大気汚染に対する秋冬の総合管理行動計画の有効性：2016-2020 年の北京・天津・河北地域を対象とした実証

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大気汚染に対する秋冬の総合管理行動計画の有効性
—2016-2020 年の北京・天津・河北地域を対象とした実証

The Effectiveness of Autumn and Winter Comprehensive Control Action on Air Pollution
—Evidence from Beijing-Tianjin-Hebei Region 2016-2020

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The article uses the Regression Discontinuity Design to calculate the policy effect coefficients for 2016-2017, 2017-2018, and 2019-2020. The data indicates that PM2.5 and PM10 contribute the most to the reduction effect. Furthermore, a panel threshold model is used to estimate the threshold at which GDP per capita has a structural impact on air quality index (AQI) and then use the threshold to classify the 28 cities into wealthy cities and less wealthy cities. The article insists that the government should provide more economic and technical support to the less wealthy cities while maintaining the scope of the existing policy.

Keywords: *Air quality, Policy effectiveness, Particulate matter, Implementation scope, BTH region.*
大気の質，政策の有効性，粒子状物質，実施範囲，BTH 地域

1.**Introduction**

The economy developed rapidly with China’s reform and opening up in 1978. Total primary energy consumption rose from 620.46 million tons of standard coal to 3644.19 million tons of standard coal. This rise has been particularly pronounced since 2000, resulting in China's per capita energy consumption quadrupling by 2020 compared to the levels observed in 1980 (CESY, 2021). And for the past 40 years, coal has always maintained a 70% share.

According to the results of the seventh census to be implemented in 2020 (BC, 2020), the population growth rate in the Beijing-Tianjin-Hebei region was higher than the national average in the past 30 years. The Beijing-Tianjin-Hebei region, situated in northern China between latitudes 36°03'N to 42°40'N and longitudes 113°27' to 119°50'E, experiences cold and dry winters. In the 1950s, the central government implemented a winter heating policy by providing free coal to the public. However, due to financial constraints, this policy was limited to northern China (Chen, 2013; Wang, 2019). As a result, the regions of the north began relying on coal for heating in winter. Notably, coal consumption in the vicinity of Beijing, Tianjin, and Hebei has surged to 1.5 billion tons, accounting for 43% of the national total (NUAQR, 2013). This situation addresses the challenge of enhancing air pollution and safeguarding the well-being of residents, which has emerged as a significant area of focus among researchers.

The earliest policy on air quality improvement began with the 2008 Beijing Olympics (Fang, 2009). Many studies started in 2012, characterized by the initial recognition of the pressing nature of the issue and appeals for governmental intervention (Guo, 2014; Huang, 2014; Zhang, 2016). A proposed approach (Wang, 2012) involves establishing unified regulatory standards and implementing a technical monitoring system within the joint prevention and control area framework.

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They insist that participating regions can adhere to a set of guidelines, ensuring consistency and coherence in pollution prevention and control efforts. Also, some other articles endeavor to put forth resolutions to tackle the problem effectively (Dong, 2015; Guan,2016; Jin, 2016; Gao, 2017).

Since 2013, the government began a plan to reduce emissions by banning the establishment of new thermal power plants in the Beijing-Tianjin-Hebei region, reducing motor vehicle pollution through vehicle restrictions, and compressing steel production (Greenstone, 2018). After this, a considerable body of research has emerged, explicitly examining policy evaluations of various individual action programs (Huang, 2018).

In 2016, the government alleviated air pollution in the Beijing-Tianjin-Hebei region, with “2+4” cities as the focus of observation, while expanding the scope of policy implementation to 20 cities. In the 2017-2018 Autumn and Winter Comprehensive Control Action on Air Pollution (hereafter referred to as the 2017-2018 action plan), the government expanded the regional joint prevention system to 28 cities. With this, many studies have considered the spatial spillover of air pollution (Liu, 2016; Ye, 2018; Chang, 2019) and recommended expanding the scope of policy implementation to enhance its effectiveness, leading to improved environmental outcomes (Yan, 2020). However, prior studies suggest blind expansion can easily lead to a decline in policy effects (Song, 2020). Therefore, it is worth studying whether improving air quality in the Beijing-Tianjin-Hebei region works.

Meanwhile, the policy approach of focusing on controlling air pollution during the autumn and winter seasons in northern China, mainly due to the initiation of heating in November, is aimed at alleviating the severe air pollution during this period. According to Li, regional joint prevention can reduce air pollution. Still, the industrial structure with a considerable proportion of secondary industries, the concentration of population, and the production activities will aggravate haze pollution in China (Li, 2021).

The impact of policy implementation exhibits variation across different cities within the region. For example, air pollution significantly impacts rural areas, but the long-term health benefits outweigh the cost of transitioning from coal to natural gas (Liu, 2020). Different co-reduction effects of air pollutants and CO2 reduction exist in economically developed and less developed regions (Dong, 2015). However, studies need to show how economic development level can affect the effectiveness of policies.

The first main objective of this article is to examine whether the autumn and winter special plan implementation is still adequate to date. Many prior studies have focused on the period of 2013-2017. Since 28 cities became the joint prevention and control area in 2017, there needed to be more ongoing concern or discussion about the scope of policy implementation. Therefore, this study evaluated the policy effectiveness among 28 cities for 2017-2018 and 2019-2020 to examine the ongoing effectiveness changes.

Secondly, prior research has explained many social factors influencing environmental quality. For instance, financial expenditures for environmental protection (Zeraibi, 2021), the proportion of secondary industry (Zheng, 2020), conventional energy generation (Xiong, 2021), and economic development (Yuan, 2015). Have these societal factors affected the implementation of the air pollution policy? Therefore, the study's second objective is to identify the social factors that influence the effects of the action plan and make recommendations for the continued implementation of the policy in the future.

2.Model and Data

2.1Study region and timeline

Before 2016, “2 + 4” cities were the air pollution policy implementation area, which was expanded to 20 cities in 2016 and 28 cities in 2017 (Table 1). They were implementing the scope of “2 + 4” cities, namely Baoding, Beijing, Cangzhou, Langfang, Tangshan, and Tianjin. In 2016, the implementation scope expanded to 20 in newly added Shijiazhuang, Handan, Xingtai, and Hengshui in Hebei province, Jinan, Zibo, Dezhou, Binzhou, Liaocheng in Shandong province, Zhengzhou, Anyang, Hebi, Xinxiang, Jiaozuoin Henan province. In 2017, the scope was further expanded and included the following eight cities: Taiyuan, Yangquan, Changzhi, and Jincheng in Shanxi province; Jining, Heze in Shandong province; Kaifeng and Puyang in Henan province (Fig. 1).

Table 1. Policy Timeline

Policy period	Start time	Scope
2016.10-2017.10	2016.11.01	20 cities
2017.10-2018.03	2017.10.01	28 cities
2019.10-2020.03	2019.10.01	28 cities

2.2Data source

The pollutant-related data used in the study was obtained from the China Air Quality Online Monitoring and Analysis Platform (http://www.aqistudy.cn/historydata/). This platform provides access to daily average value of various pollutants,

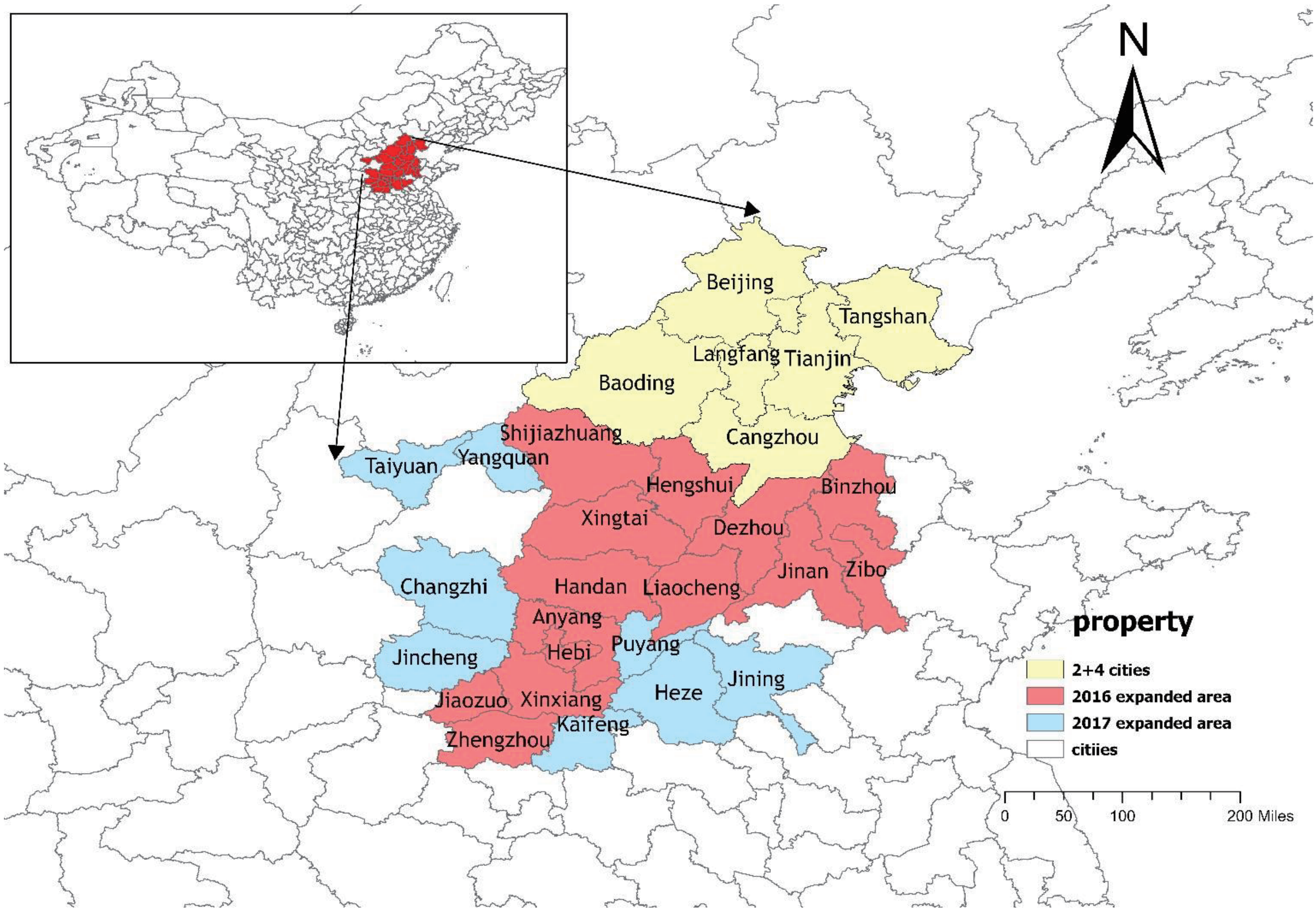

Fig. 1. Policy Implementation Scope

including fine particulate matter (PM2.5), inhalable particulate matter (PM10), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and nitrogen dioxide (NO_2). These measurements serve as indicators of air quality and are crucial for assessing the impact of air pollution.

Meteorology-related data, including daily average wind speed, average temperature, and average rainfall, were sourced from the National Environmental Protection Administration of China. These meteorological factors play a significant role in understanding atmospheric conditions and their influence on pollution levels.

GDP per capita data for each city is obtained from various official sources such as the China City Statistical Yearbook, Municipal National Economic and Social Development Statistical Bulletin, and Provincial and Municipal Regional Statistical Yearbooks.

2.3Model setting

2.3.1 RDD model

This study applies the Regression Discontinuity Design (RDD) model to analyze policy effects. The RDD model was proposed by Thistlethwaite and Campbell in 1960. It has been widely used in research related to socioeconomic factors and air pollution (Black, 1999; Chay, 2005; Chen, 2013; Wu, 2018; Guo, 2018; Wang, 2019; Zhang, 2020).

In this study, the policy implementation is treated as a quasi-natural experiment, where policy implementation leads to changes in AQI. The official implementation date of the policy was first determined, using this date as a cutoff. Completing the Autumn and Winter action plan is considered an external intervention. To examine whether there were discontinuous changes in air quality. The air quality before the action plan is regarded as the control group, while the air quality after the action plan is regarded as the treatment group. The model is constructed as follows:

$$Y_{it} = \alpha + \delta Treatment_{it} + \sum_{j=i}^{4} \beta_j \, (t-c)^j + Treatment_{it} \sum_{j=i}^{4} y_j \, (t-c)^j + \mu X_{it} + \varepsilon_{it} \quad (1)$$

2.3.2 Threshold model

This study used Threshold Regression (TR) to analyze differences in the policy implementation effect in different cities. This model was proposed by Hansen (Hansen, 1999). The basic idea of the model is to estimate the possible values of the inflection points, and then test them to find the corresponding confidence intervals. The article tests the effect of changes in per capita GDP on AQI. By estimating these parameters, the article aims to explain the impact of changes in per capita GDP on AQI levels at different income levels.

The model is constructed as follows:

$$V_{it} = \alpha\mu_{it} + \beta_1' F_{it} \mathrm{I}(q_{it} \le c) + \beta_2' F_{it} \mathrm{I}(q_{it} > c) + e_{it} \quad (2)$$

where V_{it} denotes the outcome variable, which is annual AQI. q_{it} represents a variable for city i at time t. μ_{it} denotes the control variable that has a significant control variable effect on the explanatory variable, F_{it} is also a threshold variable that varies with the explanatory variable. c is the specific threshold value e_{it} means the error. I (·) is an indicative equation, which takes 1 on a set and 0 elsewhere. The article sets the outcome variable as the yearly AQI for each city. Set the time as the threshold variable, when $q_{it} \le c$ the equation becomes:

$$V_{it} = \alpha\mu_{it} + \beta_1' F_{it} + e_{it} \quad (2.1)$$

when $q_{it} > \mathrm{c}$ the equation changes into:

$$V_{it} = \alpha\mu_{it} + \beta_2' F_{it} + e_{it} \quad (2.2)$$

3.Empirical results and discussion

3.1 RDD

The article describes air quality by AQI and regresses rain, temperature, and wind as covariates. There is a large gap between the maximum and minimum values of PM2.5 and other pollutants, indicating significant differences in air quality between cities.

3.1.1 Results

3.1.2 RDD results

When regressing with RDD, the article added wind speed, rainfall, and average temperature as covariates, and the regression results are as follows (Table 3). The data show that the effect of the policy was more significant in 2016-2017 than in 2017-2018. The policy factor increased in the following autumn and winter action plan of 2019-2020 compared to 2017-2018. The 2017-2018 implementation was expanded to 28 cities from 20 in 2016-2017, but such an expansion did not increase the emission reduction factor. In the 2019-2020 action plan, although the number of cities implemented is the same as in 2017-2018, the role of emission reduction has risen significantly. Therefore, does the implementation of this policy need to be further expanded? If the scope remains unchanged at 28 cities, from which city will the increase in implementation effect come?

3.1.3 Heterogeneity analysis

Data analysis shows that the emission reduction contribution is mainly from particulate matter (PM2.5, PM10) reduction, where SO_2, NO_2, and O_3 reduction are unstable (Table 4). This also confirms that the goal of the autumn and winter action plan is to reduce PM2.5.

3.1.4 Robustness test

3.1.4.1 Covariant test

Because atmospheric pollution is influenced by meteorological factors (Wang, 2019; Song, 2020; Wang, 2023), the article tests whether there is a jump in wind speed, rainfall, and average temperature around the cutoff (Table 5). If there is a jump, it will be excluded from the RDD regression results.

3.1.4.2 Bandwidth test

The Bandwidth determines the number of samples entering the regression, affecting the RDD results. Therefore, we performed a sensitivity test for window width and found that neither the 20-day bandwidth nor 30, 40, 50, or 70 affected the significance of the RDD results.

3.1.4.3 Placebo test

For the placebo test, the article shifted the same sample forward by 60 days and backward by 60 days. As shown in Table 6, no matter how the cutoff is moved, there is no significant reduction. This way, we can determine whether the RDD regression results have a considerable reduction effect.

3.2Threshold model

The article also collects GDP per capita, second industry contribution to GDP, percentage of secondary industry, electricity consumption, innovation input, and city green area as threshold regression variables for the threshold value test to further analyze the heterogeneity of policy effects. And the annual average AQI and PM2.5 from 2016-2020 as outcome and covariate variables, respectively.

3.2.1 Model test

Through the calculation, the article found that except for the per capita GDP (Table 7), the total output value of the secondary industry, the proportion of the secondary industry, electricity consumption, and the green area did not show the threshold value. The per capita GDP threshold is 65512 and passed the likelihood ratio test, indicating a significant shift in AQI levels when the average annual income reaches 65512 RMB.

3.2.2 Threshold model results

The regression results show that the slope of air quality is 0.889 when GDP per capita is less than or equal to 65,512 RMB, and the change in pitch of air quality is 0.971 when GDP per capita is more significant than 65,512 RMB (Table 8).

3.2.3 Heterogeneity analysis

Table 2 Descriptive statistics of variables

Variable	Unit	Obs	Mean	Std. dev.	Min	Max
AQI	index	3,416	94	37.9375	0	271
PM2.5	μg/m^3	3,416	55	30.16138	0	224
PM10	μg/m^3	3,416	138	93.15412	1	256
SO_2	μg/m^3	3,416	27	23.0779	1	94
CO	mg/m^3	3,416	12	9.175611	1	79
NO_2	μg/m^3	3,416	45	17.5338	0.7	104
O_3	μg/m^3	3,416	138	81.6191	1	252
Rain	mm	3,416	2	5.340172	0	78.63311
Temp	°C	3,416	17	8.257185	-4.942079	31.53667
Wind	km/h	3,416	2	0.6673304	0.5708576	5.28238

Table 3. The effect of Autumn and Winter action on AQI

Polynomial order	First	Second	Third	Forth
2016-2017 coefficient	-31.59***	-3.296	-8.28	-41.68***
(20cities)	-4.55	-4.572	-5.777	-7.706
Observations	2,440	2,440	2,440	2,440
2017-2018 coefficient	-14.48***	-13.77**	-25.72***	-52.67***
(28cities)	-4.497	-5.538	-7.255	-10.53
Observations	3,388	3,388	3,388	3,388
2019-2020 coefficient	-33.01***	-47.61***	-21.51	18.04
(28cities)	-7.506	-10.58	-16.34	-23.59
Observations	3,388	3,388	3,388	3,388
Bandwidth	60 days	60 days	60 days	60 days
Weather control	Y	Y	Y	Y

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively

Table 4. Robustness test of different pollutants

	PM2.5	PM10	SO_2	CO	NO_2	O_3
2016-2017	-31.79***	-56.76***	-0.15	-0.579	-0.389	-12.93***
	(5.033)	(8)	(2.248)	(1.415)	(2.314)	(3.848)
Observations	2,440	2,440	2,440	2,440	2,440	2,440
2017-2018	-10.75***	32.28**	4.403	0.979	-8.063***	23.03*
	(3.934)	(14.79)	(3.356)	(0.84)	(2.453)	(12.67)
Observations	3,388	3,388	3,388	3,388	3,388	3,388
2019-2020	-9.003	-32.76***	2.605*	0.29	1.402	-11.04
	(6.255)	(10.43)	(1.334)	(0.384)	(3.13)	(7.564)
Observations	3,388	3,388	3,388	3,388	3,388	3,388
Weather control	Y	Y	Y	Y	Y	Y

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively.

Table 5. The discontinuity of covariant

	2016-2017	2017-2018	2019-2020
Wind	-0.0421	-0.0581	-0.918***
	(0.121)	(0.0875)	(0.447)
Rain	0.826***	2.026**	0.294***
	(0.129)	(0.955)	(0.0455)
Temp	-4.800***	-0.331	1.826***
	(0.619)	(0.461)	(0.447)
Observations	730	3,354	3,377

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively.

Table 6. Robustness test of different cutoffs

	2016-2017		2017-2018		2019-2020	
	-60 days	+60 days	-60 days	+60 days	-60 days	+60 days
Coefficient	12.90***	115.2***	-4.52	53.56***	24.03***	18.43***
	(4.528)	(13.96)	(5.440)	(6.235)	(7.420)	(5.054)
Weather control	Y	Y	Y	Y	Y	Y
Observations	2,420	2,420	3,267	3,388	3,267	3,388

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively.

Table 7. Threshold effect (bootstrap = 400)

Threshold	RSS	MSE	F	P	1%	5%	10%
Single	995.7700	9.2201	15.72	0.0825	14.4641	19.5436	25.6357

Table 8. Fixed effects (within) regression

VARIABLES	AQI
Rain	924
	(2,131)
Temp	13.75***
	(2.919)
Wind	-3.823
	(3.847)
Pgdp ≤ 65512	0.889***
	(0.0423)
Pgdp > 65512	0.971***
	(0.0434)
Constant	-124.5**
	(53.76)
Observations	112
R-squared	0.878

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively

Table 9. Comparison of policy coefficients for Wealthy and Less wealthy cities

	2016-2017 Wealthy	2016-2017 Less	2017-2018 Wealthy	2017-2018 Less	2019-2020 Wealthy	2019-2020 Less
Coefficient	-17.42***	-16.56**	-38.07***	-12.84**	-19.75***	-24.60**
	(5.95)	(6.723)	(8.747)	(6.191)	(6.69)	(9.94)
Observations	1,098	2,178	1,210	2,178	1,210	2,178
Weather control	Y	Y	Y	Y	Y	Y

Note: ***, **, * represent p<0.01 p<0.05, p<0.1, respectively

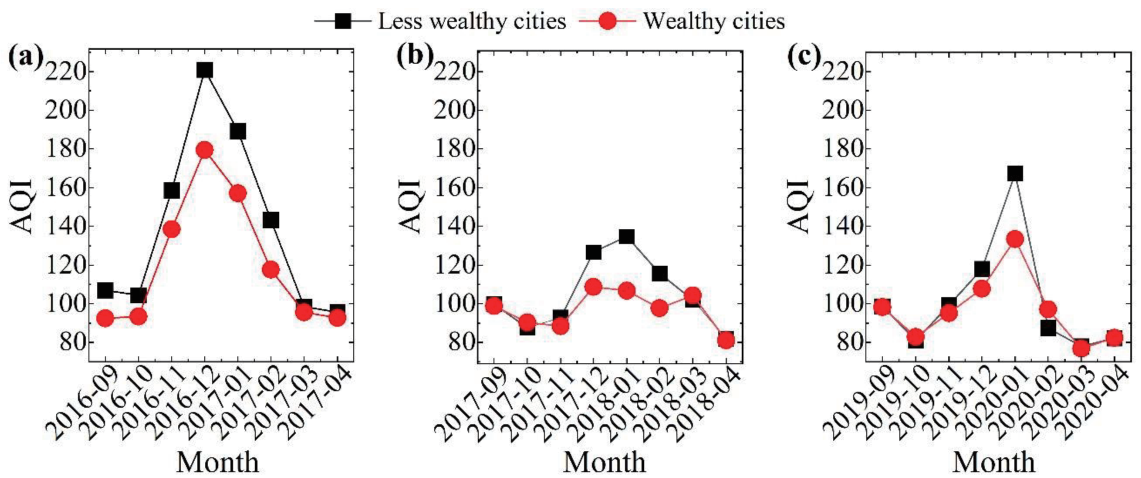

Fig.2. Comparison of AQI for Wealthy and Less wealthy cities.

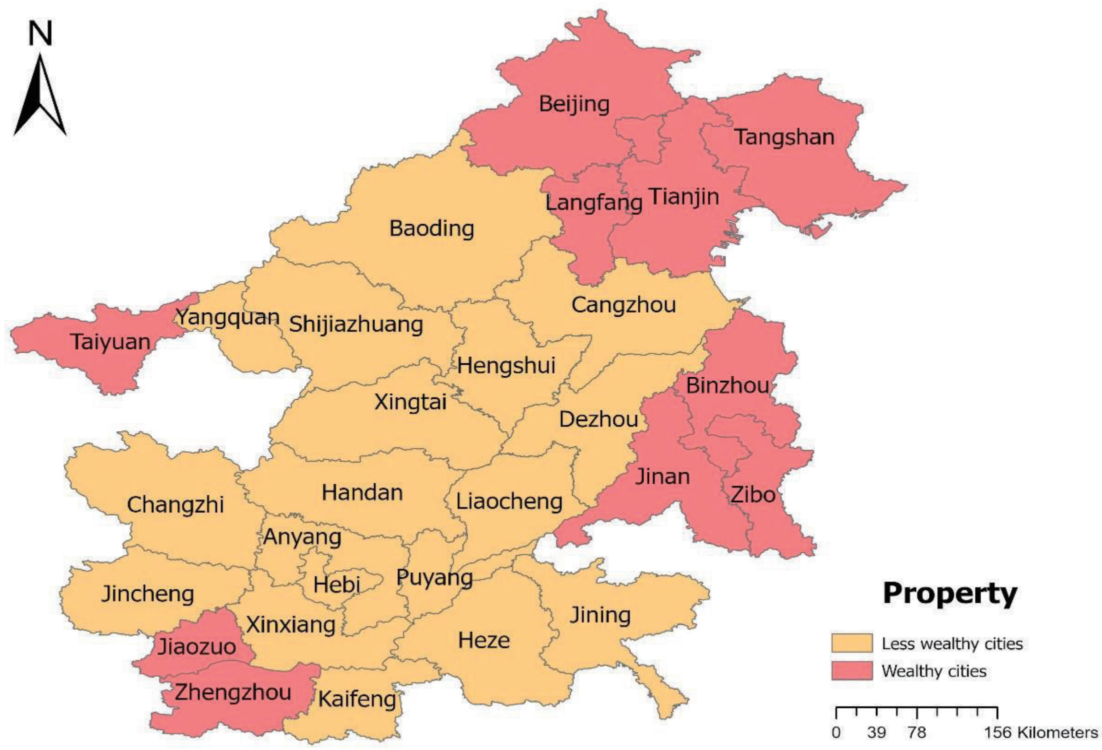

Fig.3. Wealthy and less wealthy cities

Based on the threshold model analysis above, the 20 cities (2016-2017 period) are divided into two groups. The first group is the Wealthy group, consisting of Beijing, Jinan, Langfang, Taiyuan, Tangshan, Tianjin, Zhengzhou, Zibo, and Jiaozuo. Newly added to Binzou during the 2017-2018 action plan.The Less wealthy group included Anyang, Baoding, Cangzhou, Dezhou, Handan, Hebi, Hengshui, Liaocheng, Shijiazhuang, Xinxiang, and Xingtai in the 2016-2017 action plan. After that, the scope is extended to Jining, Jincheng, Kaifeng, Puyang, Yangquan, Changzhi, and Heze (Fig.3).

The coefficient of the action plan during the policy period is shown in Table 9 and is more remarkable in Wealthy cities than in Less wealthy regions during the 2016-2017 policy period. When the policy was expanded to 28 cities in the 2017-2018 action plan, the reduction coefficients for the Wealthy cities remained higher than those for the Less wealthy regions. During the 2018-2019 policy period, the policy effect in Wealthy cities was significantly lower than in 2017-2018, while the policy effect in Less wealthy cities increased to -24.60 from -12.84 in 2017-2018. Nonetheless, the data show that Wealthy cities had lower AQI than Less wealthy cities in all three action plans, meaning that air quality was better in Wealthy cities (Fig.2).

3.3Discussion

The article demonstrates the effectiveness of the autumn and winter action plan in improving air pollution through calculations. However, should the scope of the current 28 cities in the Beijing-Tianjin-Hebei region and surrounding area continue to expand, or do we need to further consolidate the policy effect on this basis?

Firstly, in the form of the allocation of emission reduction tasks for autumn and winter action plans. In Olson's book (1965), he argues that there is such a phenomenon in the whole group and management: Minor leagues are more efficient than major leagues, and mechanical incentives or social pressures only work in minor leagues unless the major league combines minor leagues. The form of task allocation in the autumn and winter action plan is that each city designates different PM2.5 emission reduction targets while setting a collective emission reduction target, and such a management mode guarantees significant PM2.5 emission reduction.

Secondly, on whether expanding the scope of implementation will improve the overall effectiveness of emission reduction. Diederich (2016) points out that when group size becomes more extensive and there is intra-group variability, the expansion of the overall effect comes from individuals who contribute to the group rather than from individuals who are free riders. Likewise, our calculation results indicate that the expansion of the implementation of the autumn and winter action plan from 20 to 28 cities in 2017-2018 compared to 2016-2017 did not result in a significant increase in performance but rather a decrease. This suggests that there are free riders within the 28 cities.

Thirdly, how to minimize free riders. The higher the collective effort (Kolmar, 2013), the less variability there will be in the level of effort between individuals. That is, the free rider problem can be solved by continually promoting collective performance. Hence, the improvement in overall emissions reductions in 2019-2020 relative to 2017-2018 helps reduce the variability in the effort put into emissions reductions across cities. Furthermore, the solution (Kolmar, 2013) to the free rider problem arises because the individual's role in the outcome does not compensate for the costs that the individual can afford. So, this principle also reminds us that we should pay attention to the economic variability among different cities when the policy is implemented.

Fourthly, in the analysis of heterogeneity. Many prior studies have analyzed the heterogeneity of winter-related policies on air pollution. Wang's (2023) study classifies cities into mega-cities, medium-sized cities, and small cities and argues that small and medium-sized cities should implement more stringent winter heating-related policies. In Song's article (2020), the cities are divided into those that joined initially and later. It is noted that expanding the policy scope brings an increase in policy effects. The study also pointed out that the expansion of the scope of this policy should be based on the maturity of the joint defense and control air pollution system. Tao (2008) estimated a reverse U-shaped relation between air pollutant emissions and GDP per capita in China. Ding's study (2019) points out that PM2.5 and per capita GDP in the Beijing-Tianjin-Hebei region show an inverse U relationship, and the inflection point occurs when the per capita GDP is 129,239 RMB. But in a short time, in the 28 cities in the autumn and winter action plan, only Beijing has achieved a GDP per capita of 129,239 RMB. To further analyze the reasons for amplifying the policy effect, we use Threshold Regression to split 28 cities into two groups: Wealthy and Less Wealthy groups. The article insists that, at this stage, when the city's GDP per capita reaches 65,512 RMB, it will have a structural impact on AQI. When a city's GDP per capita does not reach 65,512 RMB, no structural impacts on AQI occur. At the same time, the data show that the wealthy group has lower AQI than the less wealthy group in all three action plans, meaning that air quality is better in the wealthy group during the action period. In other words, even if the less wealthy group become the main contributors to the policy effects of the action in 2019-2020, air pollution in the less wealthy regions is still worse than in the wealthy regions, and citizens in the less wealthy regions still face more significant health threats than in the wealthy regions.

Therefore, the article suggests that in the autumn-winter action plan, the government should continue to increase the emission reduction target while increasing the economic assistance to less wealthy cities to help them complete the autumn-winter action plan.

4.Conclusions and policy implications

The article uses panel data to calculate the effect coefficient of the autumn and winter action plan through RDD regression. The data proves that the autumn and winter action plans for 2016-2017, 2017-2018, and 2019-2020 have improved air quality, with particularly significant reductions in particulate matter. This coincides with the primary goal of the autumn and winter action plan to reduce PM2.5 concentrations.

Although the implementation was expanded from 20 to 28 cities in the 2017-2018 action plan, it did not increase overall emission reduction. Meanwhile, the number of cities was maintained at 28 in the 2019-2020 action plan, but the emission reduction effect was increased. This suggests that an increase in the scope of policy implementation does not necessarily lead to an increase in policy effectiveness. Therefore, the article does not recommend expanding the scope of the autumn and winter action plan. Also, considering the improvement in overall emissions reductions in 2019-2020 relative to 2017-2018 helps reduce the variability in the effort put into emissions reductions across cities. The article suggests that the government continues raising emission reduction targets for the autumn and winter programs to solve free rider problems.

To better understand the issue of variability in autumn and winter abatement effects. The article uses a threshold model to divide the cities into the wealthy and less wealthy groups and finds that cities with a per capita GDP of 65,333 RMB (wealthy group) have better air quality than the less wealthy group. Then, the data show that the less wealthy group becomes the main contributor to the policy effects in the 2019-2020 action plan, air pollution in the less wealthy regions is still worse than in the wealthy regions, and citizens in the less wealthy regions still face more significant health threats than in the wealthy regions.

Consequently, less economically developed areas require additional economic support to accelerate industrial transformation and energy structure transition. By recognizing these disparities and providing targeted assistance, policymakers can foster the desired changes in BHT regions, improving policy outcomes overall.

What's more, the article's areas need further refinement, such as the need for air pollution to consider spatial spillovers between individual cities. The RDD model is suitable for evaluating policies with precise points in time breakpoint. Some of the guidelines in the Autumn and Winter Action Plan, such as optimizing the energy mix, need to be pursued continuously over a long period, and there is no precise time breakpoint. These policies inherently require a more extended time to manifest their intended effects. Therefore, the incorporation of both long-term and short-term periods in policy evaluation is an emerging area of research.

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