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"THE IMPACT OF PM2.5 POLLUTION ON LIFE EXPECTANCY IN CHINA: EXPLORING THE ROLES OF URBANIZATION AND HEALTHCARE SPENDING"

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Abstract

This study investigates the impact of fine particulate matter (PM2.5) on life expectancy across 31 Chinese provinces from 2018 to 2022, using urbanization and healthcare expenditure as control variables. Employing panel data regression with ordinary least squares (OLS), the analysis reveals that higher PM2.5 levels are significantly associated with lower life expectancy. Specifically, a 1 μg/m³ increase in PM2.5 concentration leads to a 0.0342-year decrease in life expectancy. Urbanization shows a positive and significant effect, with urban provinces experiencing an average of 3.52 additional years in life expectancy compared to rural areas. In contrast, healthcare expenditure has a statistically insignificant effect in the short run. The model explains 39.5% of the variation in life expectancy, underscoring the critical role of air quality and urban development in shaping public health outcomes.

Literature Review

Impact of PM2.5 Pollution on Life Expectancy in China

PM2.5 are tiny particles with a diameter of less than 2.5 micrometers, allowing them to pass through the respiratory system, reach the lungs, and enter the bloodstream

(WHO, 2024). According to Yang et al. (2020), PM2.5 has long been associated with negative health impacts, contributing considerably to lower life expectancy in many Chinese cities. Several studies have found that air pollution is linked to a wide range of diseases, including cardiovascular and respiratory disorders, as well as higher mortality (Hu et al., 2021). Air pollution can damage neurocognitive functions, causing people to suffer from depression more easily, and decreasing life satisfaction levels (Cao et al., 2017). Furthermore, Hu et al. (2021) state that a 10 mg/m3 increase in PM2.5 resulted in a 0.3-year drop in adult life expectancy in China, demonstrating that human life expectancy is strongly related to air pollution. Moreover, Cao et al. (2017) state that air pollution has become an essential factor limiting China's economic progress, resulting in a range of social issues.

Urbanization and Healthcare

Urbanization has a considerable impact on both PM2.5 levels and life expectancy. A huge quantity of carbon dioxide emissions increases the greenhouse effect, and air pollution such as PM2.5 grows more significant with the rise of urbanization, causing harm to human health. (Shao et al., 2022). According to Cao et al. (2017), the eastern part of China is the most developed and inhabited. It results in higher concentrations of PM2.5, which leads to higher mortality of respiratory disease, whereas the western part of China has lower concentrations of PM2.5 and lower mortality of respiratory disease. Urbanization causes increased levels of PM2.5 pollution, which leads to poorer health and shorter life expectancy (Diao et al., 2020). However, Miao and Wu (2016) explain that urban populations may benefit from greater living conditions and health services; thus, higher degrees of urbanization can minimize health risks. Shao et al. (2022) note that some research indicated that, while urbanization in China causes problems to residents' health, those who move to urban regions tend to have better health conditions than those who stay in rural areas due to the availability of health services. Chen et al. (2019) discovered that, as compared to urban children, rural children reported more anxiety and depression symptoms and poorer self-reported

mental health due to lower education levels and insufficient access to medical services in rural areas. Nevertheless, according to Shao et al. (2022), most research concluded that urbanization's negative consequences on people's health outweigh its positive effects, resulting in a rise in medical and healthcare costs. According to Liu and Zhong (2022), increased health investment in China might increase life expectancy in the long run. Furthermore, Liu and Zhong (2022) claim that throughout the last ten years, government investment in health per capita rose quickly, with an average yearly growth of 22.9 percent, resulting in improved life expectancy during the same period. However, Li and Zhang (2024) observe that, despite the importance of healthcare expenditure, the quality and availability of medical treatments have an essential role in increasing life expectancy.

Methodology and Data

This study investigates the relationship between PM2.5 levels and life expectancy in China, using urbanization and healthcare spending as control variables. The research is based on panel data from 31 Chinese provinces from 2018 to 2022. The data was acquired from the National Bureau of Statistics of China to ensure accuracy and reliability. The data is formatted as panel data, with observations made for each province over a five-year period, for a total of 155. This enables the analysis to account for both cross-sectional variations among provinces and temporal changes within each province.

Table 1. Definition of variables

Variable Name	Definition
Life_Expectancy	Average years of life (years), dependent variable

PM2.5	Fine particulate matter levels (μg/m³), independent variable
Urbanization	Urban vs. rural (1 = urban, 0 = rural), control variable 1
Healthcare_Expenditure	Spending on healthcare per capita (local currency yuan CNY), control variable 2

Table 2. Descriptive statistics

Variable Name	Obs	Mean	Std. dev	Min	Max
Life_Expectancy	155	77.80626	2.263874	71.5	82.95
PM2.5	155	37.37755	12.63529	7.1	74.1
Urbanization	155	0.7096774	0.4553826	0	1
Healthcare_Expenditure	155	1519.681	718.4281	117.36	5285.9

In the case of life expectancy, we can observe a small standard deviation of 2.26, indicating that life expectancy does not vary significantly among regions or time periods in the dataset. In addition, the range between the lowest and maximum shows an 11-year difference between the shortest and longest life expectancies, which could be influenced by regional variances in healthcare, pollution, or urbanization. China's average PM2.5 level is 37.38 μg/m³, substantially greater than the recommended range of 5 μg/m³ set by the World Health Organization. Furthermore, the high standard deviation of 12.64 shows significant variance in air quality among the regions or time periods analyzed. The urbanization has a mean of 0.71, which suggests that 71% of

provinces can be categorized as urban. Because of the high standard deviation of 718.43 yuan, we may conclude that there is considerable variance in healthcare spending between regions and that certain areas have higher expenditure on healthcare than others. This is also demonstrated by the fact that the minimum healthcare spending is 117.36 yuan and the maximum is 5285.9 yuan.

Econometric model

The study uses the OLS method to determine the relationship between life expectancy and PM2.5 as independent variable, and urbanization and healthcare spending as control variables.

The econometric model would be:

$$Life\ expectancy_{i,t} = \beta_0 + \beta_1 PM2.5_{i,t} + \beta_2 Urbanization_{i,t} + \beta_3 HealthcareExpenditure_{i,t}$$

i: Province index

t: Year index

Life Expectancy is a dependent variable that shows life expectancy at region *i* at time *t*. PM2.5 is an independent variable thar demonstrates PM2.5 levels in region *i* at time *t*. Urbanization is a dummy control variable that indicates whether the region *i* is urban (1) or rural (0). Healthcare Expenditure is continuous control variable that shows healthcare expenditure per capita in region i at time t.

Results

In Model 2, the PM2.5 coefficient is -0.0342, indicating that a one-unit increase in PM2.5 concentration leads to 0.0342 years fall in life expectancy, while other variables remain constant. This is entirely consistent with the research conducted by Hu et al. (2021), who found that a 10 mg/m3 rise in PM2.5 resulted in a 0.3-year decline

in adult life expectancy in China, suggesting that human life expectancy is highly tied to air pollution. It also confirms the observation made by Yang et al. (2020) that PM2.5 has long been associated with poor health impacts, contributing significantly to decreased life expectancy in many Chinese cities. The standard error is 0.0141, which makes this coefficient statistically significant. In the instance of urbanization, which is a dummy control variable, the urbanization coefficient is 3.5181, indicating that urban districts have a mean life expectancy that is 3.52 years greater than that of rural regions, holding PM2.5 concentration and healthcare spending constant. This supports Shao et al.'s (2022) conclusion that, while urbanization in China has a negative impact on inhabitants' health, those who relocate to urban areas have better health outcomes than those who remain in rural areas due to the availability of health services. It further endorses Miao and Wu's (2016) claim that increasing levels of urbanization can reduce health hazards. The standard error is 0.3685, indicating a very strong effect. In the example of healthcare expenditure, which is a continuous control variable, the healthcare expenditure coefficient is 0.0000629, implying that a one-unit increase in healthcare expenditure per capita is related to a very small increase of 0.0000629 years in life expectancy. In addition, the standard error is 0.000265, which is much higher than the coefficient and contributes to an insignificant result. The insignificance of healthcare expenditure as a control variable can be attributed to the fact that the model captured the short-term relationship between healthcare expenditure and life expectancy from 2018 to 2022, whereas Liu and Zhong's (2022) research found that increased health investment in China may increase life expectancy in the long-term. Another explanation could be that, according to Li and Zhang (2024), additional major factors that impact life expectancy include the quality and availability of medical services. In Model 2 the R squared value is 0.3946, demonstrating that the model explains about 39.46% of the variation in life expectancy. Compared to Model 1, which had a R squared of 0.0255, the addition of control variables in Model 2 significantly improves the model's ability to explain the variance in life expectancy. In Model 1, PM2.5 had a positive coefficient of 0.0286, while in Model 2, it had a negative value

of -0.0342 after adding control variables urbanization and healthcare expenditure. Model 1 lacked an essential control variable, urbanization, which is associated with higher pollution and life expectancy, resulting in a bias in the coefficient of PM2.5. After including urbanization as a control variable in Model 2, an actual negative connection between PM2.5 and life expectancy emerges. Additionally, the F-statistic in Model 1 has a value of 4.00, indicating low overall significance and demonstrating that with only one independent variable, the model barely estimates life expectancy. At the same time, the F-statistic in Model 2 is 32.81, revealing that the model is significant and that adding urbanization and even healthcare spending as control variables improves the model's ability to explain life expectancy.

Table 3. The estimated models

Variables	Model 1	Model 2
PM2.5	0.0285929	-0.0341549
	(0.0142995)	(0.0141014)
Urbanization		3.518136
		(0.3684704)
Healthcare_Expenditure		0.0000629
		(0.0002265)
constant	76.73753	76.4905
	(0.5640049)	(0.7218794)
R squared	0.0255	0.3946
F-statistic	4.00	32.81
N	155	155

Limitations

Influence of External Shocks

The COVID-19 pandemic, which caused the Chinese government to irrationally increase its healthcare expenditures, falls within the analysis period of 2018 to 2022. According to the National Bureau of Statistics of China, the pandemic caused a significant increase in healthcare expenditure in most regions, which may not convert into significant increases in life expectancy. Furthermore, pandemic-related mortality may disproportionately affect provinces, distorting life expectancy estimations. Overall, the influence of Covid-19 could impact the relationships in the model, especially for healthcare spending.

Short-term nature of the data

The study covers only five years, from 2018 to 2022, and does not completely represent the long-term effects of healthcare spending on life expectancy in China. Liu and Zhong's (2022) research indicated that increasing health spending in China may increase life expectancy in the long term. The short-term nature of the study may explain why the healthcare expenditure control variable is insignificant in the model.

Missing relevant variables

The model may leave out crucial factors that have a substantial impact on life expectancy, such as education levels, wealth disparity, or the quality and accessibility of healthcare services. According to Li and Zhang (2024), other key factors that influence life expectancy include the quality and availability of medical services, which are not directly reflected in the healthcare spending control variable. The exclusion of these elements could result in inaccurate estimates. Moreover, urbanized provinces may have different healthcare and environmental conditions than rural areas, as evidenced by research conducted by Shao et al. (2022), who explains that those who migrate to urban areas tend to have better health conditions than those who remain in rural areas due to the availability of health services. This may have an effect on the coefficients, especially for urbanization.

Conclusions

This study provides empirical evidence that higher PM2.5 concentrations are significantly associated with lower life expectancy across Chinese provinces, while urbanization positively influences health outcomes. However, healthcare expenditure shows no significant short-term effect, likely due to the limited time frame and the confounding impact of the COVID-19 pandemic, which inflated spending without immediate improvements in life expectancy. The study's five-year scope restricts its ability to capture long-term dynamics, particularly in the case of healthcare investments. Additionally, the exclusion of relevant socio-economic variables such as education, income inequality, and healthcare quality may lead to omitted variable bias. Despite these limitations, the findings underscore the urgent need for environmental and public health policy coordination to enhance life expectancy in China. Future research should adopt a longer time horizon and incorporate broader determinants of health to obtain more comprehensive insights.

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