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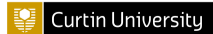
The effects of past and current air pollution exposure on multimorbidity, cognition, and disability in China

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1. Introduction

2. Data

3. Results

4. Conclusion

1 – Outline

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1 – Background

Outdoor air pollution

- 90% of world population live in places where the quality of air is not safe (WHO)
- A high level of air pollution adversely affect health (Brunekreef and Holgate, 2002)
- Particulate matter (PM) is the largest environmental risk to health (Ebenstein et al., 2017)
- PM less than 2.5 micrometres in diameter (PM_{2.5}) poses the greatest health risks (small enough to pass lung and enter blood system)

Developing countries

- Highest health burden due to air pollution
- Some are experiencing rapid population ageing
- Basic public insurance

1 – Our question

Q: What are the health effects of air pollution for the old in developing countries?

Previous studies

- Questionable extrapolation of results from developed countries (PM_{2.5} levels much smaller, e.g., 0 to 35 $\mu\text{g}/\text{m}^3$ vs. 10 to 110+ $\mu\text{g}/\text{m}^3$)
- Poor estimation of air pollution - many use simple air pollution index (limited places, or do not consider PM_{2.5}, e.g., Hu et al., 2020; Zeng et al., 2010; Zhang et al., 2018)
- Difficult to compare - most focus on single health outcome, e.g., specific diseases (N. Wang et al., 2019), cognition (J. Wang et al., 2020), or disability (Lv et al., 2020)

Importantly

- Most do not consider the effect of past exposure to PM_{2.5}, and the interaction of past and current PM_{2.5} exposure
- Most only consider the level of air pollution, but not the change of it
- Most consider a linear effect (limited PM_{2.5} range)

1 – Our paper

Study the associations between PM_{2.5} exposure and multimorbidity, cognition, and disability, using generalised additive mixed models.

Main contributions

- Both past and current exposure of PM_{2.5}
- Both level and difference of PM_{2.5} exposure
- Non-linear associations
- Comprehensive health measures with comparable results due to a consistent modelling approach

2 – Outline

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2 – Sample and health outcomes

Sample

- Data from the China Health and Retirement Longitudinal Study (CHARLS): middle- and old-aged adults, 4 waves from 2011 to 2018

Health outcomes in each survey wave

- Multimorbidity
 - Self-reported number of diseases (total out of 14)
- Cognitive function
 - The total score of 21 cognitive questions (word recall, time orientation, number subtraction, drawing)
- ADL disability
 - Any difficulty in performing the following six activities of daily living (ADL): dressing, showering, eating, getting in and out of bed, using the toilet, and continence.

2 – PM_{2.5} data

High resolution (ca. 1km by 1km grid cells) satellite-based PM_{2.5} data from 2000 to 2018 from Hammer et al. (2020).

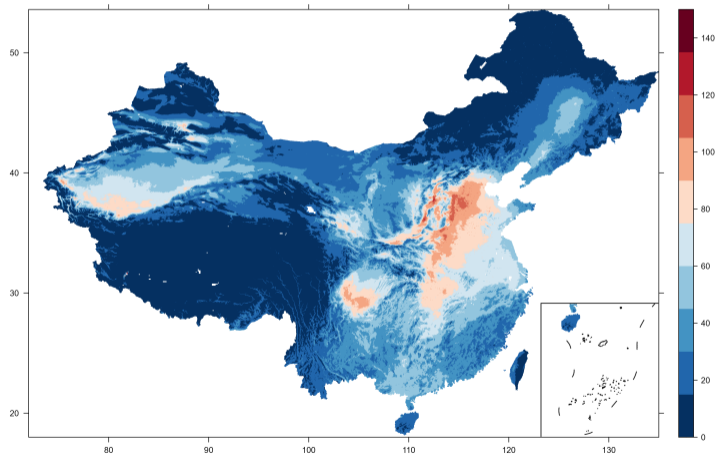


Figure 1: PM_{2.5} concentrations in 2011

2 – PM_{2.5}-related variables

Effects of current PM_{2.5} exposure

- Annual PM_{2.5} exposure in a survey year from 2011 to 2018
- Growth (in %) of annual exposure in a survey year, compared with one year ago

Effects of past PM_{2.5} exposure

- Whether average PM_{2.5} exposure from 2000 to 2010 passes 55µg/m³ (severe air pollution)
- The maximum of the growth of annual exposure from 2001 to 2010

Estimation of individual exposure to PM_{2.5}

- Living in an urban area: maximum of (average of grid cells within 1km, 2km, 4km, 10km of the centre urban area)
- Living in a rural area: average of grid cells in the prefecture-level city (not really a city, mostly rural areas)

2 – Other control variables

Variables at the individual level

- Age, gender, education, marital status,
- Urban areas, non-agricultural work, household consumption
- Body Mass Index (BMI) levels, drinking status, smoking status

The coloured variables will be used for sub-group analysis (see later)

We will compare the effect size of PM_{2.5} to that of Age (see later)

Variables at the prefecture level

- GDP, and GDP per capita (general economics)
- Number of hospital beds (healthcare)
- Population density (urbanisation)

Annual growths of the prefecture-level variables will also be used as control variables.

2 – Baseline model

Baseline model (Model A): **only current** effects

$$Y_{i,j,t} = \alpha_0 + s_1(\text{Current_PM}_{i,t}) + s_2(\text{Current_growth_PM}_{i,t}) + \mathbf{X}_{i,t}\kappa + \nu_t + \lambda_i + \eta_j + \epsilon_{i,j,t} \quad (1)$$

- $Y_{i,j,t}$: multimorbidity, cognition, ADL disability (logit link function)
- $s_1(\text{Current_PM}_{i,t})$: smooth function of the effect of current annual exposure to PM_{2.5}
- $s_2(\text{Current_growth_PM}_{i,t})$: smooth function of the effect of current growth (in %) of annual PM_{2.5}
- $\mathbf{X}_{i,t}$: individual and prefecture-city covariates, with coefficients κ
- ν_t : fixed effects for survey waves
- λ_i and η_j : random intercepts at the individual and the county level, respectively

2 – Extended models

1. Model B: Include both past and current exposure

$$\begin{aligned} Y_{i,j,t} = & \alpha_0 + \text{Past_severe_PM}_i + s_1(\text{Current_PM}_{i,t}) + s_2(\text{Current_growth_PM}_{i,t}) \\ & + s_3(\text{Max_Past_growth_PM}_i) + s_4(\text{Diff_Current_PM}_{i,t}, \text{Past_severe_PM}_i = 1) \\ & + \mathbf{X}_{i,t}\boldsymbol{\kappa} + \lambda_i + \nu_t + \eta_j + \epsilon_{i,j,t} \end{aligned} \quad (2)$$

2. Model C: Effects of current exposure by sub-groups (gender, age 65+ or not, rural or urban, smoking status, household consumption)

$$\begin{aligned} Y_{i,j,t} = & \alpha_0 + s_1(\text{Current_PM}_{i,t}) + s_2(\text{Current_growth_PM}_{i,t}) \\ & + s_5(\text{Diff_Current_PM}_{i,t}, \text{sub-group}_i = 1) \\ & + s_6(\text{Diff_Current_growth_PM}_{i,t}, \text{sub-group}_i = 1) \\ & + \mathbf{X}_{i,t}\boldsymbol{\kappa} + \lambda_i + \nu_t + \eta_j + \epsilon_{i,j,t} \end{aligned} \quad (3)$$

3 – Outline

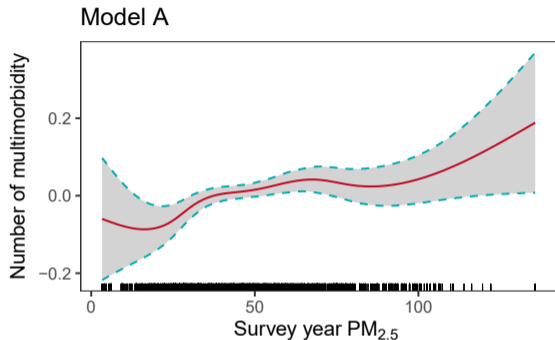
1. Introduction

2. Data

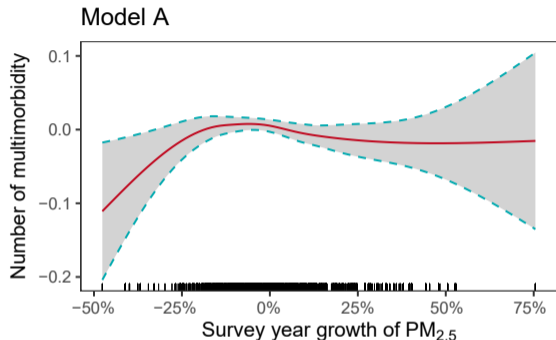
3. Results

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3 – Results: Multimorbidity, effects of current PM_{2.5} (Model A)

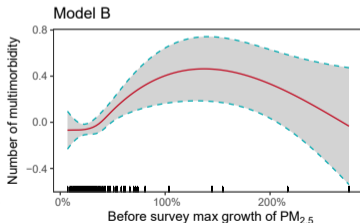
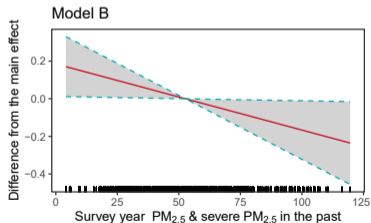
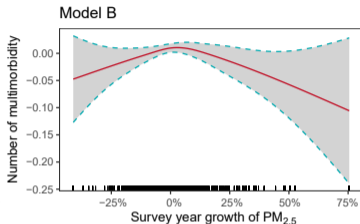
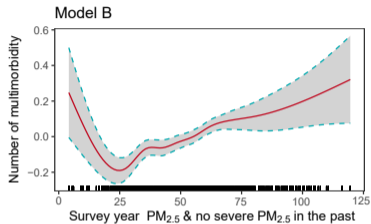


- A positive association when PM_{2.5} > 25µg/m³



- The **reduction** of PM_{2.5} is negatively associated with multimorbidity
- No significant results for the **increase** of PM_{2.5}

3 – Results: Multimorbidity, effects of past and current PM_{2.5} (Model B)



Effects of current PM_{2.5} (level)

- Greater (no severe PM_{2.5} in the past)
- Smaller (severe PM_{2.5} in the past)

Effects of PM_{2.5} growth

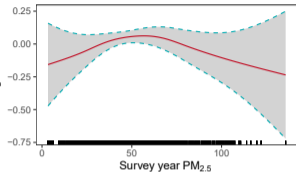
- Current: insignificant
- Past: positive association when the growth is < 100%, then a large uncertainty due to limited observations

Direct effect of past severe PM_{2.5}

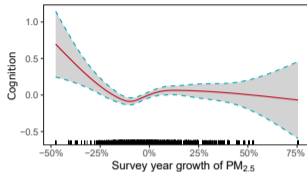
- Insignificant (not shown here)

3 – Results: Cognition, PM_{2.5} effects from Model A and B

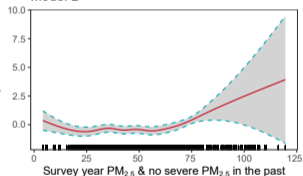
Model A



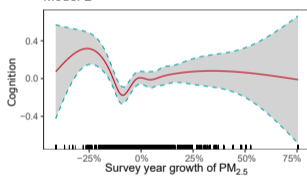
Model A



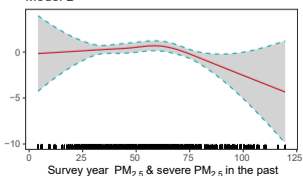
Model B



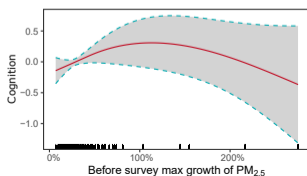
Model B



Model B



Model B



Effects of current PM_{2.5} (level)

- Negative association if PM_{2.5} < 25µg/m³ (no severe PM_{2.5} in the past)
- More sensitive if PM_{2.5} > 70µg/m³ (severe PM_{2.5} in the past)

Effects of PM_{2.5} growth

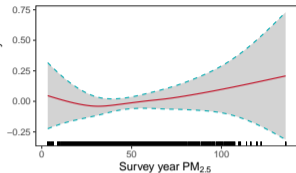
- Current: the reduction (positive), the increase (insignificant)
- Past: insignificant

Direct effect of past severe PM_{2.5} (level)

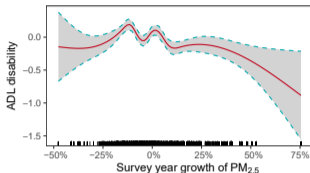
- Insignificant (not shown here)

3 – Results: ADL disability, PM_{2.5} effects from Model A and B

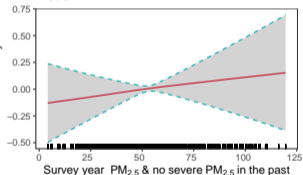
Model A



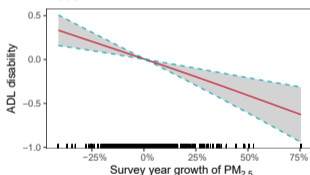
Model A



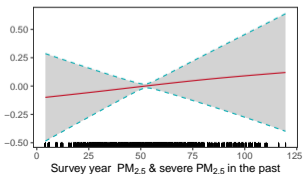
Model B



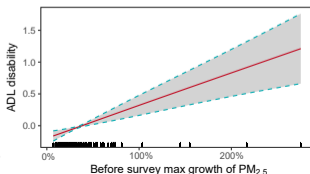
Model B



Model B



Model B



Effects of current PM_{2.5} (level)

- Insignificant (overall)
- Insignificant (no severe PM_{2.5} in the past)
- Insignificant (severe PM_{2.5} in the past)

Effects of PM_{2.5} growth

- Current: complicated (Model A), negative ? (Model B)
- Past: positive (Model B)

Direct effect of past severe PM_{2.5} (level)

- Insignificant (not shown here)

3 – Results: Compared with the effect of ageing

Multimorbidity

- Being one year older increases multimorbidity by **0.03**
- PM_{2.5} **from 35 $\mu\text{g}/\text{m}^3$ to 75 $\mu\text{g}/\text{m}^3$** increases multimorbidity by ca. **0.15**
 - The effect size \approx **5** years older

Cognition

- Being one year older decreases cognition by **0.073**
- The reduction of the PM_{2.5} exposure in a survey year **from 0 to 50%** increases cognition by ca. **0.73**
 - The effect size \approx **10** years younger

ADL disability

- Being one year older increases ADL disability by **0.073**
- Past PM_{2.5} exposure in the past **from 0 to 100%** increases the log odds of ADL disability by ca. **0.5**
 - The effect size \approx **7** years older

3 – Results: Which groups are more sensitive to PM_{2.5}?

More sensitive groups, compared with their counterparts (e.g., males vs. females):

Multimorbidity

- Adults < 65
- Urban residents
- Males
- Higher-than-median household consumption (growth of PM_{2.5})

Cognition

- Adults < 65
- Urban residents
- Higher-than-median household consumption (growth of PM_{2.5})

ADL disability

- Urban residents

Note: The results are from Model C.

4 – Outline

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4 – Conclusion

We study the effects of $PM_{2.5}$ on multimorbidity, cognition, and disability, for middle- and old-aged population:

- Long-term study, 2000-2018
- Both past and current $PM_{2.5}$
- Both the level and the difference of the $PM_{2.5}$ exposure
- Non-linear estimates of the effects

Key findings:






- Different non-linear effects of $PM_{2.5}$ exposure on health.
- Different pathways: Past exposure to $PM_{2.5}$ not only affects current health, but also modifies how current $PM_{2.5}$ exposure affects health.
- The change of annual $PM_{2.5}$ also affects health, especially for ADL disability.
- Large effect size compared with age (relevant for pricing and risk management)

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Thank you very much for your interest in our research!

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-  Brunekreef, B., & Holgate, S. T. (2002). Air pollution and health. *The Lancet*, 360(9341), 1233–1242.
-  Ebenstein, A., Fan, M., Greenstone, M., He, G., & Zhou, M. (2017). New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River Policy. *Proceedings of the National Academy of Sciences*, 201616784.
-  Hammer, M. S., van Donkelaar, A., Li, C., Lyapustin, A., Sayer, A. M., Hsu, N. C., Levy, R. C., Garay, M. J., Kalashnikova, O. V., Kahn, R. A., Brauer, M., Apte, J. S., Henze, D. K., Zhang, L., Zhang, Q., Ford, B., Pierce, J. R., & Martin, R. V. (2020). Global Estimates and Long-Term Trends of Fine Particulate Matter Concentrations (1998–2018). *Environmental Science & Technology*, 54(13), 7879–7890.
-  Hu, K., Keenan, K., Hale, J. M., & Börger, T. (2020). The association between city-level air pollution and frailty among the elderly population in China. *Health & Place*, 64, 102362.
-  Lv, Y., Zhou, J., Kraus, V. B., Li, T., Sarnat, J. A., Wang, J., Liu, Y., Chen, H., Brasher, M. S., Mao, C., Zeng, Y., Zheng, T., & Shi, X. (2020). Long-term exposure to PM2.5 and incidence of disability in activities of daily living among oldest old. *Environmental Pollution*, 259, 113910.

- 
- Wang, J., Li, T., Lv, Y., Kraus, V. B., Zhang, Y., Mao, C., Yin, Z., Shi, W., Zhou, J., Zheng, T., Kinney, P. L., Ji, J., Tang, S., & Shi, X. (2020). Fine Particulate Matter and Poor Cognitive Function among Chinese Older Adults: Evidence from a Community-Based, 12-Year Prospective Cohort Study. *Environmental Health Perspectives, 128*(6), 067013.
- 
- Wang, N., Mengersen, K., Tong, S., Kimlin, M., Zhou, M., Wang, L., Yin, P., Xu, Z., Cheng, J., Zhang, Y., & Hu, W. (2019). Short-term association between ambient air pollution and lung cancer mortality. *Environmental Research, 179*, 108748.
- 
- Zeng, Y., Gu, D., Purser, J., Hoenig, H., & Christakis, N. (2010). Associations of Environmental Factors With Elderly Health and Mortality in China. *American Journal of Public Health, 100*(2), 298–305.
- 
- Zhang, X., Chen, X., & Zhang, X. (2018). The impact of exposure to air pollution on cognitive performance. *Proceedings of the National Academy of Sciences, 115*(37), 9193–9197.

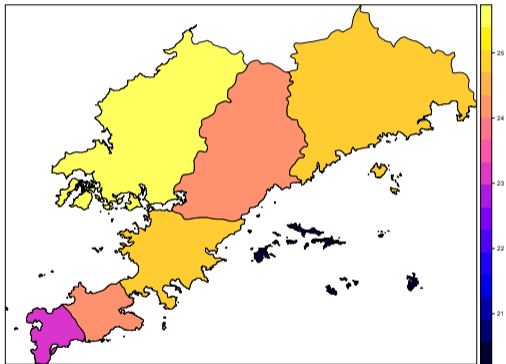


Figure 2: PM_{2.5} concentrations in the prefecture-city Dalian