Air pollution and the long-term care cost in an aging society

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Outline

Motivations

- **Population aging** represents a growing concern in both developed and developing countries around the world. The share of the population aged 65 and above is projected to increase to about 16% in 2050 globally (United Nations 2019).
- **An urgent need for long-term care (LTC) services**, posing a great financial burden to society and individuals (Ameriks et al. 2020;Wang et al. 2021).
- A deeper understanding of **determinants of LTC demand and costs** is essential for an aging society.

Motivations

- The elderly are more vulnerable than younger adults to **adverse effects of environmental degradation** on health and survival (Zeng et al. 2010).
- Numerous studies have shown that **air pollution has a significant and sizable effect on morbidity and mortality** (e.g., Anderson 2020; Chen et al. 2013; Næss et al. 2007; Schwartz et al. 2002).
- **However, little research has focused on the effect of air pollution on LTC demand.**

Motivations

- The overall effect of air pollution on LTC costs is less clear.
  - Exposure to air pollution could **increase the probability of LTC dependence** (Zeng et al. 2010; Zhang, Zhang, and Chen 2017; de Zwart et al. 2018),
  - It could also cause **a reduction in life expectancy** (Anderson 2020; Chen et al. 2013)
- In this paper, we aim to quantify the causal effect of air pollution on LTC demand and costs in China.
  - The average particulate matter less than 2.5 micrometers in diameter **(** $PM_{2.5}$**)** in major cities in China was **42.8** $\mu g/m^3$ in 2018, **eight times** higher than the air quality guideline (AQG) level for annual exposure considered by WHO (World Health Organization 2021).

Contributions

- We examine the impact of air pollution on **a new outcome of interest - LTC demand and LTC costs**.
  - Although evidence is growing for an association between air pollution exposure and physical functioning of older adults (Lv et al. 2020; Wen and Gu 2012; de Zwart et al. 2018), their health outcomes are relevant but not directly applicable to determine LTC demand.
  - We define LTC demand based on the performance of activities of daily living (ADLs), which is a key criterion for receiving public and private LTC insurance in both developing and developed countries (e.g., Ameriks et al. 2020; Zhu and Österle 2019).

Contributions

- Estimate **the causal effect** of air pollution on LTC demand by addressing potential endogeneity problems.
  - Problems of omitted variables: economic development may both affect air pollution and LTC demand.
  - Problems of simultaneity: health risk can reversely affect air pollution because poor health status could cause reduced outdoor activities and less exposure to air pollution, resulting in an underestimate of the effects of air pollution on LTC risk.
  - Measurement errors of air pollution due to human manipulation (Ghanem and Zhang 2014)
- We rely on China's Huai River heating policy and use the exogenous geographic distance to Huai River as the instrumental variable for air pollution (Almond et al. 2009; Chen et al. 2012; Lin 2017).

Contributions

- Investigate the impact of air pollution on LTC cost, considering **the heterogeneity and mechanism of the effect**.
  - Previous studies evaluating the welfare cost of air pollution focus on its effects on trade openness (Lin 2017), labor supply (Chang et al. 2016; Hanna and Oliva 2015; He, Liu, and Salvo 2019), and insurance purchase (Chang, Huang, and Wang 2018; Gao et al. 2021).
  - Other studies evaluating the LTC costs focus on its determinants such as individual and regional characteristics (Jin et al. 2020), types of LTC services (Guo, Konetzka, and Manning 2015), time to death or reasons for death (de Meijer et al. 2011), and LTC insurance (LTCI) ownership (Ariizumi 2008).

Snapshot of Our Paper

- Match high-quality satellite-based $PM_{2.5}$ dataset to the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal study for middle and old age adults, to estimate **the causal effect** of air pollution on LTC risk and LTC cost.
  - Air pollution has **an adverse effect on LTC demand and its costs are economically significant**: a 10 $\mu g/m^3$ growth of annual $PM_{2.5}$ exposure increases monthly care hours by 11.9 hours and monthly LTC costs by CNY 162.0;
  - Experiencing annual $PM_{2.5}$ exposure over 35 $\mu g/m^3$ in any of the past five years increases care hours by 1,214 and increases LTC costs by CNY 16,528;
  - However, **care costs are significantly reduced by CNY 684 if the exposure of $PM_{2.5}$ at a survey year is reduced under 35 $\mu g/m^3$,** which is the WHO air quality interim target I.

Snapshot of Our Paper

- Match high-quality satellite-based $PM_{2.5}$ dataset to the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal study for middle and old age adults, to estimate the causal effect of air pollution on LTC risk and LTC cost.
  - Low-income group is more vulnerable to air pollution than the high-income group.
  - Mediation effect of morbidity: the increase in LTC costs due to air pollution exposure mostly come through its adverse impact on cancers, mental diseases, and cardiovascular diseases.

Air pollution data

- A satellite-based $PM_{2.5}$ dataset
  - This $PM_{2.5}$ dataset provides annual estimates of $PM_{2.5}$ concentrations in both urban and rural China from 2000 to 2018 with a fine grid (a spatial resolution about 1.1km $\times$ 1.1km) (van Donkelaar et al. 2010, 2019; Hammer et al. 2020).
  - Major explanatory variable - **annual average $PM_{2.5}$ in each city**: the latitude-level and longitude-level panel data of air pollution is collapsed to a city-level panel dataset by averaging the annual location specific measures of pollution concentrations.
  - The scaled variable representing $PM_{2.5}$ into three groups: 0-35, 35-45, >45.

China Health and Retirement Longitudinal Study (CHARLS)

- CHARLS
  - Nationally representative sample in China: a stratified multi-stage PPS (probabilities proportional to size) random sampling strategy was adopted.
  - Aged 45 years and older as well as their spouses.
  - Baseline survey (2011) in 150 counties of 28 provinces across China (17,708 observations). 2013, 2015, and 2018 surveys revisit the same respondents.

China Health and Retirement Longitudinal Study (CHARLS)

- Explained variables
  - **LTC demand**: =1 if with difficulty or need help in two or more activities of daily living (ADLs) out of six ADLs (dressing, bathing, and showering, self-feeding, getting into or out of bed, controlling urination and defecation), otherwise =0;
  - **ADLs score**: score the four answers of ADLs 15, 10, 5, and 0, respectively, to sum up the total ADLs score for six ADLs;
  - **LTC costs (care hours)**: the time costs and refer to the total number of hours that others help individual with daily activities of living during the last month;
  - **LTC costs (care costs)**: the financial costs, which are the multiple of care hours and urban residents' hourly disposable income per capita.

China Health and Retirement Longitudinal Study (CHARLS)

- Control variables
  - **Individual-level** (gender, age, hukou status, ethnicity, education level, sell-reported health status, individual annual income)
  - **Household-level** (marital status, number of siblings, number of children, living arrangements, household size, and house ownership)
  - **City-level** (air temperature, wind direction, and city-level income per capita)

China Health and Retirement Longitudinal Study (CHARLS)

- Sample construction
  - Step 1: Respondents without missing values of key variables (64,192)
  - Step 2: 45 years old or older (62,680) - Sample A
  - Step 3: Respondents without missing values of care hours and care costs (8,289) - Sample B

Empirical Methods

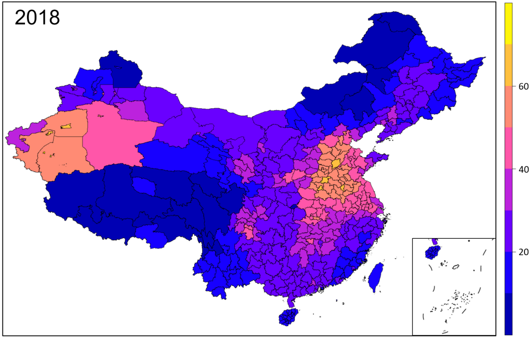
$$Y_{i,t} = \alpha_0 + \alpha_1 PM_{i,t} + \beta X_{i,t} + \lambda_i + \upsilon_t + \epsilon_{i,t}$$

$$PM_{i,t} = \alpha_0 + \kappa Distance_{i,t} + \beta X_{i,t} + \lambda_i + \upsilon_t + \epsilon_{i,t}$$

- A two-stage least squares (2SLS) estimation approach, by instrumenting air pollution $PM_{i,t}$ with variations in latitude distance to Huai River $Distance_{i,t}$.
- The long-lived different heating systems between Northern and Southern China divided by the Huai River, cause Northern China to have severer pollution (Almond et al. 2009; He et al. 2019; Ito and Zhang 2020; Lin 2017). Such heating policy should not affect LTC demand and costs directly but only through air pollution.

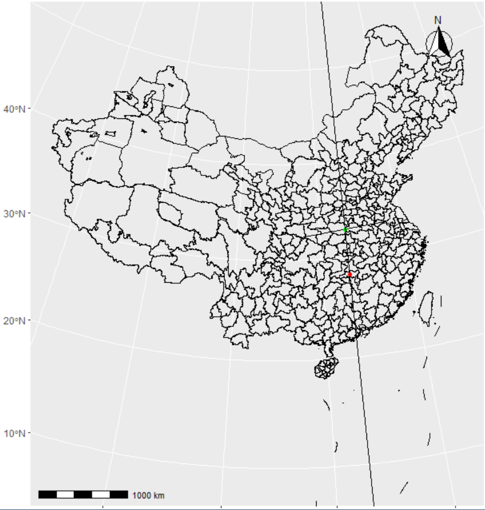
Empirical Methods

- Northern China has severer pollution ($PM_{2.5}$ in 2018).



Empirical Methods

- How to calculate the distance between one city and Huai River?



The effects of air pollution on LTC demand and costs

	ADLs and LTC demand			LTC costs	
Model	(1)	(2)	(3)	(4)	(5)
Explained variable	$PM_{2.5}$	ADLs Score	LTC demand	Care hours	Care costs
Method	OLS	IV OLS	IV Probit	IV OLS	IV OLS
$PM_{2.5}$		**-0.011***** **(0.003)**	**0.001***** **(0.000)**	**1.190***** **(0.458)**	**16.200***** **(5.839)**
Latitude distance	**3.229***** **(0.028)**				
Observations	62,680	62,680	62,680	8,289	8,289
R^2	0.411	0.143		0.031	0.047
Wald p-value			0		
Control variables	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES

A 1 $\mu g/m^3$ growth of annual $PM_{2.5}$ exposure increases monthly care services by **1.190 hours** and monthly care costs by **CNY 16.2**.

Robustness tests

- Additional analyses to test the sensitivity of the impact of air pollution on LTC
  - **Residency history**: a migration due to air pollution could yield biased results;
  - **Measure of LTC demand**: consider three or more ADLs as a requirement for LTC insurance claim;
  - **Measure of LTC costs**: the costs of care in benchmark analysis are based on disposable income, here we use employment income;
  - **Model specification**: individual random effects.

Robustness tests

	RT1: No migration			RT2: Different LTC risk measure
Model	(1)	(2)	(3)	(4)
Explained variable	LTC demand	Care hours	Care costs	LTC demand
Method	IV Probit	IV OLS	IV OLS	IV Probit
$PM_{2.5}$	**0.001***** **(0.000)**	**0.976*** **(0.527)**	**11.866*** **(6.720)**	**0.001*** **(0.000)**
Observations	46,893	6,370	6,370	62,680
R^2		0.03	0.051	
Wald p-value	0			0
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES

Robust to consider residence history and different measure of LTC demand.

Robustness tests

	RT3: Different LTC cost measure	RT4: individual random effect		
Model	(5)	(6)	(7)	(8)
Explained variable	Care costs	LTC demand	Care hours	Care costs
Method	IV OLS	IV Probit	IV OLS	IV OLS
$PM_{2.5}$	**22.732***	**1.190****	**16.200*****	**0.009*****
	(14.814)	**(0.466)**	**(6.155)**	**(0.002)**
Observations	8,289	62,680	8,289	8,289
R^2	0.049			
Wald p-value		0		
Wald chi2			263.96	408.59
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES

Robust to consider different measure of care costs and model specification, i.e., inclusion of fixed year effects and individual random effects.

Additional analysis

- Additional analyses to further understand the impact of air pollution on LTC.
  - **Effects of air pollution exposure in the past** on LTC demand and LTC costs (whether experiencing $PM_{2.5}$ exposure over a cutoff of 35 $\mu g/m^3$ in the past 5/10 years);
  - **Threshold effects of air pollution exposure** on LTC demand and LTC costs;
  - **Heterogenous effects** of air pollution on care hours and care costs ;
  - **Investigating the morbidity as the mediation factors**: how air pollution affects care hours and care costs.

The effects of past air pollution

	(1) $PM_{2.5}$ over 35 in past 5 years	(2) $PM_{2.5}$ over 35 in past 10 years
Panel B: care hours		
$PM_{2.5}$	**1,214.165***** (**467.042**)	**2,169.414***** (**834.490**)
Observations	8,289	8,289
R^2	0.031	0.031
Panel C: care costs		
$PM_{2.5}$	**16,527.538***** (**5956.998**)	**29,530.647***** (**10643.692**)
Observations	8,289	8,289
R^2	0.047	0.047
Control variables	YES	YES
Year fixed effects	YES	YES

Experiencing annual $PM_{2.5}$ exposure over 35 $\mu g/m^3$ in any of the past 5/10 years increases the care hours and care costs.

The threshold effects of air pollution

	(1)	(2)	(3)
Explained variable	***LTC demand***	***Care hours***	***Care costs***
Method	IV Probit	IV OLS	IV OLS
$PM_{2.5}$<35	**-0.009***** **(0.002)**	**-52.531***** **(15.410)**	**-684.259***** **(201.669)**
35<$PM_{2.5}$⩽45	-0.003* (0.002)	6.042 (15.382)	156.325 (205.052)
Observations	62,680	8,289	8,289
Wald p-value	0		
R^2		0.032	0.049
Control variables	YES	YES	YES
Year fixed effects	YES	YES	YES

Compared annual $PM_{2.5}$ exposure over 45 $\mu g/m^3$, a current exposure of $PM_{2.5}$ under 35 $\mu g/m^3$ decreases care hours by 52.531 hours and decreases care costs by CNY 684.

Heterogeneous effect of air pollution on care hours and care costs

	Income		Living arrangement	
	(1)	(2)	(3)	(4)
	High-level	Low-level	Living alone	Living with others
Panel A: care hours (IV OLS)				
$PM_{2.5}$	-0.263	**2.189*** **	-1.27	**1.495*** **
	(0.775)	**(0.563)**	(1.457)	**(0.482)**
Between-group diff test	FP p-value = 0.025**		FP p-value = 0.000***	
Observations	3,102	5,187	1,064	7,225
R^2	0.049	0.027	0.071	0.03
Panel B: care costs (IV OLS)				
$PM_{2.5}$	1.307	**26.896*** **	-12.957	**19.882*** **
	(10.000)	**(7.140)**	(18.858)	**(6.113)**
Between-group diff test	FP p-value = 0.055*		FP p-value = 0.015**	
Observations	3,102	5,187	1,064	7,225
R^2	0.069	0.037	0.08	0.047

Low-income group is more vulnerable to air pollution than the high-income group.

How air pollution affects care hours and care costs: mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)
		DCD			Number of chronic diseases	
	Disease	Care hours	Care costs	Disease	Care hours	Care costs
$PM_{2.5}$	**0.003***	1.098**	15.039**	**0.004***	1.047**	14.266**
	(0.000)	(0.461)	(5.881)	**(0.000)**	(0.461)	(5.867)
Disease		**26.227***	**331.217**		**22.926***	**310.615***
		(9.825)	**(128.680)**		**(6.944)**	**(94.098)**
Observations	62,680	8,289	8,289	62,680	8,289	8,289
R^2	0.127	0.031	0.047	0.151	0.032	0.048

Diagnosed with a chronic disease (DCD) and the number of DCD are adversely correlated with $PM_{2.5}$ exposure, and also associated with care hours and costs.

How air pollution affects care hours and care costs: mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)
	Cancers			Diabetes		
	Disease	Care hours	Care costs	Disease	Care hours	Care costs
$PM_{2.5}$	**0.001*** **	1.174**	15.973***	**0.002*** **	1.153**	15.619***
	(0.000)	(0.458)	(5.841)	**(0.000)**	(0.457)	(5.802)
Disease		62.45	**866.253***		17.119	271.717
		(38.982)	**(514.384)**		(15.620)	(217.450)
Observations	62,680	8,289	8,289	62,680	8,289	8,289
R^2	0.012	0.031	0.048	0.043	0.031	0.047

Diagnosed with cancer is adversely correlated with $PM_{2.5}$ exposure and also associated with care costs.

How air pollution affects care hours and care costs: mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)
	Mental diseases			Cardiovascular diseases		
	Disease	Care hours	Care costs	Disease	Care hours	Care costs
$PM_{2.5}$	**0.001*** **	1.120**	15.299***	**0.002*** **	1.142**	15.555***
	(0.000)	(0.458)	(5.838)	**(0.000)**	(0.461)	(5.879)
Disease		**54.882*** **	**701.164*** **		**19.097* **	**254.066* **
		(18.740)	**(250.548)**		**(10.105)**	**(133.366)**
Observations	62,680	8,289	8,289	62,680	8,289	8,289
R^2	0.031	0.032	0.048	0.086	0.031	0.048

Diagnosed with mental disease and cardiovascular diseases are adversely correlated with $PM_{2.5}$ exposure, and also associated with care hours and costs.

Main findings

- We examine the **causal effect** of air pollution on **LTC demand, care hours, and care costs** based on a nationally representative dataset in China during 2011–2018, by leveraging the Huai River heating policy to address endogeneity issues.

1. **Air pollution has an adverse effect on LTC risk** and the costs is economically significant.
2. **Low-income group is more vulnerable** to air pollution than the high-income group.
3. Increase of LTC cost due to air pollution exposure could mostly come through **its adverse impact on cancers, mental diseases, and cardiovascular diseases.**
4. If China has adopted the WHO air quality interim target I of 35 $\mu g/m^3$ as the National Ambient Air Quality Standards, meeting this target would **reduce LTC costs by CNY 134.25 billion in 2020**, which is 1.8% of China's GDP spending on public health (CNY 7.2 trillion).

Further research

- Future research can investigate if households are more informed about the negative effects of air pollution on LTC demand and LTC costs, do they have a higher willingness to pay for LTC insurance.
- Future research can investigate how to design policies to provide information to the public on the pollution-health relationship to affect household responses to pollution.

Thanks for listening!

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