frontiers | Frontiers in Environmental Science

RETRACTED ON 07 AUGUST 2025

ORIGINAL RESEARCH
published: 30 June 2022
doi: 10.3389/fenvs.2022.945922

RETRACTED: The Relationship Between Fiscal Decentralization and China's Low Carbon Environmental Governance Performance: The Malmquist Index, an SBM-DEA and Systematic GMM Approaches

Jing Xia[1], *Xuegang Zhan*[1]*, *Rita Yi Man Li*[2] *and Lingxi Song*[3]

[1]*School of Accounting, Chongqing Technology and Business University, Chongqing, China,* [2]*Sustainable Real Estate Research Center/Department of Economics and Finance, Hong Kong Shue Yan University, North Point, Hong Kong SAR, China,* [3]*Chakrabongse Bhuvanarth International Institute for Interdisciplinary Studies, Rajamangala University of Technology Tawan-Ok, Bangkok, Thailand*

RETRACTED

OPEN ACCESS

Edited by:
Zeeshan Khan,
Curtin University Sarawak, Malaysia

Reviewed by:
Taimoor Hassan,
Nanjing University of Science and Technology, China
Umer Shahzad,
Anhui University of Finance and Economics, China

***Correspondence:**
Xuegang Zhan
lilisan666@ctbu.edu.cn

Specialty section:
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

Received: *17 May 2022*
Accepted: *07 June 2022*
Published: *30 June 2022*
Retracted: *07 August 2025*

Citation:
Xia J, Zhan X, Li RYM and Song L (2022) The Relationship Between Fiscal Decentralization and China's Low Carbon Environmental Governance Performance: The Malmquist Index, an SBM-DEA and Systematic GMM Approaches. Front. Environ. Sci. 10:945922. doi: 10.3389/fenvs.2022.945922

Despite the People's Republic of China government being the most aggressive in pursuing the carbon neutrality goal, it remains the world's largest carbon emitter and polluting country. This study used 31 provinces' panel data from 2010 to 2019 to compare fiscal decentralization's impact on regional carbon emissions. It applied SBM-DEA undesirable models to calculate the Malmquist index and study environmental governance performance. It then used the systematic GMM model to explore fiscal decentralization's influence on environmental governance performance. It is found that fiscal decentralization in eastern China exhibited a strong positive relationship with environmental governance performance. With high tax autonomy, local governments implemented the best tax policies for clean production, raising enthusiasm for enterprises' green production. Nevertheless, there was no relationship between fiscal decentralization and environmental governance in poorer central and western regions with less tax collected. Benefits that arose from fiscal decentralization were limited. Moreover, more elite officials working in affluent cities and wealthier citizens have a higher expectation of environmental governance. These lead to better environmental and carbon emission policies. This paper also brings policy implications: 1) the central government should raise local government flexibility to use financial resources for environmental management. 2) Local government performance appraisal should include environmental protection (including carbon emission control). 3) The production taxes retained by local governments should be minimized to reduce governments' incentives to obtain taxes from polluting/high energy consumption industries. 4) Raise government officials' income in poorer regions to attract talented officials to work.

Keywords: fiscal decentralization, environmental governance performance, carbon emissions, SBM-DEA undesirable models, malmquist index

1 INTRODUCTION

China's economy has grown over the last few decades, accumulating vast wealth. Nevertheless, rapid economic expansion has been associated with massive energy and resource consumption, resulting in serious environmental problems (Lin and Liu, 2016; Song et al., 2020). Even though the Chinese government has promoted environmental protection, environmental pollution remains a severe concern (Liu L. et al., 2019; Wu et al., 2021). Indeed, many local government officials focus on economic development, which allows "pollution first" and then controls pollution problems later. Nevertheless, high-quality development needs to minimize carbon emissions to reduce related climate change adversities (Li Z.-Z. et al., 2021) and increase the effectiveness of environmental control. According to National Aeronautics and Space Administration (NASA) statistics released in 2010, the mean PM2.5 concentration from 2001 to 2006 was 50–80 ug/m3, while the mean PM2.5 concentration in developed countries was below 15 ug/m3. China has been the world's first in carbon dioxide (CO_2) and sulfur dioxide (SO_2) emissions for many years. A cost-effective method for reducing emissions and saving energy is to improve environmental performance (Zhang et al., 2020; Zhang et al., 2021). However, resource conservation and carbon emission reduction are hard to achieve without institutional incentives and fiscal support (Lin and Zhu, 2019; Cheng et al., 2021). Many countries, including China, have delegated environmental responsibility to local governments in recent years (Khan et al., 2021). Local governments benefit from power devolution by being encouraged to take on more environmental and public service responsibilities (Bhattacharyya et al., 2017; Song et al., 2018).

China's 1994 tax-sharing reform established a fiscal decentralization framework by separating the central and local governments' expenditure responsibilities and fiscal authorities. (Zhang, 2020). For example, the central government received a 75 percent value-added tax, tariffs, and other significant levies. However, local governments received 25 percent only. Furthermore, the sources and rates of taxation were severely restricted. Because of this, local governments' autonomy in receiving tax is limited. The Chinese form of fiscal decentralization allows local governments to exercise their freedom to spend rationally to promote economic growth, support public services, and environmental protection. Under China's GDP-based appraisal system, local governments invest and spend more on infrastructure to meet the goals of economic expansion (Li and Du, 2021). Local governments bore an excessive expenditure obligation under this system with few options on funding sources.

Moreover, unequal changes in revenue and spending worsened regional fiscal imbalance (Jia et al., 2020). Fiscal decentralization does not directly affect environmental pollution, but it affects environmental pollution by influencing government choices. The role of fiscal decentralization reform in strengthening environmental governance has gained importance under China's national "13th Five-Year Plan" strategy. So, what will be the impact of the reform of the fiscal decentralization system within these 10 years on urban environmental pollution in China? Does fiscal decentralization encourage local governments to govern the environment or encourage them to sacrifice the environment for a better economy? These issues will be discussed in this paper.

Environmental preservation and sustainable development promotion are inextricably linked to local government funding. Regional fiscal imbalance drives local governments to adopt measures that raise GDP and tax revenue in the short run at the expense of long-run environmental benefits (Boqiang and Yicheng, 2021). While it is foreseeable that fiscal decentralization affects environmental performance, research that throws light on China, a planned economy country, is scarce. This research aims to fill this gap.

Specifically, this study aims to: 1) study how fiscal decentralization affects China's environmental governance performance while limiting carbon emissions using panel data from 31 Chinese provinces from 2010 to 2019. 2) Quantify environmental governance performance in all regions by calculating the Malmquist index to build SBM-DEA undesirable models. 3) Study the impact of interregional fiscal decentralization differences on environmental governance performance by using a systematic GMM model. As the environmental governance performance is affected by the governance performance level of the previous period and many other factors, this paper followed Zhang et al. (2014). It used the GMM approach to study the governance lags between this year and the previous years.

This paper's contribution is threefold. First, while there is much scholarly research about the relationship between fiscal decentralization and environmental governance performance, most have not included carbon emission governance into environmental governance performance. However, the PRC government envisaged lowering carbon emissions by 40–45 percent from 2005 to 2020. This paper studied the influence of fiscal decentralization on China's environmental governance performance, including CO_2 emission control. Second, this research compared the impact of regional fiscal decentralization disparities on environmental governance performance, including carbon emission. Finally, the results have policy implications and provide insights to government officials regarding the factors that reduce CO_2. This research's results indicated that a higher level of fiscal decentralization in eastern China could inform financial officials in China when they design and implement related fiscal policies in the future.

This paper's structure is as follows: the literature review and theoretical analysis are introduced in **Section 2**. The methods and data are presented in **Section 3**. The empirical findings and discussion are presented in **Section 4**. Conclusions and policy implications are covered in **Section 5**.

2 LITERATURE REVIEW

2.1 Impact of Fiscal Decentralization on Environmental Governance Performance

Previous studies have examined the impact of fiscal decentralization on environmental governance performance but have not reached a consensus. Some studies proposed that the decentralization of government increases energy consumption and pollution. While fiscal decentralization aids economic progress, it impedes regional carbon emission reduction. Local governments choose short-term economic gains over environmental preservation in fiscal decentralization (Zhang K. et al., 2017; You et al., 2019). This phenomenon is often described as a "race to the bottom" (Liu and Ding, 2019; Li X. et al., 2021). Guo et al. (2020) used China's province data from 2007 to 2015 to build a fixed-effect model and discovered that fiscal decentralization considerably worsens environmental pollution. Liu et al. (2016) studied the Beijing-Tianjin-Hebei region's environmental policies and historical processes and found fiscal decentralization worsened government fragmentation.

On the other hand, another school of thought's justification for fiscal decentralization is decreasing energy use and pollution emissions. Fiscal decentralization benefits local governments by raising environmental awareness and expenditures on environmental management (Kuai et al., 2019). Cheng et al. (2021) and Khan et al. (2021) shared similar conclusions. Elheddad et al. (2020) conducted quantile regression on provincial panel data from 2006 to 2015. They discovered a non-linear relation between fiscal decentralization and energy use.

Some found that fiscal decentralization reduced carbon emissions. Cheng et al. (2019) conducted a time-series econometric study based on China's data from 2005 to 2018 and discovered that a higher degree of fiscal decentralization reduced carbon emissions. Song et al. (2018) came up with similar conclusions. Zhou et al. (2018) found that fiscal decentralization might increase ecological energy conservation from 2000 to 2016. Utilizing the co-integration test and CS-ARDL technique, Su et al. (2021) discovered that fiscal decentralization raised renewable energy utilization and decreased fossil fuel consumption in OECD countries from 1990 to 2018. Ahmad et al. (2021) discovered that fiscal decentralization improved ecological efficiency sometimes but worsened between 2003 and 2016. Others discovered that fiscal decentralization had no impact on pollution and even stimulated environmental investment (He, 2015).

2.2 Data Envelopment Analysis Based Environmental Governance Research

Selecting indicators, collecting data, and analyzing and evaluating outcomes are methods for assessing environmental status and performance (Godínez-Cira et al., 2010). The Environmental Performance Index (EPI), Global Reporting Initiative (GRI), and the ISO 14001 norm usage, among other approaches, have been established to measure the environmental performance (Oregi and Galera, 2013). These approaches assessed environmental legislation compliance, pollution reduction, effective use of natural resources, waste and emissions generation, and ecosystem and biodiversity protection (Quiroga, 2001).

Several aspects are involved in an evaluation, and a single and unilateral indicator is typically insufficient to demonstrate the actual environmental situation. Thus, DEA assesses a group of decision-making units' relative efficiencies by measuring each unit's efficiency score using various resources (inputs) and multiple results (outputs). DEA also allows for comparison between Decision-Making Units (DMUs) and can be used in various situations (Charnes et al., 1978; Jahanshahloo et al., 2005; Halkos and Petrou, 2019).

DEA is a sophisticated tool for examining decision alternatives and evaluating performances (Zhu, 2009). Using mathematical programming techniques, DEA reviews the effectiveness of each DMU in a collection of decision-making units about all other Decision-Making Units in the set and generates an adequate border where the most efficient units are located. Inefficient units are not on the efficient Frontier; DEA determines how decision-making units should become efficient by radial projection to the border (Avil'es-Sacoto et al., 2016). Because it allows businesses under assessment to be measured best practices that are not visible in other management methods, DEA has lately been dubbed "balanced benchmarking" (Cook and Zhu, 2013).

DEA is a linear programming method that uses a single integrated model to handle many metrics. Multiple measures are made up of inputs that should be minimized and outputs that should be optimized (Charnes et al., 1978). It has been utilized extensively in numerous contexts, including environmental applications. For example, Shabani et al. (2015) used DEA to evaluate the environmental efficiency of 163 countries. Zeng et al. (2019) designed a DEA model with two stages for evaluating renewable energy technical ideas. Wen et al. (2019) conducted another study that investigated regional differences in the energy efficiency of the construction sector, considering China's incredible regional diversity. Jiang et al. (2019) employed a DEA model to assess the efficacy of wastewater treatment plants in terms of sustainability. Finally, Finally, Mohebali et al. (2020) employed DEA considering both outputs- and input-oriented approaches to assess environmental groups considering the industrial project's positive benefits.

2.3 Literature Gap

Although academics have researched the relationship between fiscal decentralization and environmental governance or carbon emissions, research gaps remain. First, even though academics have focused on CO2 emissions and the impact of fiscal decentralization, there is still a lack of knowledge about carbon emission governance. Scholars have either studied environmental governance or carbon emissions only. Second, the study of environmental governance performance should include carbon governance because reducing carbon emissions is China's environmental governance goal. The impact of fiscal decentralization on China's environmental governance performance, including carbon control, was investigated in this research.

3 METHODOLOGY AND DATA

3.1 SBM-DEA Undesirable Model

3.1.1 Model Analysis

DEA was created by Charnes et al. (1978) as a nonparametric method for coping with multiple inputs and outputs scenarios. It is usually used to assess and quantify the effectiveness of DMUs' many impacting elements (Boussofiane et al., 1991). In general, these variables can be classified into input and output variables. Labor, money, machinery, equipment production, and materials are input factors, whereas the value of the outputs like value-added and production are output variables (Halkos and Petrou, 2019). Once the optimal operating distance has been determined in DEA, an inefficient DMU's performance and efficiency can be improved by decreasing inputs or increasing outputs (Seiford and Zhu, 2002).

The DEA is founded on the idea that inputs should be minimized while maximizing outputs. However, the assessment process might produce undesirable results and inputs in some cases. It was recommended to raise desirable output factors to improve decision-making units' efficiency while minimizing undesired outputs (Jahanshahloo et al., 2005; Rashidi and Saen, 2015).

An undesirable model can be utilized to deal with negative variables, often known as unwanted or undesirable outputs. The undesirable model is concerned with negative variables and undesired or harmful outcomes. There are a few options for dealing with negative variables.

First, consider the negative output variable to be an input variable. This technique cannot use the existing positive output variable. However, because the weight is applied in proportion to the input variables, an improper weight may be imposed during the weighting process.

Second, they can be dealt with using an analysis that includes negative output variables only. A lower efficiency score indicates that the decision-making unit is operating at a higher efficiency level.

Third, a variable can be multiplied by "−1" to deal with the undesired variables. Multiplying by a value chosen at random, the weight must be considered together with the positive output variables like the first method. However, there is a risk of applying the wrong weight.

Fourth, utilizing the SBM model, multiply the negative value of the output variable by a multiplier by using predetermined weights. This method compares efficiency fluctuations caused by an undesirable output variable. It is simple to determine the surplus in the number of variables and suggest ideas for boosting efficiency because the benchmark is surplus efficiency (You and Yan, 2011; Rashidi and Saen, 2015). The formulae are as shown as follows:

$$\rho = min\frac{1-\frac{1}{m}\sum_{i=1}^{m}\left(s_i^-/x_{i0}\right)}{1+\frac{1}{s}\left(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{r0}^g}\right)+\left(\sum_{r=1}^{s_2}\frac{s_r^b}{y_{r0}^b}\right)} \quad (1)$$

$$\text{s. t. } x_0 = x\lambda + s^-,$$
$$y_0^g = y\lambda - s^g$$
$$y_0^b = y\lambda - s^b$$
$$L \leq e\lambda \leq u$$
$$\lambda, s^-, s^g, s^b \geqq 0,$$
$$\lambda \geq 0.$$

In these equations, the product is denoted by y. The decision-making units are the topic of the evaluation and is denoted by 0. Input excess, general output shortage, and negative output excess are represented by the letters s, s^g, and s^b. The optimal values of ρ, s, s^g, s^b And λ were calculated using this equation.

3.1.2 Variable Selection

To measure the environmental governance performance indicators, scholars have used different research methods, such as the questionnaire (Zhou and Tang, 2017), principal component method composition method (Qi et al., 2015), comprehensive index method (Zhang et al., 2014) and DEA-Malmquist index method (Yang, 2016). This paper intends to use the DEA-Malmquist index method to measure environmental governance's performance level in various regions of China.

The SBM-DEA undesirable model referred to Lin Chun (2017) to select the input and output variables and added the carbon emission in undesirable output to analyze China's Low carbon environmental governance performance. We selected the investment of people, equipment, and capital in environmental governance and included 6 input variables: the number of environmental protection employees, industrial wastewater treatment facilities, industrial waste gas treatment facilities, sewage treatment plants, harmless waste treatment plants, and investment regarding the contamination of the environment treatment. Considering environmental treatment, sewage, air, solid waste, and other treatment effect indicators are selected as the output indicators. This paper chooses the output variables of solid waste, industrial wastewater reuse rate, urban sewage treatment rate, and household garbage disposal rate (**Table 1**). Total particulate, nitrogen oxide, sulfur, and carbon dioxide emissions do not have a governance effect index and are undesirable outputs.

The rate at which solid waste is fully utilized was calculated by using typical industrial solid waste in its entirety and general industrial solid waste; discharge referred to the carbon emission of each province. It represented the energy consumption j in the region I during t and the emission coefficient of j energy consumption. The formula for emission coefficient of energy consumption would be:

Discount carbon dioxide coefficient = average low calorific value * carbon content per unit calorific value * carbon oxidation rate * [10^(-6)] * 44/12"

The average low heat generation data was obtained from China Energy Statistical Yearbook, and the amount of carbon and how fast carbon burns per unit of calorific value was derived from Table 1.5 and Table 1.7 of the Guide for the Compilation of Provincial Greenhouse Gas List (Trial), respectively. Thus, the coefficients of coal, coke, gasoline, kerosene, diesel, fuel oil, and natural gas were 1.9003,

TABLE 1 | Input and output variables.

Input and output variables in the undesirable model	
Input variables	**Output variables**
Number of environmental protection employees	Comprehensive utilization of solid waste
Number of industrial wastewater treatment facilities	The industrial wastewater reuse rate
Number of industrial waste gas treatment facilities	Urban sewage treatment rate
Number of sewage treatment plants	The household garbage disposal rate
Number of harmless waste treatment plants	Total particulate emissions (undesirable output)
Investment in environmental pollution treatment	Total nitrogen oxide emissions (undesirable output)
	Sulfur dioxide emissions (undesirable output)
	Carbon dioxide emissions (undesirable output)

2.8604, 2.9251, 3.0179, 3.0959, 3.1705, and 2.1605, respectively, so carbon dioxide emissions from fossil energy and natural gas consumption in 31 provinces and cities were estimated.

3.2 GMM Model

3.2.1 Model Setting

The econometric model based on the dynamic panel data below shows the influence of fiscal decentralization on China's environmental governance performance. The system GMM estimator was used to estimate our model. It was applied to study the dynamic relationship between factors that affected the accidents' compensation (Li et al., 2017). The system GMM estimator overcomes issues such as the presence of fixed control variables' effects and endogeneity; the correlation of independent variables and the past and errors; the presence of fixed effects and endogeneity of control variables; heteroskedasticity and autocorrelation in individual variables; and omitted factors persisted across time (Roodman, 2009). The model would then be:

$$\text{Environment}_{i,t} = \beta_0 + \beta_1 \text{Environment}_{i,t-1} + \beta_2 \text{FD}_{i,t} + \beta_3 \text{Control}_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

Where environment referred to the environmental governance performance, FD represented fiscal decentralization, control indicated the control variable affecting environmental governance performance, and ε was a random disturbance term.

3.2.2 Variable Description

3.2.2.1 Independent Variables—Environmental Governance Performance.

Environmental governance performance: the DEA-Malmquist index approach has the advantage of being no need to construct the production function and could explore the reasons for the change in environmental governance performance. Therefore, this paper used it to measure the environmental governance performance.

3.2.2.2 Dependent Variable- Fiscal Decentralization.

Fiscal decentralization: regarding the measurement of fiscal decentralization indicators, scholars mainly discussed revenue decentralization (He and Miao, 2016) and expenditure decentralization (Chun and Shao, 2017). If the fiscal decentralization index is measured from a single perspective, it cannot reflect its decentralization characteristics well. The fiscal decentralization reflected local governments' fiscal revenue power and the scope of expenditure responsibility. To raise accuracy, this paper measured the fiscal decentralization index from two perspectives: fiscal decentralization (FD1) from the perspective of revenue (FD1) and fiscal decentralization from the perspective of expenditure (FD2) (Chun, 2017).

The effect of fiscal decentralization on greenhouse gas emissions is reflected in fiscal decentralization, revenues from local and national government items are detailed differences, and local governments can decide their fiscal expenditure budgets according to their revenue. In theory, local governments can attract targeted investment according to the characteristics of local economic structure and rapidly increase regional fiscal revenue to strengthen environmental governance, such as an increase in low-carbon equipment, research and development, and technical personnel training high-carbon emission enterprises to reduce regional carbon emission level.

3.2.2.3 Control Variables and Moderator Variables.

Degree of economic development (income): the per capita GDP of each province reflects the degree of economic development. To obtain the real per capita GDP, the per capita GDP of all provinces from 2010 to 2019, GDP of each year and the total population at the end of each province were obtained from the China Statistical Yearbook.

Industrial structure (ind): the proportion of the secondary industry's added value in the provincial GDP was included. Regional carbon emission was closely related to its industrial structure. To promote the rapid development of the local economy, local governments encouraged secondary industry development to fasten the pace of local economic development. However, in accelerating industrialization, the immaturity of technology that utilized energy and the inefficiency with which fossil energy directly led to increased carbon emissions.

Fixed Assets Investment (inv): the purchase and construction of fixed assets for social production reflected new production activities, increasing carbon emissions. In addition, the process promotes the development and production of advanced technology and equipment and indirectly adjusts the industrial structure. This paper used the fixed asset investment in each province from 2010 to 2019, and the deflated fixed asset

TABLE 2 | The descriptive statistics of variables.

Variables	Variable symbol	Description
Environmental governance Performance	TFP	DEA-Malmquist index
Fiscal decentralization1	FD1	The provincial financial general budget revenue/revenue from the central government's general budget
Fiscal decentralization2	FD2	The provincial financial general expenditure/expenditure in the central government's general budget
Degree in economic development	Income	Real GDP per capita in each province
Industrial structure	Ind	The value-added of the secondary industry accounts for the GDP of each province
Fixed assets investment	Inv	The real value of the local fixed-asset investment
Foreign direct investment	Fdi	The real value of the foreign direct investment in various regions
The effect of opening degree of foreign trade	Tra	The real value of the import and export volume
Total retail sales of social consumer goods	Cus	The real value of the total retail sales of local social consumer goods
Population density	Pop	The ratio of population and area at the end of the year

investment price index refers to the actual fixed asset investment. Government investment in science and technology (tech) reflects the region's production technology level. In general, the higher the production technology level, the more advanced its industrial structure and the higher the energy utilization level, conducive to regional carbon emission reduction (Boqiang and Yicheng, 2021). The data on government investment in science and technology included the potential exploration transformation of enterprises and the local financial science and technology expenditure index. The data is deducted through the regional GDP index to obtain its real value.

Foreign direct investment (fdi): The impact of foreign investment on regional environmental conditions can be divided into two categories. One is based on the "pollution paradise" hypothesis, which states that developed countries transfer heavy polluting and high-carbon industries by investing in developing countries. In addition, some scholars believed that there was a complex mechanism regarding foreign direct investment's impact on the environmental situation, and the technology spillover effect brought by foreign investment might reduce carbon emission (Zhang H. et al., 2017).

The effect of the degree of open foreign trade (tra): the import and export trade of the high-carbon industry has the most noticeable impact on carbon emissions. Developed countries may transfer carbon emissions to developing countries with greater needs for economic growth through trade than carbon emissions reduction. In this paper, each province's total import and the export amount provided insight into the degree of opening to the outside world (Zhang et al., 2011). This value is multiplied by an annual average price of the RMB exchange rate over the years and converted to RMB, and then the production price index is deduced.

Total retail sales of social consumer goods (cus): this paper measured the indirect energy consumption of consumers through total retail sales of socially beneficial products, thus reflecting the indirect generation of carbon emissions. The data was obtained from the National Bureau of Statistics website, and the deflated index is the actual provincial index of retail commodity prices.

Regarding population density (pop), some scholars believe that energy efficiency exhibits a scale effect. The more dispersed the population, the higher the cost of using energy, and vice versa. A higher population density emits more carbon. Carbon emission data of provinces and regions were obtained from the official website of the people's government. The end-of-year total population data was obtained from the National Bureau of Statistics website. Meaning of each variable are shown in **Table 2**.

3.3 Data and Analysis Methods

The panel data of 31 Chinese provinces (municipalities and autonomous regions) used in this paper are available from 2010 to 2019. The data was obtained from the China Statistical Yearbook, China Financial Yearbook, China Environmental Statistical Yearbook, China Energy Statistical Yearbook, and government statistical bulletins and yearbooks.

4 EMPIRICAL RESULTS AND DISCUSSION

4.1 Environmental Governance Performance Analysis

This study used 31 Chinese provinces' panel data from 2010 to 2019 and applied the MaxDEA software program to analyze the SBM-DEA undesirable model. The variables and their sums are given in **Table 3** after including 6 input variables and 8 output variables. Following software operation and analysis, the Malmquist index results displayed in **Table 4** measured the performance of environmental governance in all regions. It shows that the performance of environmental governance improved annually, the best performance was in 2018, and the national average environmental governance performance over the years was 1.02.

According to the classification standards of provinces and cities in eastern, central, and western China in the China Statistical Yearbook, the average Malmquist index of eastern, central, and western regions were 1.03, 1.06, and 0.99 (**Table 4**). As higher values indicate better environmental governance, the performance of environmental governance in the eastern and central areas was better than the national average (1.02). At the same time, it is inferior in the western regions.

4.2 GMM Model Regression Analysis

4.2.1 Benchmark Regression Analysis

GMM model and panel data from 31 Chinese provinces from 2010 to 2019 indicated no clear relationship between fiscal decentralization and environmental governance performance. Differences in fiscal decentralization across provinces are not

TABLE 3 | 31 Chinese provinces' input and output variables.

Variable name and category			Mean	Max	Min	Median	Standard deviation	Number
Input variables		Number of environmental protection employees	8.19	20.44	0.16	8.16	4.20	310
		Number of industrial wastewater treatment facilities	2563.71	10608.00	16.00	1943.50	2328.36	310
		Number of industrial waste gas treatment facilities	9362.69	57278.00	46.00	6404.00	8539.47	310
		Number of sewage treatment plants	62.03	301.00	0.00	48.00	52.08	310
		Number of harmless waste treatment plants	28.08	111.00	0.00	25.00	18.82	310
		Investment in environmental pollution treatment	241.42	1,416.20	0.30	197.10	193.82	310
Output variables	Desirable variables	Comprehensive utilization of solid waste	0.64	1.00	0.01	0.62	0.22	310
		Industrial wastewater reuse rate	76.55	96.70	4.14	85.10	21.17	310
		urban sewage treatment rate	87.25	100.30	0.00	91.30	14.34	310
		household garbage disposal rate	90.02	100.00	38.00	95.00	13.29	310
	Undesirable variables	total particulate emissions (Bad Output)	371759.75	1575417.00	1,000.00	330102.00	280329.08	310
		total nitrogen oxide emissions (Bad Output)	449706.43	1843045.18	2491.00	348610.50	402664.65	310
		sulfur dioxide emissions (Bad Output)	437113.77	1827397.00	880.00	334294.00	377006.57	310
		carbon dioxide emissions (Bad Output)	41320.85	147817.65	3,696.51	31374.09	28987.54	310

TABLE 4 | 2011–2019 Malmquist index test results in various provinces.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
AH	0.89	0.90	0.96	0.89	0.97	0.95	0.95	0.97	0.83	0.92
BJ	0.55	1.04	3.43	1.01	1.08	1.18	1.22	1.01	0.99	1.28
HJ	0.69	1.05	0.98	0.96	0.88	1.07	0.93	1.02	0.84	0.93
GS	0.96	0.85	1.00	0.95	1.00	1.15	1.09	0.91	0.94	0.98
GX	0.84	1.03	1.01	0.99	0.95	1.09	1.03	0.99	0.89	0.98
GD	1.04	1.05	0.89	0.99	1.02	0.88	1.20	0.84	0.84	0.97
GZ	0.28	0.97	0.90	0.87	0.98	1.05	0.90	1.00	0.94	0.88
AHN	0.88	0.98	1.02	0.96	0.99	1.12	1.01	1.04	0.98	1.00
AHB	0.82	1.00	1.02	0.96	1.03	0.95	1.02	1.04	1.04	0.99
BHN	0.90	0.92	0.97	0.96	0.97	0.87	0.90	1.03	0.92	0.94
HLJ	0.95	0.97	1.03	1.04	1.03	1.19	0.91	1.11	0.89	1.01
BHB	0.68	1.13	1.05	0.92	0.96	1.07	1.00	1.01	0.87	0.97
CHN	0.90	0.88	1.06	0.96	0.88	1.26	1.15	1.01	0.89	1.00
JL	0.93	0.99	1.09	0.96	0.93	1.22	1.07	0.94	0.96	1.01
JS	0.85	0.95	0.98	0.93	0.94	0.97	1.10	1.00	0.96	0.96
JX	0.80	1.05	0.90	0.97	0.90	0.90	0.98	0.96	0.96	0.93
LN	0.88	0.94	1.13	0.95	0.98	1.34	1.04	1.14	1.12	1.06
NMG	0.74	1.07	0.98	0.94	0.98	0.96	0.90	9.61	0.14	1.81
NX	0.76	1.58	0.97	0.99	0.82	0.99	0.74	0.95	1.92	1.08
QH	0.97	0.96	0.95	1.00	0.96	1.07	1.12	1.07	0.97	1.01
SD	0.87	0.95	0.95	0.93	0.92	0.95	0.95	0.93	0.96	0.94
ASX	0.91	0.96	0.97	0.97	0.87	0.83	1.13	0.94	0.95	0.95
BSX	1.01	1.06	0.99	0.92	0.97	0.96	0.73	0.84	0.92	0.93
SH	1.04	0.52	0.45	0.93	2.08	0.99	2.59	1.01	1.06	1.18
SC	0.83	1.01	0.86	0.94	1.09	0.91	1.00	1.10	0.86	0.95
TJ	0.95	0.99	1.00	1.00	0.99	1.08	1.02	1.02	0.96	1.00
XZ	0.82	1.09	1.02	1.01	1.01	0.97	1.00	0.89	1.02	0.98
XJ	0.86	0.86	1.36	0.91	0.85	1.01	0.95	1.26	1.10	1.02
YN	0.82	0.79	1.05	1.03	1.02	0.98	0.85	1.06	0.92	0.94
ZJ	0.91	0.90	1.03	0.93	1.00	0.91	1.22	1.03	0.94	0.99
CQ	2.18	0.95	1.04	0.89	0.97	0.91	0.96	0.97	1.08	1.11
Mean	0.89	0.98	1.07	0.96	1.00	1.02	1.05	1.28	0.96	1.02

the cause of differences in environmental governance performance between provinces. Although the role of fiscal decentralization reform heightened environmental governance under the national "13th Five-Year Plan" strategy, and the Chinese government proposed in 2009 that carbon emissions in 2020 should be reduced by 40%–45% from 2005, indicating

TABLE 5 | Results of weight heterogeneity regression.

	Revenue perspective			Expenditure perspective		
	East	Middle	West	East	Middle	West
TFP(-1)	–0.083	–0.210[a]	–0.080	–0.084	–0.216[a]	–0.073
FD1	4.359[b]	–6.206	4.356			
FD2				4.359[c]	1.884	0.158
Income	1.264e–06	0.000	4.931e–06	1.264e–06	0.000	4.030e–06
Ind	–0.006	–0.009	0.000	–0.006	–0.0175	0.001
Inv	–6.534e to 06[a]	–9.519e to 07	–0.000	–6.534e to 06[a]	–8.590e to 06	–0.000
Fdi	–0.000	0.000	–0.000	–0.000	–0.000	–0.000[c]
Tra	–5.494e to 10	–1.482e to 09	–1.834ev09	–5.494e to 10	–4.023e to 10	–6.892e to 10
Cus	3.066e–06	–0.000	0.000	3.066e–06	–0.000	0.000[b]
Pop	–0.040	7.638	–0.896	–0.040	7.118	–0.173
Hansen Test	0.3187	0.000	0.028	0.3205	0.000	0.032

[a]$p < 0.1$.
[b]$p < 0.05$.
[c]$p < 0.01$.

that the Chinese government is increasingly emphasizing the role of fiscal decentralization on environmental governance, it remained in infancy.

4.2.2 Analysis of Regional Heterogeneity

To determine the relationship between different levels of fiscal decentralization and environmental governance performance, this article classified and compared three regions: eastern, central, and western. Regarding fiscal decentralization revenue and spending, the eastern region has more fiscal decentralization than the central and western regions. The fiscal decentralization is higher than in the eastern regions. The central and western areas were below the national average; however, the central region has a modest advantage over the western sections. The regression results of fiscal decentralization on environmental governance performance in the eastern, central, and western areas are shown in **Table 5**.

The findings showed that fiscal decentralization in the eastern region had a strong and beneficial relationship with environmental governance performance. With a high tax autonomy, the government could decide preferential tax policies, provide preferential tax policies for clean production enterprises, boost enterprises' green production enthusiasm and promote environmental governance performance. There appears to be no clear relationship between fiscal decentralization and environmental governance effectiveness in the central and western regions, which are on average poorer than the eastern part of China. It is speculated that poorer regions have a lot less tax being collected, and the benefits that arise from fiscal decentralization are also limited. Moreover, there may be more elite officials working in more affluent cities, and wealthier citizens might have a higher expectation of environmental governance as poorer ones mainly focus on how to make ends meet. All these lead to more careful planning and implementation of environmental policies in more prosperous eastern China when the officials have the right to exercise their decisions on carbon emissions policies.

4.3 Robustness Check

We conducted a robustness check to confirm that the regression results are reliable for fiscal decentralization and environmental governance performance. The robustness test examined the strength of the variables' explanatory power, that is, when certain indicators changed, whether the results remained relatively consistent and stable. This study removed the control variable of industrial

TABLE 6 | Robustness testing and endogenous problem handling.

	Revenue perspective			Expenditure perspective		
	East	Middle	West	East	Middle	West
TFP(-1)	–0.063	–0.205[b]	–0.080	–0.062	–0.206[b]	–0.073
FD1	4.109[b]	–9.287	4.627			
FD2				1.126[c]	–0.842	0.164
Income	1.584e–06	0.000	5.022e–06	2.219e–06	0.000	4.077e–06
Inv	–9.358e to 06***	–5.474e to 08	–0.000	–8.875e to 06[c]	–6.908e to 06	–0.000
Fdi	–9.192e to 06	–0.000	–0.000[b]	–8.974e to 06	–0.000	–0.000[c]
Tra	–5.347e to 10	–1.731e to 09	–1.936e to 09	–3.433e to 10	1.425e–10	–7.502e to 10
Cus	3.964e–06	–0.000	0.000[b]	1.392e–06	–0.000	0.000[b]
Pop	0.034	5.716	–0.868	0.152	2.196	0.0164
Hansen test	0.1745	0.000	0.023	0.3205	0.000	0.030
R-squared	0.081	0.105	0.102	0.109	0.104	0.095

[a]$p < 0.1$.
[b]$p < 0.05$.
[c]$p < 0.01$.

structure to test whether the results remained valid. **Table 6** shows that the regression coefficients of fiscal decentralization and environmental governance performance in the eastern region of **Eq. 1** and **Eq. 2** were 4.109 and 1.126, respectively, and significant at 5% and 1% levels, indicating that fiscal decentralization promoted the performance of environmental governance in eastern China, which was consistent with the regression results of the national benchmark model.

Empirical studies demonstrated that varying levels of fiscal decentralization have different regional impacts on environmental governance performance: a high level of fiscal decentralization in eastern China has a considerable favourable influence on environmental governance performance. The eastern area has a high level of fiscal decentralization and has enough finance for environmental governance to control and eliminate pollution efficiently. Furthermore, pollution emissions lowered when most polluting companies in the east relocated to the central and western regions. Compared to national averages, central China had a higher-level environmental governance performance. But the region had low-level fiscal decentralization. The western region's environmental governance performance was lower than the national average level; nonetheless, environmental governance did not directly correlate with fiscal decentralization in both regions. Central and western regions with low fiscal decentralization fell short of funds, making it challenging to undertake industrial transfer, especially in backward areas of the west. Although the central region's environmental governance performance is comparatively high, this is not due to its high fiscal decentralization. Nevertheless, fiscal decentralization significantly promoted the performance of environmental governance in eastern China.

5 CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusion

After the Paris Climate Conference, most developing countries face challenges in reaching the goal of carbon neutrality and sustainable economic development (Shao et al., 2021). The importance of fiscal decentralization reform in improving environmental governance has been listed top of the national "13th Five-Year Plan" agenda. The impact of fiscal decentralization on the performance of environmental governance of China while regulating carbon emissions is investigated using panel data of 31 Chinese provinces from 2010 to 2019. As shown in **Table 4**, the Malmquist index quantified environmental governance performance in all regions. It was calculated using SBM-DEA undesirable models. The systematic GMM model was then utilized to investigate how fiscal decentralization affected China's environmental governance performance.

According to Guo and Yang (2014), Lin Chun (2019), fiscal decentralization has a highly detrimental impact on environmental governance performance. However, their study did not include carbon emissions in the environmental governance performance. This research fills the research gap.

The results showed that varying levels of fiscal decentralization have different regional effects on environmental governance performance: the high level of fiscal decentralization in eastern China has a considerable favourable influence on environmental governance performance, whereas environmental governance performance in low-level fiscal decentralization, compared to national averages, central and western China has a higher level. The western region's environmental governance performance was poorer than national average; nonetheless, environmental governance does not have a direct correlation with fiscal decentralization in both regions. Besides, fiscal decentralization significantly promoted the performance of environmental governance in eastern China.

To summarize, fiscal revenue strengthened environmental policies in the eastern region, with environmental and environmental governance being a prominent area of fiscal expenditure. The eastern area has a high level of fiscal decentralization and has enough finance for environmental governance to control and eliminate pollution efficiently. Furthermore, pollution emissions lowered when most polluting companies in the east relocate to the central and western regions. However, due to their low level of fiscal revenue and insufficient growth momentum, central and western regions with low fiscal decentralization fall short of financial funds, making it challenging to undertake industrial transfer, especially in backward areas of the west. Although the central region's environmental governance performance is comparatively high, this is not due to its high fiscal decentralization. We find out that there appears to be no clear relationship between fiscal decentralization and environmental governance effectiveness in the central regions the regional government prioritizes environmental degradation. They are boosting the degree of decentralization of fiscal revenue to increase it so that more funds may be invested in environmental pollution control. According to the study, the previous phase of pollution emissions and the current phase of pollution emissions, namely environmental pollution, are a continuous, cumulative process, and reasonable fiscal decentralization can prompt local governments to manage current pollution promptly, avoiding the "ratchet effect" of environmental pollution, achieving sustainable economic and social development. Capital investment positively impacts the environment, demonstrating that increasing capital investment in local governments benefits environmental governance. However, to avoid investment speed lag caused by productivity lag and excessive production and resource waste, investment speed must be maintained steadily and reasonably.

5.2 Policy Implications

Considering the above conclusion, a country should strengthen the fiscal decentralization reform, especially under the current new normal economic conditions; the central government should give local government more flexibility to use financial resources as they have the most updated local knowledge. It can improve the most effective allocation of local resources, promoting the quality of environmental protection.

Second, fiscal reform must reduce carbon emissions and increase environmental governance efficiency. The central government should continue to promote fiscal and tax system reform, incorporate the incentive mechanism that effectively improves carbon emissions and environmental protection into the local government performance appraisal index, build a multi-dimensional local government evaluation system, and realize the long-term development mechanism of local economic development.

Third, the central government should alter the current tax rate structure to provide local officials with financial incentives, link the VAT rate to commodity pollution, and raise the cost of polluting enterprises from a tax standpoint, so that local governments can strike a balance between tax base expansion, pollution prevention and control.

Finally, the federal government should overhaul the relationship between finance and the federal, state, and local governments and distribute financial and administrative power among all levels of government. The production taxes retained by local governments should be as little as possible. This can counteract local governments' incentives to obtain excessive productive taxes, minimize the "race to the bottom" phenomenon, and lower pollution levels. We should accelerate the shift in economic development, achieve effective transformation and upgrade industries with high energy consumption and pollution, improve energy recycling efficiency, reduce pollutant emissions, and lower environmental governance investment costs to fully exploit the key role of local governments in environmental governance.

5.3 Limitations and Further Research

A limitation should be pointed out: First, this paper uses the panel data model to analyze the correlation between fiscal decentralization and China's environmental governance performance, but it does not clarify the internal mechanism and transmission mechanism of the interaction between tax structure environmental quality. Second, when studying the environmental effect of fiscal decentralization, the article further analyzes the environmental effect of different fiscal policies, providing a specific basis for optimizing fiscal and tax policies. However, there is room for improvement as per the analysis depth.

In addition, the existing research conclusion realizes that the environmental effect of both tax and fiscal expenditure are closely related to the financial system. Therefore, it needs to further study the problems from the level of the financial system on the environmental effect of financial policy research; and further analysis of the tax linkage reform.

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

JX: Writing—original draft, Formal analysis, Data curation. XZ: Supervision. RL: Writing—review and editing. LS: literature review.

FUNDING

This study is partially supported by Chongqing Social Science Planning Fund (Grant No. 2020YBJJ62), Chongqing Municipal Education Commission (Grant No. KJQN202100829), and Chongqing Technology and Business University (Grant No. 950121016).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.945922/full#supplementary-material

REFERENCES

Ahmad, F., Xu, H., Draz, M. U., Ozturk, I., Chandio, A. A., Wang, Y., et al. (2021). The Case of China's Fiscal Decentralization and Eco-Efficiency: Is it Worthwhile or Just a Bootless Errand? *Sustain. Prod. Consum.* 26, 89–100. doi:10.1016/j.spc.2020.09.014

Avil'es-Sacoto, S. V., Güemes-Castorena, D., and Cook, W. D. (2016). "A Proposal for Setting Goals for Future Performance of Economic Activities in a Region," in *Case Study: Region of Nuevo Le'on in Mexico* (Mexico: Tecnológico de Monterrey).

Bhattacharyya, S., Conradie, L., and Arezki, R. (2017). Resource Discovery and the Politics of Fiscal Decentralization. *J. Comp. Econ.* 45 (2), 366–382. doi:10.1016/j.jce.2017.02.003

Boqiang, L., and Yicheng, Z. (2021). Does Fiscal Decentralization Improve Energy and Environmental Performance? New Perspective on Vertical Fiscal Imbalance. *Appl. Energy* 302, 1–11. doi:10.1016/j.apenergy.2021.117495

Boussofiane, A., Dyson, R. G., and Thanassoulis, E. (1991). Applied Data Envelopment Analysis. *Eur. J. Operational Res.* 52 (1), 1–15. doi:10.1016/0377-2217(91)90331-o

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *Eur. J. Operational Res.* 2 (6), 429–444. doi:10.1016/0377-2217(78)90138-8

Cheng, S., Fan, W., Chen, J., Meng, F., Liu, G., Song, M., et al. (2019). The Impact of Fiscal Decentralization on CO_2 Emissions in China. *Energy* 192, 116685. doi:10.1016/j.energy116685

Cheng, Y., Awan, U., Ahmad, S., and Tan, Z. (2021). How Do Technological Innovation and Fiscal Decentralization Affect the Environment? A Story of the Fourth Industrial Revolution and Sustainable Growth. *Technol. Forecast. Soc. Change* 162, 120398. doi:10.1016/j.techfore.2020.120398

Chun, L., and Shao, Y. (2017). Regional Differences in Economic Growth Quality under the Background of Fiscal Decentralization ——are Based on the Test of Systematic GMM and Threshold Effect. *Financ. Theory Clust.* 12, 33–42.

Chun, L. (2017). The Relationship between Fiscal Decentralization and China's Economic Growth Quality ——is Based on the Perspective of Total Factor Productivity. *Financial Res.* 02, 73–83.

Cook, W. D., and Zhu, J. (2013). *Data Envelopment Analysis: Balanced Benchmarking*. Scotts Valley, CA: CreateSpace Independent Publishing Platform.

Elheddad, M., Djellouli, N., Tiwari, A. K., and Hammoudeh, S. (2020). The Relationship between Energy Consumption and Fiscal Decentralization and the Importance of Urbanization: Evidence from Chinese Provinces. *J. Environ. Manage* 264, 110474. doi:10.1016/j.jenvman.2020.110474

Godínez-Cira, I., Díaz-Aguirre, S., La Rosa-Baez, M., Hernandez-Díaz, R., Hevia-Lanier, F., and G´omez-Baez, J. (2010). Indicadores para la evaluaci´on del

RETRACTED

desempẽno ambiental de los Centros de Educaci´on Superior (CES). *Rev. CENIC Ciencias Quimicas* 41, 1–12. https://www.redalyc.org/articulo.oa?id=181620500040.

Guo, P., and Yang, M. (2014). Analysis of the Influence of Chinese Fiscal Decentralization System on Environmental Pollution Control of Local Government. *Res. Urban Dev.* 7, 84–90. doi:10.3969/j.issn.1006-3862.2014.07.012

Guo, S., Wen, L., Wu, Y., Yue, X., and Fan, G. (2020). Fiscal Decentralization and Local Environmental Pollution in China. *Int. J. Environ. Res. Public Health* 17 (22), 8661. doi:10.3390/ijerph17228661

Halkos, G., and Petrou, K. N. (2019). Treating Undesirable Outputs in DEA: A Critical Review. *Econ. Analysis Policy* 62, 97–104. doi:10.1016/j.eap.2019.01.005

He, D., and Miao, W. (2016). Whether Fiscal Decentralization Affects Fiscal Decentralization Comparative Analysis of Spatial Effects Based on Interprovincial Decentralization Data in. *Econ. Res.* 2, 42–55.

He, Q. (2015). Fiscal Decentralization and Environmental Pollution: Evidence from Chinese Panel Data. *China Econ. Rev.* 36, 86–100. doi:10.1016/j.chieco.2015.08.010

Jahanshahloo, G. R., Lotfi, F. H., Shoja, N., Tohidi, G., and Razavyan, S. (2005). Undesirable Inputs and Outputs in DEA Models. *Appl. Math. Comput.* 169 (2), 917–925. doi:10.1016/j.amc.2004.09.069

Jia, J., Liu, Y., Martinez-Vazquez, J., and Zhang, K. (2021). Vertical Fiscal Imbalance and Local Fiscal Indiscipline: Empirical Evidence from China. *Eur. J. Political Econ.* 68, 101992. doi:10.1016/j.ejpoleco.2020.101992

Jiang, H., Hua, M., Zhang, J., Cheng, P., Ye, Z., Huang, M., et al. (2019). Sustainability Efficiency Assessment of Wastewater Treatment Plants in China: a Data Envelopment Analysis Based on Cluster Benchmarking. *J. Clean. Prod.* 244, 1–10. doi:10.1016/j.jclepro.2019.118729

Khan, Z., Ali, S., Dong, K., and Li, R. Y. M. (2021). How Does Fiscal Decentralization Affect CO2 Emissions? the Roles of Institutions and Human Capital. *Energy Econ.* 94, 105060. doi:10.1016/j.eneco.2020.105060

Kuai, P., Yang, S., Tao, A., Zhang, S. a., and Khan, Z. D. (2019). Environmental Effects of Chinese-style Fiscal Decentralization and the Sustainability Implications. *J. Clean. Prod.* 239, 118089. doi:10.1016/j.jclepro.2019.118089

Li, R. Y. M., Chau, K. W., and Ho, D. C. W. (2017). Dynamic Panel Analysis of Construction Accidents in Hong Kong. *Asian J. Law Econ.* 8 (3), 1–14. doi:10.1515/ajle-2016-0022

Li, T., and Du, T. (2021). Vertical Fiscal Imbalance, Transfer Payments, and Fiscal Sustainability of Local Governments in China. *Int. Rev. Econ. Finance* 74, 392–404. doi:10.1016/j.iref.2021.03.019

Li, X., Younas, M. Z., Andlib, Z., Ullah, S., Sohail, S., and Hafeez, M. (2021). Examining the Asymmetric Effects of Pakistan's Fiscal Decentralization on Economic Growth and Environmental Quality. *Environ. Sci. Pollut. Res.* 28 (5), 5666–5681. doi:10.1007/s11356-020-10876-z

Li, Z.-Z., Li, R. Y. M., Malik, M. Y., Murshed, M., Khan, Z., and Umar, M. (2021). Determinants of Carbon Emission in China: How Good Is Green Investment. *Sustain. Prod. Consum.* 27, 392–401. doi:10.1016/j.spc.2020.11.008

Lin, B., and Liu, C. (2016). Why Is Electricity Consumption Inconsistent with Economic Growth in China? *Energy Policy* 88, 310–316. doi:10.1016/j.enpol.2015.10.031

Lin, B., and Zhu, J. (2019). Fiscal Spending and Green Economic Growth: Evidence from China. *Energy Econ.* 83, 264–271. doi:10.1016/j.eneco.2019.07.010

Liu, G., Yang, Z., Chen, B., Zhang, Y., Su, M., and Ulgiati, S. (2016). Prevention and Control Policy Analysis for Energy-Related Regional Pollution Management in China. *Appl. Energy* 166, 292–300. doi:10.1016/j.apenergy.2015.06.032

Liu, L., Ding, D., and He, J. (2019). Fiscal Decentralization, Economic Growth, and Haze Pollution Decoupling Effects: a Simple Model and Evidence from China. *Comput. Econ.* 54 (4), 1423–1441. doi:10.1007/s10614-017-9700-x

Mohebali, S., Maghsoudy, S., and Doulati, F. (2020). Application of Data Envelopment Analysis in Environmental Impact Assessment of a Coal Washing Plant: a New Sustainable Approach. *Environ. Impact Assess. Rev.* 83, 106389. doi:10.1016/j.eiar.2020.106389

Oregi, A., and Galera, J. (2013). *Indice de Rendimiento ambiental EPI, EUSKADI*. New Haven, CT: Yale University Press.

Qi, Y., Lu, H., and Lu, Z. (2015). Social Capital, Institutional Environment, and Environmental Governance Performance ——is Empirical Evidence from Cities at the Prefecture-Level and above in China. *Chin. Popul. Resour. Environ.* 12, 45–52.

Quiroga, R. (2001). *Indicadores de sostenibilidad ambiental y de desarrollo sostenible: estado del arte y perspectivas*.

Rashidi, K., and Saen, R. F. (2015). Measuring Eco-Efficiency Based on Green Indicators and Potentials in Energy-Saving and Undesirable Output Abatement. *Energy Econ.* 50, 18–26. doi:10.1016/j.eneco.2015.04.018

Roodman, D. (2009). How to do Xtabond an Introduction to Difference and System GMM in Stata. *Stata J.* 9, 86–136.

Seiford, L. M., and Zhu, J. (2002). Modeling Undesirable Factors in Efficiency Evaluation. *Eur. J. Operational Res.* 142 (1), 16–20. doi:10.1016/s0377-2217(01)00293-4

Shabani, A., Torabipour, S. M. R., Farzipoor Saen, R., and Khodakarami, M. (2015). Distinctive Data Envelopment Analysis Model for Evaluating Global Environment Performance. *Appl. Math. Model.* 39 (15), 4385–4404. doi:10.1016/j.apm.2014.12.053

Shao, X. F., Zhong, Y., Liu, W., and Li, R. Y. M. (2021). Modeling the Effect of Green Technology Innovation and Renewable Energy on Carbon Neutrality in N-11 Countries? Evidence from Advance Panel Estimations. *J. Environ. Manag.* 295, 113189. doi:10.1016/j.jenvman.2021.113189

Song, M., Du, J., and Tan, K. H. (2018). Impact of Fiscal Decentralization on Green Total Factor Productivity. *Int. J. Prod. Econ.* 205, 359–367. doi:10.1016/j.ijpe.2018.09.019

Song, M., Zhao, X., and Shang, Y. (2020). The Impact of Low-Carbon City Construction on Ecological Efficiency: Empirical Evidence from Quasi-Natural Experiments. *Resour. Conservation Recycl.* 157, 104777. doi:10.1016/j.resconrec.2020.104777

Su, C.-W., Umar, M., and Khan, Z. (2021). Do fiscal Decentralization and Eco-Innovation Promote Renewable Energy Consumption? Analyzing the Role of Political Risk. *Sci. Total Environ.* 751, 142220. doi:10.1016/j.scitotenv.2020.142220

Wen, Q., Hong, J., Liu, G., Xu, P., Tang, M., and Li, Z. (2019). Regional Efficiency Disparities in China's Construction Sector: a Combination of Multiregional Input-Output and Data Envelopment Analyses. *Appl. Energy* 257, 113964. doi:10.1016/j.apenergy113964

Wu, H., Xia, Y., Yang, X., Hao, Y., and Ren, S. (2021). Does Environmental Pollution Promote China's Crime Rate? A New Perspective through Government Official Corruption. *Struct. Change Econ. Dyn.* 57, 292–307. doi:10.1016/j.strueco.2021.04.006

Yang, J. (2016). An Empirical Study on —— Provincial Panel Data on the Impact of Urbanization on Environmental Governance Performance. *China Adm.* 4, 103–109.

You, D., Zhang, Y., and Yuan, B. (2019). Environmental Regulation and Firm Eco-Innovation: Evidence of Moderating Effects of Fiscal Decentralization and Political Competition from Listed Chinese Industrial Companies. *J. Clean. Prod.* 207, 1072–1083. doi:10.1016/j.jclepro.2018.10.106

You, S., and Yan, H. (2011). A New Approach in Modelling Undesirable Output in DEA Model. *J. Operational Res. Soc.* 62 (12), 2146–2156. doi:10.1057/jors.2011.1

Zeng, Y., Guo, W., Wang, H., and Zhang, F. (2019). A Two-Stage Evaluation and Optimization Method for Renewable Energy Development Based on Data Envelopment Analysis. *Appl. Energy* 262, 114363. doi:10.1016/j.apenergy.2019.114363

Zhang, H., Fan, L. W., and Zhou, P. (2020). Handling Heterogeneity in Frontier Modeling of City-Level Energy Efficiency: the Case of China. *Appl. Energy* 279, 115846. doi:10.1016/j.apenergy.2020.115846

Zhang, H., Feng, C., and Liu, G. (2017). Chinese Style Environmental Federalism: The Impact of Environmental Separation on Carbon Emission. *Financial Res.* 9, 33–49.

Zhang, J., Patwary, A. K., Sun, H., Raza, M., Taghizadeh-Hesary, F., and Iram, R. (2021). Measuring Energy and Environmental Efficiency Interactions towards CO2 Emissions Reduction without Slowing Economic Growth in Central and Western Europe. *J. Environ. Manag.* 279, 111704. doi:10.1016/j.jenvman.2020.111704

Zhang, K., Wang, J., and Cui, X. (2011). Financial Decentralization and Environmental Pollution: The Perspective of Carbon Emissions. *Industrial Econ. China* 10, 65–75.

Zhang, K., Zhang, Z.-Y., and Liang, Q.-M. (2017). An Empirical Analysis of the Green Paradox in China: From the Perspective of Fiscal Decentralization. *Energy Policy* 103, 203–211. doi:10.1016/j.enpol.2017.01.023

Zhang, W. (2020). Political Incentives and Local Government Spending Multiplier: Evidence for Chinese Provinces (1978–2016). *Econ. Model.* 87, 59–71. doi:10.1016/j.econmod.2019.07.006

Zhang, Y., Jin, P., and Shen, Y. (2014). The Contribution of the Integration of the Two Industrialization to China's Industrial Environmental Governance Performance —— Evidence of Heavy Chemical and Chemical Stage. *Industrial Econ. Res.* (01), 40–50.

Zhou, M., Wang, T., Yan, L., and Xie, X.-B. (2018). Has Economic Competition Improved China's Provincial Energy Ecological Efficiency under Fiscal Decentralization? *Sustainability* 10 (7), 2483. doi:10.3390/su10072483

Zhou, Q., and Tang, S. (2017). Public Satisfaction of Media Use and Government Environmental Governance Performance ---An Empirical Study Based on Nationally Representative Data. *J. Beijing Inst. Technol. Soc. Sci. Ed.* (01), 162–168. doi:10.15918/j.jbitss1009-3370.2017.0122

Zhu, J. (2009). "Quantitative Models for Performance Evaluation and Benchmarking," in *Data Envelopment Analysis with Spreadsheets* (Springer US). doi:10.1007/978-0-387-859828

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.