



Influence of Environmental Pollution on Residents' Health: Evidence from Hubei, China

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ABSTRACT

To maintain the rapid development of China's economy and simultaneously maximize the existing natural resources, China discharges a large amount of waste from its life and production activities into the environment. Environmental pollution is also becoming increasingly serious. The continuous reduction and deterioration of environmental quality has substantially affected the balance of the ecosystem and caused increasingly serious harm to public health. This study organized the research status quo and research hotspots on residents' health loss caused by environmental pollution to further analyse the influence of environmental pollution on residents' health. The quantitative relationship between environmental pollution and public health level was calculated using the expanded Grossman health production function and the data of 13 prefecture-level cities in Hubei, China from 2005 to 2017. Results show that residents' health is closely related to environmental pollution and a few macroeconomic factors. The population mortality rate has a significant positive correlation with the three influencing factors of industrial sulphur dioxide emissions, industrial smoke dust emissions, and GDP per capita. A significant negative correlation exists between the death rate of the population and number of years of education per capita and the investment in environmental protection. The number of doctors per 10,000 population and urbanization rate have no evident impact on the mortality rate of the population. The conclusions have certain reference value for analysing the severity of public health value loss and reducing public health value loss caused by environmental pollution.

INTRODUCTION

Given the rapid development of China's economy, the ecological environment has been seriously damaged, while public health has been increasingly harmed by environmental pollution. The environmental pollution problem has posed a threat to people's basic life and survival. Accordingly, the public health risk caused by environmental pollution has become a worldwide topic. In particular, the health risks caused by environmental pollution are considerably severe in a few countries and regions where public services are relatively insufficient. Environmental pollution is depleting environmental resources, on which China's economic and social development depends. The sustainable development of the social economy has been facing unprecedented pressure, while environmental pollution has posed a growing threat to public health. While seeking economic development, exploiting and utilizing the existing natural resources, and creating a new living environment, humans also discharge a large amount of wastes generated from living and production activities, thereby leading to environmental pollution. The rapid economic growth has resulted in an increase in wastes produced and discharged, thereby wors-

ening environmental pollution.

The economy of Hubei Province in China remains in the industrialization development stage. Fig. 1 shows that the secondary industry accounts for a large proportion of the economy. Under such an industrialization development mode of "high pollution, high energy consumption, and low output," the environmental quality in Hubei shows a deteriorating trend, while the public health level of the province is also seriously affected. Given the continuous improvement of public living standards, the spread of environmental protection and health knowledge, popularization of mass education, and frequent exposure to environmental pollution incidents have led the public to consciously focus on the environmental problems. The awareness on environmental protection was also strengthened. Under such circumstances, actively exploring and understanding the current situation of environmental pollution and how it causes the loss of public health value have immense theoretical and practical significance. In particular, such endeavour will enable stakeholders to solve the current problems faced by Hubei, recommend policies and measures to protect the environment, and improve environmental quality.

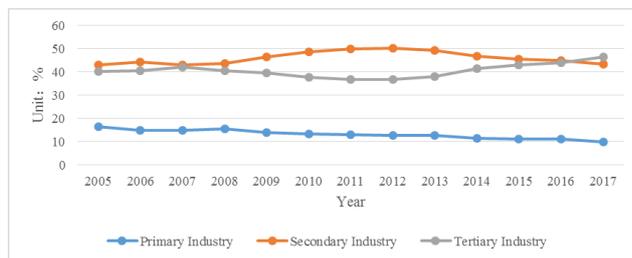


Fig. 1. Proportion of the three industries in Hubei from 2005 to 2017.

EARLIER STUDIES

The research on the impact of environmental pollution on residents' public health has long been the concern of scholars. Numerous studies have analysed the impact of air pollution on public health. Foreign scholars have studied environmental pollution and public health earlier than Chinese scholars. The environmental impact on health mainly depends on the concentration of pollutants, exposure response coefficient, and the number of exposed urban population. Analytical methods based on exposure response and dose effect principle mainly focuses on the research of environmental pollution on residents' health loss. Grossman (1972) first proposed that health should be regarded as a type of consumer good that can bring utility and income. The classic health production function was eventually obtained by introducing health into the utility function and maximizing the utility of an individual's entire life. This function shows that personal lifestyle, heredity, health care, and age are among the main factors that affect the formation of health. Pope et al. (2002) studied the causes of death of 500,000 residents in the US and determined that, in addition to controlling risk factors, such as smoking and diet, fine particulate matter, sulphur dioxide, and other related pollutants are related to the total mortality involving pulmonary heart disease and lung cancer. Wang et al. (2006) proved how the use of advanced coal gasification technology can provide substantial public health benefits in Eastern China. However, if such a control technology remains lacking, the impact of air pollution on public health will substantially increase in 2020. Mestl et al. (2006) proposed that indoor air pollution caused by the use of solid fuels has a serious impact on health and suggested that the impact of such pollution on residents' health should be avoided by switching to clean fuels. Wang (2010) analysed the impact of economic growth, population, and technological progress on energy consumption and the environment in China and predicted that the emission of PM10 and sulphur dioxide and their detrimental effects on health will increase substantially in the next 12 years. Gohlke et al. (2011) used time series data sets from 1965 to 2005 from 41 countries with

different development paths to analyse the relationship among electricity consumption, coal consumption, and mortality. The results proved that an increase in coal consumption leads to a considerable increase in mortality. Matus et al. (2012) performed policy prediction model analysis to show that China's health economic losses caused by air pollution emissions have brought substantial burden to the country's economy, with the loss of residents' welfare caused by air pollution reaching 112 billion dollars in 2005. Kan et al. (2012) explained that the decline in air quality causes and aggravates acute deaths related to various health hazards, including respiratory diseases, cardiovascular diseases, lung cancer, and even sensitive populations, thereby posing as an immense threat to public health. Chen et al. (2013) used the model of synergistic effect of atmospheric resources and studied that the change of atmospheric pollutant concentration in Taiwan has an impact on the potential loss of life. Sram et al. (2013) tracked the health status of 1,492 children in the Czech Republic and showed that air pollution seriously affects children's health and easily leads to an increase in the incidence rate of respiratory diseases among children. Voorhees et al. (2014) analysed the loss of public health caused by PM2.5 in Shanghai and showed that if the air quality in Shanghai meets the national level two standard, then the monetary value for avoiding all deaths is 1.7 to 12 billion RMB. Jiang et al. (2016) analysed the correlation mechanism between traffic-related air pollution and cardiac metabolic risks. Accordingly, long-term exposure to traffic-related air pollution may lead to the development or aggravation of cardiac metabolic disorders. Costa et al. (2017) substantiated that particular matter, nitrogen dioxide, and carbon monoxide have an impact on the increase in mortality by using the mortality rate of elderly residents in Sao Paulo, Brazil from 2000 to 2011. Yang (2017) analysed the relationship between residents' exposure to air pollution and health status and showed that air pollution had a certain correlation with health damage. Chen et al. (2018) conducted a survey among 8,497 Taipei residents over 65 years old in Taipei and confirmed that chronic exposure to traffic-related air pollution will increase the risk of chronic kidney disease. Shen et al. (2018) held that the migration of migrant workers has led to the size and spatial pattern of pollutant emissions. This research showed that large-scale interprovincial migration will lead to an increase of PM2.5 level. This result suggests that policies should be formulated to guide the migration direction reasonably to prevent the deterioration of environmental air quality in large cities. The existing literature has shown the extensive research results on the impact of environmental pollution on health, thereby enabling the public to acquire a profound understanding of the harm of environmental

pollution. However, additional practical and feasible measures are necessary, apart from formulating measures against environmental pollution, to help people improve their health. The current study uses panel data of 13 prefecture-level cities subordinate to Hubei from 2005 to 2017. On the basis of Grossman's health demand function, this study constructs a macro health production function and analyses the factors that influence the health of residents in China, including environmental pollution, public services, GDP per capita, and other related factors. To improve the residents' health level, all regions of Hubei should adopt different education, health care, environmental protection, and other related public policies on the basis of the adverse effects of environmental pollution on residents' health and the effects of different types of public services on improving their health.

MATERIALS AND METHODS

Modelling

This study draws on Grossman's theory of health production function, which holds that health is a commodity produced by a series of investments, including lifestyle, living environment, education, personal income, and medical and health services. The environmental pollution variable is added to the model, which is eventually built as follows:

$$H_{it} = \beta_1 E_{it} + x_{it} \beta_i + \mu_i + \varepsilon_{it} \quad \dots(1)$$

Where, H_{it} represents the residents' health level of city i in t year, E_{it} represents the environmental pollution situation of city i in t year, x_{it} represents the other control variables, μ_i represents the regional effects related to regional development and mainly reflects the influence of a few unobservable regional variables, ε_{it} represents random disturbance terms varying with time, and β_1 represents the parameters to be estimated and reflects the impact degree of environmental pollution on residents' health level. In this case, ε_{it} is assumed to be independent and identically distributed and unrelated to μ_i . In the estimation methods commonly used for panel data, scholars often assume that the slope of individual regression equation is the same, but the intercept terms are different, thereby determining individual heterogeneity. When μ_i is related to an explanatory variable, the fixed effect model can be selected for estimation to eliminate the estimation deviation caused by the unobservable fixed effect. However, the random effect model should be used for estimation once μ_i is not correlated with all the explanatory variables. The two estimation methods will be selected using the Hausman test.

Variable Selection

- (1) **Dependent variable:** Given that the health is a multi-dimensional and complex concept, a unified index is currently lacking to measure this concept. Hence, health can only be measured by a few approximate indicators, such as life expectancy and mortality per capita. Therefore, the current study chooses population mortality (death) as a measure of health.
- (2) **Independent variable:** To measure environmental pollution, the majority of scholars believe that solid particles, such as PM2.5 and PM10, are the main pollution sources that affect environmental quality and harm human health. However, such data are not easily available. This study refers to the industrial sulphur dioxide emissions (ECO1) and industrial soot emissions (ECO2) from different cities selected in previous studies to characterize the environmental quality of a certain region. These two indicators of environmental quality are also verified and approved by many scholars.
- (3) **Control variable:** Many reasons are cited for the considerable uncertainty in the relationship among various social and economic factors that affect health and various public policies. Therefore, this study also introduces other control variables. Per capita years of education (X_1), which is a comprehensive index that can reflect the education level of citizens in the region, is used as an index to measure the public service of education. The number of doctors per 10,000 populations (X_2) is used as an indicator to measure the provision of health care in the region. Environmental protection investment (X_3) mainly covers investment in urban environmental infrastructure construction, investment in industrial pollution source control, and environmental protection investment in environmental protection acceptance projects completed that year. Per capita GDP (X_4), it reflects the impact of per capita economic level on health, shows completely different situations in different periods when the per capita GDP increases. Urbanization rate's (X_5) impact on residents' health is uncertain.
- (4) **Data source:** The data used in this study are from the Statistical Yearbook of Hubei and China Environmental Statistics Yearbook from 2005 to 2017 and involved 13 prefecture-level cities in Hubei (i.e., 12 prefecture-level cities and 1 autonomous prefecture). To eliminate the sequence correlation, transform the possible non-linear relationship into linear relationship, and reduce the abnormal value, non-normal distribution, and heteroscedasticity of variables, this study uses logarithm processing on the industrial sulphur dioxide emissions (EOC1), industrial smoke emissions

(EOC2), per capita education years (X_1), number of doctors per 10,000 population (X_2), investment in environmental protection (X_3), per capita GDP (X_4), and urbanization rate (X_5).

RESULT ANALYSIS

This study selects “cross-section weight” as the weight item to allow heteroscedasticity in the different sections when performing regression analysis on the panel data model. In the estimation method, the panel corrected standard errors method is used to effectively deal with complex panel error structures. From the perspective of the overall effect of regression, the P value of the F value of the regression results at the national and regional levels is 0.001; thereby indicating that the model passed the F test and the overall regression effect is good. Table 1 shows the specific regression results.

Table 1 shows the following results:

- (1) The Hausman test results show that the corresponding *p*-value is 0.001, thereby indicating that the fixed effect model is suitable for analysis.
- (2) From the explanatory variables, industrial sulphur dioxide emissions (ECO1) have a significant positive correlation with population mortality. This result indicates that an increase in environmental pollution will significantly reduce the health level of the residents. The emission of industrial smoke dust (ECO2) is significantly positively correlated with the mortality rate of the population. This result indicates that the emission of industrial smoke dust is evidently unfavourable to the health status of residents. Thus, this effect is significant. Given that Hubei mainly relies on industrial manufacturing, substantial industrial pollution will inevitably occur while the economy grows rapidly. The emission of major pollutants in waste

gas and waste has exceeded the ecological environment tolerance level, thereby substantially affecting the health level of the residents.

- (3) From the perspective of control variables, per capita education years (X_1) has a significant negative correlation with population mortality. This result indicates that the provision of public education services has a positive and significant impact on residents’ health. The improvement of residents’ education level has significantly increased the life expectancy per capita, while the residents’ receiving education level and health awareness has also been significantly enhanced, thereby resulting in new lifestyles and behaviour habits. A negative correlation exists between the number of doctors per 10,000 populations (X_2) and mortality rate of the population. However, this result is not significant, thereby showing that although the number of doctors per 10,000 populations has a certain positive effect on the reduction of mortality rate, such a variable has a weak impact on health. Although the government’s investment in medical and health resources in Hubei has increased in recent years, thereby easing the total amount on the supply side, the medical and health resources allocation structure is unreasonable and the medical needs of the relatively poor and backward areas have not been relatively met. In addition, the top-level design of the government is ideal, thereby relatively verifying the underutilization of health care resources in Hubei. The significant negative correlation between investment in environmental protection (X_3) and population mortality shows that public services in this area are beneficial to residents’ health. Per capita GDP (X_4) shows a significant positive correlation with the mortality rate of the population. Given that Hubei is currently in a stage of rapid economic development, industrial output plays an important role in economic development. Meanwhile, the industrial energy consumption structure in Hubei is dominated by coal, thereby producing environmental pollution that has a relatively adverse impact on residents’ health. Urbanization rate (X_5) has a negative correlation with the population mortality rate, but is not significant. This result shows that with the acceleration of urbanization in Hubei, numerous population clusters do not use residents’ health. Meanwhile, the negative impact on residents’ health in urbanization is greater than the positive impact, thereby showing a negative impact on health in terms of net effect.

Table 1: Regression results.

Variables	Death	
	RE	FE
Constant	6.214	8.654
ECO1	0.145**	0.241**
ECO2	0.014**	0.009***
X1	-0.341	-0.274**
X2	0.015*	-0.004
X3	-1.864*	-0.687***
X4	0.541***	0.689***
X5	-0.087	-0.287
Hausman Test	8.974 (0.001)	

Note: FE and RE represent the fixed and random effect models, respectively; *, **, *** are significant at the 10%, 5% and 1% statistical levels, respectively.

POLICY RECOMMENDATIONS

Adjusting Industrial Structure and Strengthening Environmental Pollution Control

In recent years, the environmental pollution level in Hubei has increased annually. The level of environmental quality has continuously decreased, along with the degree of deterioration accelerating. The speed of industrialization and the economy in general are developing at a rapid pace. The high-intensity consumption of various resources and discharge of a large amount of smoke, waste gas, and wastewater have substantially polluted the environment. At present, Hubei remains dominated by the secondary industry, which intensively consumes non-renewable resources. The limitation of technology level makes it impossible for the secondary industry to discharge a large amount of waste while consuming energy to adopt better treatment methods in time, thereby resulting in the aggravation of environmental pollution. Therefore, the government should formulate the corresponding policies to provide guidance; vigorously develop clean tertiary industries, such as green environmental protection, service, and high and new technology industries; strictly control the emission of industrial waste; make industrial development change from resource-intensive to technology-intensive; reduce energy consumption and emission; strictly supervise and control the emission of pollutants from existing enterprises; and improve the quality of atmospheric environment and water environment.

Developing Clean Energy and Optimizing Energy Consumption Structure

The regional environmental pollution in Hubei is unbalanced and the task of environmental protection remains arduous. Hubei's overall energy consumption is dominated by coal, thereby easily producing a large amount of sulphur dioxide, smoke dust, and other pollutants. Therefore, the top priorities in China include improving the efficiency of energy utilization, vigorously developing clean energy technologies with minimal pollution, seeking alternative energy sources, enabling the country to realize energy transformation, and controlling environmental pollution from the source. Moreover, the single energy structure dominated by coal should be changed. Under the established economic conditions, particularly through energy transformation, the proportion and types of clean energy consumption should be increased, while the quantity and types of clean energy should be coordinated. Moreover, a potential clean energy should be developed and maximized, while the consumption of traditional energy, such as coal, should be considerably reduced to reduce pollutant emis-

sion, thereby reducing the loss of public health of residents.

Increase Investment in Environmental Health to Improve Public Health

The level of public health is closely related to environmental pollutants, medical research investment, number of health departments, number of health personnel, and other factors. To strengthen the research on the relationship between environmental pollution and public health, clarifying the health effects of environmental factors, comprehensively developing the evaluation and identification technology of environmental pollution's impact on public health, and proposing control methods to block and reduce the harm of pollutants to public health can provide scientific basis for the prevention and treatment of diseases caused by environmental pollution. Accordingly, the impact of environmental pollution on public health will be mitigated and the level of public health will be improved. At present, basic research in the fields of environment and health in Hubei is weak, while the mechanism of action of the relevant environmental pollutants is unclear, thereby resulting in difficulty to formulate and perfect the pertinent technical standards, quantify losses, and identify compensation, among others. Accordingly, we should maximize state-supported large-scale scientific research programs to implement such projects as risk assessment and model research of public health damage caused by different environmental pollutants, pollutant source tracking methods, and control technologies. When undertaking large-scale national projects, research institutes should maximize their project resources, forge teams, cultivate scientific research talents, and form high-quality scientific research teams.

Increasing Investments in Scientific Research in Environmental Health and Providing Policy Support

For the relevant research in the field of environmental pollution and public health impact, priority should be given to evaluate and increase the allocation of research funds in this field. Moreover, the relevant government departments and enterprises at all levels should strongly support and cooperate with the research process. To jointly address key problems, we will organize specialized environmental and health research institutions and laboratories and collaborate with scientists from such fields as environmental protection, epidemiology, biology, medicine, chemistry, and other related disciplines. Moreover, we will positively pursue regional and international cooperation and maximize all available and effective resources. Local governments should engage in public health promotion activities to raise public awareness of environmental protection and health. Through

various mass media, such as news, radio, television, and the internet, publicity and education activities related to the impact of environmental pollution on the loss of public health value can be implemented, environmental and health-related laws and regulations can be publicized, public legal awareness and environmental protection awareness can be improved. Engagements in these activities will enable the public to realize the extent of the impact of environmental pollution on public health. Moreover, the concepts of environment and health can be integrated into public concepts, thereby guiding practice to enhance public awareness of self-prevention and protection and actively contribute to national environmental and health undertakings. Thus, people will consciously adopt measures to prevent environmental pollution from negatively affecting public health.

CONCLUSION

Environmental pollution is posing an increasing threat to public health. While seeking economic development, exploiting and utilizing the existing natural resources, and creating a new living environment, humans also discharge a large amount of wastes generated from living and production activities, thereby contaminating the environment. This study takes Hubei as the research object and uses the expanded Grossman health production function to calculate the quantitative relationship between environmental pollution and public health level in this province. Lastly, this research presents a few suggestions and measures to protect the environment and improve the public health level. The results show that the population mortality rate is significantly positively correlated with the three influencing factors of industrial sulphur dioxide emissions, industrial smoke dust emissions, and GDP per capita. A significant negative correlation exists between the death rate of the population and number of years of education per capita and investment in environmental protection. The number of doctors per 10,000 population and urbanization rate has no evident impact on the mortality rate of the population. In-depth research can be conducted on the following aspects: (1) formation of a perfect and systematic evaluation system of residents' health loss caused by environmental pollution, (2) whether substantial differences exist on the impact of the different types of environmental pollution on residents' health in different regions, (3) enhancement of environmental pollution indicators, (4) government's investment in public health services, and (5) improvement of residents' health.

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