Air Pollution, Residents' Happiness, and Environmental Regulation: Evidence from China

Fang Xu

Hubei University

Xiao-Ling Luo

Hubei University

Di Zhou (✉ 201610098@oamail.gdufs.edu.cn)

Guangdong University of Foreign Studies

Research Article

Keywords: air pollution, residents' happiness, mental health, leisure activities, environmental regulation

Posted Date: October 28th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-917802/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Air Pollution, Residents' Happiness, and Environmental Regulation: Evidence from China

Fang Xu¹, Xiao-Ling Luo¹, Di Zhou^{2*}

¹ Faculty of Mathematics and Statistics, Hubei University, Wuhan 430062, China; 82690671@qq.com (F.X.); luoxl422@163.com (X.-L.L.)

² School of Mathematics and Statistics, Guangdong University of Foreign Studies, Guangzhou 510006, China; 201610098@oamail.gdufs.edu.cn

* Correspondence: 201610098@oamail.gdufs.edu.cn (D.Z.)

Abstract: Using data from the China General Social Survey and data on air pollution, this study explores the impact and the critical path of air pollution on residents' happiness in China and evaluates whether environmental regulations can alleviate these effects. A probit model is used to analyze the impact of air pollution on residents' happiness, and wind speed is taken as the instrumental variable of air pollution to overcome endogeneity. A stepwise regression is used to test the critical path of air pollution on residents' happiness. Finally, the effects of environmental regulations are considered by adding an interaction term between environmental regulation and air pollution. The following conclusions are drawn. First, air pollution can significantly impair residents' happiness, especially those who have children, are younger, are in poor health, have a lower education level, have lower income, and live in a rural area. Second, there are two critical paths through which air pollution impairs residents' happiness: mental health level and the frequency of leisure activities. Finally, command-and-control, market-based, and voluntary environmental regulations can all effectively alleviate the impact of air pollution on residents' happiness.

Keywords: air pollution, residents' happiness, mental health, leisure activities, environmental regulation

1. Introduction

An increase in happiness is conducive to the improvement of residents' health (Diener and Chan 2011), social productivity (Oswald et al. 2015), and social harmony (Clark 2018). However, since the reform and opening-up in 1978, China's rapid economic development has greatly satisfied people's material needs, but it has also created serious air pollution. Health problems caused by air pollution were estimated to have cost China US\$73 billion in net wages and US\$49 billion in lost leisure time in 2005 (Matus et al. 2012). According to the Environmental Performance Index, a 2016 report published by Yale University, China's air quality score ranked second to last in 2015, and air pollution caused about 1.1 million deaths that year (Cohen et al. 2017). Air pollution adversely affects people's health and lives, which may reduce their happiness. In this context, it is of great practical significance to clarify the relationship between air pollution and happiness to improve residents' quality of life.

Previous studies have shown that air pollution can damage residents' happiness (Ferreira et al. 2013; Zhang et al. 2017; Li et al. 2014). However, what is the mechanism of its influence? Do the measures proposed to deal with environmental pollution, such as environmental regulation, influence the relationship between air pollution and happiness? Existing studies do not provide answers to these questions, so this paper attempts to fill this gap, taking China as the research object to investigate the impact of air pollution on residents' happiness.

To answer the above questions, this paper uses matching data on air pollution and from the China General Social Survey (CGSS) to explore the impact of air pollution on residents' happiness. Analyses verify the robustness of the results by replacing the core explanatory variables, and a heterogeneity analysis is conducted by means of group regression. In addition, we explore the mechanism by which air pollution affects happiness and how environmental regulation moderates this effect.

Our study contributes to the literature in the following three ways. First, existing studies often fail to consider the possibility of endogeneity (Liu et al. 2019; Yuan et al. 2018). For the first time, this paper introduces wind speed as an instrumental variable to overcome the endogeneity problem; in doing so, we find the negative impact of air pollution on residents' happiness in China. Moreover, the conclusion of a heterogeneity effect in this paper is different from the existing literature, which holds that there are no significant differences in the impact of air pollution on happiness under different absolute income levels, community living environment, age, and education level (Huang and He 2013), and that air pollution has greater effects on the happiness of the elderly (Song et al. 2020). The heterogeneous effect of having children was also not explored in previous research.

Second, this paper enriches our understanding of the influential mechanism of air pollution on happiness. Studies on the direct impact of air pollution on happiness are relatively dated. In recent years, research has explored the mechanism of air pollution on happiness, such as through reducing the level of physical health and self-rated health (Yuan et al. 2018; Li and Zhou 2020), increasing residents' pollution perceptions (Chen et al. 2020), and reducing quality of life (Ma et al. 2019) thereby reducing residents' happiness. However, relevant studies are limited. Therefore, this paper explores two new ways in which air pollution reduces residents' happiness: by reducing the frequency of leisure activities and the level of mental health.

Third, we confirm that environmental regulation has an alleviating effect on the relationship between air pollution and happiness. There are two relevant articles. One shows that an air pollution tax has an alleviating effect on the relationship between air pollution and residents' happiness (Liu et al. 2019), and the other holds that the implementation of "China's South-to-North Water Diversion Eastern Route Pollution Control Project" will not improve happiness (Jin et al. 2020). However, the environmental regulations used in these two articles are the same policies implemented in many provinces across the country, which cannot reflect well the differences in environmental regulations. Therefore, this paper takes the three kinds of environmental regulations (The first is command-and-control environmental regulation; the second category is market-based environmental regulation, and the third refers a type of voluntary environmental regulation) as the moderating variable and finds that environmental regulations could alleviate the negative impact of air pollution on residents' happiness.

The rest of the paper is organized as follows. Section 2 is a literature review. Section 3 analyzes the theory and makes corresponding assumptions. Section 4 introduces the data source, variable selection, and model setting. Sections 5 and 6 discuss the empirical results and conclusions and offer some policy suggestions, respectively.

2. Literature Review

There is abundant literature on residents' happiness, which can be divided into two categories according to whether or not the influencing factors are economic factors. One approach has been to explore the impact of economic factors, such as absolute income (Sacks et al. 2010), relative income (Easterlin 1974), and income inequality (Oishi et al. 2011) on residents' happiness. The other includes research on the Easterlin Paradox¹ (Easterlin 1974) combined with a sociological basis and explores the non-economic factors that play an important role in residents' happiness. These include demographic characteristics (MacKerron 2012), social relations and social structure (Haller and Hadler 2006), political economy and the institutional environment (Alvarez-Diaz et al. 2010), and the natural environment (Zhang et al. 2017; Cuñado et al. 2013).

In recent years, many scholars have begun to focus on the impact of air pollution on happiness. Welsch (2006) conducted a follow-up survey of ten European countries and found that the impact of air pollution on happiness was significant, though the degree of impact varied by country. Ferreira et al. (2013) fused data from several surveys to analyze the relationship between air quality and subjective well-being in Europe and found that SO₂ concentration has a significant negative effect on life satisfaction. By establishing a structural equation model of happiness, Li et al. (2014) found that the perception of air pollution had a negative impact on happiness. Zhang et al. (2017) used data from China Family Panel Studies (CFPS) and found that air pollution reduces happiness and increases the incidence of depressive symptoms. By constructing a hierarchical spatial autoregressive probit model, Ma et al. (2020) showed that the welfare effect of air quality could not be replaced by other factors of people's livelihood.

Based on the direct impact of air pollution on residents' happiness, previous studies began to pay attention to the mechanism of the impact of air pollution on happiness. Chen et al. (2020) used China social Survey (CSS) data to establish a stepwise regression and found that air pollution corrodes citizen satisfaction via environmental perceptions. Li and Zhou (2020) used CFPS data and built a structural equation model, adopting the Sobel test, and concluded that air pollution can reduce residents' happiness via reducing health levels. Li (2015) used CGSS data, added interaction items to the regression model, and found that air pollution would reduce residents' happiness via quality of life. But in general, the research on the mechanism of air pollution affecting happiness is still limited, and the impact of air pollution on people's lives involves many aspects. Therefore, this paper argues that there may be other paths for the influence mechanism of air pollution on happiness.

Facing increasingly serious environmental pollution, China has adopted a series of measures to improve environmental quality, among which environmental regulation has become an important tool of pollutant discharge control. Some research combined environmental regulations with happiness, which can be divided into two categories. The first is to explore the direct impact of environmental regulations on happiness. For example, Guo et al. (2020) found that environmental regulations have a significant positive impact on happiness, and Guo (2020) found that

¹ This states that, after income increases to a certain level, residents' happiness does not increase with any further increase of income.

environmental regulations can affect happiness through green technology innovation, employment indicators, and health. The other approach is to explore whether environmental regulation can alleviate the impact of environmental pollution on happiness. Liu et al. (2019) compared the impact of environmental pollution (air and water) in baseline-tax areas and high-tax areas on residents' happiness and showed for the first time that environmental tax can alleviate the negative impact of environmental pollution on residents' happiness. Jin et al. (2020) analyzed happiness data collected before and after China's South-to-North Water Diversion Eastern Route Pollution Control Project and found that the pollution abatement project may not enhance happiness in its duration. However, the latter literature related to this paper only involves a relatively small part of the environmental regulation system, which may not be representative. Therefore, it remains to be verified whether other environmental regulations have a moderating effect on the relationship between air pollution and happiness.

3. Theory and Hypotheses

Individual needs are one of the most important sources of subjective happiness (Li and Shi 2017), with the satisfaction of needs directly affecting residents' happiness. Human needs are varied, but they are not chaotic. Maslow's Hierarchy of Needs Theory divides human needs into five levels from low to high, namely, physiological needs, safety needs, love and belonging, esteem needs, and self-actualization (Maslow 1943). With the most basic physiological needs, such as food, clothing, shelter, and transportation, people begin to pursue higher-level needs, such as health, safety, leisure, and spirituality. Low-level needs are material needs that are affected by income, where income growth can increase happiness. However, high-level needs are non-material needs that cannot be satisfied by an increase in income, and where non-economic factors may be at work. As one of the non-economic factors, air quality suffers from pollution, which will hinder the satisfaction of human higher-level needs. When humans' needs are not satisfied, their happiness will also decrease. Therefore, we propose the following hypothesis:

H1: Air pollution has a negative effect on happiness.

At present, there are limited studies on the mechanism of the effect of air pollution on happiness. A few studies have found that environmental pollution reduces residents' physical health levels (Yuan et al. 2018; Li and Zhou 2020) and increase residents' pollution perceptions (Chen et al. 2020), thereby reducing their happiness. In addition, there may be other paths of influence. On the one hand, people living in areas with severe air pollution are more likely to suffer from anxiety and depression (Zhang et al. 2017), and air pollution can reduce the mental health level of residents (Wang and Lu 2020). However, good mental health is the basis for residents to enjoy and discover a better life, and an important factor in improving happiness (Liang and Wang 2018).

On the other hand, according to stress reduction theory (Ulrich 1983) and attention restoration theory (Kaplan and Kaplan 1989), the visual features of natural environments can relieve tension, tiredness, and daily stress, while restoring attention and enhancing positive emotions. Therefore, adequate outdoor leisure can alleviate the loss of residents' happiness caused by tiredness and tension (Chang et al. 2019). However, outdoor leisure may pose health risks to residents as a result of exposure to air pollution, which can be avoided by reducing the frequency of outdoor leisure time (Noonan 2014). For most people, in addition to the strict sense of outdoor activities, participating in common leisure activities, such as shopping, watching movies, getting together with friends, and exercising, increases direct contact with the natural environment and outdoor air. If the frequency of exposure to air pollution reduces leisure activities, this is equivalent to reducing the possibility of happiness. Therefore, we propose the following hypothesis:

H2: Air pollution will reduce residents' happiness via reducing the level of mental health and frequency of leisure activities.

In the relationship between air pollution and happiness, there is still insufficient evidence on whether or not environmental regulation plays a moderating role. First, environmental pollution causes a series of problems that reduce residents' happiness, such as quality of health, and increase residents' dissatisfaction with environmental management (Shi and Guo 2019), resulting in a decrease of happiness. Likewise, environmental regulation allows residents to see the action of environmental managers and reduces their discontent with environmental managers, thereby promoting happiness. Second, moderate environmental regulation is conducive to reducing pollutant emissions and energy consumption, thus improving environmental quality (Song et al. 2020). Thus, the implementation of environmental regulations will indirectly promote the improvement of residents' happiness. In addition, studies have shown that environmental taxation, as one of these environmental regulations, has a moderating effect on the relationship between air pollution and happiness (Liu et al. 2019). Therefore, we have reason to propose the following hypothesis:

H3: Environmental regulations have a moderating effect on the relationship between air pollution and happiness.

4. Research Design

4.1. Data Sources

The data were obtained from the 2013, 2015, and 2017 versions of the CGSS, which is recognized as the authoritative data for studying residents' happiness and values. CGSS is a nationwide continuous survey initiated by the Department of Sociology at Renmin University of China. The researchers use random sampling to select households across the country, and one person in each household is randomly selected from the family members aged 18 or older for the interview. The survey area covered 28 provinces, with the exceptions of Tibet, Xinjiang, Hainan, Hong Kong, Macao, and Taiwan. After deleting missing and abnormal value cases, 30,745 observations remained.

The data on SO₂ emission, regional economy, industrial structure, medical conditions, and education levels were obtained from the *China Statistical Yearbook*. Government investment in combating environmental pollution as a proportion of gross domestic product (GDP) was obtained from the *China Environmental Statistics Yearbook*. Pollutant discharge fees came from the *China Environment Yearbook*, and the number of complaints about environmental pollution came from the Ministry of Ecology and Environment of the People's Republic of China.² Air quality indicators (AQI), concentrations of particulate matter PM_{2.5}, PM₁₀, CO, and NO₂, were obtained from the Air Quality Online Monitoring and Analysis Platform.³

Since the data only include respondents' residence information at the province level, the final data were obtained by merging individual characteristics and provincial characteristics by the addresses of the respondents.

4.2. Variable Selection

The dependent variable in the analysis is residents' happiness, measured using question 36 in the CGSS: "Overall, do you think your life is happy?" The response options were: very unhappy, unhappy, unclear, happy, and very happy. In Chen et al. (2020), happiness is defined as a binary dummy variable, with values of one indicating relatively happy and very happy, and zero otherwise.

The independent variable used is air pollution. SO₂ emissions are the main cause of the increase in PM_{2.5}, and they are the most irritating to humans (Liu et al. 2019). Therefore, we selected the logarithm of SO₂ emissions as a proxy variable for air pollution level. On this basis, we used AQI, PM_{2.5}, PM₁₀, CO, and NO₂ concentrations to replace SO₂ emissions in the robustness test. Since the CGSS survey period is from June to December in 2013, 2015, 2017, this paper used crawler technology to obtain monthly air quality monitoring data for each prefecture-level city from January to May. The average provincial data were matched with data from CGSS.

We also added several control variables. Based on several studies (Yuan et al. 2018; Chen et al. 2020; Jin et al. 2020; Li and Fan 2016), we introduced individual, family, and provincial characteristic variables to control for their influence on residents' happiness. Individual and family characteristic variables mainly include: age, gender, marital status, self-rated health, years of education, income status, social security participation, political status, residence type, and whether or not the individual has children. Provincial characteristic variables include regional economic development level (GDP), industrial structure (proportion of GDP of the secondary industry), medical conditions (number of beds per 10,000 people), and education levels (number of higher education teachers per 10,000 people). Residual information (e) represents the regional economic development level excluding the part overlapped with SO₂ information (Mei et al. 2020).⁴

The mediator variables were mental health and leisure activities. The CGSS includes the following question about mental health: "How often did you feel depressed in the past four weeks?" Answer choices (coded 1–5) were: always, often, sometimes, rarely, and never, with higher score indicating a higher level of mental health (Wang and Lu 2020). Leisure activities explored in this paper include shopping, watching movies, getting together with friends, and exercising. They were measured using the following CGSS question: "In the past year, did you often engage in the following activities in your spare time?" Answer choices (coded 1–5) were: never, several times a year or less, several times a month, several times a week, and every day, with higher scores indicating a higher frequency of leisure activities.

The moderator variable was environmental regulations. Based on current research, this paper divides environmental regulations into three types. The first is command-and-control environmental regulations, which are government-led and mandatory and are mainly implemented through laws and regulations. Existing work mainly uses the number of environmental policies newly issued each year (Zheng and Shi 2017), the number of environmental administrative penalty cases (Guo et al 2020), and investment in environmental pollution control (He 2019). Considering data availability, this paper uses government investment in combating environmental pollution as a proportion of GDP.

² Ministry of Ecology and Environment of the People's Republic of China: <http://www.mee.gov.cn/hdjl/>.

³ Air Quality Online Monitoring and Analysis Platform: <https://www.aqistudy.cn/historydata/>.

⁴ First, $\ln\text{so}_2$ and $\ln\text{GDP}$ are obtained by taking the logarithm of SO₂ and GDP, respectively. Then $\ln\text{so}_2$ is used to regress $\ln\text{GDP}$, and the residual term is e, which is called the residual information of GDP.

The second category of market-based environmental regulation refers to a series of measures implemented by the government to improve environmental pollution through economic means. Pollutant discharge fees are widely used to measure market-based environmental regulation (Li and Ramanathan 2018), so this paper adopts the same proxy. The third type of voluntary environmental regulation mainly functions as the supervision of enterprises by residents in polluted areas. Considering previous researches, we use the number of complaints about environmental pollution as the measure (Guo et al 2020).

Table 1. Summary statistics.

Variable	Variable Meaning	Obs	Mean	SD
<i>happiness</i>	Residents' happiness (happiness = 1, others = 0)	30,745	0.76	0.42
<i>lnSO₂</i>	logarithm of SO ₂ emission	84	3.71	0.87
<i>AQI</i>	Average AQI from January to May	56	89.49	18.17
<i>PM_{2.5}</i>	Average PM _{2.5} from January to May	56	54.67	14.77
<i>PM₁₀</i>	Average PM ₁₀ from January to May	56	92.39	26.16
<i>CO</i>	Average CO from January to May	56	1.14	0.25
<i>NO₂</i>	Average NO ₂ from January to May	56	34.80	10.30
<i>age</i>	Age	30,745	55.26	16.47
<i>age²</i>	Age squared	30,745	3324.55	1855.14
<i>gender</i>	Gender (male = 1, female = 0)	30,745	0.49	0.50
<i>married</i>	Marriage (married = 1, others = 0)	30,745	0.78	0.41
<i>health</i>	self-rated health (health = 1, others = 0)	30,745	0.59	0.49
<i>education</i>	Education years	30,745	8.82	4.74
<i>lnincome</i>	Logarithm of income	30,745	8.38	3.62
<i>socinsure</i>	Participate in at least one type of social security (yes = 1, no = 0)	30,745	0.94	0.23
<i>polity</i>	Political status (party member = 1, others = 0)	30,745	0.11	0.31
<i>urban</i>	Place of residence (city = 1, country = 0)	30,745	0.61	0.49
<i>children</i>	Have at least one child (yes = 1, no = 0)	30,745	0.88	0.33
<i>e</i>	Remaining information in GDP that overlaps when SO ₂ is removed	84	-0.04	0.36
<i>sindustry</i>	Proportion of GDP of the secondary industry	84	44.74	7.59
<i>bed</i>	Beds per 10,000 people	84	51.61	7.51
<i>high</i>	Higher education teachers per 10,000 people	84	12.37	4.86
<i>impress</i>	Frequency of depression in the last four weeks	30,696	3.86	0.96
<i>movie</i>	Frequency of watching movies	30,699	1.45	0.73
<i>shop</i>	Frequency of shopping	30,694	2.57	1.09
<i>friend</i>	Frequency of getting together with friends	30,689	2.39	0.98
<i>exercise</i>	Frequency of physical exercise	30,692	2.35	1.53
<i>investment</i>	Percentage of environmental pollution governance investment in GDP	84	1.39	0.65
<i>lnfee</i>	Logarithm of pollutant discharge fees	84	10.85	0.81
<i>complaint</i>	Complaints about environmental pollution (standardization) ⁵	84	0.24	0.23

208

209 4.3. Models

210 4.3.1. Total Effect Analysis Model

211 This paper mainly analyzes the impact of air pollution on residents' happiness and establishes the following regression model:
212

$$happiness_i = \beta_0 + \beta_1 \ln SO_2 + \beta_2 X_i + Year_t + \varepsilon_i \quad (1)$$

213 where i represents the individual, $\ln SO_2$ represents air pollution, X is the vector of individual characteristics and provincial conditions, $Year_t$ is time fixed effects, and ε_i is the error term.

214

⁵ In 2013, the complaint channel was the environmental protection report hotline. In 2015, a WeChat report option was added, and in 2017, an online report option was added. The statistical caliber of the three years was not consistent and not comparable, so the annual number of complaints was standardized.

215 Residents' happiness is a binary dummy variable, so we used a probit model to estimate Equation (1). The risk of
 216 direct estimation of Equation (1) is that there may be endogeneity problems caused by missing variables and meas-
 217 urement error, which makes the estimation inaccurate. One of the most effective methods to solve endogeneity prob-
 218 lems is to use instrumental variables. Referring to research on the construction of instrumental variables, this paper
 219 uses the instrumental variables of air pollution and a two-stage least squares (2SLS) regression, as shown in Equations
 220 (2) and (3). The first stage isolates the exogenous part of the endogenous variable:

$$\ln SO_2 = \gamma_0 + \gamma_1 IV + \gamma_3 X_i + \varepsilon_{1i} \quad (2)$$

221 In the second stage, the estimated value of $\ln SO_2$ in (2) is used to make a regression model of happiness:

$$happiness_i = \beta_0 + \beta_1 \ln \hat{SO}_2 + \beta_2 X_i + \varepsilon_{2i} \quad (3)$$

222 where IV represents the instrumental variable, and $\ln \hat{SO}_2$ represents the estimated value of $\ln SO_2$ in Equation (2).

223 Meteorological conditions are often chosen as the instrumental variable for air pollution. Li and Zhang (2019)
 224 designated the wind speed at 10 m as the instrumental variable for air pollution. On one hand, wind speed, as a natural
 225 meteorological condition, meets the requirements of exogenous conditions; on the other hand, when wind speed is
 226 higher, the diffusion speed of pollutants is faster and the transverse diffusion area is larger, which meets the require-
 227 ments of the correlation between air pollution and instrumental variables. Based on this, we use ArcGIS and the 0.125 x
 228 0.125 accuracy of the meteorological grid data from the European Center for Medium Range Weather Forecast⁶ and
 229 merge it with the provincial surface area vector data published by the National Geomatics Center of China.⁷ We then
 230 extract the annual average wind speed at the provincial level. Figure 1 reports the correlation between average wind
 231 speed and air pollution (SO_2 emission) in each province, and the two are negatively correlated, which is consistent with
 232 the expectation.

233
 234 **Figure 1.** Correlation between wind speed and air pollution

235 4.3.2. Mediation Effect Model

236 To test whether air pollution affects residents' happiness by reducing their mental health level and frequency of
 237 leisure activities, this paper refers to Baron and Kenny's (1986) stepwise regression, and constructs the following
 238 mechanism analysis model:

$$happiness_i = \gamma_0 + c \cdot \ln SO_2 + \gamma_1 \cdot X_i + Year_t + \varepsilon_{1i} \quad (4)$$

⁶ See the European Center for Medium Range Weather Forecast: <https://apps.ecmwf.int/datasets/data/interim-full-moda/levtype=sfc/>.

⁷ See the National Geomatics Center of China: <http://www.tianditu.gov.cn/>.

$$Mediation_i = \alpha + a \cdot \ln SO_2 + \alpha_1 \cdot X_i + Year_i + \varepsilon_{2i} \quad (5)$$

$$happiness_i = \beta_0 + c' \cdot \ln SO_2 + \beta_1 \cdot X_i + b \cdot Mediation_i + Year_i + \varepsilon_{3i} \quad (6)$$

Here, mediation refers to mediating variables such as mental health and leisure activities. Testing the mediating effect involves the following steps:

Step 1: Test the total effect. If the regression coefficient c in Equation (4) is significant, the overall effect of $\ln SO_2$ on $happiness$ is significant; if not, the test is stopped.

Step 2: Test the mediation effects. If the regression coefficients a and b in Equations (5) and (6) are significant, then the mediation effect is significant; if one of the regression coefficients, a or b , is not significant, then the Sobel and Bootstrap tests are conducted. If the test result is significant, the mediating effect is established; if not, the mediating effect is not established.

Step 3: Test whether there is a complete mediating effect. In the case of a significant mediation effect, if the regression coefficient c' in Equation (6) is significant, there is partial mediation, otherwise it is complete mediation.

4.3.3. Moderation Effect Model

To explore whether environmental regulation has a moderating effect on the relationship between air pollution and happiness, this paper constructs a model based on Equation (1), adding the interaction term between environmental regulation and air pollution:

$$happiness_i = \beta_0 + \beta_1 \ln SO_2 + \beta_2 X_i + \beta_3 Mod + \beta_4 \ln SO_2 \cdot Mod + \varepsilon_i \quad (7)$$

where Mod represents environmental regulation, and $\ln SO_2 \cdot Mod$ represents the interaction term between environmental regulation and air pollution.

5. Empirical Results

5.1. Baseline Estimate

Using ordinary least squares (OLS) estimation with Equation (1), Columns (1)–(3) of Table 2 report the estimated results for the individual characteristics, provincial characteristics, and time fixed effects that were controlled by stepwise, respectively. Specifically, Columns (1) and (2) show that the coefficient for air pollution ($\ln SO_2$) are -0.0394 and -0.0414 , and both with $p < 0.01$, which indicates that air pollution significantly reduce residents' happiness. However, Column (3) shows that, in this model, the coefficient for air pollution is -0.0194 with $p > 0.1$, which mean the effect of air pollution on residents' happiness not significant. This likely occurs because the models in Columns (1) and (2) did not control for time fixed effects, leading the impact of air pollution on happiness to be overrated.

Table 2. Regression results of the effect of air pollution on residents' happiness.

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
<i>happiness</i>	OLS			2SLS		
<i>lnSO₂</i>	−0.0394*** (0.0083)	−0.0414*** (0.0126)	−0.0194 (0.0174)	−0.5706*** (0.0754)	−0.3584*** (0.0546)	−0.3130*** (0.0523)
<i>age</i>	−0.0485*** (0.0039)	−0.0479*** (0.0039)	−0.0471*** (0.0039)	−0.0516*** (0.004)	−0.0474*** (0.0038)	−0.0487*** (0.0038)
<i>age2</i>	0.0005*** (0.0000)	0.0005*** (0.0000)	0.0005*** (0.0000)	0.0005*** (0.0000)	0.0005*** (0.0000)	0.0005*** (0.0000)
<i>gender</i>	−0.1737*** (0.0171)	−0.1736*** (0.0172)	−0.1720*** (0.0172)	−0.1279*** (0.0193)	−0.1617*** (0.0174)	−0.1631*** (0.0173)
<i>health1</i>	0.4991*** (0.0175)	0.5139*** (0.0176)	0.5174*** (0.0177)	0.6193*** (0.0253)	0.5424*** (0.0186)	0.5247*** (0.0179)
<i>lnincome</i>	0.0033 (0.0024)	0.0038 (0.0024)	0.0045* (0.0024)	−0.0109*** (0.0033)	(0.0000) (0.0025)	0.0009 (0.0025)
<i>urban</i>	−0.1165*** (0.0185)	−0.1212*** (0.0191)	−0.1183*** (0.0191)	−0.3103*** (0.0338)	−0.1735*** (0.0214)	−0.1547*** (0.0203)
<i>married</i>	0.3393*** (0.0241)	0.3475*** (0.0241)	0.3496*** (0.0242)	0.3889*** (0.0265)	0.3625*** (0.0243)	0.3510*** (0.0241)
<i>children</i>	0.1400*** (0.0358)	0.1295*** (0.0359)	0.1242*** (0.036)	0.1776*** (0.0381)	0.1240*** (0.0358)	0.1450*** (0.0358)
<i>socinsure1</i>	0.2231*** (0.0333)	0.2265*** (0.0333)	0.2205*** (0.0334)	0.1924*** (0.0359)	0.2036*** (0.0339)	0.2218*** (0.0335)
<i>polity</i>	0.2977*** (0.0311)	0.2975*** (0.0312)	0.2962*** (0.0312)	0.2983*** (0.0327)	0.2949*** (0.0313)	0.3006*** (0.0312)
<i>education</i>	0.0287*** (0.0023)	0.0285*** (0.0023)	0.0291*** (0.0023)	0.0102*** (0.0036)	0.0267*** (0.0024)	0.0270*** (0.0024)
<i>e</i>		0.1319*** (0.0277)	0.1039*** (0.0292)		0.3084*** (0.041)	0.2904*** (0.0431)
<i>sindustry</i>		−0.0030** (0.0015)	−0.001 (0.0015)		0.0100*** (0.0026)	0.0058*** (0.0019)
<i>high</i>		−0.0079*** (0.0024)	−0.0034 (0.0028)		−0.0363*** (0.0053)	−0.0331*** (0.0057)
<i>bed</i>		0.0097*** (0.0012)	0.0057*** (0.0016)		0.0100*** (0.0012)	0.0172*** (0.0025)
<i>_cons</i>	0.9129*** (0.1075)	0.6201*** (0.1644)	0.4598*** (0.1677)	3.2325*** (0.3454)	1.6267*** (0.2342)	1.2824*** (0.2157)
Year dummy	No	No	Yes	No	No	Yes
Observation	30,745	30,745	30,745	30,745	30,745	30,745

283 Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

284

285 As for the regression coefficient for air pollution is not significant in Column (3) of Table 2. In view of the limited
286 data obtained, this paper considers that endogeneity may be caused by the omission of variables. We use 2SLS esti-
287 mation to solve the endogeneity. Wind speed was selected as an instrumental variable to estimate Equations (2)–(3).
288 The first stage shows that the value of F is much greater than 10, which rejects the hypothesis of the weak instrumental
289 variable test. Therefore, wind speed is an effective instrumental variable.⁸

290 Columns (4)–(6) of Table 2 report the estimated results for Phase 2 in which individual characteristics, provincial
291 characteristics, and time fixed effects were controlled by stepwise, respectively. The regression coefficients for air
292 pollution are −0.5706, −0.3584 and −0.3130 respectively, and both with $p < 0.01$. These results indicates that air pollution

⁸ For the weak instrumental variable test, in the first stage of the regression, the test hypothesis is: H_0 : the coefficient of the instrumental variable is 0 (weak instru-
mental variable). The rule of thumb is that if the F statistic of the test is greater than 10, the null hypothesis of weak instrumental variables can be rejected (Chen 2014).
The F statistics in all the one-stage regression results in this paper are greater than 10. Due to limited space, the test results are not listed but can be provided by the
authors upon request.

has a significant negative impact on happiness, which supports Hypothesis 1. In addition, compared with the OLS results, the 2SLS results show that the absolute value of the regression coefficient of air pollution becomes larger and significant after controlling for the time fixed effects. This indicates that the influence will be underestimated without considering the endogeneity.

5.2. Robustness Tests

5.2.1. Replace the Dependent Variable

The dependent variable was replaced by tri-classification⁹ and five-classification¹⁰ variables representing happiness, and an ordered probit model was used to reevaluate Equations (2)–(3). The results are shown in Columns (1) and (2) of Table 3, and the regression coefficients for air pollution ($\ln SO_2$) are -0.2173 and -0.3838 with $p < 0.01$. These indicate that air pollution has a significant negative impact on happiness, which is consistent with the baseline regression results obtained in this paper.

Table 3. Robustness checks: Different definitions of happiness and different years.

Dependent variable	(1)	(2)	(3)	(4)	(5)
<i>happiness</i>	tri-classification	five-classification	2013	2015	2017
$\ln SO_2$	-0.2173^{***} (0.0501)	-0.3838^{***} (0.0402)	-0.4079^{***} (0.0956)	-0.3103^{**} (0.1473)	-0.2192^{***} (0.0711)
Control variables	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	—	—	—

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

5.2.2. The Degree of Influence in Different Years

Columns (3)–(5) of Table 3 are the estimated results for the reevaluation of Equations (2) and (3) that used data from 2013, 2015, and 2017, respectively. The results show that the regression coefficients for air pollution in all three years are negative and significant, which is consistent with the baseline results, indicating that the results are robust in different years. In addition, in terms of the absolute value, the regression coefficient for air pollution in 2013 was -0.4079 , which was larger than that for 2015 (-0.3103) and 2017 (-0.2192), indicating that the impact of air pollution on happiness gradually decreased over time. This may be related to the continuous improvement of air quality from 2013 to 2017 (see the appendix). Lower air pollution levels directly or indirectly reduce the impact on residents' happiness.

5.2.3. Replace the Independent Variable

The independent variable was replaced by an air quality index using AQI, PM_{2.5}, PM₁₀, CO, and NO₂ concentrations, and Equations (2) and (3) were reevaluated. Here, due to the absence of monitoring data on air pollution in 2013, only the combined data of 2015 and 2017 were used. Columns (1)–(5) of Table 4 report the estimated results obtained when the independent variable was replaced by AQI, PM_{2.5}, PM₁₀, CO, and NO₂ concentrations, respectively. The results show that the regression coefficients are all negative and significant at the 5% level, which is consistent with the baseline results in this paper. This suggests that the results are robust when the independent variable is replaced with different air pollution indicators.

⁹ The answer choices for the CGSS question about residents' happiness are: 1 = very unhappy and unhappy, 2 = can't say happy or unhappy, 3 = happy and very happy.

¹⁰ The answer choices for the CGSS question about residents' happiness are: 1 = very unhappy, 2 = unhappy, 3 = can't say happy or unhappy, 4 = happy, 5 = very happy.

Table 4. Robustness checks: Replace the independent variable.

Dependent variable <i>happiness</i>	(1)	(2)	(3)	(4)	(5)
<i>AQI</i>	−0.0800*** (0.0267)				
<i>PM_{2.5}</i>		−0.0185*** (0.0047)			
<i>PM₁₀</i>			−0.0310*** (0.009)		
<i>CO</i>				−1.2726*** (0.3254)	
<i>NO₂</i>					−0.1345*** (0.0391)
Control variables	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Observation	21,274	21,274	21,274	21,274	21,274

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

5.2.4. Eliminate Regional Samples

For this study, China was divided into seven geographic regions: East, South, Central, North, Northwest, Southwest, and Northeast. Then, the sample from one of the regions was removed from the analysis and Equations (2) and (3) were reevaluated. Columns (1)–(7) of Table 5 report the results after excluding one region per model. Regardless of which region was excluded, the regression coefficients for air pollution are negative and significant at the 5% level, indicating that the influence of air pollution on happiness is not affected by regional influence.

Table 5. Robustness checks: Eliminate regional samples.

Dependent variable <i>happiness</i>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Eliminate region	East	South	Central	North	Northwest	Southwest	Northeast
<i>lnSO₂</i>	−1.2985*** (0.2129)	−0.3070*** (0.055)	−0.2182*** (0.0486)	−0.5665*** (0.0963)	−0.2641*** (0.0694)	−0.2451*** (0.0435)	−0.2786*** (0.0464)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	22,645	28,561	25,061	26,100	28,640	26,686	26777

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

344

5.3. Heterogeneous Effect Analysis

There may be differences in the impact of air pollution on happiness among different groups. Huang and He (2013) found that there was no significant difference in the impact of air pollution on happiness under different absolute income levels, community living environment, age, and education levels. However, Yang and Zhang (2014) found that air pollution had a greater negative impact on the happiness of low-income, male, and rural residents. Some scholars have also explored the greater effects of air pollution on people with poor health status and the elderly (Song et al. 2020). To summarize, existing studies have not reached consistent conclusions on the differences among these groups. Therefore, this paper conducts heterogeneity analysis using different family roles, age structure, health status, education level, income status, and residence type (urban vs. rural).

According to whether or not the interviewees have children, we conducted a sub-sample regression, and the results are presented in Row (1) of Table 6. The absolute value of regression coefficient for air pollution ($\ln SO_2$) is larger for the group with children (−0.3466) than for the group without children (−0.2105), indicating that air pollution has a greater impact on the happiness of people with children. This may be because parents may pay more attention to the environment in which their children live compared to when they live alone. Similarly, the samples were divided into young (18–34 years), middle-aged (34–54 years), and older (> 54 years) groups for a sub-sample regression; the results are shown in Row (2) of Table 6. Here, air pollution has the greatest impact on young people. On the one hand, their work and life are not stable at this stage, and they often feel greater pressure to succeed, so they may be likely to have a

more pessimistic attitude compared to their older counterparts. On the other hand, it is easier for young people to obtain information about air pollution, which increases their aversion to air pollution if it exceeds their expectations.

Table 6. Heterogeneous analysis results.

Dependent variable <i>happiness</i>		$\ln SO_2$	SD	Control variable	Year dummy	Obs
(1) Have children	No	-0.2105**	(0.1000)	Yes	Yes	3,774
	Yes	-0.3466***	(0.0601)	Yes	Yes	26,971
(2) Age	Young	-0.6324***	(0.1376)	Yes	Yes	4,043
	Middle	-0.3237***	(0.0957)	Yes	Yes	10,735
	Old	-0.2677***	(0.0722)	Yes	Yes	15,967
(3) Subject health	Unhealthy	-0.3932**	(0.1949)	Yes	Yes	5,654
	Normal	-0.1884**	(0.0949)	Yes	Yes	6,963
	Healthy	-0.3301***	(0.0663)	Yes	Yes	18,128
(4) Education	Primary	-2.1181***	(0.5283)	Yes	Yes	10,984
	Secondary	-0.2604***	(0.0641)	Yes	Yes	14,466
	Higher	-0.1580**	(0.0686)	Yes	Yes	5,295
(5) Income	Lowest 25%	-2.3113***	(0.8569)	Yes	Yes	7,687
	Middle 50%	-0.4879***	(0.1091)	Yes	Yes	15,467
	Highest 25%	-0.0632	(0.0529)	Yes	Yes	7,591
(6) Residence type	Urban	-0.1133***	(0.0431)	Yes	Yes	18,786
	Rural	-4.6520***	(1.1135)	Yes	Yes	11,959

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

Another sub-sample regression was conducted according to respondents' self-rated health status (good, average, or poor), and the results are provided in Row (3) of Table 6. Air pollution is found to have the greatest impact on the happiness of residents with poor self-rated health. Such people may have poor immunity, so air pollution will do more harm to their bodies, thereby increasing their sensitivity to air pollution. Next, all the samples were divided into three groups according to education level: low, medium, and high.¹¹ The regression results of these three sub-samples are shown in Row (4) of Table 6. Here, air pollution has the greatest impact on the happiness of less educated people, perhaps because people with higher education may have a better working environment, making them less affected by air pollution.

Ranking income levels from low to high, we defined the groups as low income (bottom 25%), middle income (25%–50%), and high income (over 50%). Sub-sample regressions were conducted, and the results are displayed in Row (5) of Table 6. Air pollution had the greatest impact on the lowest income group, but it had no significant impact on people in the top of the income distribution. People with higher income can choose a better living environment with lower air pollution and have a better ability to deal with air pollution by buying better equipment, such as air purifier.

Finally, another sub-sample regression was conducted according to residential region (urban vs. rural), and the results are shown in Row (6) of Table 6. Here, air pollution has a greater impact on rural residents. This may be because rural residents work outdoors and are exposed to air pollution for a longer period of time each day. Moreover, they are less aware and less able to take protective measures against air pollution, which leads to more loss of happiness.

5.4. Mechanism Analysis

According to the steps of the stepwise regression, the first step tests the total effect. Column (6) of Table 2 indicates that the regression coefficient for air pollution ($\ln SO_2$) is -0.3130 with $p < 0.01$, indicating that air pollution has a negative overall effect on residents' happiness. Next, we discuss the second and third steps of the test.

First, we introduce psychological health (*impress*) as the mediating variable in the estimation of Equation (5), and the results are reported in Column (1) of Table 7. The regression coefficient for $\ln SO_2$ is -0.0996 with $p < 0.01$, indicating that air pollution significantly reduced residents' mental health. Column (2) of Table 7 reports the regression results for the estimation of Equation (6), which uses mental health as the mediating variable. We find that the regression coefficient for *impress* is 0.2859 with $p < 0.01$, indicating that residents' mental health has a significantly positive impact on

¹¹ The grouping was based on the definition of those with primary school education or less as the low-education group. The secondary education group is defined as those who attended high school (junior high school, senior high school). Those with higher education were defined as the higher-education group.

393 happiness. Meanwhile, the regression coefficient for $\ln SO_2$ is -0.3081 with $p < 0.01$, suggesting that partial mediating
394 effects exist. The above results indicate that the overall negative effect of air pollution on residents' happiness is partly
395 generated by reducing residents' mental health.

396 Similarly, according to the results in Columns (3)–(10) of Table 7, we find that the partial mediating effects of the
397 frequency of four types of leisure activities—watching movies, shopping, friends, and exercise—also exist. In other
398 words, the total negative effect of air pollution on residents' happiness is partly created by reducing the frequency with
399 which residents participate in leisure activities. Thus, Hypothesis 2 is supported.

400

Table 7. Regression results for the mediating effect.

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	impress	happiness	movie	happiness	shop	happiness	friend	happiness	exercise	happiness
lnSO ₂	-0.0996*** (0.0142)	-0.3081*** (0.0533)	-0.0667*** (0.0154)	-0.3115*** (0.0525)	-0.0903*** (0.0125)	-0.3307*** (0.0523)	-0.0416*** (0.0124)	-0.3405*** (0.0522)	-0.0468*** (0.0139)	-0.3006*** (0.0525)
impress		0.2859*** (0.0093)								
movie				0.0399*** (0.0138)						
shop						0.0562*** (0.008)				
friend								0.0788*** (0.009)		
exercise										0.0798*** (0.0061)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	30,696	30,696	30,699	30,699	30,694	30,694	30,689	30,689	30,692	30,692

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

5.5. Further Study: The Moderating Effect of Environmental Regulation

Command-and-control environmental regulations are mandatory, mainly rely on the government formulating a series of emission standards, which are mandatory for enterprises to meet (Blackman 2010). If enterprises do not comply with the relevant rules and regulations, they will face government punishment. Therefore, this kind of environmental regulation can effectively reduce the environmental pollution of enterprises, but it lacks flexibility. Market-based environmental regulations guide enterprises to reduce emissions according to market signals (Tang et al. 2020) so that the pollution tends to be controlled and optimized. In addition, market-based environmental regulations may reduce income inequality by providing more jobs for people to govern the environment through government spending (Guo et al. 2020). Voluntary environmental regulation comes from the supervision of residents. When the other two types of environmental regulations are weak or inadequate, residents can exert pressure on enterprises and government to increase governance and control its scope, thereby reducing pollution emissions (Li and Ramanathan 2018).

Table 8. Regression results for the moderating effect.

Dependent variable	(1)	(2)	(3)
<i>happiness</i>	Command-and-control	Market-based	Voluntary
<i>lnSO₂</i>	−0.2568*** (0.0461)	−4.2146*** (0.7190)	−0.5211*** (0.0794)
<i>investment</i>	−0.1284** (0.0579)		
<i>investment*lnSO₂</i>	0.0875*** (0.0171)		
<i>lnfee</i>		−1.0170*** (0.1970)	
<i>lnfee*lnSO₂</i>		0.3578*** (0.0621)	
<i>complaint</i>			−2.6166*** (0.4770)
<i>complaint*lnSO₂</i>			0.7214*** (0.1199)
Control variables	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observation	30,475	30,475	30,475

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; standard errors in parentheses.

Columns (1)–(3) of Table 8 report the estimated results for Equation (7), which uses command-and-control, market-based, and voluntary environmental regulations as moderators. As shown in Column (1), the interaction term's (*investment*lnSO₂*) coefficient is 0.0875, which is significant at the 1% level. This indicates that command-and-control environmental regulations have a significant alleviating effect on the relationship between air pollution and happiness. Similarly, both market-based and voluntary environmental regulations have significant alleviating effects on the relationship between air pollution and happiness. This supports Hypothesis 3.

There are three reasons why environmental regulations can alleviate the impact of air pollution on happiness. First, command-and-control and market-based policies represent the government's attention to environmental pollution, which reduces residents' dissatisfaction with the government to some extent, thereby improving their happiness. Second, the three types of environmental regulations can all improve air quality. When people believe that environmental regulations will reduce air pollution, and the level of environmental regulations is improved, they will have a positive outlook about the improvement of air quality, thus alleviating their aversion to air pollution. Finally, voluntary environmental regulation enables the government to obtain more comprehensive information about the level of pollution and take timely measures. Moreover, residents with environmental awareness and who participate in environmental protection are more likely to feel happy (Binder and Blankenberg 2016). Therefore, the effect of air pollution on happiness is alleviated.

434 6. Conclusions

435 In this study, we combine provincial characteristics data with individual characteristics data from the CGSS (2013,
436 2015, and 2017), and use wind speed as the instrumental variable of air pollution. A 2SLS regression was used to em-
437 pirically study the effects of air pollution on residents' happiness. In addition, mediating and moderating variables
438 were introduced to explore the mechanism and the alleviating effect of air pollution's impact on residents' happiness.
439 The main conclusions are as follows.

440 First, air pollution has a significant negative impact on residents' happiness, and the effect is different among
441 groups with different family roles, ages, residence types, self-rated health, education levels, and income levels. Second,
442 there is a significant mediating effect on the level of mental health and the frequency of leisure activities—that is, air
443 pollution reduces residents' happiness by reducing their level of mental health and the frequency of their leisure ac-
444 tivities. Third, command-and-control, market-based, and voluntary environmental regulations can all alleviate the
445 negative impact of air pollution on residents' happiness.

446 On the question of how to improve residents' happiness based on the current development situation in China, the
447 answer offered in this paper is that we should first strengthen mental health education and construct facilities to sup-
448 port leisure activities to help residents reduce the loss of happiness caused by air pollution. Second, we should make
449 good use of environmental regulation tools and have stricter control over environmental governance to fundamentally
450 solve the problem of air pollution.

451 -Ethical Approval

452 This study does not involve ethical issues

453 -Consent for Participation

454 Not applicable

455 -Consent to Publish

456 The authors agree to publicaition in the journal

457 -Availability of data and materials

458 Not applicable

459 Authors Contributions

460 Conceptualization, F.X. and D.Z.; Data curation, X.-L.L.; Formal analysis, F.X. and D.Z.; Methodology, F.X. and X.-L.L.; Supervision,
461 F.X., D.Z. and X.-L.L.; Visualization, X.-L.L.; Writing original draft, X.-L.L. F.X., and D.Z.; Writing review and editing, F.X. and
462 X.-L.L.

463 **Funding:** This research was funded by the National Social Science Fund of China (Grant No. 18BTJ011), Humanities and Social
464 Science Fund of the Ministry of Education of China (Grant No. 20YJC790191), National Statistical Science Research Project of the
465 National Bureau of Statistics of China (Grant No. 2020LY101), National Natural Science Foundation of China (Grant No. 72003049),
466 and Fundamental Research Funds for the Central Universities, Zhongnan University of Economics and Law(Grant NO.
467 2722019JCG023).

468 **Conflicts of Interest:** The authors declare no conflict of interest.

469 Appendix A

Figure A1. SO₂ emission in each province.

References

- Alvarez-Diaz A, Gonzalez L, Radcliff B (2010) The politics of happiness: On the political determinants of quality of life in the American States. *J Polic* 72(3):894-905. <https://doi.org/10.1017/S0022381610000241>
- Baron RM, Kenny DA (1986) The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J Personality and Soc Psychol* 51(6):1173-1182. <https://doi.org/10.1037/0022-3514.51.6.1173>
- Binder M, Blankenberg AK (2016) Environmental concerns, volunteering and subjective well-being: Antecedents and outcomes of environmental activism in Germany. *Ecol Econ* 124:1-16. <https://doi.org/10.1016/j.ecolecon.2016.01.009>
- Blackman A (2010) Alternative pollution control policies in developing countries. *Rev Environ Econ Policy* 4(2):234-253. <https://doi.org/10.1093/reep/req005>
- Chang PJ, Song R, Lin Y (2019) Air pollution as a moderator in the association between leisure activities and well-being in urban China. *J Happiness Stud* 20(8):2401-2430. <https://doi.org/10.1007/s10902-018-0055-3>
- Chen L, Zhang J, You Y (2020) Air pollution, environmental perceptions, and citizen satisfaction: A mediation analysis. *Environ Res* 184:109287. <https://doi.org/10.1016/j.envres.2020.109287>
- Chen Q (2014) In *Advanced Econometrics and Stata Application*; Higher Education Press: Beijing, China.
- Clark AE (2018) Four decades of the economics of happiness: Where next? *Rev of Income and Wealth* 64(2):245-269. <https://doi.org/10.1111/roiw.12369>
- Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, ... Forouzanfar MH (2017) Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *The Lancet* 389(10082):1907-1918. [https://doi.org/10.1016/S0140-6736\(17\)30505-6](https://doi.org/10.1016/S0140-6736(17)30505-6)
- Cuñado J, De Gracia FP (2013) Environment and happiness: new evidence for Spain. *Soc Indic Res* 112(3):549-567. <https://doi.org/10.1007/s11205-012-0038-4>
- Diener E, Chan MY (2011) Happy people live longer: Subjective well-being contributes to health and longevity. *Appl Psychol: Health and Well-Being* 3(1):1-43. <https://doi.org/10.1111/j.1758-0854.2010.01045.x>
- Easterlin RA (1974) Does economic growth improve the human lot? Some empirical evidence. Academic Press, New York, pp 89-125. <https://doi.org/10.1016/B978-0-12-205050-3.50008-7>
- Ferreira S, Akay A, Brereton F, Cuñado J, Martinsson P, Moro M, Ningal TF (2013) Life satisfaction and air quality in Europe. *Ecol Econ* 88:1-10. <https://doi.org/10.1016/j.ecolecon.2012.12.027>
- Guo S (2020) Exploring the Impact of Environmental Quantity and Environmental Regulations on Subjective Well-Being. Master's thesis, China University of Mining and Technology, Xuzhou, China.
- Guo S, Wang W, Zhang M (2020) Exploring the impact of environmental regulations on happiness: new evidence from China. *Environ Sci Pollut Res* 27(16):1-18. <https://doi.org/10.1007/s11356-020-08508-7>
- Haller M, Hadler M (2006) How social relations and structures can produce happiness and unhappiness: An international comparative analysis. *Soc Indic Res* 75(2):169-216. <https://doi.org/10.1007/s11205-004-6297-y>

He XB (2019) Investigating environmental regulation and income inequality of urban residents: The perspective of idiosyncratic regulatory tools. *Collected Essays on Finance and Econ* (06):104-112. <https://doi.org/10.13762/j.cnki.cjlc.20190218.002>

Huang YM, He LY (2013) Urbanization, environmental pollution and subjective well-being: An empirical study on China. *China Soft Sci* (12):82-93.

Jin Z, Zeng S, Cao C, Ma H, Sun D (2020) Impacts of pollution abatement projects on happiness: An exploratory study in China. *J Clean Prod* 274:122869. <https://doi.org/10.1016/j.jclepro.2020.122869>

Kaplan R, Kaplan S (1989) *The experience of nature: A psychological perspective*. Cambridge university press.

Li F, Zhou T (2020) Effects of objective and subjective environmental pollution on well-being in urban China: A structural equation model approach. *Soc Sci Med* 249:112859. <https://doi.org/10.1016/j.socscimed.2020.112859>

Li LL, Shi L (2017) Economic growth and subjective well-being: Analyzing the formative mechanism of the Easterlin paradox. *Sociol Stud* 32(03):95-120+244. <https://doi.org/10.19934/j.cnki.shxyj.2017.03.005>

Li M, Zhang YR (2019) The effect of air pollution on migration: A study based on the choice of university city by international students in China. *Econ Res J* 54(06): 168-182.

Li MJ (2015) Environmental pollution, governmental regulation and the happiness sense of residents: An empirical analysis based on CGSS (2008) micro-survey data. *Modern Econ Sci* 37(05):59-68+126.

Li R, Ramanathan R (2018) Exploring the relationships between different types of environmental regulations and environmental performance: Evidence from China. *J Clean Prod* 196:1329-1340. <https://doi.org/10.1016/j.jclepro.2018.06.132>

Li T, Fan WT (2016) Parenthood and subjective well-being: A life-cycle and life-course perspective. *Popul Res* 40(05):6-19.

Li Z, Folmer H, Xue J (2014) To what extent does air pollution affect happiness? The case of the Jinchuan mining area, China. *Ecol Econ* 99:88-99. <https://doi.org/10.1016/j.ecolecon.2013.12.014>

Liang XY, Wang C (2018) The influence of emotional intelligence on well-being of left-behind children: The mediating role of emotional experience and mental health. *Chinese J of Clinical Psychol* 26(2):387-390+386. <https://doi.org/10.16128/j.cnki.1005-3611.2018.02.038>

Liu Y, Li RL, Song Y, Zhang ZJ (2019) The role of environmental tax in alleviating the impact of environmental pollution on residents' happiness in China. *Int J Environ Res and Public Health* 16(22):4574. <https://doi.org/10.3390/ijerph16224574>

Ma JY, Han ZZ, Cai HD (2020) The effect of air quality on life satisfaction: Based on the ordered hierarchical spatial autoregressive probit model. *Stat Res* 37(11):30-43. <https://doi.org/10.19343/j.cnki.11-1302/c.2020.11.003>

Ma XJ, Wang CX, Zhang ZY (2019) Quantitative study of residents' wellbeing from the perspective of a "two-dimensional" environment: New evidence from China CGSS data. *Stat Res* 36(09):56-67. <https://doi.org/10.19343/j.cnki.11-1302/c.2019.09.005>

MacKerron G (2012) Happiness economics from 35,000 feet. *J Econ Surv* 26(4):705-735. <https://doi.org/10.1111/j.1467-6419.2010.00672.x>

Maslow AH (1943) A theory of human motivation. *Psychol Rev* 50(4):370. <https://doi.org/10.1037/h0054346>

Matus K, Nam KM, Selin NE, Lamsal LN, Reilly JM, Paltsev S (2012) Health damages from air pollution in China. *Glob Environ Change* 22(1):55-66. <https://doi.org/10.1016/j.gloenvcha.2011.08.006>

Mei DZ, Wu MT, Qian TF, Tan ST (2020) Income inequality, government expenditure, and real exchange rate: A study based on cross-country panel data. *J Financial Res* (04):31-47.

Noonan DS (2014) Smoggy with a chance of altruism: The effects of ozone alerts on outdoor recreation and driving in Atlanta. *Policy Stud J* 42(1):122-145. <https://doi.org/10.1111/psj.12045>

Oishi S, Kesebir S, Diener E (2011) Income inequality and happiness. *Psychol Sci* 22(9):1095-1100. <https://doi.org/10.1177/0956797611417262>

Oswald AJ, Proto E, Sgroi D (2015) Happiness and productivity. *J Labor Econ* 33(4):789-822. <https://doi.org/10.1086/681096>

Sacks DW, Stevenson B, Wolfers J (2010) Subjective well-being, income, economic development and growth. *National Bureau of Econ Res*. <https://doi.org/10.3386/w16441>

Shi Q, Guo F (2019) Do people have a negative impression of government on polluted days? Evidence from Chinese cities. *J Environ Plann and Man* 62(5):797-817. <https://doi.org/10.1080/09640568.2018.1443801>

Song Y, Yang T, Li Z, Zhang X, Zhang M (2020) Research on the direct and indirect effects of environmental regulation on environmental pollution: Empirical evidence from 253 prefecture-level cities in China. *J Clean Prod* 269, 122425. <https://doi.org/10.1016/j.jclepro.2020.122425>

Song Y, Zhou A, Zhang M (2020) Exploring the effect of subjective air pollution on happiness in China. *Environ Sci and Pollut Res* 27(34):43299-43311. <https://doi.org/10.1007/s11356-020-10255-8>

Tang K, Qiu Y, Zhou D (2020) Does command-and-control regulation promote green innovation performance? Evidence from China's industrial enterprises. *Sci Total Environ* 712:136362. <https://doi.org/10.1016/j.scitotenv.2019.136362>

Ulrich RS (1983) Aesthetic and affective response to natural environment. *Behavior and the Natural Environ*:85-125. https://doi.org/10.1007/978-1-4613-3539-9_4

Wang LP, Lu C (2020) Influence of air pollution on mental health of working population: Data analysis based on CLDS. *World Surv and Res* (12):48-52+59. <https://doi.org/10.13778/j.cnki.11-3705/c.2020.12.007>

Welsch H (2006) Environment and happiness: Valuation of air pollution using life satisfaction data. *Ecol Econ* 58(4):801-813. <https://doi.org/10.1016/j.ecolecon.2005.09.006>

Yang JD, Zhang YR (2014) Pricing air pollution: An analysis based on happiness data. *J World Economy* 37(12):162-188. <https://doi.org/CNKI:SUN:SJJJ.0.2014-12-009>

Yuan L, Shin K, Managi S (2018) Subjective well-being and environmental quality: the impact of air pollution and green coverage in China. *Ecol Econ* 153:124-138. <https://doi.org/10.1016/j.ecolecon.2018.04.033>

- 569 Zhang X, Zhang X, Chen X (2017) Happiness in the air: How does a dirty sky affect mental health and subjective well-being? J En-
570 viron Econ Manag 85: 81-94. <https://doi.org/10.1016/j.jeem.2017.04.001>
- 571 Zheng D, Shi M (2017) Multiple environmental policies and pollution haven hypothesis: evidence from China's polluting industries.
572 J Clean Prod 141:295-304. <https://doi.org/10.1016/j.jclepro.2016.09.091>