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Coping with Air Pollution: The Role of Cognitive and Non-cognitive Abilities on Mental Health

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ABSTRACT

Considered as a key component of human capital, mental health has drawn substantial scholarly attention for its effect on people's health status and economic outcome. When facing the challenge of stress, people's heterogeneity in cognitive ability and non-cognitive ability causes difference in patterns of coping, resulting in different manifestations in mental health. Previous researches have shown that cognitive and non-cognitive abilities have positive and direct effects on mental health, as well as indirect effects on mental health. But few studies research the role of cognitive ability and non-cognitive ability on the relationship between air pollution and mental health. By using the China Family Panel Survey (CFPS) data, we found that air pollution has negative effect on mental health, and the effect can be channeled through the damage on cognitive ability. In addition, individuals with high non-cognitive abilities are able to accurately diagnose problems and select the optimal coping strategies, thus restoring positive mental health. We discussed implications for policy making on the basis of the results.

Keywords: Air Pollution; Cognitive Ability; Non-cognitive Ability; Mental Health

I. Introduction

Mental health is a global matter, and it is so common that people across ages, jobs, locations may all suffer from mental illness. According to the World Health Organization 2017 Report, the two most common types of mental health problems are depression and anxiety disorders, and these two mental health diseases together have caused up to one billion U.S. dollars annual global productivity loss. More than 322 million (4.4% of the global population) are suffering from depression, making it the worldwide most epidemic disease; and more than 264 million (3.4% of global population) are suffering from anxiety disorders, whose number of patients ranked sixth among all diseases (WHO, 2017). These mental illnesses are more common among people who are poor, unemployed, and elderly, as well as those suffering from adverse events such as the death of their loved ones or people with physical disabilities, alcoholism and drug addiction (WHO, 2017). The developing countries have a large group of low-income population, and the number of elderly people in these countries is growing rapidly. These are the population more vulnerable to depression and anxiety, making the number of people in developing countries suffering from mental illnesses grow even faster than in developed countries, which has drawn our attention on this problem of China.

[Insert Figure 1 about here]

Numerous studies have shown that individual with poor mental health have a negative impact on personal performance and employees' productivity (Zivin & Neidell, 2012; Chang et al., 2016a; Chang et al., 2016b). As a component of human capital, people's mental health status can significantly affect their work efficiency and effectiveness, which in turn affects organizational performance. Therefore, health element of human capital should be considered as an engine for production and the role of environmental pollution should not be underrated (Zivin & Neidell,

2013). Furthermore, mental health is considered as core dimension in life to love and be loved, to work happily and to live happily, and to expect or hope for the future (Cederblad et al., 1995).

Studies about adverse effects of environmental pollution on health have emerged in recent decades. A stream of literature has already confirmed that air pollution is negatively connected with physical health. Exposure to pollutants such as ambient participate matter and ozone has been associated with increases in mortality and hospital admissions due to respiratory and cardiovascular disease (Qureshi et al., 2015). There are significant effects of air pollution on incidence of cardiac arrhythmia (Peters et al., 2000), non-malignant respiratory deaths (Atkinson et al., 2001), lung cancer mortality (Abbey et al., 1999), asthma mortality (Beasley et al., 1998; Mcconnell, 2002), non-malignant cardiopulmonary deaths (Peters et al., 1997), and total mortality (Schwartz, 1994; Schwartz, 2000; Katsouyanni et al., 2001), thus shortening life expectancy (Abbey et al., 1999). Also individuals exposed in PM2.5 concentrated environment are potentially more vulnerable to cardiovascular disease (Sørensen et al., 2003). The mechanisms are that air pollutants, including ozone, oxides of nitrogen, and suspended particulates, being potent oxidants, can exert toxic effects on the respiratory and cardiovascular systems either through direct effects on lipids and proteins or indirectly through the activation intracellular oxidant pathways (Rahman & Macnee, 2010).

However, compared to the number of researches studying the effects of air pollution on physical health, the number of those studying the effects of air pollution on mental health is far less. Extant studies suggest that air pollution has general negative effect on mental health. Nitrogen oxides together with other annoying environmental factors are positively related with anxiety (Persson et al., 2007). Some pollutants such as particulate matter, nitrogen oxides and

ozone may increase depressive symptoms among the elderly (Lim et al., 2012).

The optimal state of mental health is sought by everyone; however, mental health is closely related to personal characteristics such as thinking mode, emotion control ability and other external conditions such as social, cultural, economic, political and environmental (WHO, 2018). Even under the same external conditions, the individual's mental health is also related to differences in individual traits, such as cognitive ability, which is the synthesis of memory, information processing ability, intelligence, language skill, motor skill and problem solving ability (Borghans et al., 2008; Knudsen et al., 2006), and non-cognitive ability, which is the sum of all the stable dimensions of personality traits, including locus of control, self-esteem, curiosity, motivation, responsibility, perseverance, social ability and other traits (Heckman & Kautz, 2012).

When facing with environmental stress and pollution, heterogeneity of individuals in cognitive ability and non-cognitive ability causes difference in patterns of coping, resulting in different manifestations in mental health. The heterogeneity determines the difference in reactions and coping responses when faced with stressors. Individual subjective diagnosis and assessment of the problem will determine the coping strategies with the mental problem (Parkes, 1990; Skinner & Zimmer-Gembeck, 2007). Personal traits such as degree of responsibility, the ability of self-control, eagerness to be recognized etc. will affect the individual's impression of change and perception of stressors (Carver & Connor-Smith, 2010). When coping with air pollution and environmental stress, it is important to observe the influence of cognitive and non-cognitive abilities on mental health. Under great risks and pressures, the differences in the individual's cognitive ability and non-cognitive ability result in diverse subjective judgments and analyses, which further lead to different ways of response and coping styles. Cederblad and associates (1995)

suggested that intelligence, perseverance, reliability, controls of impulses, kindness and other personality traits are protective factors which promote positive mental health. Cognitive ability and non-cognitive ability are positively associated with labor market outcomes that positively affect mental health (Heckman et al., 2006; Carneiro et al., 2007; Heckman et al., 2014).

The present study focuses on the relationship among air pollution, mental health, cognitive ability and non-cognitive ability. By using the micro data, we explored the influence of air pollution on mental health, and the role played by cognitive and non-cognitive abilities in the relationship between air pollution and mental health. Consistent with the previous arguments (Davis & Humphrey, 2012a; Davis & Humphrey, 2012b) about the role of coping, we found that cognitive ability and non-cognitive ability contribute to maintaining positive mental health. More specifically, cognitive ability plays a mediating role as a protective factor of maintenance and stability coping with environment pollution, and non-cognitive ability plays a moderating role as coping with the air pollution thus decreasing the negative effect on mental health.

II. Theory and Hypotheses

The pollution exposures have negative impacts on the long run health status (Kim et al., 2017). Air pollution also reduces subjective well-being, causes anxiety and depression, and seriously increases the risk of suicide among people exposed to air pollution (Persson et al., 2007; Lim et al., 2012). The mechanism through which air pollution damages mental health is that air pollutants are neurotoxic, and people's neural system will be harmed when exposed to these pollutants. Long-term exposure to ambient particulate matter and ozone causes decline in motor response speed to a visual stimulus, coding ability, attention and short-term memory (Chen & Schwartz, 2009). Also long exposure to black carbon, a marker of traffic-related air pollution, can cause

decreased cognitive function in older men, such as attention, working memory, long-term verbal memory, visuoconstruction and global cognition (Power et al., 2011). There is also positive association between exposure to fine particulate matter and mild cognitive impairment which is associated with a high risk of progression to Alzheimer's disease in older women by damaging their cognitive abilities of attention, information processing, confrontation naming, executive functions, verbal memory, nonverbal memory, visuoconstruction, global cognition, and olfactory function (Ranft et al., 2009; Weuve et al., 2012). When using a holistic measurement such as Air Pollution Indicator, empirical results also support that air pollution can impair global cognition, ability to perform everyday activities, and satisfaction with health (Sun & Gu, 2008; Zeng et al., 2010). Considering the harm of air pollution to mental health, consistent with similar research on China context (e.g., Zhang, Zhang & Chen, 2017; Chen, Oliva & Zhang, 2018), this paper proposes the hypothesis of the effect of air pollution:

Hypothesis 1: Air pollution has a negative influence on mental health.

Empirical research also supports that cognitive ability, measured in IQ, math test scores and literacy test scores, has positive influence on mental health (Cederblad et al., 1995; Carneiro et al., 2007). What's more, cognitive ability has indirectly positive influence on mental health by affecting academic achievement, personal wages, and employment positively or reducing drug use, alcoholism, and risky social behavior such as teenage pregnancy and criminal activity (Heckman et al., 2006; Carneiro et al., 2007; Heckman et al., 2014). But air pollution also damages cognitive capability. It directly affects decision making by damaging cognitive ability strategic thinking (Chew et al., 2018). Evidence shows air pollution exposure would harmfully affect cognitive ability in academic performance (Bensnes, 2016). Pronounced evidence has been found especially

on elderlies (Zhang, Chen & Zhang, 2018). The mechanism through which air pollution affect cognitive ability is that air pollution, as a threat to health, will reduce people's motivation to go out, and also reduce people's daily outdoor activities and travel to avoid air pollution damage to their own health, limiting the individual's communication and social interaction that in turn leads to increased negative emotions (Noonan, 2014; Calderón-Garcidueñas et al., 2015), resulting in decreased adjustment function of cognitive ability on mental health. Through accurate appraisal, selecting the optimal coping strategies, and better implementation of coping strategies, cognitive abilities are protective factors of mental health to have better diagnosis of problem, perceiving situations accurately as challenge or threat.

Hypothesis 2: Air pollution indirectly and negatively affects mental health by deteriorating cognitive ability.

As for the moderation mechanism of non-cognitive ability, empirical research supports that non-cognitive ability, such as perseverance, locus of control, self-esteem, has positive influence on mental health (Cederblad et al., 1995; Carneiro et al., 2007). Through positive appraisal and successfully seeking out social support, people have less exposure to stressor and more effectiveness of coping strategy. Also non-cognitive ability has indirectly positive influence on mental health by affecting academic achievement, personal wages, and employment positively (Heckman et al., 2006; Carneiro et al., 2007; Heckman et al., 2014). According to person-environment fit theory, individuals prefer their own consistent values and produce optimal results, striving to solve problems and make adjustments in an effort to adapt to the environmental change (Vianen, 2018). Non-cognitive ability partly determines personal capacity to cope with environment effect on mental health across individuals endowments (Cuesta & Budría, 2015).

Thus, individuals will diagnose problems and react in diverse manners; for the existence of human heterogeneity, specifically, the difference in individual non-cognitive ability will lead to difference in their subjective judgment.

Hypothesis 3: Non-cognitive ability reduces the negative effect of air pollution on mental health.

III. Methodology

Data

The data used in this study are collected from China Family Panel Studies (CFPS) and merging China Statistical Yearbook on Environment from 2010 to 2016. CFPS provides data on mental health, cognitive ability, non-cognitive ability, demographic characteristics, and family characteristics. In China Statistical Yearbook on Environment, data of atmospheric environment are collected every year, including industrial waste gas emissions, industrial and household sulfur dioxide emissions, nitrogen oxides emissions, industrial soot, and dust emissions. CFPS is launched by the Institute of Social Science Survey of Peking University. It is a nationally representative and longitudinal survey of Chinese society, covering twenty-five provinces and 94.5 percent of the total population in Mainland China, collecting individual-, family-, and community-level longitudinal data, focusing on the economic as well as the noneconomic well-being of the Chinese population. CFPS survey data was initiated in 2010, collected from households on a large scale every two years, about the individual characteristics, including the date of birth, gender, education, literacy, mathematical ability, expressive ability, mental health status, personal income, occupation, social status, etc. CFPS survey data also include other family and community characteristics. The current CFPS survey data has been updated to 2016. Selection

process includes keeping those who are employed or self-employed, including people engaged in agricultural job and non-agricultural job; keeping those when respondent' cooperation and reliability are above 3 (full score is 7) to ensure respondents' effort and devotion, thus guarantee data validity.

Variables

Mental health

The dependent variable in this paper is mental health. In the literature, two methods are commonly used to measure mental health. The first is the diagnosis of specific mental illnesses through interviews and surveys. The most widely used measure is Composite International Diagnostic Interview and its various translated and revised versions. The second method is to measure the psychological pressure in a broad range, rather than diagnose specific mental illness through specific symptoms. The best example is General Health Questionnaire (GHQ) by Goldberg (1972) and Mental Health Inventory (MHI-5) by Veit & Ware (1983). Das et al., (2009) used the GHQ method which included 20 self-reported questions about depression that required the respondent to answer the frequency of a mental state occurrence within the last month, for example, the frequency of feeling depressed, nervous and anxious, unable to sleep, and unable to concentrate on doing things. According to the frequency, each item is scored, 1 point for never, 2 points for seldom, 3 points for often, 4 points for almost every day, and then takes average score, finally the standardized value is used to measure mental health, which means worse mental health status with higher score.

The mental health measurement from CFPS database used in this paper is similar to Das et al. (2009), and also contains a series of questions about the frequency of mental states.

There are two differences between this paper and Das et al. (2009). The first is that scores in this paper are reversely related to the mental state frequency. The lower the frequency, the higher the score; and the higher the frequency is, the lower the score is. The reason of doing so lies in the final outcome, the higher the score of mental health, the better the psychological state, which is more in line with our intuition. The second difference is the use of Principal Component Analysis (PCA) to synthesize these sub-dimensions as a measure of mental health. In social surveys, when a series of questions are used to measure a person's opinion, PCA can be used to construct one representative measurement.

The measurement of mental health is composed of six dimensions, including:

During the last 1 month, the frequency that you feel depressed;

During the last 1 month, the frequency that you feel nervous;

During the last 1 month, the frequency that you feel restless or fidgety;

During the last 1 month, the frequency that you feel hopeless;

During the last 1 month, the frequency that you feel that everything was difficult;

During the last 1 month, the frequency that you feel that life was meaningless.

Each dimension is scored according to frequency; with 1-5 scale representing almost daily, half time, sometimes, never. In this paper, Principal Component Analyses (PCA) was used to construct the measurement of mental health, which means the higher the score is, the better the state of mental health.

The mental health measurement constructed from the CFPS questionnaire is fully characterized by six sub-dimensions. The evidence is that in 2010 data, when using the variable

Depression to regress on these six sub-dimensions, the R square is 1, that is to say, Depression can be completely explained by the six sub-dimensions.

There is only depression in 2010, but depression data are absent in other years; fortunately there are six sub-dimensions of mental health throughout all years. Therefore, the indicators are constructed separately for each year and then combined.

Air pollution

This paper deploys industrial waste gas emissions, which contains several pollutants such as nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), soot and dust and so on, as measurement of air pollution. Air pollution is generally measured by air pollutant concentration and air pollution index.

Air pollutants include nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), particulate matter and so on. China's official air quality monitoring standards is Ambient Air Quality Standards, released in 1982, first revised in 1996, second revised in 2000, third revised in 2012. The index before 2012 was the Air Pollution Index (API) calculated based on the concentration of sulfur dioxide, nitrogen dioxide, and PM10. The index published after 2012 is the air quality index (AQI) calculated based on concentrations of sulfur dioxide, nitrogen dioxide, PM10, PM2.5, ozone, and nitrogen oxide.

Due to the statistical inconsistency between API and AQI, the two indexes cannot be directly used in 2010-2016. The China Statistical Yearbook on Environment publishes soot and dust emission, nitrogen oxides (NOx) emission, sulfur dioxide (SO_2) emission, and industrial waste gas emission. This paper chooses industrial waste gas emission as measurement of air pollution for it contains various pollutants and is the major pollutant and it’s more holistic than other emission

data. Since the CFPS database hides information about the respondents' counties in order to protect privacy, and only the provincial information is provided, the air pollution selects the provincial level data to match the data in the CFPS database.

Cognitive ability

Many empirical studies related to cognitive ability use math test scores and literacy test scores as measurement. Generally we used math test scores and word test scores to measure cognitive ability. The standardized mathematic questions and verbal questions are examined in CFPS from ascending level questionnaire. The answer depends on interviewee's starting question and ends with 3 incorrect questions in succession. Then cognitive ability in our study is constructed of math test scores and word test scores using Principal Component Analyses or PCA, in which the higher the value, the higher the cognitive ability.

Non-cognitive ability

Most of the literature uses self-reported personality traits to measure non-cognitive ability (Carneiro et al., 2007; Heckman et al., 2014), but self-reported measurements have problems with inaccurate and unstable estimates. The more stable and valid data are added with the interviewer's observation and measurement data. Interviewers observed and measured data on non-cognitive ability relating to comprehensive ability, expressive ability, politeness, cooperation, and reliability. Interviewers performed two rounds of scoring and then averaged them as the measurement of non-cognitive ability. This paper uses similar measurement as comprehensive ability, expressive ability, politeness, cooperation, and reliability. Respondents were rated by the interviewer in the range of 1-7 scale.

It is reasonable to choose the comprehensive ability, expressive ability, cooperation, reliability, and politeness as measurements. People with higher comprehensiveness can better understand themselves and others, have higher empathy and sympathy, thus we can say comprehensive ability if a protective factor for mental health. People with higher expressive ability can better express their feelings and opinions, help to promote communication and gain external support, thus expressive ability is also a protective factor of mental health. Those with a higher degree of cooperation are more cooperative, helpful, reliable, and sympathetic, and more people are willing to provide help to people with higher levels of cooperation when faced with difficulties and challenges. People with higher levels reliability are more likely to gain trust because of their personality trait; people with high levels of politeness tend to get goodwill from people. Therefore, cooperation, reliability, and politeness are all protective factors. Protective factors help people to maintain a positive mental health while coping with stress. In this paper, the comprehensive index of non-cognitive ability is composed of comprehension, expressiveness, cooperation, reliability, and politeness using Principal Component Analyses, in which the higher the value, the higher the non-cognitive ability.

Control variables

In the literature on mental health, the influencing factors include the demographic characteristics, social characteristics, and economic characteristics of individuals. According to Das et al., (2007) and Das et al., (2009), factors that affect mental health include demographic characteristics, social characteristics, and economic characteristics such as age, gender, education attainment, marital status, and physical health. Control variables that affect mental health in this paper include: income status, social status, monthly work hour, age, gender, and the level of

education received, marital status. Income status is relative income in local area, scored in the range of 1-5 from the low to the high; Social status is determined by the respondent's status in the local area, scored in the range of 1-5. Monthly work hour is represented by the average monthly work hours. Gender is a dummy variable, in which 1 stands for male. The level of education received includes illiterate or semi-literate, primary schools, junior high schools, senior high schools, 3-year colleges, undergraduates, masters, all are dummy variables. Marital status includes unmarried, cohabitation, divorce, and widowhood. All the variable names, definitions, and data sources and references are summarized in Table 1.

[Insert Table 1 about here]

The sample used in this paper contains 42,344 observations from 2010 to 2016. The descriptive statistics of variables such as mental health, cognitive ability, non-cognitive ability, and air pollution are shown in Table 2.

[Insert Table 2 about here]

The correlation coefficients of variables such as mental health, cognitive ability, non-cognitive ability, and air pollution are shown in Table 3.

[Insert Table 3 about here]

Empirical Model

We studied the main effect, the impact of air pollution on mental health, as well as the indirect effect of air pollution on mental health through influencing cognitive ability, and the moderating effect of non-cognitive ability on the relationship between air pollution and mental health. The empirical model is built as follows:

$$Mental\ Health = \beta_1 * Air\ Pollution + \beta_2 * Cognitive\ Ability + \beta_3 * Non\text{-}Cognitive\ Ability +$$

$$B_4 * Air\ Pollution\ X\ Non\text{-}cognitive\ Ability + \beta_5 * Income\ Status + \beta_6 * Social\ Status + \beta_7 * Gender + \beta_8 * Education + \beta_9 * Marital\ Status + error\ term$$

It's noted that *Air Pollution X Non-cognitive Ability* is the interaction term.

To investigate the indirect effect of air pollution through cognitive ability, we used the Sobel-Goodman test to study the mediating role of cognitive ability, controlling for income status, social status, age, gender, education attainment, and marital status. The results of VIF test (Table 4) show no serious multicollinearity problem in the estimates.

[Insert Table 4 about here]

IV. Results and Discussion

The Direct Effect of Air Pollution

Previous studies suggest that the effects of air pollution on mental health are adverse, increasing depressive symptoms and anxiety (Persson et al., 2007; Lim et al., 2012). The empirical results in Table 5 show that air pollution can significantly and negatively affect mental health, thus supporting Hypothesis 1, and consistent with prior research (Zhang, Zhang & Chen, 2017; Chen, Oliva & Zhang, 2018). In column (1), the estimate only includes air pollution in the regression, controlling for demographics and year fixed effects, demonstrating that 1 standard deviation of air pollution will cause mental health to worsen by 0.043 standard deviation, which is statistically significant at the 1% level. In column (2), the estimate adds cognitive ability; in column (3), the estimate adds non-cognitive ability; and in column (4), the estimate adds both cognitive ability and non-cognitive ability, and the results are similar in magnitude and still statistically significant at the 1% level. It's also demonstrated that cognitive ability and non-cognitive ability can significantly and positively affect mental health.

[Insert Table 5 about here]

The Indirect Effect of Air Pollution through Damaging Cognitive Ability

Theoretical research shows that air pollution damages the neural system and harms cognitive ability, and further affects mental health. Therefore, Hypothesis 2 is proposed that air pollution has a negative influence on cognitive ability and further influence mental health. Sobel-Goodman test can be used to test the mediating effect of cognitive ability.

The purpose of Sobel-Goodman test is to determine whether there is a mediating effect of the mediator on the relationship between the dependent variable and the independent variable. Generally speaking, the mediator needs to meet the following four conditions: (1) The independent variable has a significant influence on the mediator; (2) When the model does not contain the mediator, the independent variable has a significant influence on the dependent variable; (3) The mediator has a significant influence on the dependent variable; (4) When the model contains mediator, the effect of the independent variable on the dependent variable will be weakened.

Table 6 shows that (1) air pollution (independent variable) has a significant influence on cognitive ability (mediator); (2) air pollution has a significant influence on mental health (dependent variable) when the model does not contain the mediator; (3) cognitive ability has a significant influence on mental health; (4) and the effect of air pollution shrinks after adding cognitive ability in the model. Therefore we can conclude that there exists a mediating effect of cognitive ability on the relationship between air pollution and mental health. Hypothesis 2 is supported.

[Insert Table 6 about here]

The Moderating Effect of Non-cognitive Ability

Air pollution is a stressor which negatively affects mental health, as demonstrated in column (1) to column (4) in Table 5. When faced with stressors, the individuals will pursue the fit between the individual and the environment. And the individual heterogeneity in non-cognitive ability will lead to difference in subjective judgments, diagnosis and coping strategies, leading to differences in their mental health status (Davis & Humphrey, 2012a; Davis & Humphrey, 2012b). Therefore, Hypothesis 3 tests whether non-cognitive ability moderates the negative effect of air pollution on mental health.

In the regression results using industrial waste gas as the proxy of air pollution (Table 5), column (5) includes air pollution, non-cognitive ability, and their interaction term. The interaction term suggests that non-cognitive ability can significantly moderate the negative effect of air pollution. Individuals with one higher standard deviation of non-cognitive ability can alleviate the negative effect of air pollution on their mental health by 0.016 standard deviation, at the significant level of 1%. Column (6) adds cognitive ability, and obtained similar estimate in both magnitude and significance. We can conclude that non-cognitive ability offset the negative impact of air pollution on mental health, and the empirical results support Hypothesis 3. This is reasonable, because people who have higher non-cognitive ability have better interpersonal relationships, and they are more likely to obtain social support which is beneficial for mental health, thus relieving the impairments of air pollution on mental health.

Figure 2 clearly displays the moderating role of non-cognitive ability. At the medium level of air pollution, individuals with higher non-cognitive ability have better mental health than those with lower non-cognitive ability. And this gap even becomes larger at high level of air pollution.

[Insert Figure 2 about here]

V. Conclusions

In this paper, we study the relationship between air pollution and mental health considering the individual heterogeneity of cognitive ability and non-cognitive ability. The results show that air pollution not only has directly negative effect on mental health, but also can significantly damage cognitive ability, thus further deteriorating mental health; while non-cognitive ability can moderate the negative effect of air pollution on mental health.

The main findings also include that cognitive ability and non-cognitive ability contribute to maintaining positive mental health, which is consistent with the arguments made by Davis and Humphrey (2012a, 2012b) about the mediating role of coping strategies. According to the protective factors of mental health, cognitive ability help stay maintenance and stability, and non-cognitive ability is a reactive protective factor. These two factors will prompt people to accurately diagnose problems and actively cope with stress in an appropriate manner. But Air pollution can significantly damage cognitive ability and further influences mental health. Non-cognitive ability can significantly moderate the effect from air pollution such as increasing social interaction and communication to improve the mental health.

This empirical study has made the following contributions to the literature. First of all, the paper provides evidence that air pollution can deteriorate mental health and suggests one path to exert negative effect through damaging the cognitive ability. Secondly, using micro data from China, this paper adds evidence that cognitive and non-cognitive abilities are positively correlated with mental health, which is consistent with previous literature. Thirdly, it provides evidence that there exists moderating effect of non-cognitive ability on the relationship between air pollution and mental health. Finally, the significance of this paper is attracting more attention to environmental

protection for the reason that air pollution can impair people's mental health and cognitive abilities. As such, we should improve individual non-cognitive abilities to protect mental health in human capital formation in coping with environment pollution.

We do not provide evidence for the mechanism of non-cognitive ability moderating process on the relationship between air pollution and mental health. The deficiency of this paper is that it has not captured other factors that affect mental health. These factors are called unobserved effects and fall into the error term, which makes the part of the mental health variance explained by cognitive ability, non-cognitive ability and other control variables to be very small, resulting in a smaller R square (less than 0.2), due to the missing information from the survey instrument. Future research can make up for this deficiency. If both individual-level and company-level data are available, the empirical test could increase the explanatory power of the model.

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Figure 1 Global Prevalence of People Suffering Depression across Locations and Gender in 2016

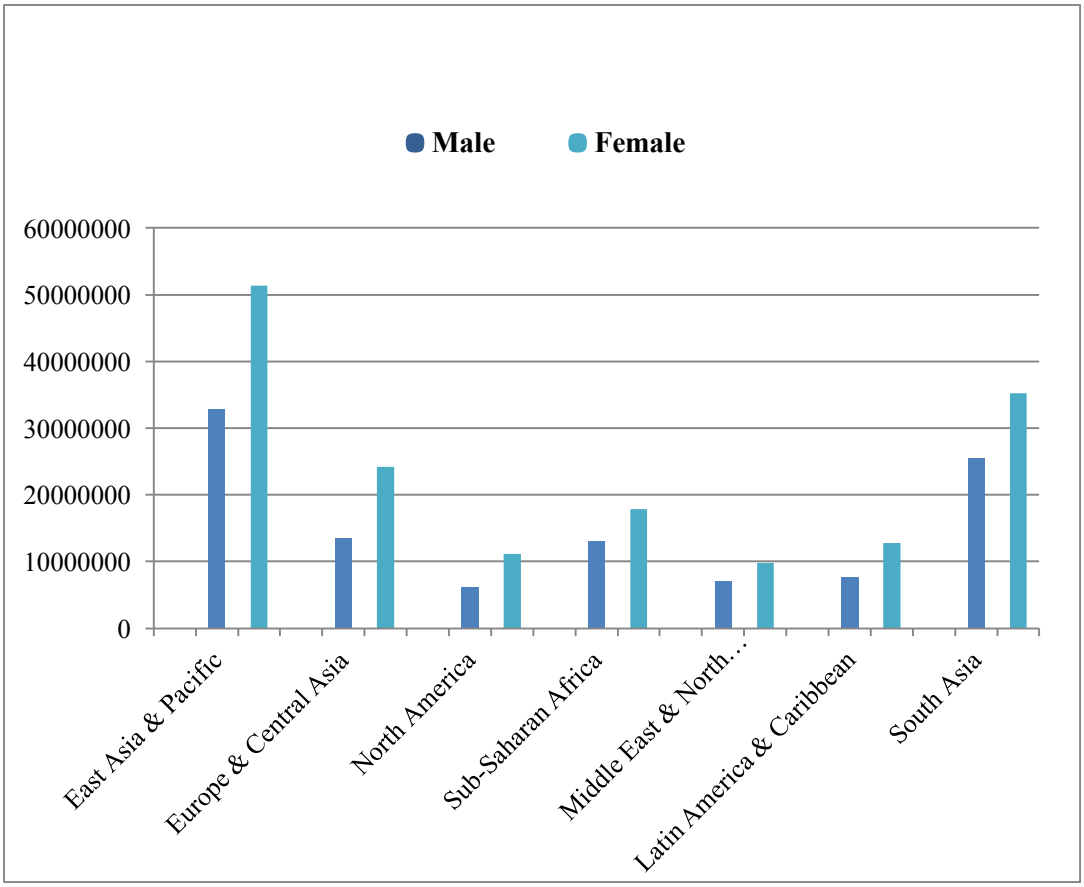

Figure 2 Moderating Effect of Non-cognitive Ability

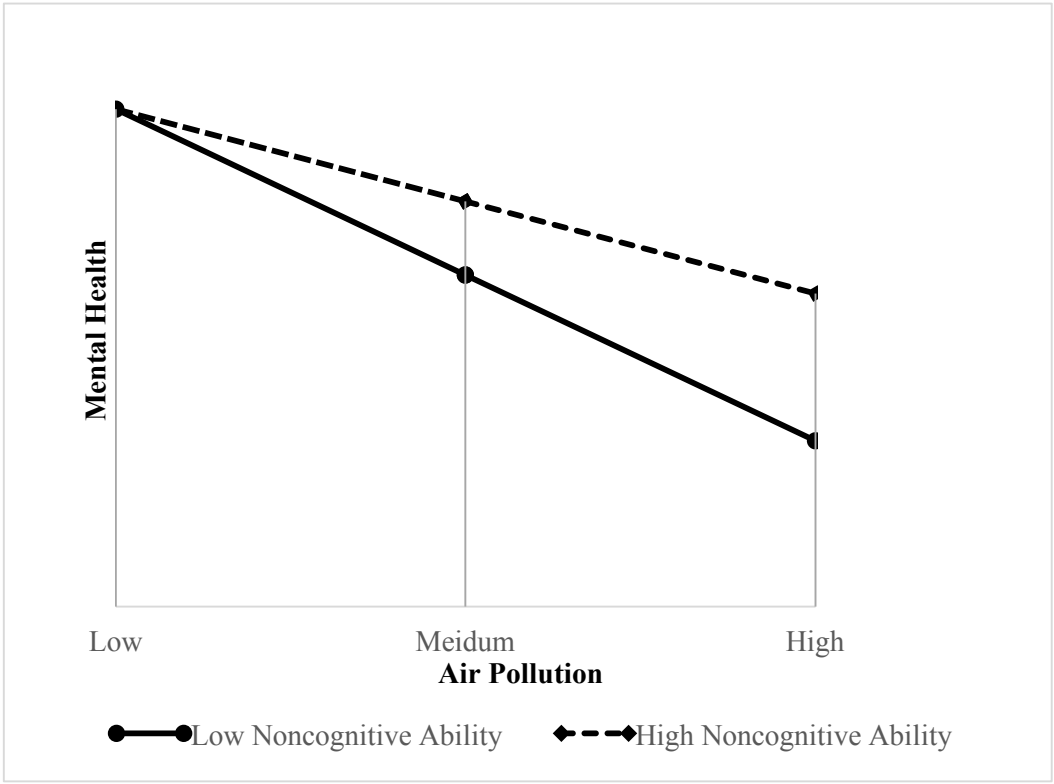

Table 1 Variable Definition and Data Source

Variable Name	Definition	Data Source
Dependent Variable		
Mental Health	Mental health	CFPS
Independent Variables		
Industrial Waste Gas	Emission of industrial waste gas	China Statistical Yearbook on Environment
WG_Facility	Sets of centralized facilities for treatment of industrial waste gas	
Control Variables		
Cognitive Ability	Composed by math test scores and word test scores	
Non-cognitive Ability	Composed by comprehensive ability, expressive ability, cooperation, reliability, and politeness	
Income Status	Respondent's relative income level in your local area	
Social Status	Respondent's social status level in your local area	
Work Hour	Monthly work time (hour)	
Age	Age	
Gender	Gender dummy, 1 if male, 0 otherwise	
Edu_Degree1	Illiterate/Semi-literate	
Edu_Degree2	Primary school	
Edu_Degree3	Junior high school	
Edu_Degree4	Senior high school/secondary school/technical school	CFPS
Edu_Degree5	3-year college	
Edu_Degree6	4-year college/Bachelor's degree	
Edu_Degree7	Master's degree	
Marital_Status1	Never married	
Marital_Status2	Married (having a spouse)	
Marital_Status3	Cohabitation	
Marital_Status4	Divorced	
Marital_Status5	Widowed	

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Mental Health	42,344	0.00961	0.990	-6.936	1.034
Cognitive Ability	42,344	0.0341	1.003	-3.777	2.554
Non-cognitive Ability	42,344	-0.00354	0.977	-3.758	1.430
Industrial Waste Gas	42,344	-0.00927	0.976	-1.513	2.926
WG_Facility	42,344	10604	5951	2962	25673
Income Status	42,344	2.474	0.930	1	5
Social Status	42,344	2.799	0.964	1	5
Work Hour	42,344	167.9	99.40	0	720
Age	42,344	41.52	13.22	16	90
Gender	42,344	0.578	0.494	0	1
Edu_Degree1	42,344	0.0916	0.289	0	1
Edu_Degree2	42,344	0.192	0.394	0	1
Edu_Degree3	42,344	0.385	0.487	0	1
Edu_Degree4	42,344	0.180	0.384	0	1
Edu_Degree5	42,344	0.0784	0.269	0	1
Edu_Degree6	42,344	0.0512	0.220	0	1
Edu_Degree7	42,344	0.00357	0.0596	0	1
Marital_Status1	42,344	0.118	0.323	0	1
Marital_Status2	42,344	0.839	0.367	0	1
Marital_Status3	42,344	0.00468	0.0682	0	1
Marital_Status4	42,344	0.0171	0.130	0	1
Marital_Status5	42,344	0.0209	0.143	0	1
Year	42,344	2013	1.940	2010	2016

Table 3 Pearson Correlation

	Variable	1	2	3	4	5	6	7	8	9	10	11
1	Mental Health	1.000										
2	Cognitive Ability	0.121***	1.000									
3	Non-cognitive Ability	0.056***	0.252***	1.000								
4	Industrial Waste Gas	0.056***	0.028***	-0.024***	1.000							
5	WG_Facility	0.094***	0.025***	-0.019***	0.749***	1.000						
6	Income	0.031***	0.120***	0.039***	-0.032***	-0.019***	1.000					
7	Income Status	0.114***	0.022***	0.037***	0.007*	0.006	0.054***	1.000				
8	Social Status	0.093***	-0.074***	0.006	0.019***	-0.004	-0.005	0.473***	1.000			
9	Work Hour	0.004	0.118***	0.058***	-0.004	0.046***	0.079***	0.024***	-0.054***	1.000		
10	Age	-0.064***	-0.430***	-0.152***	0.007	0.030***	-0.100***	-0.004	0.146***	-0.134***	1.000	
11	Gender(Male)	0.099***	0.074***	0.023***	-0.002	-0.016***	0.064***	0.039***	-0.019***	0.086***	0.053***	1.000

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 VIF Test

	VIF	1/VIF
Cognitive Ability	1.970	0.507
Non-cognitive Ability	1.090	0.919
Industrial Waste Gas	2.340	0.427
WG_Facility	2.430	0.411
Income Status	1.330	0.750
Social Status	1.350	0.741
Work Hour	1.070	0.931
Age	1.670	0.600
Gender(Male)	1.070	0.933
Edu Degree2	2.720	0.368
Edu Degree3	4.160	0.240
Edu Degree4	3.420	0.292
Edu Degree5	2.420	0.413
Edu Degree6	2.070	0.482
Edu Degree7	1.090	0.919
Marital Status2	1.700	0.589
Marital Status3	1.040	0.962
Marital Status4	1.170	0.853
Marital Status5	1.350	0.743
Mean	VIF	1.780

Table 5 Effects of Air Pollution on Mental Health and Moderating Effect of Non-cognitive Ability

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Industrial Waste Gas	-0.043***	-0.044***	-0.043***	-0.043***	-0.042***	-0.042***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Cognitive Ability		0.055***		0.053***		0.054***
		(0.006)		(0.006)		(0.006)
Non-cognitive Ability			0.016***	0.012**	0.016***	0.012**
			(0.005)	(0.005)	(0.005)	(0.005)
Industrial Waste Gas*					0.011**	0.012***
Non-cognitive Ability					(0.005)	(0.005)
All set of Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42344	42344	42344	42344	42344	42344
Overall R^2	0.050	0.052	0.050	0.052	0.051	0.052

Notes:

(1) Standard errors in parentheses

(2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(3) Industrial Waste Gas* Non-cognitive Ability is the interaction term of air pollution and non-cognitive ability. Control variables include industrial waste gas (which is the proxy of air pollution), sets of facilities to process industrial waste gas, income status, social status, monthly work hour, age, gender, education attainment dummies, marital status dummies, and year dummies. Data are collected from China Family Panel Studies (CFPS) from 2010 to 2016, every two years. Random effects model is used in this table, for the model contains variables that are invariant with time, such as gender; and contains variables that vary little with time, such as education attainment dummies and marital status dummies.

Table 6 Effect of Air Pollution on Cognitive Ability

	(1)	(2)	(3)
Variables	Mental Health	Cognitive Ability	Mental Health
Cognitive Ability			0.061***
			(0.007)
Industrial Waste Gas	-0.050***	0.019***	-0.051***
	(0.007)	(0.005)	(0.007)
All set of Controls	Yes	Yes	Yes
Observations	42344	42344	42344
Adjusted R^2	0.050	0.486	0.052

Notes:

(1) Standard errors in parentheses

(2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(3) Control variables include sets of facilities to process industrial waste gas, income status, social status, monthly work hour, age, gender, education attainment dummies, marital status dummies, and year dummies. Data are collected from China Family Panel Studies (CFPS) from 2010 to 2016, every two years. OLS Model is used in this table. Model (1) is run with dependent variable (mental health) regressed on independent variable (industrial waste gas); model (2) with mediator (cognitive ability) regressed on independent variable (industrial waste gas); and model (3) with dependent variable (mental health) regressed on both independent variable (industrial waste gas) and mediator (cognitive ability).