Effect of Air Pollution and Rural-Urban Difference on Mental Health of the Elderly in China

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Abstract

Background: China has become an aging society, and the mental health problem of the elderly is increasingly becoming prominent. This paper aimed to analyze the effect of air pollution and rural-urban difference on mental health of the elderly in China.

Methods: Using the data from the China Health and Retirement Longitudinal Survey (CHARLS, 2013), after controlling the social demography variable via Tobit and Probit, a regression analysis of the effect of air pollution and rural-urban difference on mental health and psychological disorder was conducted on 6,630 old people ($\geqq$60 yr old) of China from February to April 2015. Mental health and psychological disorder of the elderly were measured by the CES-D score of respondents. Air pollution degree of counties and cities (n=123) were measured by SO_2 emission.

Results: 27.8% of old people had psychological disorders. Air pollution significantly influenced the mental health of the elderly, showing a positive "U-shaped" curve (*P*<0.001). In China, the urban elderly had better psychological status than the rural elderly had. The female elderly had more serious mental health problems. Marriage, education, and social activities had positive effects on the mental health of the elderly.

Conclusion: China's local governments should consider the influence of air pollution on the mental health of the elderly during economic development. This paper recommends paying attention to the difference in mental health between the urban and rural elderly when making public health policies. Governments could improve the mental health of the elderly by enriching social activities and increasing employment opportunities of the elderly.

Keywords: Air pollution, Urban, Rural, The elderly, Mental health

Introduction

China has the largest elderly population in the world. The health of the elderly has elicited considerable social attention. With the social and economic development, health care conditions and living standards improve continuously, thus improving the physical health of the elderly and prolonging their life span. According to statistics from the Chinese Ministry of Health, in 60 years of development, the average life span has increased by 39.5 years, reaching 74.8 years old in 2010 (1). However, mental health problems of the elderly are increasingly becoming prominent. Reports show that 74 million Chinese elderly suffer serious depressive symptoms (2). Serious psychological problems not only hurt physical and mental health and family happiness of the elderly, but also cause various social problems. Mentally and physically healthy old people save public resources and national finance. Being healthy enables the elderly to maintain high productivity and contribute to society. Therefore, studying the mental health of the Chinese elderly is important.

Since the reform and opening-up policy, China has sacrificed high environmental cost for rapid economic development, consequently bringing serious threats to public health. Approximately 300,000 to 500,000 people are killed early by indoor air pollution every year in China (3). However, controversy has arisen in the academe concerning the effect of air pollution on mental health. The tradeoff between rapid economic development and environmental degradation has complicated this controversy (4). Economic development improves the quality of living and social welfare, and thereby, improves the mental health of the public. However, with the further worsening of environmental problems, its negative effects on people's mental health have gradually surfaced. Such a complicated relationship introduces difficulties in comprehending the influence of air pollution and other environmental problems on mental health. Meanwhile, China is a country with an outstanding urban-rural dual structure. Significant differences occur between urban and rural regions in terms of medical insurance, living standards, social culture, and lifestyle. Whether those differences will be reflected on the mental health level of the elderly in urban and rural areas is an important question to be considered when studying the mental health of Chinese elderly. Thus, this paper addresses three problems by using data from China, namely, 1) Will air pollution influence the mental health of the elderly? How? 2) Is mental health different between the elderly from urban and rural regions? In what ways? 3) Which factors determine the psychological disorder of the elderly?

Literature review

Medical and sociological research reported that the SO_2 concentration in air would threaten physical health and even cause respiratory system diseases (5). Being healthy is not only being free from diseases or weakness, but also the perfect combination of body, mental, and social adaptation (6). Hence, research on health also focuses on mental health. Clark et al. studied the 9 to 10-year-old British children and noted that air pollution (NO_2) in schools will not influence their cognition and health. After the NO_2 level was controlled, they found that aircraft noise and road traffic noise have significant different effects on cognition and health of children (7). A study on 1,546 samples collected from Salt Lake County, Utah, USA found that higher SO_2 and NO_2 particles would increase risks of suicide (8). From a medical perspective, tiny particles in air pollution will hurt the nervus centralis in humans after entering the brain and may cause depression and apoplexy (9). Considering the physiological and psychological differences of the elderly with children and youth, the relationship between the mental health of the elderly and air pollution has elicited considerable attention in medical research attention. Madrigano et al. studied the 699 elderly males and found the internal relation between PM2.5 and people's mood (optimistic or pessimistic) (10). However, Yi et al. stated in a study of 732 old people ($\geqq$65 years old) in Boston that no correlation had been found between air pollution and depressive symptoms (11). These two studies report different results primarily because most medical researchers are based on individuals or non-random samples, which may incur selection bias. Therefore, we shall maintain a cautious attitude toward the corresponding research conclusions and policy implications.

Scholars have also focused on the relationship between various social demographic characteristics and mental health. Small changes in smoking, drinking, sports, and diet would significantly affect both physical and mental health (12). Reducing smoking and increasing recreational sports could improve physical and mental health (13). Some scholars explored mental health from the perspective of social relations, and pointed out that social communication positively affected the health of the aged (14, 15).

Studies on the mental health of Chinese elderly are numerous. Some scholars studied the mental health of the elderly from the perspective of urban-rural difference. A study on 404 old people ($\geqq$60 years old) done in Chinese rural and urban regions, found a significant difference in mental health between these regions (16). The urban old

people have better mental health than do rural old people (17). However, Mikael et al. offered the opposite conclusion, and they believed that rural old people had better mental health than urban old people had (18). Some studies are based on the relation between chronic diseases and mental health. Sun et al. studied 64,000 old people (≧65 years old) in Hong Kong and revealed a significant correlation between depression and chronic diseases, such as cardiovascular disease and coronary artery disease (19). Moreover, Norstrand and Xu analyzed the health conditions of Chinese old people (≧65 years old) from the perspective of social relations, and found a significant relationship between mental health of urban old people and social relations (20). Based on demography, mental health deteriorated greatly with aging, while physical health and income could improve mental health (21).

To sum up, although many research results concerning the mental health of the elderly have been achieved, mental health is characterized by complicated and diverse influencing factors. These factors lead different research perspectives and thereby inconsistent conclusions, which may be caused by the lack of comprehensive and representative data. Moreover, only few studies on the relationship between mental health of Chinese elderly and air pollution have been reported. Based on previous studies, this paper establishes a model to analyze comprehensively the influencing factors of the mental health of the elderly in China from the perspective of urban-rural difference and by combining local air quality, individual characteristics, and lifestyle. This study also applies the representative data from China Health and Retirement Longitudinal Survey (CHARLS) (22) and regional air pollution to conduct verify the established analysis model.

Materials and Methods

Data specification

The data were from the 2013 CHARLS published by the National School of Development of Peking University. The CHARLS project covered 28 provinces, cities, and municipalities in China and investigated the health, economy, and family of the population (≧45 years old). The respondents in this paper were at least 60 years old. After missing and inappropriate data were deleted, 6,630 effective samples for final statistics were chosen, including 3,930 rural samples and 2,700 urban samples. Air pollution data of different regions were provided by China City Statistical Yearbook (23).

Variable design

The mental health of the Chinese elderly was the explained variable of this paper. Chinese Ministry of Health announced that mental diseases, like depression and senile dementia, were the main threats to the health of the Chinese elderly (24). Surveys reported that the population aged 65 or more years has a 4.4% chance of having depression. As a result, this paper evaluated the mental health degree of the elderly using cognition and depression data in the CHARLS questionnaire. Using the method of the Center for Epidemiological Studies Depression Scale (CES-D) as reference (25), CHARLS designed a simple questionnaire of 10 problems, including feeling annoyed by trifles, difficulties in concentration, feeling down in the dumps, encountering difficulties in doing anything, being hopeful for the future, feeling frightened, experiencing poor sleep, feeling happy, feeling lonely, and encountering difficulties in continuing life. Each problem has four answers based on time span, namely, 0 for <1d; 1 for 1d<answer<2d; 2 for 3d<answer<4d; 3 for 5d<answer<7d. Among these 10 questions, the 5th and 8th questions adopt reverse scoring. Finally, scores of these 10 problems are added to identify cognition and depression degrees of respondents. The higher the CES-D score is, the more depressed the elderly will be.

Based on the design principle of CES-D, psychological disorder occurs when mental health problems become serious. Therefore, the influencing factors of the psychological disorder of the elderly were further observed. Based on the processing method of Yi et al. and Zhao Yaohui et al. (2,11), respondents with more than 10 CES-D scores were determined to have depression symptoms, that is, having a psychological disorder.

Explanatory variables included urban-rural variable and air quality variable. The former was a two-value virtual variable. The latter variable, using the method of Chen Shuo et al. (26), was measured by SO_2 discharge in cities and counties in which the respondents live. The study area covered 123 cities and counties in 28 Chinese provinces. To further analyze the effect of respondent background on mental health, this paper controlled demo-graphic variables, including age, gender, marriage, education, and physical health. Among the variables, physical health was measured with chronic disease and physical disability. Meanwhile, the lifestyle of the elderly was introduced as a variable, including smoking, drinking, social activity participation, and employment. The definition of variables was shown in Table 1.

Table 1: Definition of variables included in the study

Variables		Definition
Dependent variables		
Mental health		Total CES-D scores: 0-30
Psychological disorder		1 for psychological disorder; otherwise, 0.
Explanatory variables		
Air quality	Air pollution	SO_2 drainage of places where respondents are living in (2012) (unit: 10,000 tons)
	Square of air pollution	Square of SO_2 drainage
Urban-rural variable		1 for urban areas and 0 for rural areas.
Personal features	Age	$\geqq$60 years old
	Gender	1 for male respondents and 0 for female.
	Marriage	1 for married respondents and 0 for single respondents.
	Primary school	Respondents having primary school education background are scored 1; otherwise, 0.
	Middle school	Respondents having middle school education background are scored 1; otherwise, 0.
	Vocational education, junior college and above	Respondents having education background of vocational education, junior college and above are scored 1; otherwise, 0.
	Physical disability	Disabled respondents are scored 1 and rest are scored 0.
	Assets	Amount of deposit in 2013 (unit: 1000 RMB)
	Chronic disease 1	Respondents with one or more chronic diseases are scored 1; otherwise, 0.
	Chronic disease 2	Respondents with three or more chronic diseases are scored 1; otherwise, 0.
Lifestyle	Smoking	Smoking respondents are scored 1 and rest scored 0.
	Drinking	Drinking respondents are scored 1 and rest scored 0.
	Social activity	Respondents having social activities in the past one month are scored 1; otherwise, 0.
	Employment	Respondents having jobs are scored 1; otherwise, 0.

Note: 1) Chronic disease data in CHARLS included 12 common diseases of the elderly, namely, hypertension, hyperlipidemia, diabetes mellitus, cancer, chronic lung diseases, liver disease, heart disease, apoplexy, kidney disease, gastric disease or digestive system disease, arthritis or rheumatism, and asthma. 2) Education background was divided into four groups, namely, illiteracy, primary school, middle school, as well as vocational education and junior college or above. The illiteracy is used as the control group. 3) Disability included five options, namely, physical disability, brain damage,

blindness or half-blindness, deafness or half-deafness, and dumb or serious stammer. In this paper, a virtual variable "Disability" was designed. Respondents without disability were scored 0; otherwise, 1.

Empirical model
1) *Tobit model for evaluating mental health condition of the Chinese elderly*

Total CES-D score is the indicator of mental health of the elderly, which ranges between 0 and 30. Using the least square method directly will render the estimate of parameters partial and inconsistent (27). Hence, this paper used Tobit model for regression analysis. The basic model is:

$$y_i^* = \alpha + \beta_1 Rural_i + \beta_2 SO_i + \beta_3 SO_i^2 + Z_i X_i + \varepsilon_i \quad [1]$$

$$y_i = \begin{cases} y_i^*, & 0 \le y_i^* \le 30 \\ 0, & y_i^* > 30 \text{ or } y_i^* < 0 \end{cases} \quad [2]$$

where y_i^* is a potential variable. y_i is the total CES-D score of respondent i, which is used to assess their mental health. SO_i is the SO_2 drainage of the city in which respondent i lives. SO_2 drainage has two effects on mental health of the elderly. On the one hand, SO_2 drainage amount reflects the industrial and economic development of cities, thereby affecting mental health of local residents through income level. On the other hand, SO_2 will affect physical and mental health of residents. Therefore, the square of SO_2 drainage was added into the model analysis to determine the influence factor of air quality on mental health. $Rural_i$ is the urban-rural variable, 1 for urban regions and 0 for rural regions. X_i is the control variable, involving age, gender, marriage, education, physical health, smoking, drinking, social activity, and employment. ε_i is the error item and Z_i is the regression parameter vector.

2) *Probit model for analyzing psychological disorder of the Chinese elderly*

Respondents will be evaluated depressed when y_i^* (CES-D score) in Equation [1] increases to a certain extent (10 score). A virtual variable D_i is defined, which represents if respondent i has psychological disorder (Yes:1; No: 0), which is identified by the presence of depressive symptoms. D_i and y_i^* are then correlated:

$$D_i = \begin{cases} 1, & 11 \le y_i^* \le 30 \\ 0, & 0 \le y_i^* < 11 \end{cases} \quad [3]$$

Considering that D_i is a 0, 1 binary discrete variable, we chose the binary selection Probit model to analyze the influencing factors of psychological disorder of the elderly. The Probit model is expressed as:

$$\begin{aligned} Pr(D_i = 1) &= Pr(y_i^* \ge 11) = Pr(\alpha + \beta_1 Rural_i + \beta_2 SO_i + \beta_3 SO_i^2 + Z_i X_i + \varepsilon_i \ge 11) \\ &= Pr(\varepsilon_i \ge 11 - \alpha - \beta_1 Rural_i - \beta_2 SO_i - \beta_3 SO_i^2 - Z_i X_i) \\ &= \Phi(\alpha - 11 + \beta_1 Rural_i + \beta_2 SO_i + \beta_3 SO_i^2 + Z_i X_i) \end{aligned} \quad [4]$$

Results

Statistical description

The descriptive statistics of all samples, urban samples, and rural samples are listed in Table 2. Rural samples have significantly higher CES-D scores than do the urban samples. The average CES-D score of all samples is 8.09, which is close to the critical value of depression in the simple CES-D questionnaire ($\geqq 10$). The proportion of respondents with higher than 10 CES-D scores and evident depressive symptoms reaches as high as 27.8%. SO_2 drainage is higher in urban regions than in rural regions. However, no significant difference was observed between urban and rural samples in terms of age, gender, marriage, physical health indicators, and social activity. The average age of the elderly was 67.66 years, and 67% old people had at least one chronic disease. A total of 15% respondents had physical disability. With respect to lifestyle, smoking and drinking respondents accounted for 46% and 41% of the total samples, respectively. In terms of educational background, urban samples present nearly 10 times higher proportions of vocational education or above than rural samples. Only 1% rural sample had received vocational education, junior college or above. Furthermore, deposit per capita of the urban samples was more than four times higher than that of the rural samples, but employment showed the opposite. A total of 63% rural samples had jobs, but only 28% of urban samples were employed. Urban and rural samples had both similarities and differences in terms of mental health and various influencing factors, which deserves further analysis.

Table 2: Statistics description of samples

Variables	All samples (n=6630)		Urban samples (n=2700)		Rural samples (n=3930)	
	Means	Standard deviation	Means	Standard deviation	Means	Standard deviation
CES-D scores	8.09	5.86	7.08	5.37	8.79	6.08
Psychological disorder	0.278	0.45	0.22	0.414	0.317	0.465
Urban-rural	0.41	0.49				
SO_2 drainage	6.63	7.4	7.04	6.56	6.34	7.91
Square of SO_2 drainage	98.78	337.07	92.79	266.62	102.9	377.92
Age	67.66	6.35	67.78	6.55	67.56	6.21
Gender	0.52	0.499	0.5	0.5	0.53	0.499
Marriage	0.84	0.43	0.84	0.425	0.84	0.436
Primary school	0.46	0.49	0.43	0.496	0.48	0.5
Middle school	0.16	0.37	0.24	0.427	0.11	0.32
Vocational education, junior college and above	0.05	0.22	0.11	0.309	0.01	0.114
Physical disability	0.15	0.36	0.15	0.358	0.15	0.36
Social activity	0.55	0.497	0.62	0.484	0.51	0.5
Smoking	0.46	0.498	0.43	0.496	0.48	0.5
Drinking	0.41	0.49	0.39	0.488	0.41	0.493
Chronic disease 1	0.67	0.467	0.68	0.464	0.67	0.47
Chronic disease 2	0.41	0.407	0.23	0.421	0.19	0.397
Assets	7.6	47.04	13.9	71.55	3.33	13.04
Employment	0.49	0.49	0.28	0.451	0.63	0.483

The density distribution of CES-d (Fig. 1) reflects obvious differences among all samples, urban samples, and rural samples. The CES-D distribution of rural samples inclines to the right end of all samples and urban samples because the average CES-D score of rural samples is 8.79, which is higher than that of all samples (8.09) and urban samples (7.08). Moreover, the CES-D score of female samples is at the right end of the male samples.
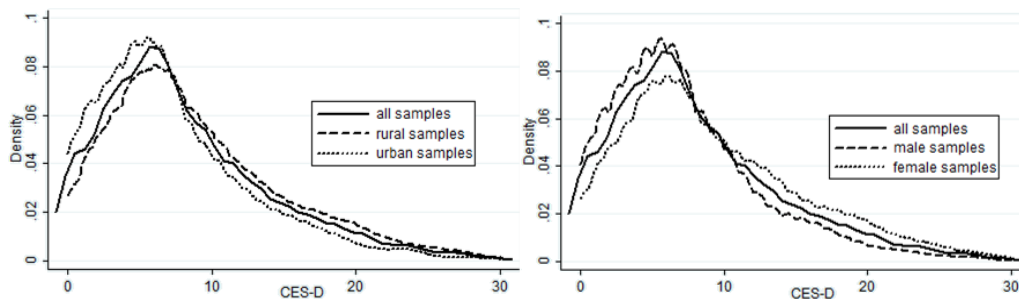

Fig.1: Density distribution of CES-D

Empirical results
1) Tobit regression results
This paper conducted a Tobit regression on all samples, urban samples, and rural samples using the total CES-D score as dependent variable. Results are listed in Table 3. Explanatory variables include air quality, urban-rural variable, demographic variables, and lifestyle variable.

Table 3 shows that the regression result of urban-rural variable is negative (the coefficient is -1.43, $P<0.001$), indicating that the CES-D score of urban old people is significantly lower than that of rural old people. This result reflects that urban old people have better mental health than rural old people do. SO_2 drainage has a significant negative effect on the mental health of all samples, urban

samples, and rural samples ($P<0.001$). This result reflects that SO_2 drainage lowers the CES-D score significantly, that is, reducing the depression degree of the elderly. The square of SO_2 drainage is positive, which means that increasing SO_2 drainage will intensify the depression degree of the elderly ($P<0.001$). The effect of SO_2 drainage on the mental health of the elderly presents a positive "U-shaped" curve.

The regression results of age, gender, and marriage are the same. With the increase in age, the mental health of both urban and rural old people improves significantly (the regression coefficients of all samples, urban samples, and rural samples are -0.062, -0.07, and -0.057, respectively, ($P<0.001$). The regression results of gender show that in both urban and rural areas, females have far better mental health than males ($P<0.001$). The regression coefficients of all samples, urban samples, and rural samples are -1.77, -1.38, and -2.07, respectively. Married old people have better mental health than single ones ($P<0.001$).

With respect to educational background, illiteracy is viewed as the control group. Different educational backgrounds affect urban and rural old people in similar ways but to various extents. Compared with the control group, primary school, middle school, and vocational education significantly improve the mental health of the elderly ($P<0.001$). However, only vocational education or higher educational background greatly improve the mental health of rural old people ($P<0.01$).

Physical disability greatly intensifies the mental problem of the elderly ($P<0.001$). The regression coefficients of all samples, urban samples, and rural samples are 2.02, 1.78, and 2.13, respectively. Samples with social activity present better mental health than those without ($P<0.001$). The regression results of smoking and drinking are very interesting. Viewed from all samples, smoking samples show poorer mental health than non-smoking samples. Regression coefficients of urban and rural samples have the same direction, but they have no statistical significance perhaps because old people struggling with mental problems often ease their mental problems by smoking. However, rural samples prefer drinking to smoking to alleviate mood. Therefore, drinking could significantly improve the mental health of rural samples ($P<0.01$).

Table 3: Tobit regression results on the influencing factors of the mental health of the Chinese elderly

Variables	All samples	Urban samples	Rural samples
Urban-rural	-1.43 *** (-8.90)		
SO_2 drainage	-0.174 *** (-7.61)	-0.118*** (-3.52)	-0.212*** (-6.79)
Square of SO_2 drainage	0.003*** (6.80)	0.0019** (2.29)	0.004*** (6.47)
Age	-0.062*** (-5.00)	-0.07*** (-3.96)	-0.057*** (-3.36)
Gender	-1.77*** (-8.37)	-1.38*** (-4.51)	-2.07*** (-7.19)
Marriage	-0.997*** (-5.70)	-1.16*** (-4.39)	-0.892*** (-3.85)
Primary school	-0.247 (-1.41)	-0.814*** (-2.80)	0.18 (0.81)
Middle school	-1.16*** (-4.81)	-1.766*** (-5.16)	-0. 426 (-1.22)
Vocational education, junior college and above	-1.73*** (-4.66)	-1.93*** (-4.54)	-2.14** (-2.48)
Physical disability	2.02*** (10.01)	1.78*** (6.02)	2.13*** (7.86)
Social activity	-1.05*** (-7.17)	-1.44*** (-6.42)	-0.719*** (-3.74)
Smoking	0.378* (1.94)	0.39 (1.38)	0.326 (1.24)
Drinking	-0.234 (-1.43)	0.154 (0.63)	-0.472** (-2.18)
Chronic disease 1	0.948*** (5.77)	1.03*** (4.19)	0.87*** (3.98)
Chronic disease 2	1.699*** (9.01)	1.42*** (5.24)	1.94*** (7.54)
Assets	-0.0026* (-1.72)	-0.0017 (-1.13)	--0.02*** (-2.76)
Employment	-0.281* (-1.73)	0.26 (1.04)	-0.68*** (-3.18)
R^2	0.0211	0.0194	0.0188
LRchi^2	870.78	314.63	468.91
Obs.	6630	2700	3930

Note: 1).t statistics in parentheses. 2).*$P<0.05$, **$P<0.01$, ***$P<0.001$. Two-tailed test.

The aged with more chronic diseases have poorer mental health ($P<0.001$). Deposit and employment are vital to the mental health of rural old people and are the main way for them to maintain life, which is why rural old people with more deposit and employment have better mental health ($P<0.001$). By contrast, these two factors are insignificant to urban old people.

Table 4: Probit model estimation results of psychological disorder of the Chinese elderly

Variables	All samples		Urban samples		Rural samples	
	coefficient	dy/dx	coefficient	dy/dx	coefficient	dy/dx
Urban-rural	-0.233***	-0.074***				
	(-6.06)	(-6.16)				
SO$_2$ drainage	-0.035***	-0.011***	-0.026***	-0.007***	-0.04***	-0.014***
	(-6.35)	(-6.36)	(-3.52)	(-2.94)	(-5.67)	(-5.68)
Square of SO$_2$ drainage	0.0007***	0.0002***	0.00036	0.0001	0.0008***	0.0003***
	(5.71)	(5.71)	(1.62)	(1.62)	(5.51)	(5.52)
Age	-0.011***	-0.0037***	-0.012**	-0.003**	-0.012***	-0.0044***
	(-3.88)	(-3.88)	(-2.50)	(-2.50)	(-3.24)	(-3.24)
Gender	-0.339***	-0.11***	-0.268***	-0.076***	-0.379***	-0.133***
	(-6.71)	(-6.73)	(-3.29)	(-3.30)	(-5.83)	(-5.86)
Marriage	-0.15***	-0.049***	-0.144**	-0.04**	-0.15***	-0.053***
	(-3.69)	(-3.69)	(-2.14)	(-2.14)	(-2.94)	(-2.94)
Primary school	-0.039	-0.0127	-0.121*	-0.033*	0.016	0.006
	(-0.96)	(-0.96)	(-1.65)	(-1.67)	(0.32)	(0.32)
Middle school	-0.217***	-0.067***	-0.297***	-0.078***	-0.124	-0.042
	(-3.69)	(-3.90)	(-3.29)	(-3.55)	(-1.53)	(-1.57)
Vocational education, junior college and above	-0.335***	-0.098***	-0.301**	-0.076***	-0.818**	-0.215**
	(-3.28)	(-3.74)	(-2.50)	(-2.82)	(-2.88)	(-4.47)
Physical disability	0.359***	0.125***	0.386***	0.12***	0.34***	0.125***
	(7.83)	(7.42)	(5.23)	(4.82)	(5.78)	(5.57)
Social activity	-0.187***	-0.061***	-0.292***	-0.084***	-0.114***	-0.04*** (-2.64)
	(-5.42)	(-5.40)	(-5.01)	(-4.90)	(-2.64)	
Smoking	0.032	0. 01	-0.031	-0.008	0.059	0.02
	(0.69)	(0.69)	(-0.42)	(-0.42)	(0.98)	(0.98)
Drinking	-0.092**	-0.03**	-0.085	-0.023	-0.093*	-0.032*
	(-2.35)	(-2.36)	(-1.29)	(-1.30)	(-1.89)	(-1.90)
Chronic disease 1	0.148***	0.047***	0.237***	0.064***	0.093*	0.032*
	(3.71)	(3.78)	(3.51)	(3.66)	(1.87)	(1.89)
Chronic disease 2	0.31***	0.106***	0.281***	0.084***	0.332***	0.12***
	(7.15)	(6.86)	(4.09)	(3.88)	(5.91)	(5.72)
Assets	-0.0018**	-0.0006**	-0.0008	-0.0002	-0.007***	-0.002***
	(-2.24)	(-2.25)	(-1.02)	(-1.02)	(-3.17)	(-3.18)
Employment	-0.032*	-0.01*	0.104	0. 03	-0.122**	-0.043**
	(-0.84)	(-0.84)	(1.59)	(1.56)	(-2.56)	(-2.54)
R^2	0.0727		0.0749		0.0648	
LRchi^2	570.03		212.97		318.46	
Obs.	6630		2700		3930	

Note: 1). Z statistics in parentheses. 2). *$P<0.05$, **$P<0.01$, ***$P<0.001$. Two-tailed test

2) *Probit regression results*

The Probit model estimation results of psychological disorder of all samples, urban samples, and rural samples are shown in Table 4. To better analyze the effect of explanatory variables on psychological disorder of the aged, Table 4 presents the marginal effect of explanatory variables. According to the estimation result of all samples, rural old people are more likely to suffer psychological disorder than urban old people are (the marginal

effect is -0.074, ($P<0.001$). SO_2 drainage imposes a great effect, presenting a positive "U-shaped" variation ($P<0.001$), which reflects that air pollution affects the psychological disorder and mental health of the elderly in the same way.

Aging could greatly reduce the probability of psychological disorder ($P<0.001$). On the average marginal effect, the probability of psychological disorder of females is 11% higher than that of males, which is significant at 1% level. The probability of psychological disorder of married samples is 4.9% lower than that of single samples ($P<0.001$). Viewed from all samples and urban samples, middle school and higher educational background could significantly reduce risks of psychological disorder ($P<0.001$). However, only vocational education, junior college, and higher educational background could greatly reduce risks of psychological disorder of rural samples ($P<0.01$).

Compared with physically healthy samples, disabled samples have 12.5% higher risks of having mental diseases ($P<0.001$). However, social activity could reduce the risk of mental diseases by 6.1% ($P<0.001$). Smoking is significant to psychological disorder occurrence. Drinking could significantly lower the probability of psychological disorder of rural samples ($P<0.01$), possibly because rural old people in China prefer to drink at parties. Compared with samples without chronic diseases, samples with one or more chronic diseases have 4.7% higher probability of psychological disorder and those with three or more chronic diseases have 10.6% higher probability of psychological disorder. For rural samples, deposit amount and employment are inversely proportional to the probability of psychological disorder (the marginal effects are -0.002 and -0.043, respectively). However, these two variables are insignificant to urban samples.

Discussion

Based on the effect of urban-rural difference on mental health and psychological disorder of the elderly, rural old people are facing more serious mental health problems due to poor living envi-

ronment, entertainment culture conditions, and health care facilities. This result was further confirmed by the regression results of urban and rural samples. For example, deposit amount and employment could significantly improve the mental health of rural samples, but only slightly influence the mental health of urban samples. This result indicated that the aged in rural areas needed more assets to buy basic insurances, like medical service. Drinking was one similar variable. Drinking could improve the mental health of rural samples, but did not influence urban samples. The aged in urban areas paid more attention on their health and drank less, while the aged in rural areas enjoyed limited social activities and entertainment activities. The elderly in rural areas communicated with others and relieved pressure through drinking.

The effects of air pollution on mental health and disorder of the elderly confirm the opinion proposed early in this paper, i.e., during the industrialization in China, SO_2 drainage facilitates urban economic development, improves people's living standard, enriches life of the aged, and thus improves the mental health and reduces risks of psychological disorder of the elderly. However, with the further increase of SO_2 drainage, the negative effects of air pollution on the mental health of the elderly become more prominent.

The conclusion that the mental health of the elderly is improved with the increase of age agrees with the opinions of Luan Wenjing and Li Jianxin's studies (17, 21) possibly because old people become introversive and easy-going with age, thus having better mental health conditions (28).

The female elderly have far poorer mental health and more serious psychological disorders than do males. This result revealed that in both urban and rural areas, Chinese males have higher position in the family and additional social relationships, thus having better mental health.

Higher educational background could improve mental health and greatly reduce the probability of psychological disorder (the coefficient is increasing continuously). This result implied that the elderly with higher educational background have richer and more diversified spiritual and cultural

life, as well as pay more attention to knowledge on mental health.

In terms of chronic diseases, the elderly without or with fewer chronic diseases have better mental health. Disabled samples have poorer mental health and more serious psychological disorders. This result showed the close relationship between mental health and physical health of the elderly. Hence, more attention must be paid on psychological changes of the elderly with poor physical health.

Owing to the data limitations, these results, based on the cross-sectional micro-data, are more likely to be established within a specific period. Further research is necessary to analyze the change trend of the mental health of the elderly in China from the perspective of urban-rural difference when the data are available.

Conclusion

The mental health of the Chinese elderly is studied based on CHARLS data. Results show that air quality significantly influences mental health and psychological disorder of the aged, showing a positive "U-shaped" curve. Urban old people have better psychological conditions than rural old people do. Personal features and lifestyle have different effects on the psychological health of the elderly. The research conclusion enriches academic research on the mental health problems of the elderly. The conclusion also has certain practical significance. During economic development, local governments should consider the influence of air quality on the mental health of the aged. Specifically, regions with developed industries should adopt strict environmental protection measures to reduce effectively the emission of air pollutants. Moreover, local governments should be aware of the differences in mental health of urban and rural old people when making associated policies. Governments should reasonably allocate public resources, remove city-countryside dualization barrier, and accelerate urban-rural integration. Special attention should be paid to the psychological conditions of the female elderly and the aged with chronic diseases and physical disability. Great efforts should be made to enrich social activity of and increase employment opportunities for the elderly.

Ethical considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been completely observed by the authors.

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