How Do Household Energy Transitions Work?*

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1 Introduction

China is deploying an ambitious policy to transition up to 70% of households in northern China from residential coal heating to electric or gas "clean" space heating, including a large-scale roll out across rural and peri-urban Beijing, referred to in this document as China's Coal Ban and Heat Pump (CBHP) subsidy policy. To meet this target the Beijing municipal government announced a two-pronged program that designates coal-restricted areas and simultaneously offers subsidies to night-time electricity rates and for the purchase and installation of electric-powered heat pumps to replace traditional coal-heating stoves. The policy was piloted in 2015 and, starting in 2016, was rolled out on a village-by-village basis. The variability in when the policy was applied to each village allowed us to treat the roll-out of the program as a quasi-randomized intervention and evaluate its impacts on air quality and health. Household air pollution is a well-established risk factor for adverse health outcomes over the entire lifecourse, yet there is no consensus that clean energy interventions can improve these health outcomes based on evidence from randomized trials (Lai et al. 2024). Households may be differentially affected by the CBHP due to factors such as financial constraints and user preferences, and there is uncertainty about whether and how the policy may affect indoor and outdoor air pollution, as well as heating behaviors and health outcomes.

1.1 Subheading

1.1.1 Sub-subheading

1.1.2 Personal exposure

Table 1: Descriptive characteristics by district.

	Fangshan (n=11)		**Huairo (n=18)**		**Miyun (n=12)**		**Mentougou (n=9)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of households	699.1	514.4	163.1	111.6	274.4	198.8	204.3	73.20
Per capita income (RMB, 1000s)	7.2	1.4	20.0	2.8	17.3	2.8	11.3	2.30
Distance to Beijing center (km)	67.2	2.3	88.6	8.9	83.0	3.7	45.0	5.70
Altitude (m)	146.0	36.9	353.9	121.3	283.1	85.9	312.4	133.90
Winter briquette quantity (tonnes)	3.7	1.2	4.0	1.6	2.8	1.2	2.4	1.00
Winter wood quantity (kilograms)	1180.0	1192.0	2411.0	3845.0	2309.0	1997.0	1493.0	3144.00
Participant age	59.0	9.1	60.0	8.8	60.0	8.9	62.0	9.70
Education (0-None or primary school; 1-secondary +)	0.4	0.5	0.3	0.5	0.3	0.4	0.3	0.46
Participant weight	69.0	11.0	66.0	11.0	65.0	10.0	68.0	11.00
Participant height	161.0	8.6	161.0	8.2	159.0	8.4	161.0	8.60

Note: Number of villages given in parenthesis. SD = Standard deviation

Table 2: Impact of adding district-level fixed effects to models for personal and indoor air pollution.

	Personal PM2.5		**Black carbon**		**24-hr indoor**		**Seasonal indoor**	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
ATT	0.2	0.0	-0.4	-0.3	-20.0	-21.8	-20.3	-22.0
	(10.1)	(9.4)	(0.5)	(0.5)	(12.4)	(13.3)	(7.8)	(8.6)
Observations	1,270	1,270	1,161	1,161	399	399	366	366
Year fixed effects	X	X	X	X	X	X	X	X
Cohort fixed effects	X	X	X	X	X	X	X	X
District fixed effects		X		X		X		X

Note: (a) excludes and (b) includes district fixed effects. All models adjusted for household size, smoking, outdoor temperature, and outdoor dewpoint. Standard errors (in parenthesis) clustered by village.

Table **?@tbl-a-het-personal** shows limited evidence that the ATTs across cohorts and time demonstrate meaningful heterogeneity.

ANMB	absolute normalized mean bias
ATT	Average Treatment Effect on the Treated
BAM	Beta Attenuation Monitor
BC	Black carbon
BP	Blood pressure
CI	Confidence Interval
CIE	International Commission on Illumination
CHP	Clean Heating Policy
cDBP	Central diastolic blood pressure
CRP	C-reactive protein
cSBP	Central systolic blood pressure
DAG	Directed acyclic graph
DiD	Difference-in-Differences
EC	Elemental carbon
EDXRF	Evo energy-dispersive X-ray fluorescence
ETWFE	Extended Two-Way Fixed Effects
FEM	Federal equivalent method
FID	Flame ionization detector
FeNO	Fractional exhaled nitric oxide
HAPIN	Household Air Pollution Intervention Network
HPLC	High-performance liquid chromatography

IL-6	Interleukin-6
MDA	Malondialdehyde
NISP	National Improved Stove Program
NIST	National Institute of Standards and Technology
ns-S	Non-Sulfate Sulfur
OC	Organic Carbon
OD	Optic densities
PKU	Peking University
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerodynamic diameter
RMSE	Root mean square error
SRM	Standard reference material
TNF-α	Tumour necrosis factor alpha
UCAS	University of Chinese Academy of Sciences
UPAS	Ultrasonic Personal Aerosol Samplers
W1, W2, W3, W4	Wave 1, Wave 2, Wave 3, Wave 4
wi	Water Insoluble Species
ws	Water Soluble Species

Abbreviations and other terms

ATT

Lai PS, Lam NL, Gallery B, Lee AG, Adair-Rohani H, Alexander D, et al. 2024. Household Air Pollution Interventions to Improve Health in Low- and Middle-Income Countries: An Official American Thoracic Society Research Statement. American Journal of Respiratory and Critical Care Medicine 209:909–927; doi:10.1164/rccm.202402-0398ST.