天津大學

Does clean heating improve air quality? Evidence from Chinese cities

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Contents

Introduction

➢ Implementation of clean heating

- To control the air pollution in Jing-Jin-Ji and surrounding areas, clean heating has been proposed (MEEC, June 2016) .
- “2+26” cities were selected as the clean heating pilot cities.
- Promote the clean transformation of coal-fired facilities
- Promote new heating modes

Table 1. The list of “2+26” cities

Beijing, Tianjin	
Hebei	Shijiazhuang, Tangshan, Baoding, Langfang, Cangzhou, Hengshui, Handan, Xingtai
Shanxi	Taiyuan, Yangquan, Changzhi, Jincheng
Shandong	Jinan, Zibo, Liaocheng, Dezhou, Binzhou, Jining, Heze
Henan	Zhengzhou, Xinxiang, ,Hebi,, Anyang, Jiaozuo, Puyang, Kaifeng

➢ Financial subsidies for clean heating

- 12 cities: Tianjin, Shijiazhuang, Tangshan, Langfang, Baoding, Hengshui, Taiyuan, Jinan, Zhengzhou, Kaifeng, Hebi, Xinxiang,
- Municipalities: 1 billion Yuan/year
- Provincial capital city: 700 million Yuan/year
- Prefecture level city: 500 million Yuan/year

Question 1: Does the clean heating project and its subsidies improve air quality?

Introduction

➢ **Implementation of clean heating**

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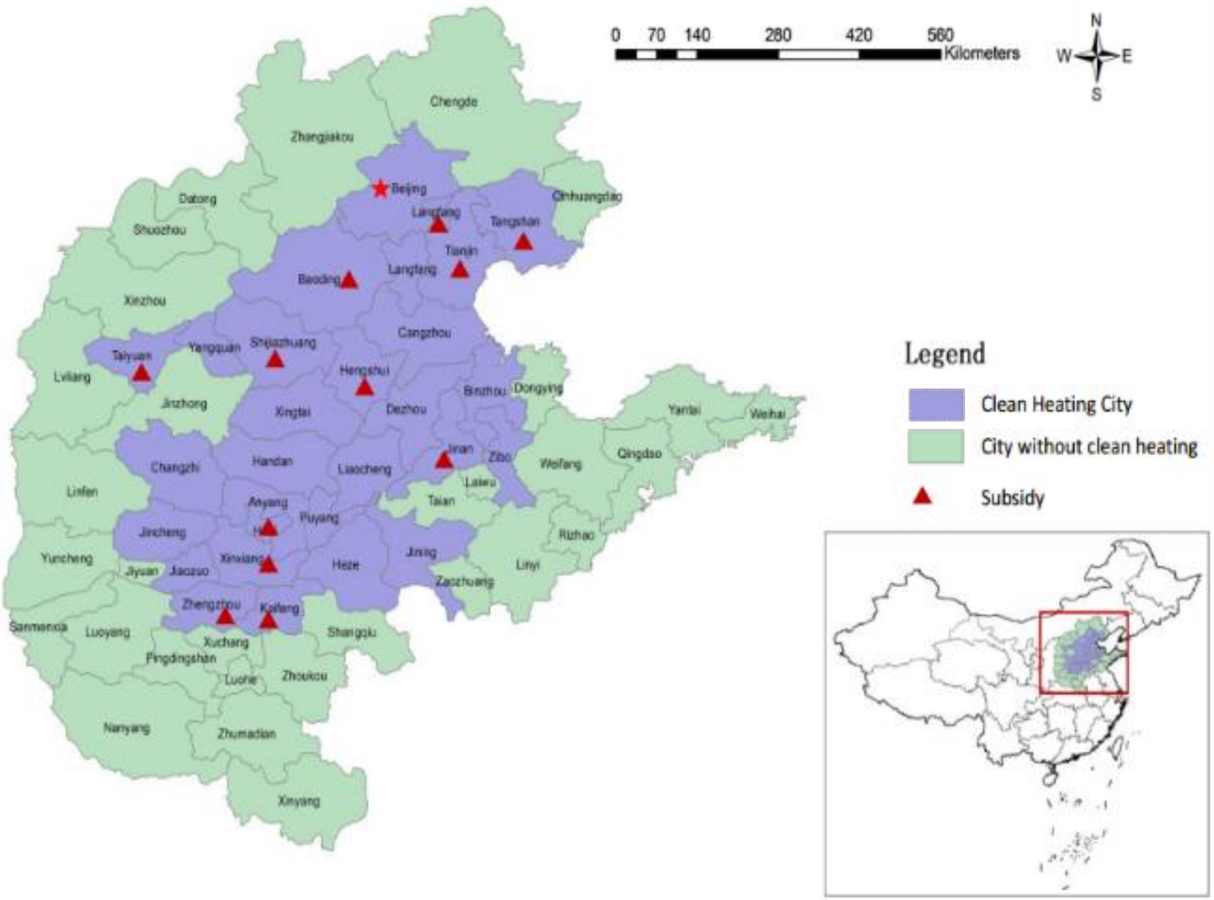


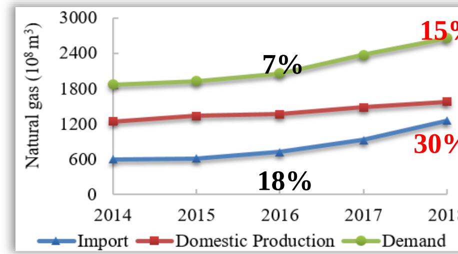
Question 1: Does the clean heating project and its subsidies improve air quality?

Introduction

➢ Natural gas or clean coal ?

- Promote new heating modes, such as replacing coal with natural gas

- **Different views on whether natural gas heating emit less pollutants than coal-fired heating**
  - Air pollution induced by gas are much lower than that induced by coal. (SO_2 1.7%, NOx 15.8%, smoke dust 8.7%) (Wu et al.,2015)
  - Gas-fired TPP needs more fuel value and emits more NOx because it generates less heat. (Liu et al., 2016)



- **The project of replacing coal with natural gas was called off in Nov 2018**
  - Gas shortage
  - Insufficient heating supply
  - Lack of financial investment

Question 2: Whether it is necessary for replacing coal heating with gas heating.

⬇

We estimate the effects of clean heating policy and its financial subsidy on air quality with difference-in-differences method and give evidence to prove whether it is necessary for replacing coal with gas heating.

Methodology

➢ **Model specification for evaluating the effect of clean heating on air pollution**

$$ap_{ij} = \beta_0 + \beta_1 During_{ij} \times Trt_{ij} + \beta_2 X_{ij} + v_{ij} + \varepsilon_{ij} \qquad (1)$$

- ap_{ij} is the dependent variable associated with city *i*'s air pollution at date *j*.
- Different dependent variables: daily AQI, concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_x.
- $During_{ij}$ is a dummy variable indicate whether date *j* is during clean heating period.
- Trt_{ij} is a dummy variable and has a value of 1 if city *i* is in treatment group and 0 if it is in control group.
  - Treatment group: "2+26" clean heating cities
  - Control group: 30 cities located in Jing-Jin-Ji and surrounding areas
- β_1: measure the clean heating treatment effects after the changing from coal to gas or to electricity.
- X_{ij}: control variable $Temp$, $Humi$, $wind\_sp$, $preparation$, $weekend$, $holiday$.
- v_i: individual fixed effects, to control for city heterogeneity.

The effects of clean heating on air quality

➢ Effects on daily air quality

Table 2. The effects of clean heating on daily air pollution

Variables	(1) AQI	(2) $PM_{2.5}$	(3) PM_{10}	(4) NO_2	(5) SO_2
During×Trt	-0.065***	-0.058***	-0.101***	-0.058***	-0.115***
	(-7.55)	(-5.30)	(-10.45)	(-8.02)	(-11.39)
During	-0.079***	-0.089***	-0.086***	-0.145***	-0.957***
	(-5.34)	(-4.74)	(-5.15)	(-11.49)	(-52.56)
Trt	0.001	-0.054	-0.288***	0.480***	-1.199***
	(0.02)	(-1.52)	(-9.37)	(21.84)	(-36.70)
R^2	0.416	0.477	0.396	0.500	0.633

Note:.Standard errors are clustered at the city level. ***p<0.01; **p<0.05;*p<0.1

- Clean heating project decreased daily air pollution by 6%-12% significantly.

➢ Effects on monthly polluted days

Table 3. The effects of clean heating on pollution days

Variables	(1) Grade I	(2) Grade II	(3) Grade III	(4) Grade IV	(5) Grade V	(6) Grade VI
During×Trt	0.249	1.170**	-0.104	-0.975***	-0.166	-0.376*
	(1.22)	(2.79)	(-0.32)	(-3.90)	(-0.68)	(-2.51)
During	-1.985***	3.976***	-2.923***	-2.031***	-1.429***	-0.540*
	(-3.89)	(4.67)	(4.55)	(-4.38)	(-3.33)	(-2.43)
Trt	7.160***	-0.388	-5.917***	-1.734**	-0.321	1.197**
	(7.16)	(-0.28)	(-7.80)	(-2.84)	(-0.44)	(3.21)
R^2	0.713	0.588	0.429	0.431	0.606	0.497

Note:.Standard errors are clustered at the city level. ***p<0.01; **p<0.05;*p<0.1

- The number of days which reaching the standard of NAAQ increased by 1.2 days per month.
- There is a decline in the number of polluted days by 1.4 days per month.

The effects of subsidy on air quality

➢ **Difference-in-differences estimation**

$$ap_{ij} = \gamma_0 + \gamma_1 During\_subsidy_{it} \times Trt\_subsidy_{it} + \gamma_2 Subsidyamount_{it} + \gamma_3 X_{it} + v_{ij} + \varepsilon_{ij} \quad (2)$$

Table 4. The effects of subsidies for clean heating on air pollution

Variables	(1) AQI	(2) $PM_{2.5}$	(3) PM_{10}	(4) NO_2	(5) SO_2
Panel 1: 16 clean heating cities without subsidy as the control group					
During_subsidy×Trt_subsidy	-0.027**	-0.049***	-0.024	-0.046***	-0.009
	(-2.06)	(-2.84)	(-1.61)	(-2.67)	(-0.57)
During_subsidy	-0.121***	-0.097***	-0.183***	-0.235***	-0.964***
	(-5.80)	(-3.58)	(-7.86)	(-13.67)	(-35.68)
Trt_subsidy	0.243***	0.487***	0.364***	0.373***	1.417***
	(3.71)	(6.02)	(4.95)	(6.11)	(18.75)
R^2	0.439	0.488	0.413	0.444	0.630
Panel 2: 30 cities without clean heating as the control group					
During_subsidy×Trt_subsidy	-0.113***	-0.111***	-0.146***	-0.077***	-0.147***
	(-9.54)	(-7.25)	(-10.95)	(-7.77)	(-10.40)
During_subsidy	-0.084***	-0.083***	-0.101***	-0.093***	-0.991***
	(-5.00)	(-3.87)	(-5.34)	(-6.40)	(-45.82)
Trt_subsidy	0.309***	0.373***	0.684***	0.145***	0.977***
	(5.09)	(4.97)	(10.10)	(3.03)	(14.09)
R^2	0.426	0.497	0.402	0.528	0.630

Note:. *t* statistics are in the parentheses. Standard errors are clustered at the city level.***p<0.01; **p<0.05;*p<0.1

The financial subsidy for pilot cities **decreases the AQI and air pollutants furtherly** by 1%-5%.

The effects of subsidy on air quality

- **Subsidy elasticity of different air pollutants**

Table 5. Subsidy elasticity of air pollution

Variables	(1)	(2)	(3)	(4)
Panel 1: dependent variable: *log(aqi)*				
Subsidyamount	-0.424***	-0.172***	-0.176***	-0.232***
	(-5.15)	(-2.92)	(-2.98)	(-3.50)
R^2	0.042	0.489	0.493	0.371
Panel 2: dependent variable: $log(PM_{2.5})$				
Subsidyamount	-0.567***	-0.208***	-0.212***	-0.289***
	(-5.33)	(-2.82)	(-2.88)	(-3.48)
R^2	0.163	0.551	0.553	0.449
Panel 3: dependent variable: $log(PM_{10})$				
Subsidyamount	-0.934***	-0.629***	-0.632***	-0.688***
	(-11.20)	(-9.44)	(-9.47)	(-9.13)
R^2	0.164	0.447	0.449	0.318
Panel 4: dependent variable: $log(NO_2)$				
Subsidyamount	-0.082	-0.434***	-0.442***	-0.385***
	(-1.37)	(-9.48)	(-9.85)	(-8.10)
R^2	0.180	0.477	0.494	0.401
Panel 5: dependent variable: $log(SO_2)$				
Subsidyamount	-1.402***	-0.950***	-0.951***	-1.000***
	(-18.38)	(-14.11)	(-14.12)	(-10.75)
R^2	0.511	0.617	0.617	0.346

Note: *t* statistics are in the parentheses. Sample size: 7260. Standard errors are clustered at the city level. $^{***}p<0.01$; $^{**}p<0.05$; $^{*}p<0.1$

- Subsidy elasticities of different air pollutants vary greatly when subsidy increases by 1%.
- The central government should consider the air pollution differences among provinces, when deciding the subsidy level.

Clean coal or natural gas?

➢ **The effects of energy consumption growth on air quality**

Table 6. The effects of clean coal or natural gas on air pollution

Variables	(1) AQI	(2) $PM_{2.5}$	(3) PM_{10}	(4) NO_2	(5) SO_2
Panel 1: Growth of clean coal consumption impacts					
During×Cleancoal	-0.0007***	-0.0008***	-0.0008***	-0.0005***	-0.0009***
	(-4.57)	(-4.31)	(-4.31)	(-3.68)	(-3.75)
During	-0.290***	-0.365***	-0.212***	0.013	-0.881***
	(-9.03)	(-9.52)	(-5.16)	(0.36)	(-15.14)
Cleancoal	0.0003***	0.0004***	0.0002***	0.0002***	0.0004***
	(5.03)	(4.94)	(3.47)	(4.24)	(3.88)
Observations	986	986	986	986	986
R^2	0.757	0.783	0.713	0.756	0.833
Panel 2: Growth of natural gas consumption impacts					
During×gas	-0.00005	-0.00004	-0.00009**	-0.00004	-0.00009**
	(-1.88)	(-1.88)	(-2.87)	(-1.88)	(-2.78)
During	-0.241***	-0.308***	-0.144***	0.050	-0.808***
	(-7.70)	(-8.18)	(-3.59)	(1.44)	(-14.41)
Gas	0.00000	-0.00001	0.00001	-0.00002	0.00001
	(0.17)	(-0.21)	(0.55)	(-1.26)	(0.24)
Observations	986	986	986	986	986
R^2	0.752	0.788	0.711	0.755	0.832

Note: The sample includes 58 cities. *t* statistics are in the parentheses. Standard errors are clustered at the city level. ***p<0.01; **p<0.05; *p<0.1

- The increased use of clean coal contributes to the reduction of air pollutant by 0.5% to 0.9%.
- The growth of natural gas consumption does not decrease $PM_{2.5}$, NO_2 and AQI significantly.
- The cost of natural gas heating is nearly 2.6 times of that of coal heating in terms of households.

Table 7. Economic cost for different heating modes

	Natural gas heating		Coal-fired heating	
Urban household	3228	6917	1236	2649
Rural household	4684	10037	1794	3844

Robustness check

- **Placebo test:** pretend the clean heating policy began in Nov 2015
- **Different samples**: drop samples with missing data, drop municipalities
- **Different control variables**
- **Estimation by PSM-DID**
- **Estimation at province level** (Hebei, Henan, Shandong, Shanxi)
    - The effects of clean heating on different air polutants vary greatly at province level.

Table 7. Estimation at Province Level

Variables	(1) AQI	(2) $PM_{2.5}$	(3) PM_{10}	(4) NO_2	(5) SO_2
*Panel 1: Cities in **Hebei Province***					
During×Trt	-0.120^{***}	-0.104^{***}	-0.126^{***}	-0.081^{***}	-0.129^{***}
	(-5.77)	(-3.93)	(-4.94)	(-4.37)	(-5.24)
R^2	0.583	0.631	0.571	0.616	0.578
*Panel 2: Cities in **Henan Province***					
During×Trt	-0.093^{***}	-0.092^{***}	-0.043^{***}	-0.116^{***}	-0.045^{***}
	(-2.84)	(-2.71)	(-2.62)	(-9.65)	(-1.87)
R^2	0.377	0.439	0.317	0.489	0.650
*Panel 3: Cities in **Shandong Province***					
During×Trt	-0.052^{***}	-0.048^{**}	-0.054^{***}	-0.013^{*}	-0.134^{***}
	(-3.41)	(-2.43)	(-3.29)	(-1.00)	(-8.48)
R^2	0.448	0.477	0.471	0.501	0.667
*Panel 4: Cities in **Shanxi Province***					
During×Trt	-0.137^{***}	-0.095^{***}	-0.221^{***}	-0.064^{***}	-0.335^{***}
	(-7.00)	(-3.72)	(-9.88)	(-3.77)	(-12.65)
R^2	0.386	0.456	0.358	0.493	0.472

Note: *t* statistics are in the parentheses. Standard errors are clustered at the city level. $^{***}p<0.01$; $^{**}p<0.05$; $^{*}p<0.1$

Conclusion

1. **Clean heating policy helps to improve air quality**.

2. **The financial subsidy** improves the air quality furtherly. Central government should **not only consider city's administrative level**, but also the **air pollution differences across provinces** as well as **different effects of subsidy on pollutants**, when designing the subsidies.

3. **Growing clean coal use improves air quality significantly**, while replacing coal with natural gas has no obvious effect according to the our results. The **advanced coal-fired** boilers for **centralized heating will be helpful for air quality improvements** when considering the security of energy supply, livelihood demand and economic cost.

4. **Future research**:

   - Explore the optimal clean heating mode and the optimal financial subsidy schemes for regions in China
   - Evaluate and compare the effects of different kinds of policies

THANK YOU FOR YOUR TIME!

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