Dynamic Impact of Environmental Regulation on Environmental Performance in China: New Evidence from a Semiparametric Additive Panel Analysis

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Abstract: Environmental protection is the core of sustainable economic development, and environmental policy plays a key role in achieving protection goals. Therefore, it is extremely crucial to evaluate the effectiveness of environmental policies. Existing studies mainly focus on the average impact of environmental policies on environmental pollution but ignore their dynamic impact, which is prone to misestimate the effect of environmental policies. To make up for the deficiency, a semiparametric additive panel data model is used to explore the dynamic impact of China’s sewage charging policy on environmental performance at each level of the levy. The results show that the relationship between sewage charge level and environmental degeneration is an “M-shaped” pattern, indicating that the current sewage charge policy is not absolutely effective. Moreover, the results also reveal an “N-shaped” linkage between economic growth and environmental pollution, indicating that economic development is not sustainable. Moreover, the factors of energy consumption, population growth, and industrialization contribute to increasing environmental degeneration. Although technological development has a positive impact on environmental performance, its impact is insignificant. This study could provide new evidence for strengthening environmental regulatory reform and promoting green economic development.

Keywords: dynamic and nonlinear impact; economically sustainable development; environmental regulation; semiparametric additive panel regression; sewage charges

1. Introduction

Environmental pollution is not only a serious hazard to public health but also a burden to the economy and society, causing a loss of national income [1]. Landrigan et al. [2] found that the annual welfare loss due to pollution amounts to USD 4.6 trillion dollars, accounting for 6.2% of global economic output. Additionally, 80–90% of human cancers are linked to environmental factors [3]. Environmental factors are responsible for approximately 12.6 million deaths each year, which is 23% of the global death toll (26% of all deaths among five-year-olds) [4]. Since the reform and opening-up, China’s economy has been growing at a high rate for a long time. However, in the midst of rapid economic growth, some problems, such as excessive resource consumption and serious environmental pollution, have become increasingly prominent [5]. Ebenstein [6] argued that the impact of pollution from economic growth on the life expectancy of Chinese people is considered a serious obstacle to improving health. According to the World Health Organization, China holds 21% of the annual burden of disease caused by environmental and related factors, which is 8% higher than that of the United States. Watts [7] highlights that 16 of the world’s 20 most polluted cities are in China. As shown in the 2018 Global Environmental Performance
Index, China ranks 120th out of 180 economies in terms of environmental performance. Apparently, China faces very serious environmental problems and is under tremendous pressure to control pollution.

In order to combat pollution, the Chinese government has introduced a series of environmental regulations to control corporate behavior [8]. Environmental regulation can encourage enterprises to develop environmentally friendly production technologies and achieve the twin goals of economic efficiency and environmental protection [9]. Sewage charges are one of the tools used by governments to enforce environmental regulation and provide an economic incentive to curb environmental damage [10]. As China’s earliest and longest-running economic incentive-based environmental regulation policy tool, charging for emissions is an important means of reducing emissions in China. China’s sewage charging system began in 1979, and then, in July 2003, regulations on the collection, management, and use of sewage charges were implemented to prevent and control pollution more effectively. The China Environmental Yearbook shows that since the implementation of the regulation to the end of 2017, the revenue from sewage charges has increased from 2003 with 7.090 billion yuan to 22 billion yuan in 2017, which is a nearly three-fold increase. The environmental charging system for key industrial pollution sources has been fully covered in China. The cumulative number of units paying sewage charges reached 6,778,200 from 2003 to 2017. Investment in pollution control grew from 110 billion yuan in 2003 to 953.9 billion yuan in 2017. Nonetheless, along with rapid economic growth, China is experiencing serious environmental problems. This paradox directly leads us to consider the effects of environmental regulation in China, especially the abatement effect of sewage charges policies. What is the relationship between sewage charges and environmental pollution? Has the policy of sewage charges played a role in improving the state of environmental pollution in China?

In response to the above question, this study examines the effects of the environmental regulatory policy of sewage charges in China. Although many scholars have discussed the role of sewage charges, there are two shortcomings. First, most existing studies have focused on the linear impact of sewage charges on environmental pollution, ignoring their dynamic and nonlinear effects [11,12]. Second, most of the existing studies use parametric modeling methods, which require artificially setting the model structure and therefore may lead to bias in the estimated results [11]. To address the above questions, this study adopts a semiparametric additive model to explore the dynamic impact of sewage charges on environmental degradation.

The study contributes to existing research in the following three aspects: (1) Different from prior research concentrate on the positive or negative impacts of environmental policies. We propose that the effects of environmental regulation on environmental performance are dynamic and nonlinear, and the dynamic and nonlinear effects of sewage charges on the environment at each cumulative level are also explored, which is more in line with reality; (2) Consider the nonlinear effects of sewage charges while simultaneously testing the nonlinear effects of economic development on the environment. The sewage charges and economic growth are integrated into one framework to explore their joint nonlinear impact on the environment. This will provide some evidence for studying how to achieve sustainable economic growth through effective environmental policies; (3) A semiparametric additive panel model developed recently is used instead of the parametric model used in most current studies to obtain accurate results. The semiparametric additive panel model is data-driven and does not need to be artificially structured, which can explore potential linear or nonlinear relationships between variables and solve the problem of structural misspecification of the parametric model.

The remainder of the study is structured as follows: Section 2 reviews related literature; Section 3 introduces the method; Section 4 is empirical results; Section 5 presents results and discussion; and Section 6 includes conclusions and policy recommendations.
2. Literature Review

2.1. Studies on the Effects of Economic Growth on Environment Pollution

How to effectively improve the current situation of environmental pollution and achieve sustainable economic development has become a hot issue in academic circles. Numerous studies have investigated the influencing factors of environmental pollution from different angles. One of the most famous theories is the Environmental Kuznets curve (EKC) hypothesis, which discusses the relationship between economic growth and environmental pollution. The hypothesis states that there is an inverted “U-shaped” relationship between environmental degeneration and income level. Many scholars have tested the hypothesis using a variety of data. Adejumo [13] explored the relationship between environment and economic growth in Nigeria and found an inverted U-shaped linkage between environmental quality (CO$_2$) and economic output (per capita and GDP growth). In contrast, Begum et al. [14] proved that there is a U-shaped relationship between economic growth and carbon emissions in Malaysia. Moreover, Sinha et al. [15] found an N-shaped linkage between economic growth and environmental degradation from 11 emerging countries.

The EKC hypothesis has also been examined by various studies related to Chinese situations. For example, Xie et al. [16] found that China’s economic growth has an inverted U-shaped impact on PM2.5 concentrations. Similarly, Xi and Jing [17] analyzed the evolution of ecological deficits and surplus areas and their per capita coal consumption in 30 provinces in China, and the results demonstrated that there is an inverted U-shaped relationship between the ecological environment and economic growth in each region. However, Wang et al. [18] proved an N-shaped relationship between CO$_2$ emissions and economic growth in the same region. In addition, Kang et al. [19] found an inverted N-shaped linkage between carbon emissions and economic growth in China. Rao and Yan [20] took Wuhan as a research area, using the time-lag correlation analysis method and the time-lag EKC model to explore the impact of economic growth on environmental pollution, and found that Wuhan’s economic growth is still at the expense of the environment. These contradictory findings indicating that the relationship between economic growth and the environment is complex and needs to be further explored.

2.2. Related Research on the Impacts of Sewage Charges on Environment Pollution

Studies on the relationship between sewage charges and environmental pollution can be divided into two categories. The first is about the principle of sewage charges. Existing research on sewage charges is based on the ideas of the “Pigouvian taxes” and the “polluter pays”. Pigou [21] firstly proposed a tax on polluters based on the harm caused by pollution. Subsequently, Tullock [22] proposed the “double dividend” theory of environmental taxation, following the idea of “polluter pays”. As one of the manifestations of the “Pigouvian Taxes”, sewage charges are an important way to internalize the external costs of the enterprise environment. Since the “Pigouvian Taxes” were proposed, the effects of environmental charges have been widely recognized [23]. As an important form of environmental economic policy, a number of countries have started to use environmental taxes as a means to protect the natural environment and maintain ecological balance [24]. As the largest developing country, China established a sewage charging system by law in 1979 and began to collect sewage charges on a pilot basis. However, there is an endogenous law enforcement problem due to the significant difference in the actual collection rate of sewage charges among provinces [25]. Meanwhile, the effectiveness of China’s sewage charging policy has been widely questioned because of low standards and local protectionism [26].

The second is about the effectiveness of sewerage charges. The research findings on the impact of sewage charges on environmental pollution are inconsistent. Most scholars hold the view that sewage charges can reduce environmental pollution. For example, Ji et al. [27] analyzed China’s emission reduction results based on the pollution discharge fee and the five-year plan, and proposed that the parallel of the five-year plan and environmental tax is an inevitable choice for environment and emission management. Some scholars have
also found that the government can guide enterprises to reduce pollution emissions by increasing sewage charges [28]. Moreover, fewer scholars also propose that China’s sewage charge fees are relatively low and pollution control is inefficient. For example, Li and Li [26] used a panel quantile model to explore the impact of different types of environmental regulations on haze pollution in China and proved that the sewage charges are much lower than the total profit that have no deterrent effects on enterprises.

2.3. Existing Methods for Sewage Charges on Environmental Pollution

Much of the research on the impact of sewage charges on environmental pollution has been analyzed from a theoretical perspective [29]. With the development of data analysis, some scholars began to use econometric methods to conduct relevant empirical studies, which are mostly based on cross-sectional data and panel data. Compared with the panel data approach, the cross-sectional data approach has several shortcomings. First, when using cross-sectional data to build regression models, the independent variables were chosen according to the specific problem and are often closely correlated in an economic sense, leading to multicollinearity. Second, the cross-sectional data approach does not take into account heterogeneity among economic individuals and is prone to underestimate or overestimate the relevant results. Due to the limitations of the cross-sectional data approach, some studies have applied panel data techniques to study the impact of sewage charges on environmental pollution. For example, He et al. [24] used data from OECD countries from 1995 to 2016 to study the impact of transportation tax, energy tax, and environmental tax on energy efficiency. The results proved that environmental taxes could improve energy efficiency. Nevertheless, the models used are parametric models, which may suffer from model misspecification problems. Moreover, these studies mainly evaluated the linear relationship between sewage charges and environmental pollution but ignored the dynamic and nonlinear relationship between them.

Therefore, the semiparametric additive panel model is proposed and used, which provides a balance between the traditional parameter linear panel models with strong artificial characteristics and the flexible nonparametric regression model with heterogeneous effects and generalizes the nonparametric additive panel model [30]. The semiparametric additive panel model adopts a flexible function form for each independent variable, including the traditional linear or nonlinear structures [31]. Compared to the traditional models, the semiparametric regression model has several advantages. First, the model does not require prior knowledge of the links between economic or social variables, and the regression function form is not restricted. Second, it is a data-driven model, which means the specific form of the regression model is determined by the sample data. Third, the problems of missing variables and incorrect dimensions in nonparametric and semiparametric models can be solved to a certain extent.

Exploring the impacts of economic development and sewage charges on environmental performance helps to effectively adjust policies and achieve the goal of green development. Through the above literature analysis, we can find that existing research on environmental regulation effects has several deficiencies. First, most existing studies have focused on the linear impact of sewage charges on environmental pollution, ignoring their dynamic, complex, and nonlinear effects, and the reliability of the results is questionable. Second, most of the current studies use parametric modeling methods, which require artificially setting the model structure and therefore may lead to bias in the estimated results. Third, previous studies separately explored the impact of sewage charges and economic development on environmental performance and failed to incorporate the two into a unified research framework.
3. Method and Data
3.1. Method
3.1.1. Semiparametric Additive Panel Model

To avoid using linear models with the incorrect setting, one of the main directions of the current model and data analysis is determining how to develop implicit and flexible structures among the variables. In this context, nonparametric and semiparametric models have gained the interest of researchers and have recently been used in the fields of economics and energy [32]. In particular, the nonparametric additive panel model has received great attention due to its potential flexibility [33]. However, it is clear that their model does not consider the influence of individuals and time, thus ignoring the potential heterogeneity. More importantly, the roles of the relevant variables are not included. To remedy these defects, this study adopts the semiparametric additive panel model with heterogeneous effects suggested by Xie and Liu [31], as follows.

\[
Y_{it} = \mu_i + \gamma_t + \sum_{j=1}^{p} g_j(X_{it,j}) + \sum_{l=1}^{q} Z_{it,l}\phi_l + e_{it}, \quad i = 1, \ldots, N; \quad t = 1, \ldots, T
\]

where \(\mu_i\) and \(\gamma_t\) are individual and temporal parameters to describe the heterogeneous impacts of individuals and time; \(Y_{it}\) denotes the dependent variable and \(X_{it,j}\) represents the independent variables, where \(j = 1, \ldots, p; g_j(X_{it,j})\) is an unknown function and signifies the linear or nonlinear linkages between the dependent variables and independent variables; \(Z_{it,l}\) denotes the control variables, where \(l = 1, \ldots, q\) and corresponds to the coefficient \(\phi_l\); \(e_{it}\) refers to the errors terms. Therefore, this study adopts the semiparametric additive panel model (1) to reveal the linear and nonlinear relationships between financial development and \(\text{CO}_2\) emissions. To obtain a valid estimator, this article follows the idea of Xie and Liu [31] and uses a three-stage global-local procedure. The advantage of the three-stage regression is that it can make the estimates available for computational convenience and facilitate the establishment of highly credible theoretical results and statistical inferences.

3.1.2. Semiparametric Additive Panel Model

The IPAT model is often used to explore the impact of human activities on the environment, which can be expressed as follows.

\[
I = P \times A \times T
\]

where \(I\) represents the level of pollutant emissions; \(P\) signifies population; \(A\) denotes affluence; and \(T\) refers to the technical level. However, model (2) only involves fewer variables that have some limitations in analyzing the influencing factors of pollution. To compensate, Dietz and Rosa [34] proposed the STIRPAT model on the basis of model (2), which added random variables to achieve a better analysis. To evaluate the effects of each driving factor and reduce the heteroscedasticity in the model, logarithms were taken from both sides to transform the STIRPAT model into a linear regression model, which is obtained as follows.

\[
\ln I_{it} = a + b \ln P_{it} + c \ln A_{it} + d \ln T_{it} + \ln e_{it}
\]
sewage charges are adopted to denote environmental regulation. Second, energy consumption and industrialization are incorporated into the analytical framework in many studies [38, 39]. Therefore, we incorporate energy consumption and industrialization into the model to analyse their effect on environmental quality. In addition, the parameters of individual and time effects are included in the model to control the heterogeneity of individuals and time. The extended STIRPAT model can be expressed as follows.

\[
\ln POL_{it} = \lambda_i + \phi_t + \delta_1 \ln SCH_{it} + \delta_2 \ln GDP_{it} + \delta_3 \ln POP_{it} + \delta_4 \ln IND_{it} + \delta_5 \ln SCH_{it} + \delta_6 \ln POP_{it} + \delta_7 \ln IND_{it} + \delta_8 \ln ENC_{it} + u_{it}
\]

where \(\delta_1, \delta_2, \text{ and } \delta_3, j = 1, \ldots, 4 \) represent unknown parameters; \(POL\) denotes the comprehensive environmental pollution index; \(SCH, GDP, POP, TEC, IND\) and \(ENC\) are sewage charges, \(GDP\) per capita, total population, number of patents granted, industrialization, and energy consumption per capita, respectively; and \(u_{it}\) is the random error term.

However, model (4) only reveals the linear correlation between environmental regulation and environmental pollution, ignoring other possible correlations between them. In fact, due to the obvious regional and time differences in the effectiveness of environmental regulation, the effect of environmental regulation on pollution is complicated. If only the parametric model (4) is used to evaluate the impact of environmental regulation on environmental quality, it is easy to obtain a biased estimation. To remedy this defect, a semiparametric additive panel model was used to investigate the effect of environmental regulation on environmental conditions. Specifically, a nonparametric form of \(\ln SCH\) is added to explore the uncertain relationship between environmental regulation and pollution performance. In addition, the nonparametric form of \(\ln GDP\) is also introduced in the model to investigate the existence of the EKC hypothesis. Accordingly, model (4) can be expressed as follows.

\[
\ln POL_{it} = \lambda_i + \phi_t + \psi_1 (\ln SCH_{it}) + \psi_2 (\ln GDP_{it}) + \psi_3 (\ln POP_{it}) + \psi_4 (\ln IND_{it}) + \psi_5 (\ln ENC_{it}) + u_{it}
\]

where \(f_k(\cdot)\) is the unknown function, which determines the potential linear or nonlinear correlation between environmental pressure, environmental regulation, and environmental quality, and income.

3.2. Data Collection

This article collects panel data for 30 Chinese provinces from 2005 to 2017. The data include the environmental pollution index (\(POL\)), sewage charges (\(SCH\)), gross domestic product per capita (\(GDP\)), energy consumption per capita (\(ENE\)), number of patents granted (\(PEO\)), and level of industrialization (\(IND\), ratio of value added of secondary sector to \(GDP\)). The \(POL\) is from the China Environmental Yearbook; the \(SCH\) is from the China Environmental Yearbook; the \(ENE\) is from the China Energy Statistics Yearbook; and the \(PEO, TEC, IND, \text{ and } GDP\) are from the website of the National Bureau of Statistics of the People’s Republic of China.

3.3. Variable Measurements

3.3.1. Dependent Variable

The environmental pollution index (\(POL\)) is regarded as the dependent variable. This study chooses the emissions of three industrial wastes as the measurement of the environmental pollution index. The study provides de-quantization and weighting of industrial wastewater, industrial waste gas, and industrial solid waste. For the \(k\)-th pollutant, the following equation is first used to remove the effect of the different units.

\[
X_{ij,k} = \frac{(x_{ij,k} - \min(x_{ij,k}))}{(\max(x_{ij,k}) - \min(x_{ij,k}))}
\]

where \(X_{ij,k}\) is the \(k\)-th pollutant after standardization, \(x_{ij,k}\) is the emission of the \(k\)-th pollutant, and \(\min(x_{ij,k})\) and \(\max(x_{ij,k})\) denote the minimum and maximum values for the
$k$-th pollutant, respectively. The weight $w_k$ is calculated using the independent weighting factor method. The primary weights are calculated as follows.

$$
\varphi_k = (\text{adj}R^2)^{-1/2} = \left[ 1 - (1 - R^2)(n - 1)/(n - \mu) \right]^{-1/2}
$$

(7)

where adj$R^2$ is the adjusted goodness-of-fit and $\mu$ is the number of parameters to be evaluated. The final weights can then be obtained by standardizing $\varphi_i$, namely, $w_k = \varphi_k / \sum_{k=1}^3 \varphi_k$. The ultimate POL can be obtained by adding the product of the $j$-th indicator under individual $i$ and the weight $100 \ast w_j$.

3.3.2. Independent Variables

The purpose of this study is to analyze the impact of sewage charges and economic development level on environmental performance. Therefore, this study has two explanatory variables, namely sewage charges and economic development level. Specially, as Xie and Liu [31] pointed out, the economic development level is usually signified by GDP per capita.

3.3.3. Parameter Variables

Referring to the research of Zhao et al. [38], Zhang and Wu [39], and IPAT model, the energy consumption, industrialization, technology level, and population are selected as parameter variables. Specially, according to Zhao et al. [38], energy consumption per capita is used to represent energy consumption, industrialization is usually measured by the ratio of the output value of the secondary industry to GDP, and the number of patents granted is adopted to represent the technology level. Moreover, Li et al. [35] pointed out that the population variable is measured by the total population. There, the parameter variables include energy consumption per capita ($ENЕ$), total population ($PEО$), number of patents granted ($TEC$), and level of industrialization ($IND$, ratio of value added of secondary sector to GDP).

Table 1 shows the descriptive statistics. From the table, it can be seen that POL has a minimum value of 0.037, a maximum value of 78.625, and a standard deviation of 8.078. These results show that the values of POL have a large disparity with individual and time variation, indicating strong individual and time heterogeneity. SCH has a minimum value of 1,799.3 and a maximum value of 276,863.7, implying that there is also some heterogeneity in SCH. The remaining other variables have significant differences between the maximum and minimum values, and all have large standard deviations. It is shown that all these variables have more significant individual and temporal heterogeneity.

### Table 1. Descriptive statistics.

| Variable | Units          | Mean  | Std. Dev. | Min   | Max    |
|----------|----------------|-------|-----------|-------|--------|
| POL      | /              | 6.232 | 8.078     | 0.037 | 78.625 |
| SCH      | 10,000 Yuan    | 60,217.09 | 49,559 | 1,799.3 | 276,863.7 |
| GDP      | Yuan per person| 38,782.07 | 24,193.15 | 5052 | 128,994 |
| ENE      | Tons per person| 3.214 | 1.614     | 0.974 | 9.515  |
| PEO      | 10,000 persons | 4452.067 | 2671.463 | 543 | 11,169 |
| TEC      | Number         | 29,458.76 | 50,569.76 | 79 | 332,652 |
| IND      | Percent        | 46.369 | 8.073     | 19.014 | 59.045 |

4. Empirical Results

4.1. Test the Linkages between the Independent and Dependent Variables

Before giving the results of the semiparametric additive model, we apply a scatter diagram to visualize the relationships between the dependent variable and independence variables. A scatter plot of the connection between environmental pollution and its influencing factors was obtained by using the data of 30 provincial panels from 2005 to 2017. The results are shown in Figure 1.
As shown in Figure 1, there are linear and nonlinear links between sewage charges, economic growth, and environmental performance. This finding also confirms that it is reasonable and feasible to study environmental impact factors based on the semiparametric additive model because the model is data-driven and is effective in identifying linear and nonlinear associations between socioeconomic variables.

### 4.2. The Linkages between the Independent and Dependent Variables

To show the non-parameter part more vividly, graphics are used to depict the effects of sewage charges and economic growth on environmental degeneration. Figure 2a illustrates the relationship between sewage charges and environmental pollution. As shown in the figure, sewage charges have a nonlinear “M-shaped” effect on environmental performance, and this effect is significant at the 1% level. This result shows that when the level of environmental tax payment is low, an increase in the level of sewage charges increases environmental degeneration, and when a certain level of environmental taxation is reached, an increase in the level of sewage charges decreases environmental pollution. As environmental taxes continue to increase, pollution will continue to grow until it reaches higher levels.

Figure 2b shows the relationship between income levels and environmental quality. The figure shows that economic development and environmental performance have a nonlinear “N-shaped” relationship, which is significant at the 1% level. The results suggest that growth in income levels increases environmental pollution during the initial stages of
economic development, and when a certain level of income is reached, economic growth decreases environmental pollution, but pollution continues to grow with further increases in income.

4.3. The Linkages between the Parametric and Dependent Variables

Table 2 presents the estimates for the parameter components, including energy consumption, total population, technology level, and industrialization.

| Variables | lnENE | lnPEO | lnTEC | lnIND |
|-----------|-------|-------|-------|-------|
| Coefficients | 1.038*** | 0.567* | −0.024 | 0.549** |
| (0.184) | (0.321) | (0.021) | (0.235) |

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

The coefficient of lnENE is 1.038 and is significant at the 1% significance level. This indicates that a 1% increase in per capita energy consumption will cause pollutant emissions to increase by 1.038%. The coefficient of lnPEO is 0.567 and is significant at the 10% significance level, which indicates that a 1% increase in the total population will bring about an increase in pollutant emissions of 0.567%. The coefficient of lnTEC is −0.024, which does not pass the significance test. The negative coefficient indicates that technological advances can curb pollutant emissions. However, the impact is not significant. The coefficient of lnIND is 0.549 and is significant at the 5% significance level, indicating that a 1% increase in the level of industrialization will lead to the pollutant emissions increasing by 0.549%.

4.4. Robustness Test

To test the merits of semiparametric additive model estimation results, this study re-estimates these variables using linear panel models. The linear panel models include the pooled, fixed-effects, and random-effects models. The results are shown in Table 3.

| Variables | Pooled Model | Fixed-Effects Model | Random-Effects Model |
|-----------|--------------|---------------------|----------------------|
| Intercept | −2.784***    | —                   | −12.437***           |
|           | 0.0099       | 0.0032              | 0.0425***            |
| lnSCH     | 0.1293**     | −0.0032             | 0.0189               |
| lnGDP     | −0.0057      | −0.111              | −0.1203              |
| lnENE     | −0.0833      | −0.1659             | −0.0836              |
| lnPEO     | −0.4594***   | 1.9288***           | 0.8608***            |
| lnTEC     | −0.01359     | 0.4698*             | 0.2220**             |
| lnIND     | 2.4667***    | −0.3302***          | −0.2368***           |
| lnSCH     | −1.6284*     | 0.4698*             | 0.2220**             |
| lnGDP     | −0.8745      | −0.2553             | −0.1102              |
| lnENE     | 2.4667***    | 1.8988**            | 0.2619               |
| lnPEO     | −0.1580**    | −0.3302***          | −0.2368***           |
| lnTEC     | 0.0769       | −0.058              | −0.0667              |
| lnIND     | 18.245       | 10.173              | 17.345               |
| R²        | 0.32788      | 0.41664             | 0.31178              |
| SSR       | 33.8028 (p < 0.001) | 1916.8 (p < 0.001) |
| F         | 1916.8 (p < 0.001) | 1916.8 (p < 0.001) |

Note: Standard errors in parentheses, ***, **, and * indicate significance at the 1%, 5%, and 10% levels. SSR denotes the sum of squared residuals.

As shown in Table 3, the estimates of the fixed-effects model are similar to the random-effects models and differ significantly from the pooled model. The F-test statistics reveal that the null hypothesis of the pooled model was rejected, and the alternative hypothesis of the fixed-effects model was accepted because of the large F statistics. The statistics of the
Hausman test imply the acceptance of the alternative hypothesis of the fixed-effect model and rejection of the null hypothesis of the random-effects model. Thus, fixed-effects models are superior to pooled and random-effects models in testing the relationship between environmental pollution and its driving factors. In addition, the choice of a fixed-effects model also supports that the semiparametric additive model is correctly set because it takes into account individual and temporal heterogeneity. By comparing the fixed-effects model and the semiparametric additive model, some interesting findings can be drawn. First, the sewage charges and economic growth variables are not significant and have low significance in the fixed-effects model, which is different from the strong significant estimation results of the semiparametric additive model. Second, the direction of the signs of the control variables obtained from the fixed-effects model is generally consistent with the results of the semiparametric addable model, although there are slight differences in the level of significance. The possible causes of these results are attributed to the structural settings of the model.

To further determine which is better between fixed-effects and semiparametric additive models, we employ the mean of squared residuals (MSR) and Akaike information criterion (AIC) as the assessment criterion. Here, AIC is defined as follows:

\[
AIC = -2 \log \hat{L} + 2df
\]

where \(\hat{L}\) is the mean square error and \(df\) refers to the degree of freedom of the model. Obviously, a smaller AIC value means that the model is better.

Table 4 gives the results of the evaluation of the model. As shown in the table, the MSR and AIC values of the semiparametric additive model are both smaller than those of its competitor of fixed-effect panel models. This suggests that the semiparametric additive model is superior to the fixed-effects panel model. The usage of semiparametric additive models can reduce model error settings and improve model fit accuracy.

|                | MSR     | AIC      |
|----------------|---------|----------|
| Fixed effects model | 0.031   | -2.689   |
| Semiparametric additive model | 0.022   | -5.145   |

5. Discussion
5.1. The “M-Shaped” Effect of Sewage Charges on Environmental Performance

The results proved that there is an “M-shaped” effect of sewage charges on environmental performance. This result is different from Guo et al. [40], who showed that sewage charges have a positive effect on environmental pollution. One possible explanation for this result is as follows. When the level of environmental regulation is low, enterprises are insensitive to regulation, and the cost of pollution control is higher than the sewage charges paid by enterprises. In such cases, the company prefers to pay fees rather than treat pollution, which increases the pressure on the environment from its production. With the increase in sewage level, there is an inflection point at A (7.94, 0.05). Once this inflection point is crossed, the sewerage discharge system begins to play a role, stimulating the R&D investment of enterprises for green technology and reducing the pressure on the environment to some extent. When reaching B (9.31, -0.11), there is a significant negative effect of sewage charges on environmental performance. This is due to the limited scope of sewage charges and the fact that some of the charges are returned to polluters as the scale of the economy increases, which will discourage enterprises from treating pollution. Meanwhile, pollution control funds may be diverted, and environmental pollution will begin to increase again. In the face of the severe environmental situation, the government began to increase environmental regulations, and companies will invest more in the research and
development of green technology. When $C (10.49, -0.02)$ is reached, the inflection point occurs again, and the trend of environmental degradation is halted. Therefore, the current sewage charges are not particularly effective, and environmental regulations should be strictly enforced to accelerate the green transformation of enterprises.

5.2. The Nonlinear “N-Shaped” Relationship between Economic Development and Environmental Performance

The study demonstrated that a nonlinear “N-shaped” relationship existed between economic development and environmental performance. This result is inconsistent with Xie et al. [16], who find that income growth has an inverted “U-shaped” effect on environmental degeneration. However, our results can be supported by Wang et al. [18]. The possible reasons for this result are as follows. In China, economic growth will cause firms to expand their production, which will inevitably generate more pollution emissions, resulting in a scale effect of economic growth on pollution emissions. This scale effect has been dominant throughout China’s economic growth. In addition, as China’s economic level continues to improve, clean technology in China has been advancing, which has led to lower pollution emissions in China, producing the technological effect of economic growth on pollution emissions. In summary, the relationship between economic growth and pollution in China is complex, with pollution emissions being affected differently by economic growth at different stages and regions. According to the findings, we know that the relationship between China’s economic growth and environmental performance is not fully consistent with the EKC curve. In particular, some resource-based provinces with high per capita incomes also have a large number of polluting enterprises. Some environmental regulations should be strictly enforced, and the industrial structure should be upgraded as soon as possible so that low-pollution industries can become the main driving force of economic outputs, thus achieving sustainable economic development.

5.3. The Role of Parametric on Environmental Performance

The study reveals that ENE is positively related to pollutant emissions, which is consistent with the findings of Shahbaz et al. [41]. Energy consumption, especially of fossil fuels, significantly increases pollutant emissions [42]. According to data published on the website of China’s National Bureau of Statistics, China’s per capita energy consumption increased from 1646.9 kg of standard coal in 2004 to 3161.2 kg of standard coal in 2016, with an average growth rate of 5.58%. This is evidence that the rapid increase in energy consumption has led to an increase in environmental pollution in China. Similarly, there is a positive relationship between PEO and pollutant emission. The empirical result is consistent with the findings of Li et al. [35]. On the one hand, an increase in the total population will lead to an increased demand for natural resources, the extraction and use of which will generate pollutant emissions. On the other hand, population growth will cause society to add additional outputs to meet the needs of the new population, including clothing, food, housing, transportation, and other aspects. The production of these goods and services will also inevitably lead to an increase in environmental degeneration. Differently, the result finds that there is a negative relationship between TEC and pollutant emissions, but the impact of technological progress on pollutant emissions is not significant. This finding is inconsistent with He et al. [43], who argued that technological advances contribute to pollutant emissions. In general, technologies include clean technologies and production technologies. The development of clean technologies can reduce the emission of pollutants, while production technologies can promote the emission of pollutants. The interaction of the two roles has resulted in insignificant effects of technological progress on environmental pollution. Moreover, the research also confirms that IND can promote pollutant emissions. This finding is consistent with Wu et al. [44]. Most existing studies show a clear link between industrialization level and environmental quality [45]. Compared with the primary and tertiary industries, the secondary industry, especially the heavy industry, accounts for a high proportion of energy consumption and pollutant emissions in China. Under the premise of creating the same output, the primary and
tertiary industries consume much less energy and pollute much less than the secondary industries. This is mainly determined by the nature of the industries themselves.

6. Conclusions and Policy Implications

6.1. Conclusions

This study is based on data from 30 provinces in China from 2005 to 2017. The dynamic effects of environmental regulations on environmental pollution are investigated using a semiparametric additive panel model. In contrast to the linear influence in prior literature, we adopt sewage charge as a proxy for environmental regulation to investigate its nonlinear effects on environmental quality when considering the nonlinear effects of economic levels simultaneously. The estimated result was further confirmed by performing a series of linear panel regression methods and model selection technology.

The results show that the impact of sewage charges on pollution is an “M-shaped” pattern with three inflection points. After the first and third inflection points are passed, the pollutant emissions will decrease with the increase in sewage charges; however, before this, sewage charge increases will aggravate environmental degeneration. This result indicates that China’s sewage charge policy does not always play a positive role in improving environmental quality. In addition, economic growth has an “N-shaped” influence on environmental performance. When the economy reaches a certain level of growth, its contribution to environmental pollution shows a sharp increase after a brief decline. This means that China’s current economic development model is not fully consistent with the principle of sustainable development and is not always conducive to improving environmental quality.

6.2. Policy Implications

Based on the findings, the following policy recommendations can be obtained.

The “M-shaped” linkage between sewage charges and environmental performance shows that China’s current environmental tax policy is not always effective in improving environmental quality. In this regard, the Chinese government should carefully design and formulate environmental regulatory tools, establish a scientific and rational environmental policy system, and give full play to the decisive role of environmental regulatory tools in environmental governance. On the one hand, differentiated environmental regulatory policies should be implemented, a regional environmental taxation model should be established, and the level of taxation should be raised appropriately to achieve an overall balance between economic and environmental performance. On the other hand, we should actively explore the establishment of an emissions trading market suitable for China’s national conditions. It is also necessary to improve the mechanism for public participation in environmental governance, broaden the system and channels through which the public can obtain environmental information, increase the breadth and depth of environmental information disclosure, and consciously accept public oversight.

The effect of economic growth on environmental pollution is “N-shaped”. According to this finding, we know that the present mode of economic growth will have a negative impact on environmental quality in the long run. As a policy implication, the Chinese government should commit itself to changing the economic growth style and focus on improving the quality and efficiency of output increase to achieve sustainable economic development. This means that the traditional economic growth pattern of high pollution and high energy consumption can no longer meet the requirements of economic and social development. For areas with a higher level of economic development, enterprises are encouraged to achieve energy conservation and emission reduction through equipment upgrades and technological progress. For regions with a low level of economic development, we should actively introduce capital and advanced technology to narrow the gap with regions with a high level of economic development in areas such as environmental management.
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