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Air pollution, environmental regulation and migration

Huang Qianqian[1,*], Sheng Yuxue[1], Jiang Cheng[2]

[1]School of Economics/China-ASEAN School of Economics/China-ASEAN Financial Co-operation Institute, Guangxi University, Nanning, China
[2]Institute of Educational Economics, Peking University, Beijing, China
[*]Corresponding author

Abstract: *This paper empirically examines the impact of air pollution on the employment migration of college graduates using micro-survey data and a logit model. The results reveal three key findings: First, air pollution has a significant impact on the employment migration of college graduates. The higher the PM2.5 levels in a college city, the more likely graduates are to migrate for employment. Second, environmental regulation serves as an important mechanism that weakens the effect of air pollution on graduate migration. Third, the study found that environmental regulation policies more effectively retain graduates who perceive that their college city actively implements environmental regulations. The conclusions of this paper not only contribute to research on air pollution and talent migration but also provide an empirical basis for policies related to urban environmental governance and talent retention in China.*

Keywords: *air pollution, migration, environmental regulation, college graduates*

1. Introduction

The relationship between environment and population migration has long been a focus in economics. Existing studies have highlighted the influence of environmental factors, such as temperature, rainfall, and urban greening, on human migration decisions. However, a research gap remains regarding the migration patterns of highly educated individuals, especially college graduates. Globally, air pollution is a significant environmental health threat. This not only affects humans' health and quality of life but also may reduce the region's appeal to highly educated individuals. Thus, examining the impact of air pollution on the migration of college graduates is essential.

China's air quality has steadily improved each year, and China is the first developing country globally to comprehensively control PM2.5 pollution. From 2013 to 2022, national GDP rose by 69%, the average concentration of PM2.5 declined by 57%, and the number of days with heavy pollution dropped by 92%. To address air pollution, China began implementing various pollution prevention and control policies as early as the last century to reduce emissions of key pollutants. For instance, in 1998, to control SO2, the primary pollutant at the time, the government of China introduced the first national air pollution law, the "Plan for Delimiting Acid Rain Control Zones and Sulfur Dioxide Pollution Control Zones" (Two Control Zones, TCZ). In 2013, the "Air Pollution Prevention and Control Action Plan" with ten measures issued, considered the most stringent air governance action plan in China's history.

From a personal health perspective, air pollution can drive population migration (Gao, 2023)[2]. Research indicates that environmental pollution contributes to the outward migration of highly educated individuals, leading to a loss of specialized talent with significant human capital (Chu et al., 2015)[1]. Air pollution significantly increases the likelihood of human capital migration, which may diminish the region's innovation capacity, thereby affecting high-quality economic development (Luo et al., 2019)[3]. The key questions that remain are: Is air pollution a driver of college graduate migration? What is the mechanism of air pollution influences the migration of college graduates?

In response to these questions, we employs a logit model and micro-survey data for empirical analysis, leading to the following main conclusions: First, air pollution has a significant impact on the migration of college graduates. Higher PM2.5 concentrations in a college city increase the likelihood of graduates migrating for employment. Second, environmental regulation serves as an important mechanism by which air pollution influences graduate migration. Specifically, environmental regulations reduce the impact of air pollution on graduate migration, effectively retaining graduates

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who perceive that their university city implements environmental policies. While existing literature on the relationship between air pollution and population migration generally lacks a focus on highly educated individuals, even fewer studies address this topic from an environmental perception perspective or consider the combined effects of air pollution, environmental regulation, and population migration. Thus, we makes three key contributions: we uses a micro database to analyze the impact of air pollution on the migration of college graduates; it examines the mechanism from the perspective of environmental perception; and it provides a comprehensive analysis of the interactions between air pollution, environmental regulation, and population migration.

The paper is organized as follows: Section 2 reviews relevant theories and literature on migration, air pollution, and environmental regulation. Section 3 introduces the model and data employed in this study. Section 4 reports the empirical results, and Section 5 provides the study's conclusions.

2. Literature Review

2.1. Factors Affecting Migration and Spatial Distribution

College graduates are an important part of the talent. The migration of college graduates is influenced by both micro and macro factors. At the micro level, gender, marital status, family status, and the number of children all significantly affect migration patterns. At the macro level, labor remuneration, natural environment, public service levels, and other factors have a substantial impact on the spatial distribution of college graduates. The migration of college graduates in China is relatively concentrated spatially, primarily in economically developed areas. Specifically, while college graduates tend to remain in their place of study, significant regional differences exist. Graduates are particularly concentrated in first-tier cities, where urban attractiveness varies significantly. Some cities have implemented talent policies to compensate for deficiencies in local economic and amenity offerings. Economic factors and urban amenities can effectively attract graduates. A higher house price-to-income ratio may lead to a "crowding-out effect" (Wang et al., 2021)[4]. Moreover, the migration preferences of highly educated individuals, varying by gender, age, and inflow areas, exhibit spatial heterogeneity.

2.2. The impact of air pollution on population migration

Existing studies generally believe that the difference in economic development levels between regions is the most important factor in shaping the spatial pattern of talent, while other studies highlight environmental factors as significant drivers of population migration. To explain why some individuals migrate while others remain under similar pressures, Slovic (1987)[5] suggests that the stronger residents' perception of disaster risks, the more likely they are to migrate when encountering disasters.

Currently, there is limited research on the impact of air pollution on population migration in China, though existing studies generally confirm that air pollution promotes population migration. Given that air pollution poses a significant threat to public health, it exerts a substantial crowding-out effect on labor. For every one percentage point increase in the air pollution index, the net inflow of labor decreases by approximately 158,000 individuals (Zhang and Huang, 2022; Zhang et al., 2022)[8][9].

2.3. The impact of environmental regulation on population migration

An increasing number of studies have sought to explore the impact of environmental regulation from the perspective of the labor market. Existing studies have generally reached a consensus: environmental regulation reduces employment in related manufacturing industries; however, studies that limit the effects of environmental regulation to polluting industries tend to overestimate the losses caused by such regulation. From a broader labor market perspective, Yamazaki (2017)[6] shows that environmental regulation increases total employment by promoting creative destruction and improving the technological level of enterprises. However, this study primarily focuses on closed regions, and the impact of environmental regulation on labor allocation across regions is rarely considered.

3. Method and Data

3.1. Empirical Model

To explore the relationship between air pollution, environmental regulation, and the migration of

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college graduates, we presents the following logit model:

$$\text{Migration}_i = \beta_0 + \beta_1 \ln\text{PM2.5} + \beta_2 \text{ER} + \gamma_1 X_i + \gamma_2 X_c + \varepsilon \quad (1)$$

In this model, i represents individual college graduates, and c represents the city where the graduate's college is located. The migration of the graduate is captured by a binary variable "Migration", which equals 1 if the graduate migrates and 0 otherwise. LnPM2.5 represents the logarithm of the annual average PM2.5 concentration in the city where the college is located, lagged by one year. ER represents the intensity of environmental regulation in the city where the college is located, lagged by one year. X_i represents a set of individual control variables, including age, gender, education, whether the graduate is an only child, household registration status, type of college, family income, and the nature of the employment. Since graduates may also migrate when selecting a college, which their college location differs from the hometown, we further control for school migration (denoted as migration1). X_c represents a set of city-level control variables, lagged by one year, including the number of museums, the number of doctors per capita, the number of buses per capita, the average wage, population size, house price, and the proportion of green space. β_0 is the constant term; β_1 represents the regression coefficient for air pollution; β_2 represents the impact coefficient of environmental regulation intensity on the migration of college graduates; γ_1, γ_2 represents the coefficient corresponding to the control variables. Finally, ε represents the random factors affecting individual i.

3.2. Data Source

3.2.1. Individual-level data

The individual data is from the 2019 National College Graduate Employment Status Survey, conducted by the School of Education/Institute of Educational Economics at Peking University. As some college cities are located outside the Chinese mainland, the individual data are processed as follows: first, colleges located outside the Chinese mainland are excluded; second, each graduate's college is matched with the corresponding city. Following this processing, 31 distinct college cities and 6,470 graduates were identified.

3.2.2. City-level data

Air pollution data is from Columbia University's socioeconomic dataset, and other city-level data comes from the China City Statistical Yearbook, and the China Economic Net Statistical Database. To ensure data stability, logarithmic transformations are applied to the city-level data.

3.3. Variables

3.3.1. Dependent variable

We focuses on the migration between the city of colleges and the city of employment, defining migration in the explained variable as occurring whenever the city of employment differs from the city of the college. If a graduate's city of employment differs from the city of the college, migration is coded as 1; otherwise, it is coded as 0.

3.3.2. Independent variable

PM2.5 remains the primary indicator of environmental monitoring in China. We employs PM2.5 as the key proxy variable for air pollution. PM2.5 measures particulate matter with a diameter of 2.5 microns or less in the atmosphere. Due to its small particle size, PM2.5 carries a high concentration of toxic and harmful substances. We employs the average annual PM2.5 concentration of prefecture-level cities in 2018 as the value for this variable.

3.3.3. Moderator variable

We adopts the comprehensive index approach to measure the level of environmental regulation. The index is calculated using five individual indicators: industrial smoke emissions, industrial SO2 emissions, the comprehensive utilization rate of industrial solid waste, the harmless treatment rate of domestic waste, and the centralized treatment rate of sewage treatment plants. First, each indicator is standardized. Next, the entropy method is applied to determine the weight of each indicator, and the comprehensive environmental regulation index is calculated based on the weights and standardized values. A higher score on the comprehensive index indicates stricter government control over the environment.

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3.3.4. Other control variables

We includes the following additional control variables: 1) Individual controls including school migration, gender, age, whether they are only children, household registration, education, family income, the nature of employment and the college type (vocational college, general undergraduate, 211 project, and 985 project); 2) City controls including the number of museums, the number of doctors per capita, the number of buses per capita, the average wage, population size, house price, and the proportion of green space, lagged by one period, with the logarithmic transformation applied. We introduces additional control variables in the robustness tests, and the results remain consistent.

4. Empirical Analysis

4.1. Baseline regression

Table 1 presents the baseline regression results for the relationship between air pollution and the migration of college graduates. Columns (1) - (3) display the results of the stepwise regression, while columns (4) and (5) show the results of subsample regressions based on educational level. Individuals with a bachelor's degree or below are classified as having a low educational level (column 4), whereas those with a bachelor's degree or higher are classified as having a high educational level (column 5).

The regression results presented in columns (1) - (3) of Table 1 indicate that the regression coefficients for air pollution (lnPM2.5) and the migration of college graduates are significantly positive. This suggests that air pollution encourages the migration of college graduates; specifically, the more severe the air pollution, the lower the likelihood that graduates will remain in the college city to work. Similarly, the regression coefficient for environmental regulation (ER) and the migration of college graduates is also significantly positive, indicating that environmental regulation also fosters the migration of college graduates. In other words, stricter environmental regulations reduce the probability of graduates staying in the college city for employment.

Columns (4) and (5) of Table 1 show that environmental regulation only affects the migration of low-educated graduates. High-educated graduates are more adaptable to cities with environmental regulations than low-educated graduates. This indicates that environmental regulation has a heterogeneous impact on the migration with different educational backgrounds. If a city implements stricter environmental regulation policies, many companies may reduce their employment positions due to restrictions, and graduates with lower educational backgrounds may face a higher risk of unemployment. This suggests that the environmental improvements driven by environmental regulations are more appealing to high-educated graduates, leading to an increased probability of high-educated graduates staying in the city where the college is located for employment.

Table 1: Air pollution and graduate employment migration-baseline regression

	(1)	(2)	(3)	(4)	(5)
Variables	Migration	Migration	Migration	Migration (low-educated)	Migration (high-educated)
lnPM2.5	0.524***	1.340***	1.307***	1.075*	19.428
	(3.47)	(5.90)	(2.74)	(1.88)	(0.91)
ER	0.421***	-0.686***	1.879***	1.633***	51.094
	(2.90)	(-3.07)	(3.54)	(2.79)	(0.78)
edu		-0.869***	-0.245	0.173	0.451
		(-6.38)	(-1.61)	(0.63)	(0.88)
Individual Controls	NO	YES	YES	YES	YES
City Controls	NO	NO	YES	YES	YES
Constant	-0.751	-3.895***	33.713***	24.179**	100.214
	(-1.33)	(-3.61)	(3.61)	(2.03)	(1.57)
N	6470	2806	2603	2258	341

4.2. Mechanism analysis

To examine the mechanism of air pollution on graduate migration, the interaction term of lnPM2.5 and ER is added to column (3) of Table 1. Table 2 presents the results of the mechanism analysis.

Column (1) shows that the interaction term of lnPM2.5 and ER is significantly negative, indicating

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that environmental regulation mitigates the effect of air pollution in promoting the migration of graduates. Cities with stricter environmental regulations exhibit better air quality management, and consequently, the probability of graduates migrating to other cities due to air pollution is also reduced.

In 2013, the State Council launched the "Air Pollution Prevention and Control Action Plan", which includes ten measures. We uses the policy impact to divide the sample into two groups: perceived (post=1) and non-perceived (post=0), based on the 2013 graduates' awareness of the environmental regulations in the college city, i.e., whether their enrollment year was after 2013. Regression analysis is performed separately to examine how graduates' awareness of the environmental regulations in the college city influences their migration decisions. Theoretically, compared to non-perceived graduates, graduates who enrolled after 2013 are more likely to perceive environmental risks and consequently make migration decisions. Table 2, columns (2)-(3), reports the impact of air pollution on graduate migration among these two groups. The interaction term between lnPM2.5 and ER shows no significant impact on non-perceived graduates but has a significantly positive impact on perceived graduates. Therefore, in cities with stringent environmental regulations, the impact of air pollution on graduate migration is relatively weak.

Table 2: Air pollution and graduate employment migration-mechanism analysis

	(1)	(2)	(3)
Variables	Migration	Migration (post = 1)	Migration (post = 0)
lnPM2.5	2.621***	2.586***	3.656
	(3.05)	(2.78)	(0.37)
ER	8.955**	9.000**	-6.052
	(2.31)	(2.19)	(-0.12)
lnPM2.5×ER	-1.865*	-1.978*	2.359
	(-1.84)	(-1.86)	(0.17)
Individual Controls	YES	YES	YES
City Controls	YES	YES	YES
Constant	30.483***	27.578***	45.819
	(3.20)	(2.59)	(0.84)
N	2603	2337	264

4.3. Robustness test

To conduct robustness tests, we employs four methods: (1) modifying the model, (2) eliminating outliers, (3) adding important control variables, and (4) replacing air pollution indicators.

Table 3: Air pollution and graduate employment migration-robustness test

	(1)	(2)	(3)	(4)
Variables	Migration (Probit model)	Migration (Remove outliers)	Migration (Add control variables)	Migration (Replace PM2.5)
lnPM2.5	0.763***	1.290***	5.797***	
	(2.76)	(2.70)	(3.94)	
hi2016			-1.211**	
			(-1.98)	
$lnSO_2$				0.396***
				(4.69)
ER	1.046***	1.857***	2.550	2.455***
	(3.38)	(3.50)	(1.57)	(4.01)
Individual Controls	YES	YES	YES	YES
City Controls	YES	YES	YES	YES
Constant	19.650***	33.976***	-17.167	25.753***
	(3.57)	(3.64)	(-0.76)	(2.70)
N	2603	2599	1824	2301

Table 3 presents the results of the robustness test. Specifically, column (1) changes the model from logit to probit, column (2) excludes cities with a sample size of fewer than 20 graduates based on the original regression model, column (3) adds an important control variable (hi2016) to represent the

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talent settlement threshold, with the value being the talent introduction settlement threshold index calculated by Zhang and Lu (2019)[7], as talent introduction policies are also a key factor influencing graduate migration, and column (4) replaces the air pollution measurement indicator from PM2.5 to industrial SO2 emissions. The regression results from all four methods consistently show that air pollution promotes graduate migration, which aligns with the baseline regression results.

5. Conclusion

By combining city PM2.5 data with the 2019 National College Graduate Employment Status Survey, we thoroughly examines the effects of air pollution and environmental regulation on the migration behavior of graduates, as well as the heterogeneity of these effects, and draws the following conclusions:

First, air pollution has a significant effect on the migration of graduates. After controlling for individual controls and city controls, it is found that higher PM2.5 concentrations in the college city lead to a greater outflow of graduates seeking employment in other cities. Second, environmental regulation is a key mechanism through which air pollution influences the migration of graduates. Specifically, environmental regulation weakens the impact of air pollution on graduate migration. In cities with more severe air pollution, higher levels of environmental regulation can reduce the outflow of some graduates. Third, the mechanism by which environmental regulation influences the impact of air pollution on graduate migration is heterogeneous across different graduates. Compared with those who are unaware of the implementation of environmental regulation in the college city, graduates who perceive the city's environmental regulation are more likely to remain, as information about improved air quality reduces the outflow of these graduates.

In summary, the findings of this paper have significant policy implications for Chinese cities in attracting talent, enhancing human capital, and evaluating environmental regulatory policies through improvements in environmental quality.

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