 rows in Table 2, grid management facilitates air quality obviously when we do not exclude time and weather effect. But, when we exclude it, as we can see in the last 2 rows, grid management still improves air quality obviously.

3.2. Analysis of pollutant heterogeneity

Because grid management is based on senses of people, thus, SO2 and O3 are both supervised by grid members. SO2 has irritant smell, so grid members can sense by smelling. Moreover, O3 forms from volatile organic compound(VOCs) and NO2 through chemical reaction. NO2 color is red, so grid members can sense by seeing, and VOCs also have irritant smell. Thus, we have to launch regressions about the relationship between grid management and pollutant heterogeneity.
As we can see in Table 3, grid management improves NO$_2$ and SO$_2$ obviously, but O$_3$. More important, industrial value added aggravates NO$_2$ and O$_3$, which manifests NO$_2$ pollution is very serious, and thus further converts to O$_3$(secondary pollution).

Table 1. Data declaration and variable descriptive statistic

| Variable Symbol | Variable name | Unit | Data source | Observation | Mean  | Std. Dev | Min  | Max  |
|-----------------|---------------|------|-------------|-------------|-------|----------|------|------|
| $a_{t}$         | AQI           | Index| Website a, b| 1526        | 110.10| 68.75    | 19   | 500  |
| $s_{o_{t}}$     | SO$_2$        | μg · m$^{-3}$ | Website a, b | 1526        | 24.29 | 21.17    | 2    | 145  |
| $n_{o_{t}}$     | NO$_2$        | μg · m$^{-3}$ | Website a, b | 1526        | 49.06 | 18.73    | 13   | 126  |
| $c_{o_{t}}$     | O$_3$         | μg · m$^{-3}$ | Website a, b | 1526        | 42.92 | 28.50    | 5    | 141  |
| $coverage_{t}$  | Policy dummy variable |        | XEEB$^c$    | 1526        | 0.88  | 0.32     | 0    | 1    |
| $industry_{t}$  | industrial value added | Billions of RMB (monthly unchanged) | XSB$^d$    | 1526        | 113.45| 22.90    | 82.79| 178.11|
| $vehicle_{t}$   | social vehicles value added | Ten thousands of social vehicles (yearly unchanged) | XEEB$^c$    | 1526        | 25.47 | 3.81     | 19.44| 29.71|
| $hightemp_{t}$  | Highest temperature | °C  | Website a    | 1526        | 20.08 | 10.30    | -2   | 42   |
| $lowtemp_{t}$   | Lowest temperature | °C  | Website a    | 1526        | 10.69 | 9.49     | -12  | 29   |
| $windspeed_{t}$ | Wind speed     | km·h$^{-1}$ | Website a | 1526        | 15.47 | 1.99     | 3    | 29   |
| $rain_{t}$      | Rain or not    | Dummy variable |          | 1526        | 0.24  | 0.43     | 0    | 1    |
| $snow_{t}$      | Snow or not    | Dummy variable |          | 1526        | 0.02  | 0.14     | 0    | 1    |
| $holiday_{t}$   | Holiday dummy variable | Dummy variable |          | 1526        | 0.08  | 0.27     | 0    | 1    |
| $weekend_{t}$   | Weekend dummy variable | Dummy variable |          | 1526        | 0.27  | 0.45     | 0    | 1    |

$^a$ www.tianqihoubao.com.
$^b$ www.aqistudy.cn/historydata.
$^c$ Xi’an Ecology and Environment Bureau.
$^d$ Xi’an Statistical Bureau.
$^e$ General Office of the State Council.
### Table 2. Grid management and the air quality of Xi’an<sup>a,b</sup>

| Explained variable: AQI | (1) | (2) | (3) | (4) | (5) |
|-------------------------|-----|-----|-----|-----|-----|
| Grid management         | -58.91*** | -49.96*** | -50.44*** | -32.96*** | -33.33*** |
|                         | (7.89)   | (7.44)   | (7.49)   | (7.76)   | (7.89)   |
| industrial value added  | 1.11***  | 1.14***  | 0.38**   | 0.41***  |       |
|                         | (0.08)   | (0.09)   | (0.19)   | (0.20)   |       |
| Social vehicle          |       | -0.51   | -1.41*** | -0.25    |       |
|                         |       | (0.48)   | (0.44)   | (0.39)   |       |
| Time effect             | NO    | NO      | NO      | YES      | YES   |
| Weather effect          | NO    | NO      | NO      | YES      | YES   |
| Sample size             | 1526  | 1526    | 1526    | 1526     | 1526  |

<sup>a</sup> These numbers, in parenthesis, are adjusted by newey; <sup>***</sup>, <sup>**</sup> and <sup>*</sup> represents 1%, 5% and 10% significance level, respectively.

<sup>b</sup> Author estimates based on Stata.

### Table 3. Grid management and the air quality of Xi’an(pollutant heterogeneity)<sup>a,b</sup>

| NO<sub>2</sub> | SO<sub>2</sub> | O<sub>3</sub> |
|---------------|---------------|---------------|
| (1)           | (2)           | (3)           | (4)           | (5)           | (6)           |
| Grid management | -7.40***     | -4.13***     | -33.91***     | -24.13***     | 20.10***     | 2.99***     |
|                | (1.41)  | (1.46)  | (2.20)  | (1.80)  | (1.04)  | (0.71)  |
| industrial value added | 0.30*** | 0.28*** | 0.35*** | -0.24*** | -0.44*** | 0.28*** |
|                | (0.02)  | (0.04)  | (0.02)  | (0.03)  | (0.02)  | (0.03)  |
| Social vehicle | -0.11  | -0.08  |        | 0.30  | -0.56*** |        |
|                | (0.13)  | (0.1)  |        | (0.19)  | (0.11)  |        |
| Time effect    | NO     | YES    | NO     | YES    | NO     | YES    |
| Weather effect | NO     | YES    | NO     | YES    | NO     | YES    |
| Sample size    | 1526   | 1526   | 1526   | 1526   | 1526   | 1526   |

<sup>a</sup> These numbers, in parenthesis, are adjusted by newey; <sup>***</sup>, <sup>**</sup> and <sup>*</sup> represents 1%, 5% and 10% significance level, respectively.

<sup>b</sup> Author estimates based on Stata.

### 4. Conclusion

Grid management is come up with innovatively by Xi’an, becoming a new approach to govern haze. But the research about it from academic circles is relatively scanty, let alone empirical research. This paper launches empirical research in the way setting policy dummy variable, providing proof about relationship between grid management and air quality.

According to the result of this paper, we can safely and confidently draw a conclusion that grid management improves air quality of Xi’an obviously, because grid management has obviously negative correlation with AQI. Further, we also find grid management has obviously negative correlation with NO<sub>2</sub> and SO<sub>2</sub>, which manifests that grid management works in governance NO<sub>2</sub> and SO<sub>2</sub>. On the contrary, that grid management has obviously positive correlation with O<sub>3</sub> manifests that grid management governs O<sub>3</sub> ineffectively.

According to our conclusion, we come up with some policy proposals. First, enhance grid management about VOCs governance, which can further limit O<sub>3</sub> pollution in Xi’an. Second, further encourage citizens to purchase new-energy vehicle. Because social vehicle value added can increase O<sub>3</sub> pollution obviously, this phenomenon can illustrate that government encouragement of purchasing new-energy vehicle can improve O<sub>3</sub> pollution in Xi’an.
The result of empirical research suggest that grid management can improve air quality of Xi’an. But there are still some extreme weather situations in winter days. the reasons of existence of these phenomena may be from pollutant spill-over from adjacent provinces. After all, winter is the time heating period in northern areas, and a lot of energy consumptions make the air quality of whole northern areas aggravated. In this empirical research, we can get policy enlightenment that grid management to govern haze is an effective approach. So this approach should be imitated by other cities which have trouble in haze governance, forming collaborative governance pattern to eliminate winter haze and make blue sky reappeared.

5. References

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