# Would Educational Inequality Aggravate Environmental Pollution? —Evidence From Spatial-Based Panel Analysis in China

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Educational inequality has always been the most discussed topic in China, and it may also result in a series of social problems with an expansionist trend. More specifically, education issues have possible influences on environmental activities, while some of them are unaccounted for. To fill in the gaps where few studies focus on the relationship between inequality and environmental pollution, we empirically study the impact of educational inequality on air quality as fine particulate matter ($PM_{2.5}$) using panel data from 30 provinces and cities in China. Based on an analysis of the imbalanced distribution of educational level and individual behaviors, we theoretically infer that deepening educational inequality weakens individual environmental behaviors and thus aggravates environmental quality. We undertake a panel data analysis and, to a certain extent, confirm our expected negative relation. To precisely estimate the causality, we consider the spatial spillover effect to be a key property of air pollutants. We find that widening educational inequality, which is measured by the Gini coefficient of education, causes environmental deterioration. More specifically, educational inequality will inhibit the level of regional technological innovation, thereby damaging environmental quality. In addition, we estimate a series of other variables about education and find that enhancing educational expenditure and educational resources at the regional level of education would improve air quality. Our results suggest that even from an environmental perspective, governments should take measures to prevent the potential excessive centralization of educational resources. Efforts to achieve equality in education engender not only social fairness but also practical significance for environmental protection.

Keywords: educational inequality, gini coefficient of education, the imbalance of urban and rural development, air quality, spatial spillover

## 1 INTRODUCTION

Education is traditionally one of the most contentious livelihood issues in China. It is an essential motive force of social and intergenerational mobility, especially in developing countries. Over the past 3 decades, along with its outstanding achievement on economic growth, China has substantially promoted the average schooling years of Chinese citizens (10.7[1] years with working-age population up to 2019).

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[1]http://www.moe.gov.cn/fbh/live/2020/52692/mtbd/202012/t20201201_502753.html.

Conversely, as the wealth of Chinese residents accumulates rapidly, public concern on environmental issues have upsurged unprecedentedly.

## 1.1 Literature Review

There is considerable evidence that education significantly contributes to individual benefit and has positive externality to the society (e.g., Yue, 2004; Iranzo and Peri, 2009; Ricci and Zachariadis, 2013; Chapman, and Lounkaew, 2015; Azadi et al., 2021; Hinata et al., 2021; Nguyen et al., 2021). Besides the overall level of supply, equity of educational resources allocation has also been concerned widely. Numerous studies have extensively focused on measuring educational inequality around the world, especially in developing countries and regions. Until recently, the changing trend of educational inequality from a global perspective has remained debatable; some researchers believe that absolute and intermediate educational inequality is widening (Permanyer and Boertien, 2021). Some other studies state that the educational gap has narrowed along with its higher attainability (Tasseva, 2021). As cross-national studies often draw ambiguous conclusions, it is better to discuss educational inequality issues within the scope of one country. Lam and Levison. (1991) found that Brazilian males born between 1925 and 1963 experienced both increases in mean schooling and a decrease in educational inequality; Breen et al. (2010) studied seven European countries and found class and gender differences in inequality in educational attainment had declined significantly over the 20th century. Shukla and Mishra (2019) verified the educational Kuznets Curve in India and found the turning point of inverted U-shaped relationship between mean and dispersion (measured in standard deviation, but not in Gini coefficient) of schooling occurs around a mean schooling of about 7 years. Agrawal (2014) studied another aspect of educational inequality in India and argued that although educational inequality declined significantly between 1993 and 2009, the inequality indicator in the rural sector remained much higher than that in the urban sector. Lei and Shen (2015) investigated educational inequality in China and found it deteriorated for both educational attainment and expectations over the past several decades.

As a prevalent social and economic issue, educational inequality may significantly affect other economic variables and social issues. Persistently high level of educational inequality might aggravate the mismatch of resources and cause low efficiency of economic activities in a variety of ways. The previous literature has mainly focused on the impact of educational inequality on income inequality. The latest research by Clement and Piaser (2021) showed a negative relationship between income and educational inequality. The research in Brazil, as mentioned earlier (Lam and Levison, 1991), also indicated that a reduction in educational inequality would fundamentally improve the earnings inequality. Checchi and van de Werfhorst (2017) found skill inequality to be a more important predictor of income inequality than educational attainment inequality, thus supporting the prediction of the neoclassical economic theory. Munir and Kanwal (2020) confirmed the positive impact of educational inequality on

income inequality in six South Asian countries and investigated heterogeneity in different educational stages. The controversial findings of Yang et al. (2008) asserted that reducing educational inequality did not improved the income inequality in China, while income inequality could aggravate educational inequality. In their later study, Yang and Huang (2010), investigated the mechanism between educational and income inequality and found that it was necessary for educational inequality to be sufficiently low to reduce income inequality. In addition to income inequality, several other variables are considered when studying educational inequality. Danler and Pfaff (2021) testified to the positive association between educational inequality and inequality in life expectancy. Xiao and McCright (2012) used panel data of 29 provinces in China between 1988 and 2006 and studied the effect of human capital inequality on total factor productivity (TFP). Their results showed that such educational inequality had a significantly negative effect on TFP growth in China.

Several studies have focused on education vis-à-vis its seemingly close link with environmental activities and behaviors (Wang, 2008; Xiao and McCright, 2012; Chen et al., 2019). Moreover, the academic community usually considers income inequality and TFP as important independent variables in environmental studies, and it can be summarily concluded that educational inequality probably has an impact on environmental pollution through several special mechanisms. The analysis of both educational inequality and environmental quality within a framework should be helpful for public policy-making. However, the possible relationship between educational inequality and environmental behavior has been barely discussed in previous literature. Thus far, the impact of educational inequality on environmental pollution remains unaccounted for. In this study, we focus on fine particulate matter ($PM_{2.5}$), which is the most representative air pollutant. Our interest in these questions ensues some contributions.

With the advancement of information technology, the issue of educational inequality is gradually changing. The impact of information technology on users is becoming increasingly profound, and such an impact has both positive (Abbas et al., 2019a) and possibly negative effects (Lebni et al., 2020; Khazaie et al., 2021). On the one hand, the dissemination of more negative or misleading information and news has negative influences on society and residents (Su et al., 2021). On the other hand, the coronavirus disease 2019 (COVID-19) epidemic also promotes knowledge sharing, which leads to the accelerated integration of traditional education and information technology, thus improving the availability of educational resources (Maqsood et al., 2021), and online education may further affect fairness in education to a certain extent. Therefore, exploring the relationship between educational inequality and environmental problems seems more interesting and significant.

## 1.2 Problem Statement and Research Objectives

With the rapid development of China's economy, its overall educational level has significantly improved (Yuan et al.,

2020), while the equality of education and its related social problems have become increasingly important (Yang et al., 2008; Yang and Huang, 2010; Lei and Shen, 2015). However, China's attention to environmental protection has increased to an unprecedented level in recent years. Albeit there are many high-level studies on the factors that cause and affect China's environmental pollution (e.g., Guan et al., 2019; Liu et al., 2021; Mei et al., 2021; Zhao et al., 2021), merely a few have focused on the relationship between the distribution of education and environmental pollution. With the continuous promotion of China's education reform, it is important to study whether potential changes in educational inequality will result in environmental pollution.

Our research aims to investigate the potential relationship between educational inequality and environmental pollution through theoretical analysis, and then quantify the impact of educational inequality on some specific environmental variables based on empirical research.

The Objectives Are as Follows:

1) To estimate the degree of educational inequality in China based on the Gini coefficient of education at the provincial level;
2) To estimate the impact of some educational variables on environmental variables;
3) To accurately assess the impact of educational inequality on air pollution considering the spatial spillover effect of air pollutants;
4) To explore the internal mechanism of how educational inequality works on the environment.

Our theoretical analysis starts with the known Lorenz curve, which shows the degree of inequality of some schooling distribution. In this analysis, education is the fundamental determinant of individual environmental behaviors, and the overall beneficial behaviors are influenced by educational inequality. With the help of former literature and its mathematical contribution to inequality measurement and stochastic dominance, we infer that educational inequality might theoretically have a positive impact on pollution under a series of assumptions.

We collect data from China Statistical Yearbook, the China Statistical Yearbook on Environment, the China Statistical Yearbook on Education, the China Statistical Yearbook on Population, CNRDS, and CSMAR covering schooling years and PM2.5 of 30 Chinese provinces from 2000 to 2016. We form the Gini coefficient of education—most commonly used in measuring educational inequality (e.g., Thomas et al., 2001; Xiao and McCright, 2012; Agrawal, 2014; Yang et al., 2014; Yu et al., 2015; Munir and Kanwal, 2020), standard deviation of education and index of urban and rural educational inequality to measure and represent the educational inequality.

Based on the dataset mentioned above, we use panel data regression for this empirical study and investigated how widening educational inequality affects air quality. For the precision of our estimation, we consider the spatial spillover effect. Our major contribution follows that:

1) This study expands the research framework of the interaction between social and environmental problems. Studying the impact of educational inequality, causing wide public concern, on environmental quality could provide new ideas for the government to alleviate environmental pollution from the perspective of educational inequality.
2) Theoretically, this study expands the analysis of educational inequality through the mathematical thought of the Lorenz curve and stochastic dominance theory; then, we try to explain the impact of educational inequality on environmental quality by this expansion. Because of this theoretical method, we deduce that educational inequality probably has a negative impact on environmental quality by influencing residents' environmental behavior and confirm such conjecture in our empirical part.
3) Empirically, combined with spatial factors, this study estimates the specific impact of educational inequality on environmental quality for the first time. This study also expands the research perspective of the impact of educational level on environmental quality. We use the panel datasets of 30 provinces in China considering the spatial factors to estimate the causality in which we are interested. We also measure the impact of educational level on environmental quality by using different indicators that can represent the regional educational level. Finally, it is concluded that educational inequality has a negative effect on environmental quality and educational level has a positive effect on environmental quality.

This study is organized as follows. We establish the theoretical analysis in **Section 2**. We provide methods in **Section 3**. The results of the impact of educational inequality on environmental pollution are stated in **Section 4**. In **Section 5**, we discussed the results of the study in combination with the real society. Finally, **Section 6** concludes.

## 2 THEORETICAL ANALYSIS

Based on the brilliant research about decision-making under uncertainty (Hanoch and Levy, 1969; Harder and Russell, 1969; Rothschild and Stiglitz, 1969; Atkinson, 1970) proved that if the Lorenz curve for a specified income distribution, for example, a distribution with probability density function f(x), lies above another one for all x, then the former is preferred to the latter from an overall utility perspective. Inspired by previous literature, we try to study qualitatively how educational inequality affects individual environmental behaviors and our theoretical analysis infers that educational inequality aggravates air pollution—to some extent confirmed by our empirical study.

Consider a population, in which educational level of individual measured in years is denoted by $y$. There are several kinds of different possible distributions of educational level of residents, denoted by $F_i(y)$, $i = 1, 2, \ldots, n$, and thus their respective frequency distributions, denoted by $f_i(y)$, $i = 1, 2, \ldots, n$. Besides, these distributions share the same mean, denoted by $\mu$, and a finite range of educational level $[\underline{y}, \bar{y}]$. Then, the mean of such distribution is given by

$$\mu = \int_{\underline{y}}^{y} tf(t)dt$$

and the educational inequality is shown by a function similar to Lorenz curve defined by Atkinson (1970), which could be given by

$$\Phi(F_i) = \frac{1}{\mu} \int_{\underline{y}}^{y} tf_i(t)dt$$

where $F_i = \int_{\underline{y}}^{y} f_i(t)dt$. Assume that

$$\Phi(F_1) > \Phi(F_2) \tag{1}$$

for any $y$ on $[\underline{y}, \bar{y}]$, that is, the curve corresponding to $F_1$ lies everywhere above that for $F_2$, then the educational level of $F_2$ is more unequal than $F_2$. Therefore, such function characterizes the degree of educational inequality of a population compared with another one.

Given $\Phi(F_1) > \Phi(F_2)$ for any $y$ on $[\underline{y}, \bar{y}]$, a series of elementary rearrangements and substitutions (Atkinson, 1970) yield

$$\int_{\underline{y}}^{y} F_1(t)dt - \int_{\underline{y}}^{y} F_2(t)dt < 0 \tag{2}$$

In this population, environmentally friendly behaviors (e.g., recycling, conserving energy, or any other public environmental behaviors) affected by individuals' education level are represented by the function b(y) (assumed to be twice continuously differentiable). In the previous literature, some argued that better educated individuals perform better on environmental issues (e.g., Wang, 2008; Wang and Han, 2016; Amore et al., 2019), that is, more years of education related to more environmental behaviors [b'(y) > 0]. Furthermore, assume that b''(y) < 0.

To manifest how educational inequality affects environmental protection, define average level of environmental behaviors in this population as

$$B = \int_{\underline{y}}^{y} b(y)f(y)dy.$$

The environmental effects of an educational level distribution dominating another imply:

$$B_1 = \int_{\underline{y}}^{y} b(y)f_1(y)dy > B_2 = \int_{\underline{y}}^{y} b(y)f_2(y)dy \tag{3}$$

Based on the mathematical ideas of stochastic dominance theory (Hanoch and Levy, 1969), it could be proved that if inequality 1) holds for two distributions mentioned above, then inequality 2) and subsequently inequality 3) would also hold. Eventually, we approach our important conclusion of theoretical analysis.

Proposition. Given two distributions mentioned above, if condition $\Phi(F_1) > \Phi(F_2)$ is satisfied, then $B_1 > B_2$ holds.

Our proposition implies that educational inequality could reduce positive environmental behaviors. In other words, educational inequality should aggravate environmental pollution, which will be confirmed by our following empirical study.

# 3 MATERIALS AND METHODS

## 3.1 Overview

Based on the aforementioned theoretical analysis, this study aims to examine the two major themes of educational inequality and environmental quality to conduct an empirical analysis. First, this study mainly used the spatial autoregressive model to estimate the impact of educational inequality on environmental quality. Considering that China has a large geographic space and regional development is not balanced, this study divides the sample into eastern, middle, and western regions, and conducts a heterogeneous analysis. Second, considering that educational inequality and environmental quality belong to the two macro aspects of the economy and society, the connection between the two may need to rely on intermediate variables. Our study analyzes the mechanism of the link between educational inequality and environmental quality. Ultimately, educational inequality is a relative variable that involves distribution. To fully analyze the impact of education on environmental quality, we also appraise the impact of absolute educational level on environmental quality.

## 3.2 Variables and Data
### 3.2.1 Explanatory Variables

The explanatory variable in this study is the degree of educational inequality. We select the Gini coefficient of education (*gini_edu*), the standard deviation of education (*std*), and the urban-rural educational inequality (*ineqcx*) to measure the degree of regional educational inequality.

Similar to Gini coefficient of income—the most prevalent indicator for measuring income inequality—Gini coefficient of education can be calculated using basic data on enrollment rate, educational input, and educational attainment (Mass and Criel, 1982; Thomas et al., 2003). The education attainment is the ultimate goal of education. Compared with other indicators, such as enrollment rate or educational input, educational attainment is commonly considered as a better barometer of the overall educational level of a certain population, and it is also the most appropriate indicator to reflect the human capital stock (Psacharopoulos and Arriagda, 1986). Based on the educational attainment data of the population over 6 years old from the China Statistical Yearbook on Population, we estimate the Gini coefficient and the standard deviation of education in 30 provinces (cities) of China from 2000 to 2016 by applying the improved formula of Thomas et al. (2003). The calculation formula is as follows:

$$gini\_edu = \left(\frac{1}{\mu}\right)\sum_{i=2}^{n}\sum_{j=1}^{i-1} p_i |y_i - y_j| p_j$$

$$\mu = \sum_{i=1}^{n} p_i y_i$$

$$sd = \sqrt{\sum_{i=1}^{n} p_i (y_i - \mu)^2}$$

Where *gini_edu* is the Gini coefficient of education; *sd* is the standard deviation of education; $\mu$ is the average schooling year;

$p_i$ and $p_j$ are the share of the population corresponding to certain schooling year of $y_i$ and $y_j$ ; $n$ is the number of groups of education where we divide the population into five groups according to their educational level: illiteracy ($y_1 = 0$), primary school ($y_2 = 6$), junior high school ($y_3 = 9$), senior high school (including technical secondary school) ($y_4 = 12$) and university (including junior college and graduate students) ($y_5 = 16$).

However, the imbalance between urban and rural development is a long-standing problem in China. Paying attention to the impact of educational inequality between different groups on environmental quality is also a robust perspective to fully explore the relationship between educational inequality and environmental quality. Therefore, in this study, we also selected the ratio of the average schooling years of urban and rural residents (*ineqcx*) to measure the imbalance of education among different groups, as another manifestation of educational inequality.

### 3.2.2 Explained Variables

Air pollution is a pollution indicator that is closely related to individual microscopic activities and life. This study uses the annual average concentration of $PM_{2.5}$ as an indicator of environmental pollution to reversely characterize environmental quality. The concentration data of $PM_{2.5}$ are originally derived from the grid data of global concentration average of $PM_{2.5}$ based on satellite monitoring released by the social and economic data and application center of Columbia University (Van Donkelaar et al., 2015). We further use ArcGIS software to parse the grid data into the annual average $PM_{2.5}$ concentration data of China's provincial level.

### 3.2.3 Control Variables

In addition to educational inequality, other economic and social variables affect environmental quality. Based on the existing literature and considering the availability of data, in this study, we select the proportion of the secondary industry (*indus*), level of urbanization (*urban*), use of foreign capital (*fdi*), and scientific and technological expenditure (*exp_tech*) as control variables. In estimating the impact of educational inequality on environmental quality, we also introduce the educational level of local residents (*ay_edu*) as one of the control variables to more accurately control the relevant variables and obtain the degree of impact of educational inequality on environmental quality.

### 3.2.4 Path Variables

Educational inequality and environmental quality are two relatively macroscopic variables. The connection between the two may need to rely on a specific intermediate transmission path. Therefore, this study attempts to explore a possible mechanism path between the two. Technological innovation is a manifestation of regional human capital. The difference in the regional technological innovation level is a possible result of educational inequality. The effect of the level of regional technological innovation on environmental quality has been confirmed in previous studies. Therefore, this study selects the regional technological innovation level (*tech*) as a path variable to

empirically analyze whether educational inequality will affect it, thereby affecting environmental quality.

### 3.2.5 Education-Level Variable

A lot literatures have already focused on the sustainable development of human (e.g., Paulson, K et al., 2021; Abbas, J et al., 2019c) or environment (e.g., Gracia and Siregar, 2021). From the perspective of economic analysis, this problem largely depends on the continuous investment of funds. Therefore, to compare the analysis results of the effect of educational inequality on environmental quality and to consider educational issues and environmental issues from more perspectives, this study introduces three variables to analyze the impact of regional educational levels on environmental quality. Specifically, the regional educational funding input (*fund_edu*) is used to measure the level of educational input. The number of high school classes per 100 people (*class_high*) are used to measure the level of regional basic educational level. Because the size of high schools varies considerably in different provinces, albeit the number of classes, resources, and so on are relatively similar, we use the number of high school classes instead of the number of high schools. The average schooling year (*ay_edu*) is used for measuring the overall level of education. These three indicators measure the regional education level from different aspects, providing us with more perspectives on the relationship between education level and environmental quality.

## 3.3 Sample Size and Descriptive Statistics

We develop a panel dataset from 2000 to 2016 spanning 30 Chinese Provinces (data from Hong Kong, Macao, Taiwan, and Tibet are partially missing). The data are sourced from the China Statistical Yearbook, the China Statistical Yearbook on Environment, the China Statistical Yearbook on Education, the China Statistical Yearbook on Population, CNRDS and CSMAR. A small amount of missing data are obtained by interpolation. In the following empirical analysis, to alleviate the problem of heteroscedasticity and eliminate the impact of inflation, we took the logarithm of some variables and deflated all nominal variables expressed in currency based on 2000.

The descriptive statistical characteristics of all the variables in this study are listed in **Table 1**. The Gini coefficient of education fluctuates between 0.169 and 0.393, showing that the degree of educational inequality varies significantly among provinces in China. The urban–rural educational inequality fluctuates between 1.079 and 1.806, with an average of 1.331. This shows that the degree of educational inequality within administrative divisions is equally large under the dual structure of urban and rural areas in China. The overall and partial balance of education are aspects that we should pay attention to. To show the correlation between the main explanatory variables more clearly, we drew distribution maps of $PM_{2.5}$ concentration and the Gini coefficient of education, as shown in **Figure 1** and **Figure 2**. The figures illustrate that the distribution of $PM_{2.5}$ concentration has the following trend and correlation with the distribution of Gini coefficient of education, especially in the western region.

**TABLE 1 |** Summary statistics for all the variables.

| Variable | Obs | Mean | Std.Dev | Min | Max |
|---|---|---|---|---|---|
| lnpm25 | 510 | 3.250 | 0.630 | 0.854 | 4.415 |
| gini_edu | 510 | 0.229 | 0.0365 | 0.169 | 0.393 |
| std | 510 | 3.653 | 0.289 | 3.050 | 4.570 |
| ineqcx | 480 | 1.331 | 0.0988 | 1.079 | 1.806 |
| lnay_edu | 510 | 2.131 | 0.119 | 1.785 | 2.510 |
| lnurban | 510 | 3.850 | 0.310 | 3.144 | 4.540 |
| lnindus | 510 | 3.825 | 0.198 | 2.960 | 4.119 |
| lnfdi | 510 | 7.332 | 1.408 | 3.867 | 10.42 |
| lnexp_steh | 510 | 4.591 | 1.521 | 0.651 | 8.362 |
| lntech | 510 | 8.644 | 1.657 | 4.248 | 12.51 |
| lnfund_edu | 510 | 5.540 | 0.879 | 2.551 | 7.571 |
| class_high | 510 | 3.205 | 0.699 | 1.120 | 5.090 |

## 3.4 Spatial Econometric Model

In recent years, more and more studies (e.g., Yang and Xu, 2020; Local Burden of Disease, 2021) take spatial effects into account. Therefore, considering the spatial diffusion of $PM_{2.5}$, we mainly study the relationship of educational inequality and environmental quality by constructing a spatial regression model.

### 3.4.1 Spatial Autocorrelation Test

The spatial correlation of variables is the basis for building a spatial econometric model, so the spatial correlation test must be carried out before building a spatial measurement model. Notably, $PM_{2.5}$ concentrations are spatially dependent because of their strong spatial diffusion (Pan et al., 2015; Shao et al., 2016). That is, pollutants in a region are not only related to local emissions but also affected by neighboring regions. In our study, the global and local spatial correlation indexes in ESDA are used to test the spatial spillover effect of $PM_{2.5}$, and the $Moran's\ I$ statistic is calculated based on this.

In the calculation of $Moran's\ I$, the spatial weight matrix is first constructed. On the one hand, air pollutants have diffusibility, which is mainly manifested in geographic and spatial correlation. On the other hand, with the advancement of industrialization, the concentration of $PM_{2.5}$ as an environmental pollutant is also related to the level of regional



**FIGURE 1 |** PM2.5 concentration distribution. Notes: We sort PM2.5 concentrations from large to small and divided them into four groups. In the figure, group 1 represents the high pollution group, group 2 represents the medium pollution group, group 3 represents the low pollution group, and group 4 represents the lowest pollution group. From 1 to 4, the degree of pollution gradually decreased.
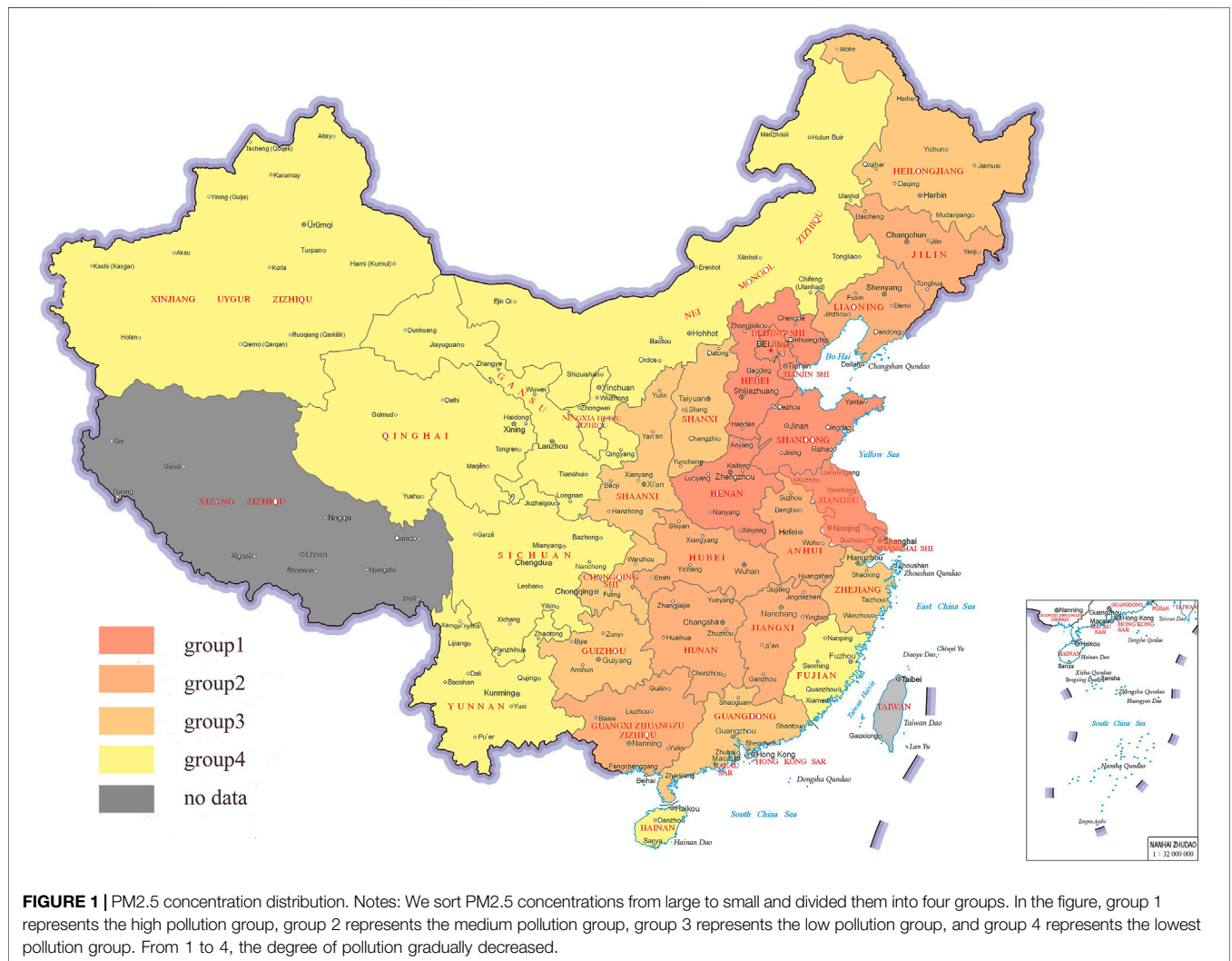
**FIGURE 2** | The distribution of educational inequality. Notes: We rank the Gini coefficient of education in each province from small to large in 2016 and divide it into four groups. In the figure, group 1 represents more equality, group 2 represents equality, group 3 represents inequality, and group 4 represents the most inequality. From 1 to 4, the degree of inequality gradually increased.

economic development. Many scholars (e.g., Nie and Liu, 2015) believe that $PM_{2.5}$ is closely related to the level of economic development. Furthermore, in this study, we draw a line chart of the economic development level and $PM_{2.5}$ concentration of each province and city in 2016. As shown in **Figure 3**, it was also found that the changes in the two showed evidently similar trends. Therefore, considering the geographical diffusion and economic dependence of $PM_{2.5}$, we mainly calculate the *Moran's I* statistic based on the geographical distance spatial weight matrix and the geographical economic distance spatial weight matrix.

Based on the spatial weight matrix of the geographic distance (Wd), the formula is defined as follows:

$$Wd_{ij} = \begin{cases} 1/d_{ij}, i \neq j \\ 0, i = j \end{cases}$$

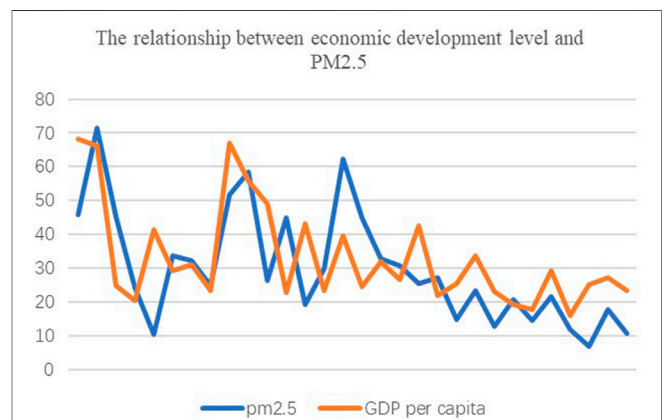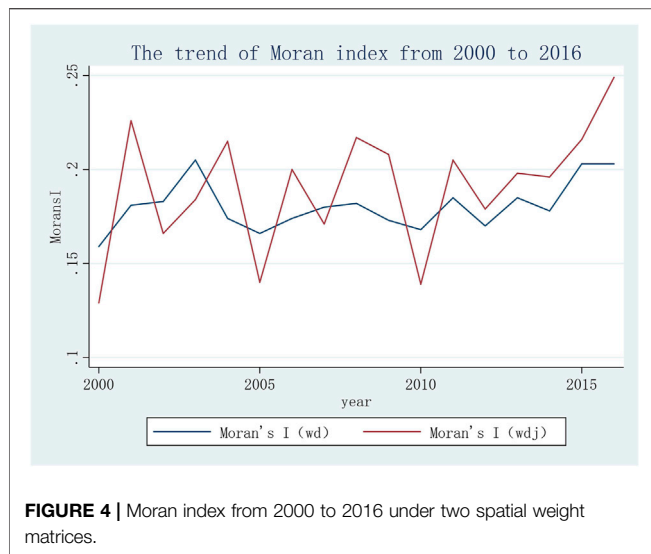where $d_{ij}$ represents the geographical distance between provinces $i$ and $j$.



**FIGURE 3** | The relationship between economic development level and PM2.5. Notes: In Figure 3, we show the relationship between the economic development level and PM2.5 concentration of each province in 2016.

**FIGURE 4 |** Moran index from 2000 to 2016 under two spatial weight matrices.

The spatial weight matrix of the geographic economic distance can not only consider the influence of geographic distance but also reflect economic factors have regional spillover and radiation effects. Therefore, it can reflect the degree of spatial correlation between cross-sectional elements more objectively (Shao et al., 2016). The specific formula is as follows:

$$
Wdj_{ij} = \begin{cases} Wd_{ij}\dfrac{1}{y_i - y_j}, i \neq j \\ 0, i = j \end{cases}
$$

where $y_i$, $y_j$ represent the real per capita GDP of the two provinces in 2016, respectively.

Based on the above-mentioned spatial weight matrix, this study calculates the $Moran's\ I$ of the year included in the sample. As shown in **Figure 4**, under spatial weight matrices Wd and Wdj, $Moran's\ I$ is greater than 0 (approximately 0.2). The $Moran's\ I$ of all years under the two spatial weight matrices is significant at the 5% level. This shows that PM$_{2.5}$ presents the characteristics of high-high and low-low agglomeration. Meanwhile, it can be found that compared with the spatial weight matrix based on geographic distance, the $Moran's\ I$ under the spatial weight matrix based on geographic economic distance fluctuates significantly. This may be because the economic relevance of concentration is unstable in terms of geographic relevance, which presents a fluctuating trend.

To illustrate the spatial correlation of PM$_{2.5}$, we also provide a scatter diagram of the provincial PM$_{2.5}$ concentration distribution in the beginning and end years of the sample interval. As shown in **Figure 5** and **Figure 6**, the graph illustrates that most of the provinces are in the first and third quadrants, thereby further showing that PM$_{2.5}$ has a positive spatial spillover effect.

### 3.4.2 Model Specification

Based on the aforementioned analysis of the spatial correlation of PM$_{2.5}$, and considering the spatial spillover effect, this study constructs a spatial autoregressive model to further analyze the relationship between educational inequality and environmental quality. The model is presented as follows:

$$
ln\ pm_{2.5it} = \rho W\ ln\ pm_{2.5it} + \beta_1 A_{it} + \beta_2 X_{it} + \mu_{it}
$$

Among them, the $A_{it}$ represents the Gini coefficient of education, the standard deviation of educational inequality, and the degree of urban and rural educational inequality. W represents the spatial weight matrix, which is the spatial weight matrix of geographic distance and geographic economic distance constructed above. $\rho$ is the spatial weight coefficient. i represents the $i$-th province. $t$ represents the $t$-th year. X represents a group of other control variables that may affect the regional environmental quality. $\mu_{it}$ is the error term and is assumed to be normally distributed at zero mean value and constant variance (Elahi et al., 2021; Elahi et al., 2022a; Elahi et al., 2022b). Because there are large individual differences between each province, and most variables have fixed time trends, all the regression analyses in this study use fixed effects models to eliminate the influence of individual and time effects to estimate the causality between the variables more objectively.

## 4 RESULTS
## 4.1 Analysis of Non-Spatial Panel Model Results

To compare our results with those of the spatial panel model, we first use the non-spatial panel model for analysis. The results are shown in **Table 2**. The first column shows the regression result of the effect of the Gini coefficient of education on environmental quality. Evidently, educational inequality has a significant negative effect on environmental quality, and this result is in line with the expectations of the aforementioned theories. The second column shows the regression results after adding the corresponding control variables. The third column entails the time lag of education as a way of human capital accumulation and estimates the impact of the lagging Gini coefficient of education on the environmental quality. We find that after adding the corresponding control variables, the effect of the Gini coefficient of education on environmental quality is correspondingly weakened, but it still has a strong negative effect. In the fourth and fifth columns, the standard deviation of education and the urban–rural educational inequality also have a negative impact on environmental quality, which further shows that the negative impact of the regional imbalance of education on environmental quality is sound. In summary, the degree of educational inequality, represented by many aspects, has a significant negative impact on environmental quality. Possible explanations for this conclusion include the following aspects: first, education affects residents' environmental awareness, and educational inequality may affect residents' environmental behavior, which in turn affects environmental quality; second, educational inequality leads to income inequality through the imbalance of human capital accumulation, which intensifies environmental pollution. Thus, educational inequality may be detrimental to technological innovation, thereby deteriorating environmental quality. Finally, educational inequality may affect environmental quality by restraining the upgrading of industrial structure. This suggests that to alleviate environmental pollution,
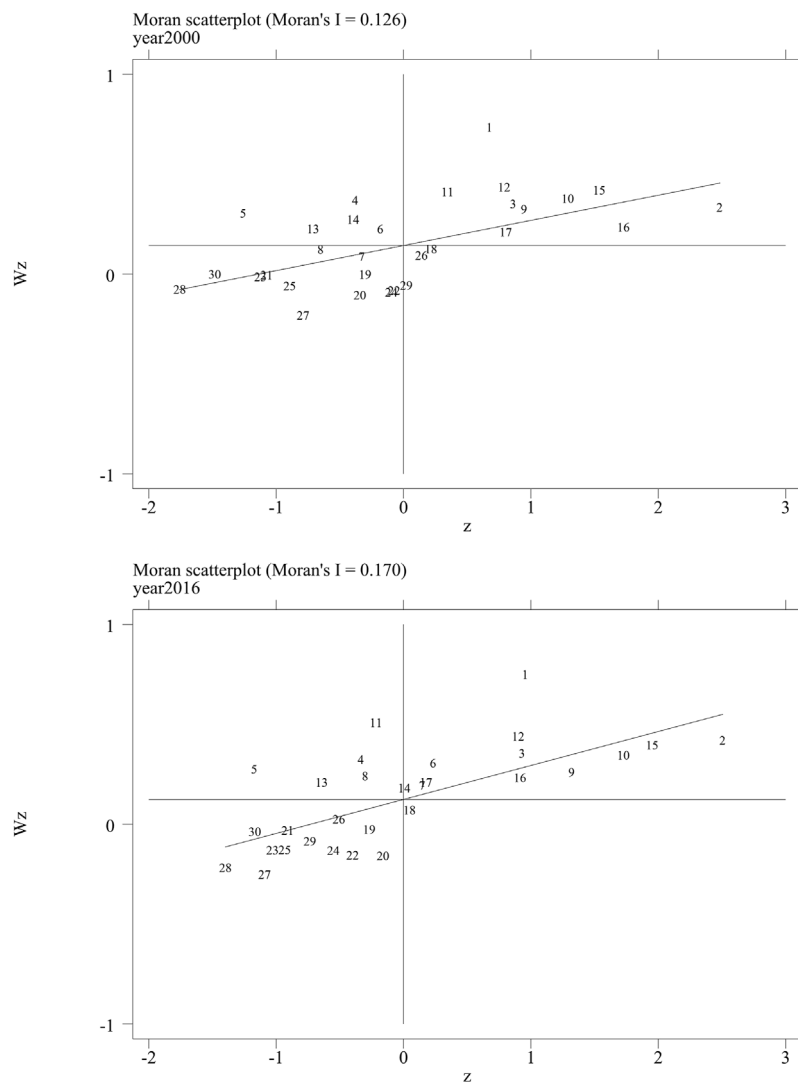
**FIGURE 5 |** Moran scatter under the spatial weight matrix of geographical distance in 2000 and 2016.

we should not only focus on the government and enterprise level but also pay attention to the social level, promote the equalization of education, and facilitate the improvement of environmental quality from a more macroscopic and long-term perspective.

In the regression results of the control variables, educational level, urbanization and foreign direct investment (FDI) all have a significant effect on environmental quality. This shows that, in terms of macro policies, vigorously promoting the process of urbanization is a desirable move to alleviate environmental pollution. Meanwhile, we can also alleviate regional pollution by vigorously introducing foreign capital, promoting capital mobility, and making full use of the technological innovation effect brought by FDI. From another perspective, based on promoting the equalization of education, it is necessary to increase educational investment to ensure the absolute supply of educational level, improve the overall level of residents' enjoyment of educational resources, and promote the improvement of residents' educational level to alleviate environmental pollution. The proportion of industry has a positive impact on environmental quality, but it is not significant. This may be because the polluting industry pays more attention to innovation in technology and process than other industries while generating pollution, which offsets part of the impact of pollution. The impact of science and technology expenditure on environmental quality is uncertain and insignificant. A possible reason for this is that the application of fiscal expenditure to production technology, process upgrade, and innovation requires a long intermediate transmission process and influencing factors.

What are the results of the above-mentioned correlation in geographic space? We need to further verify the Spatial autoregressive model.

## 4.2 Analysis of Spatial Autoregressive Model Results

We established a spatial autoregressive model and used a geographic distance matrix and geographic economic distance matrix to perform regression analysis. The results are shown in
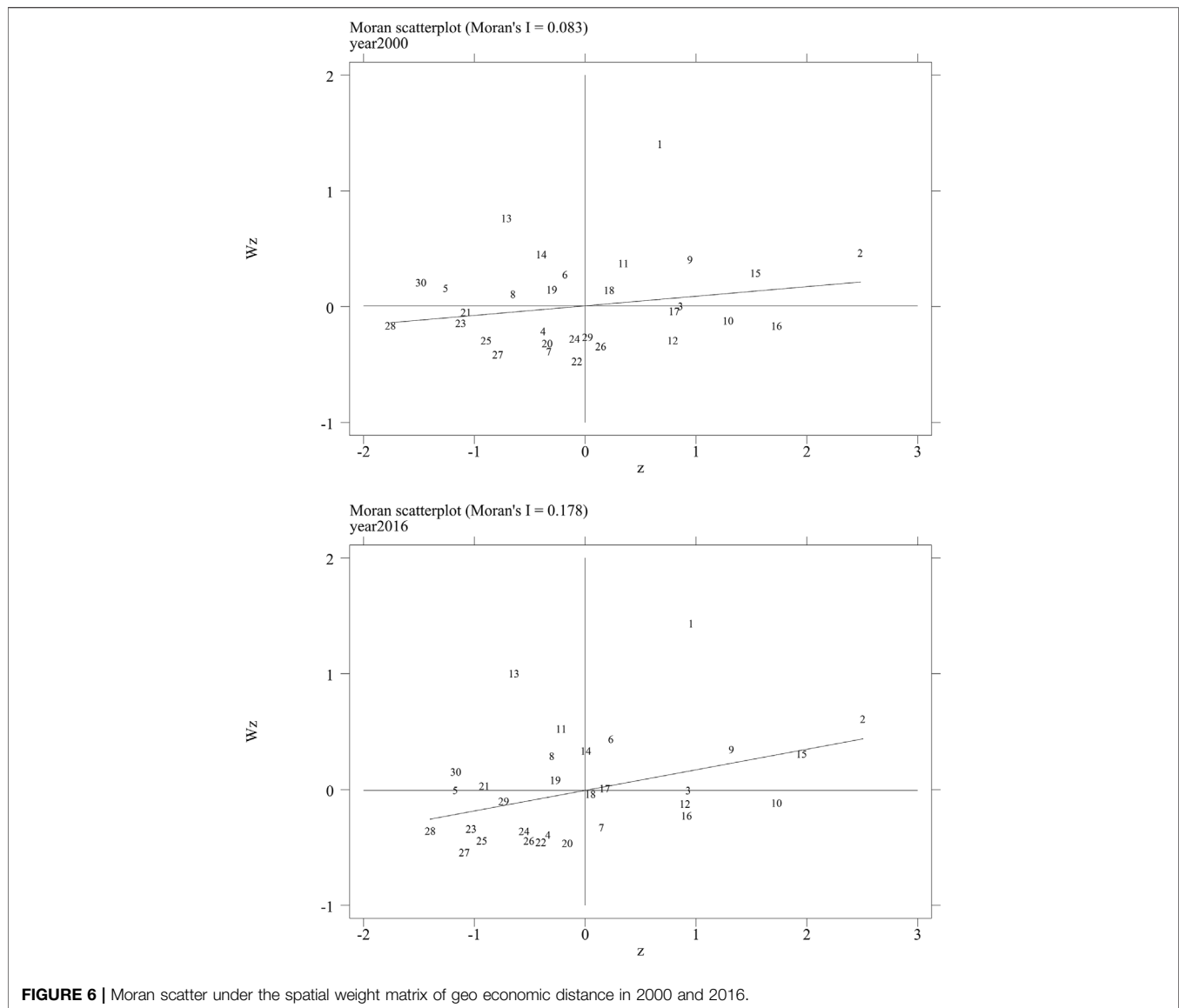
**FIGURE 6 |** Moran scatter under the spatial weight matrix of geo economic distance in 2000 and 2016.

**Supplementary Table S1**. The first and second columns are the regression results of the Gini coefficient of education on the environmental quality under the spatial weight of geographic distance and economic geographic distance, respectively. The third and fourth columns are the regression results of the standard deviation of education under the two spatial weight matrices. The fifth and sixth columns are the regression results of urban and rural educational inequality under the two matrices, respectively. It can be seen from the table that after considering the spatial spillover effects, the negative impact of educational inequality on environmental quality remains significant. Compared with the regression results that do not introduce spatial factors in the previous section, we find that the impact of all the indicators of educational inequality on environmental quality has been reduced. This shows that the spatial correlation of $PM_{2.5}$, which is an important factor that affects the negative impact of educational inequality on environmental quality.

Nonetheless, Comparing the impact coefficients of the three educational inequality indicators on the environmental quality under the two spatial weight matrices, it can be found that relative to the geographic spatial weight matrix, under the economic geographic spatial weight matrix considering economic factors, educational inequality has a greater impact on environmental quality. That is, in addition to the spatial spillover of geographic distance, the spatial correlation of the economy is also an important aspect of the spatial spillover characteristics of $PM_{2.5}$. In the application of spatial econometric models, LESAGE J,PACE R K. (2009) have proposed the use of partial differential methods to decompose the regression results of direct and indirect effects to test whether the spatial spillover effect exists. We also used this method to study the direct and indirect effects (see **Table 3**). It can be found that educational inequality has a significant negative effect on the local environmental quality. However, the indirect effect is not significant, which

**TABLE 2 |** The regression results of educational inequality.

|  | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
|  | lnpm25 | lnpm25 | lnpm25 | lnpm25 | lnpm25 |
| gini_edu | 1.790*** | 1.021* |  |  |  |
|  | (3.73) | (1.82) |  |  |  |
| L. gini_edu |  |  | 1.294** |  |  |
|  |  |  | (2.56) |  |  |
| std |  |  |  | 0.088* |  |
|  |  |  |  | (1.85) |  |
| ineqcx |  |  |  |  | 0.221** |
|  |  |  |  |  | (2.47) |
| lnay_edu |  | −0.494** | −0.515** | −0.794*** | −0.776*** |
|  |  | (−2.00) | (−2.36) | (−3.71) | (−3.79) |
| lnurban |  | −0.142*** | −0.125*** | −0.143*** | −0.128*** |
|  |  | (−3.19) | (−2.59) | (−3.22) | (−2.66) |
| lnfdi |  | −0.032* | −0.032* | −0.032* | −0.029 |
|  |  | (−1.69) | (−1.71) | (−1.72) | (−1.57) |
| lnexp_steh |  | 0.006 | −0.017 | 0.009 | −0.016 |
|  |  | (0.33) | (−0.86) | (0.46) | (−0.83) |
| lnindus |  | −0.011 | −0.042 | −0.017 | −0.022 |
|  |  | (−0.20) | (−0.76) | (−0.31) | (−0.39) |
| year | YES | YES | YES | YES | YES |
| ind | YES | YES | YES | YES | YES |
| _cons | 2.424*** | 4.367*** | 4.726*** | 4.939*** | 5.178*** |
|  | (20.47) | (7.29) | (8.95) | (10.75) | (11.30) |
| N | 510 | 510 | 480 | 510 | 480 |
| adj. $R^2$ | 0.578 | 0.594 | 0.420 | 0.594 | 0.419 |
| Hausman | 10.02*** | 15.83** | 36.62*** | 19.30*** | 40.39*** |

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

proves that local educational inequality has no impact on the environmental quality of neighboring areas, and the degree of local educational inequality only has a negative impact on the local environmental quality. This may be because the degree of educational inequality in the region is a relatively regional objective variable. Chinese administrative division barriers cause educational inequality to affect only the residents of the region and therefore only have a major impact on the environmental behavior of the residents in the region. The degree of the educational inequality of urban and rural residents has the most significant negative impact on the environmental quality of the region, which also proves that the serious imbalance of educational resources has an important impact on environmental quality under the dual urban–rural structure in China. When formulating policy ideas to alleviate environmental pollution, more attention must be paid to the equalization of urban and rural education.

## 4.3 Heterogeneity Analysis

Considering the possibility of heterogeneity among the samples, we divide the 30 sample provinces into three parts—east, middle, and west—according to the classification standard of the national geographic system. **Table 4** presents the regression results. We find that the degree of educational inequality has a negative impact on environmental quality in the eastern and middle regions, but not in the eastern region. We suspect that the higher level of economic and technological development in the eastern region may conceal the impact of educational inequality on environmental quality. The impact of educational inequality

on environmental quality in western region is positive. This abnormal phenomenon might result from the regional imbalance in development in China. An increase in the relatively low level of education in some parts of western areas may temporarily raise educational inequality, while it benefits the environment. This result highlights the need to pay more attention toward alleviating educational inequality in the middle region to better achieve pollution control effects. This phenomenon is also in line with objective reality. The middle region has a large population and vast territory, and it is the backbone of national development. By vigorously promoting the equalization of education in the middle region, environmental problems can be alleviated more effectively.

## 4.4 Path Analysis

Educational inequality and environmental pollution are two major social issues at the macro level, which belong to different areas of the economy and society. The mutual influence between the two may depend on a specific intermediate path. The level of regional technological innovation may be hindered by inequality in regional education, and regional technological innovation can improve environmental quality. Therefore, this study attempts to verify the level of regional technological innovation as one of the ways whereby educational inequality affects environmental quality to explore the complex impact mechanism between educational inequality and environmental quality. The results are listed in **Supplementary Table S2**. It can be found that in the regression results of the Gini coefficient of education and urban-rural educational inequality, as the degree of educational inequality deepens, the regional technical level declines. Although the standard deviation of education has a positive impact on the level of technological progress, it is not significant. This shows that the degree of educational inequality can have a negative impact on environmental quality by restraining regional technological progress. This result suggests that to achieve better environmental governance effects, we must create a good technological innovation environment, while alleviating educational inequality, and unblock the mitigation effect of educational inequality on environmental pollution.

## 4.5 The Regression Results of Regional Educational Level

Because educational inequality is a relative variable, it represents the distribution of education. In the above-mentioned analysis,

**TABLE 3 |** Decomposition of direct and indirect effects.

|  | direct effect | | Indirect effect | |
|---|---|---|---|---|
|  | Wd | Wdj | Wd | Wdj |
| gini_edu | 0.792 | 0.999* | 1.513 | 0.349 |
|  | (1.45) | (1.83) | (1.11) | (1.32) |
| std | 0.077* | 0.089* | 0.147 | 0.031 |
|  | (1.65) | (1.91) | (1.20) | (1.35) |
| ineqcx | 0.191** | 0.193** | 0.524 | 0.095 |
|  | (2.18) | (2.22) | (1.39) | (1.64) |

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

**TABLE 4 |** Heterogeneity analysis.

|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
|  | East | Mid | West | East | Mid | West | East | Mid | West |
| gini_edu | 0.764 | 1.244*** | −0.987** |  |  |  |  |  |  |
|  | (1.61) | (2.62) | (-2.29) |  |  |  |  |  |  |
| std |  |  |  | 0.013 | 0.106*** | −0.031 |  |  |  |
|  |  |  |  | (0.33) | (2.64) | (−0.85) |  |  |  |
| ineqcx |  |  |  |  |  |  | 0.040 | 0.244*** | −0.063 |
|  |  |  |  |  |  |  | (0.63) | (3.58) | (−1.08) |
| N | 204 | 153 | 153 | 204 | 153 | 153 | 192 | 144 | 144 |
| adj. $R^2$ | 0.271 | 0.162 | 0.064 | 0.267 | 0.162 | 0.055 | 0.177 | 0.138 | 0.028 |

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

we have verified the negative impact of educational inequality on environmental quality. To better understand the impact of education on environmental quality, in this section, we empirically analyze the impact of the absolute amount of regional educational level on environmental quality to contrast it with the relative variable of educational inequality and provide us with more reference in policy instructions. We examine the impact of regional educational level on environmental quality from different perspectives, and the results are shown in **Supplementary Table S3**. In the first column, we estimate the impact of the average schooling years on the air quality and find that with the promotion of the average schooling years of residents, the regional air quality also gradually improves. Every 1% increase in the average schooling years will decrease the PM$_{2.5}$ concentration by 0.727%, which, to some extent, confirms the positive relationship between educational level and environmental quality. A similar result reported in the second column shows the impact of the number of high school classes per 100 people on air quality. The *p*-value is 0.101, which indicates that the regional high school education resources have a significant positive impact on environmental quality. The tired column shows the regression results of educational expenditures on environmental quality. The higher the regional educational expenditures, the better the educational conditions, which has a positive effect on environmental quality. This also suggests that when contemplating ways to improve environmental quality from an educational perspective, in addition to promoting the equalization of education, we must also vigorously increase the absolute level of education to eliminate the negative impact of educational inequality on environmental quality. It is necessary to work from two dimensions: eliminating the negative impact of educational inequality on environmental quality and improving the positive impact of educational level on environmental quality to achieve better environmental quality improvement effects.

## 5 DISCUSSION

### 5.1 Findings

Specific findings are as follows:

Finding 1: Educational inequality, measured by the Gini coefficient of education and standard deviation of education,

has a significant negative impact on environmental quality. Considering the spatial spillover effect of PM$_{2.5}$, such a negative impact is weakened. Based on the spatial econometric analysis, inequality in one region has a much more significant impact on the local environment than its neighbors.

Finding 2: Urbanization and FDI significantly improve environmental quality, while industrial structure, science and technology expenditure do not.

Finding 3: Educational inequality in central China has a significant negative impact on environmental quality. Eastern China also shows a negative but insignificant impact, while western China shows a significant positive impact.

Finding 4: Educational inequality will inhibit the level of regional technological innovation, thereby threatening environmental quality.

Finding 5: Regional educational expenditure and average schooling years can significantly improve local environmental quality, while it is not significant from the perspective of the number of high school classes per 100 people.

Finding 1 corresponds to the theoretical analysis. Based on a framework with a concave behavior (sometimes utility) function (Hanoch and Levy, 1969; Harder and Russell, 1969; Rothschild and Stiglitz, 1969), a more balanced distribution is barely undesirable. Finding 2 is consistent with those of Zeng and Eastin (2012) and Zhu et al. (2016), who have demonstrated that FDI or urbanization is associated with lower levels of pollution, but inconsistent with those of Demena and Afesorgbor (2020) and Chen et al. (2020), who have demonstrated that FDI or urbanization has a negative or inapparent impact on the environment. Similar to many environmental and economic studies focusing on China (e.g., Zhan, 2018; Chen et al., 2020), Finding 3 shows significant regional heterogeneity. The study of regional and geographical factors should be one of the core objectives of future research. Finding 4 reveals one of the paths by which educational inequality leads to environmental deterioration, while more possible mechanisms remain ambiguous. This is a limitation of the present study.

## 5.2 Educational Inequality and Social Change Under the COVID-19 Pandemic

At present, the main background issue of recent sociological research is the COVID-19 epidemic. Although some industries

(e.g., health insurance) have developed during the epidemic (Ye et al., 2021), the adverse economic effects are more evident (Rababah et al., 2020; Shen et al., 2020; Lee and Lu, 2021). The epidemic has a significant impact on the companies' financial situation (Shaharuddin et al., 2021), and robust financial strategies are conducive toward improving companies' performances during the epidemic (Golubeva, 2021). Meanwhile, the change in the company's office mode also poses a challenge to the company's management level (Muttaqin et al., 2020).

In addition, the negative impact of the pandemic and menta on humans is both physical and psychological, while the latter one could also cause mental diseases (Abbas et al., 2019b; Aqeel et al., 2021). Moreover, taking measures to address the epidemic often has high social costs and ethical disputes (Su et al., 2021). In the post-epidemic era, information exchange and information technology are not only very important for economic recovery (Li et al., 2021) but also may have a certain impact on educational inequality.

In general, the impact of COVID-19 on inequality in education remains unclear. On the one hand, more online courses and conferences promote the exchange of knowledge and reduce the acquisition cost of some educational resources during the COVID-19 pandemic (Maqsood et al., 2021). On the other hand, whether changes in the economic situation will lead to an excessive concentration of educational resources is now a very interesting question.

## 5.3 Policy Implication

Our major finding on educational inequality suggests that the pursuit of educational equalization not only entails social fairness but also presents practical significance for environmental protection. When solving educational inequality and environmental problems, the two can be combined for policy design to achieve the maximum effect of the policy. The government should vigorously increase educational investment, carry out educational resource construction, improve the educational level of residents, and focus on solving the problem of regional educational inequality to achieve a win–win situation in alleviating educational inequality and environmental problems simultaneously.

Specifically, to solve environmental problems in the direction of alleviating educational inequality, the focus is on both reducing the negative impact of educational inequality on environmental quality and improving the positive impact of educational level on the environment. More measures are presented as follows: first, promote the equalized development of education at the overall global level and gradually deregulate household registration and administrative divisions. Second, it is necessary to break the imbalance of urban and rural education and ensure the equalization of education among different groups. Third, attention should be paid toward improving the absolute level of regional educational resources and increasing the construction of educational facilities. Finally, provide a suitable environment for technological innovation, strengthen the protection of intellectual property rights, promote regional innovation vitality.

## 6 CONCLUSION

This study analyzes the impact of educational inequality on environmental quality by establishing a theoretical and empirical framework. Our theoretical analysis infers that educational inequality should have a negative impact on environmental behaviors and thus cause more pollutant emissions, which is then confirmed by the estimation result of our empirical model. Therefore, we conclude that widening educational inequality would lead to higher environmental pollution. Meanwhile, this study analyzes the level of regional technological innovation as the path through which educational inequality affects environmental quality and concludes that the deepening of educational inequality will inhibit the regional technological innovation level, which will subsequently have an impact on environmental quality. Furthermore, this study divides the research sample into three parts: east, middle, and west. It is found that educational inequality in the eastern and middle regions has a negative impact on environmental quality, while the western region shows that as the degree of educational inequality deepens, environmental quality improves. In addition, we estimate the impact of the regional level of education on air quality and testify the negative relationship between some typical variables (average schooling years, education expenditure, the number of senior high school classes per 100 students) of educational level and air pollutants.

A limitation of our study is that our model implies the negative impact of an imbalanced level of education on individual environmental behaviors, while how exactly this internal connection is established is not revealed. Except for technological innovation, educational inequality may affect other factors that cause environmental issues. However, these potential mechanisms remain unaccounted for and should be empirically verified. To improve our theoretical analysis in future research, we expect to introduce more assumptions and specifications to characterize individual behaviors and recognize the interactions among groups at different levels of education. Another limitation is that there is a certain deviation in the accuracy of the estimation results, and the methodology of our study does not completely solve the problem of missing variables. Although we have controlled the relevant factors that affect environmental quality from as many aspects as possible, limited by the availability of data and the unpredictability of some micro-variables, the analysis of this study cannot cover most of the economic and social factors that affect environmental quality. Consequently, the impact of other factors on environmental quality cannot be completely eliminated, which leads to the inability to accurately estimate the degree of the impact of educational inequality on environmental quality. We consider adding more socioeconomic variables that affect environmental quality at the micro-individual level, such as enterprises and residents, and improve the accuracy of estimating the impact of educational inequality on environmental quality.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

## AUTHOR CONTRIBUTIONS

XL: Supervision, Methodology, Formal analysis, and Project administration. HL: Software, Validation, and Investigation. JY: Conceptualization, Writing—Original Draft, Writing—Review and Editing.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.813254/full#supplementary-material

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