

Retraction

Retracted: Impact of Energy Price Distortion on Green TFP Based on Spatial Econometric Model

Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] H. Guan and M. Xing, "Impact of Energy Price Distortion on Green TFP Based on Spatial Econometric Model," *Mathematical Problems in Engineering*, vol. 2022, Article ID 1117675, 8 pages, 2022.

Research Article

Impact of Energy Price Distortion on Green TFP Based on Spatial Econometric Model

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With environmental regulation as the intermediary, this paper studies the influence mechanism and mediating effect of energy price distortion on green total factor productivity. On the basis of the panel data of 30 provinces in China (except Tibet, Hong Kong, Macao, and Taiwan), the research results from the study of panel and spatial metrology show that energy price distortion has a significant negative effect on the improvement of green total factor productivity. Different environmental regulation tools have different impacts, and the impact effect of fiscal energy conservation and environmental protection expenditure is better than that of pollution punishment. The transmission effect of energy price on environmental regulation policies is different when environmental regulation is the intermediary. The increase of the degree of energy price distortion will increase the financial expenditure of energy conservation and environmental protection, while the energy factor price will increase the green total factor productivity with the increase of pollution punishment.

1. Introduction

China's economy is growing at a high speed, and energy consumption is highly dependent on economic growth. Although the elasticity coefficient of energy consumption has a downward trend, the gap with developed countries is still obvious. China is "rich in coal, poor in oil, and little in gas." The situation dominated by coal causes unreasonable energy structure and serious damage to the environment. In the face of the uneven distribution of energy and resource endowment and the overall situation of energy and resource shortage, improving energy utilization efficiency, optimizing the allocation of factors, and focusing on improving green total factor productivity are the key to the high quality development of China's economy and the coordination of economic and environmental protection and green development. Chinese enterprises should also actively adapt to the trend of green development, carry out green innovation activities, and strengthen green technology progress.

As the core of green development, green total factor productivity is equivalent to green development to a certain extent. The relationship between energy issues and green development that has always been the focus of academic circles both at home and abroad mainly includes four aspects. The first is energy consumption and environmental pollution [1, 2]. Researches show that energy consumption causes environmental pollution and has a positive effect on it. The second is energy structure and environmental pollution [3, 4]. The improvement of energy structure is conducive to the improvement of environmental quality. The third is energy efficiency and environmental pollution [5, 6]. Research shows that improving energy efficiency can significantly improve China's environmental pollution. The last is energy tax and environmental pollution [7, 8]. The relevant study found that the collection of energy tax could effectively improve environmental pollution. However, the above empirical studies did not consider the possible impact of factors in energy market system on haze pollution in

China. China is in a transition period at present, in which the factor market, especially the energy marketization, lags far behind the product market [9]. The acquisition and allocation of China's energy sources such as coal, oil, and natural gas are not determined by the market mechanism freely, and the resource accounting paid by the production enterprises is far lower than the administrative charges of the market equilibrium price. The resource use is granted for free, and the government's symbolic charge causes incomplete energy price structure, low price level, and unreasonable price parity. The attempts to raise prices are regulated by the government, which leads to severe price distortions in the energy market.

Unreasonable energy pricing mechanism hinders the promotion and application of clean energy technology in China and inhibits the green transformation to low-carbon and circular economy. Because of the implementation of the planned economic system early in China, the government for a long time has regulated energy prices. Although, in recent years, the reform of marketization has been constantly promoted, unreasonable energy prices have not been able to fully reflect the supply and demand of energy as well as environmental costs. The price mechanism is difficult to play an effective role in regulating the allocation of resources in the energy market, because the unreasonable price comparison in energy products, domestic and international energy, and the phenomenon of such wholesale price difference still exist. Therefore, persisting in deepening the reform of the energy price mechanism is a long-term task for China as a guarantee to provide a sustained impetus for development. This paper will analyze China's green productivity from the perspective of energy price distortion.

2. Influence Mechanism

2.1. Impact of Energy Factor Price Distortion on Green TFP. First of all, the changes in energy prices will directly affect the energy utilization efficiency, which is the key to regulate the industrial energy consumption. Therefore, the changes in energy prices will have a direct impact on industrial energy consumption and the demand for factors. But whether the rising energy prices will bring positive or negative impacts on energy consumption is uncertain. On the one hand, rising energy prices will bring high production costs to enterprises. In reducing the losses caused by production costs, enterprises choose to strengthen technological innovation input to improve energy efficiency or select other alternative factors to increase production input. On the other hand, in the face of rising energy prices, enterprises will actively expand production scale to meet higher energy demand, which is not conducive to the realization of the industry's goal of reducing energy consumption and improving energy efficiency.

Hypothesis 1. Energy factor price distortion reduces green TFP

2.2. Mediating Role of Environmental Regulation. "Porter hypothesis" holds that environmental regulation has a positive effect on the improvement of green TFP of enterprises in the long term. Porter proposed that short-term government environmental regulation would increase production and innovation costs of enterprises. However, government environmental regulation would bring technological progress to enterprises in the long term, and the compensation benefit of innovation forced by technological progress would offset or even exceed the costs of environmental compliance, so environmental regulation is conducive to improving enterprises' green TFP. According to the "Porter hypothesis," this paper argues that reasonable environmental regulation can promote the improvement of enterprises' green TFP. The current environmental regulation policies have been made by the government to solve the problems such as air and water pollution with formulating the standards of environment, emission, and the establishment of a pollution levy system. For the stringent environmental regulation, enterprises have to counter the additional costs caused by environmental regulation externalities through increasing the investment of green technology innovation, saving resources, reducing pollution emission, and improving the green TFP. This also complies with the trend of green and high-quality economic development in China. Different tools of environmental regulation policy have different effects on green TFP. This paper examines the different effects of investment environmental regulation and cost-based means of environmental regulation on green TFP.

Government environmental regulation policies affect the formation of energy factor prices to a certain extent. For a long time, the government has intervened the formation of energy prices in China. The previous economic development mode required the government to implement a subsidy system for traditional fossil energy to reduce production costs and achieve rapid economic development. Energy prices cannot truly reflect the market supply and demand situation, as well as the degree of energy scarcity, resulting in distorted energy prices. Under the general background that the whole world advocates green development, China gradually introduces a series of environmental regulation policies, including reducing the regulation of traditional fossil energy, increasing the support for clean energy, and issuing pollution emission standards. The enterprises that fail to meet the standards are given penalties and those that do are given incentives such as financial subsidies. Therefore, environmental regulation can affect energy prices by influencing production costs and supply prices.

Hypothesis 2. Environmental regulation affects green total factor productivity.

Hypothesis 3. Environmental regulation plays a mediating role in the impact of energy factor price on green total factor productivity.

3. Model Building and Variable Selection

3.1. Model Building. An econometric model is constructed according to the three hypotheses mentioned above. The explained variable of the proposed model in this paper is the green TFP at the provincial level. The core explanatory variable is energy price distortion. And the intermediate variable is fiscal expenditure on energy conservation and environmental protection (investment tool) and the levy of enterprises' expense on pollutant emission (cost tool); the control variables are R&D investment, economic development level and foreign direct investment, and energy factor prices. The basic econometric regression model constructed is as follows:

$$\begin{aligned} \text{LnGTFP}_{kt} &= \beta_{10} + \beta_{11}\text{LnGTFP}_{kt-1} \\ &\quad + \beta_{12}\text{LnPE}_{kt} + \varepsilon_1 X + \varepsilon_1, \\ \text{LnGTFP}_{kt} &= \beta_{10} + \beta_{11}\text{LnGTFP}_{kt-1} + \beta_{12}\text{LnTI}_{kt} \\ &\quad + \beta_{13}\text{LnSC}_{kt} + \varepsilon_1 X + \varepsilon_1. \end{aligned} \quad (1)$$

In the model, GTFP_{kt} represents the green TFP value in k region in the t year, and GTFP_{kt-1} represents the explained variable lagging behind by one period, which is used to investigate the empirical results. TI_{kt} represents the fiscal expenditure data of energy conservation and environmental protection in region k in year t ; SC_{kt} denotes the pollution punishment of region k in t year; X is several control variables; ε_1 represents the residual. Model (1) tests the impact of government environmental regulation on the enterprise's green TFP and the different impact effects of different regulatory tools, that is, to verify the results of Hypothesis 1.

The constructed mediating effect model is as follows:

$$\begin{aligned} \text{TI}_{kt} &= \beta_{20} + \beta_{21}\text{TI}_{kt-1} + \beta_{22}\text{LnPE} + \varepsilon_2 X + \varepsilon_2, \\ \text{SC}_{kt} &= \beta_{20} + \beta_{21}\text{SC}_{kt-1} + \beta_{22}\text{LnPE} + \varepsilon_2 X + \varepsilon_2, \\ \text{LnGTFP}_{kt} &= \beta_{30} + \beta_{31}\text{GTFP}_{kt-1} + \beta_{32}\text{LnTI}_{kt} + \beta_{33}\text{LnSC}_{kt} \\ &\quad + \beta_{34}\text{PE}_{kt} + \varepsilon_3 X + \varepsilon_3. \end{aligned} \quad (2)$$

Here, the intermediary variables are fiscal expenditure on energy conservation and environmental protection and pollution punishment, the explained variable is energy factor price, and ε_3 is the residual. Model (2) tests Hypothesis 2, that is, examining the impact of energy factor prices on environmental regulation. Models (3), (4), and (5) verify Hypothesis 3, that is, studying the mediating role of environmental regulation in the influence of energy factor price on the green TFP.

$$\begin{aligned} \text{LnGTFP}_{kt} &= \beta_{30} + \rho\text{GTFP}_{kt-1} + \beta_{32}\text{LnTI}_{kt} \\ &\quad + \beta_{33}\text{LnSC}_{kt} + \beta_{34}\text{PE}_{kt} + \varepsilon_3 X + \lambda\text{Mu} + \varepsilon_3. \end{aligned} \quad (3)$$

ρ is the spatial interaction effect coefficient between provinces, and λ is the spatial error coefficient.

3.2. Variable Selection

3.2.1. Green Total Factor Productivity. This paper adopts DEA-Malmquist index model to measure provincial green total factor productivity. DEA is used to solve the distance function (closely related to efficiency) as an important method to solve nonparametric linear programming. According to the solved distance function, the Malmquist productivity index is obtained, and it includes technical progress and technical efficiency. The input-output index selected to measure green total factor productivity requires the data on capital, labor, and energy elements, including fixed asset investment, the number of employees in various industries, and the data of input factors measured by terminal energy consumption in various regions. Output indicators are measured according to expected output and nonexpected output indicators. Expected output selects GDP, since carbon emissions are closely related to pollutants, and nonexpected output selects green total element of dioxide. All these data above are selected from *China Statistical Yearbook*, *China Energy Statistical Yearbook*, *China Science and Technology Statistical Yearbook*, etc.

3.2.2. Energy Price Distortion. Energy price distortion means that energy is not optimally allocated in the industrial structure of the national economy. At this time, energy prices cannot reflect the supply and demand of energy and do not match its value. As a result, it cannot reflect the role and status of energy in economic activities. The C-D production function is generally used for measurement.

3.2.3. Environmental Regulation. Environmental regulation consists of two important tools, that is, TI_{kt} and SC_{kt} , in which the former is local fiscal expenditure on energy conservation, and the latter is environmental protection and local pollution punishment. According to the classification methods proposed by Yuan Yijun, the environmental regulation tools are divided into investment and cost tools, the provincial fiscal energy saving and environmental protection expenditures are regarded as investment tools, and the provincial expenses on pollutant emissions are regarded as cost tools. Then, the econometric models are constructed to verify the impact of different environmental regulation tools on enterprises' green TFP. The 10-year data of environmental regulation indicators are selected from *China Environmental Statistics Yearbook*, etc.; they are organized into the same unit according to the research purpose.

(3) Control variables include the ones that have a direct impact on enterprises' green TFP except for core explanatory variables. In accordance with economic theories and the current situation, this paper selected R&D investment (GS_{kt}) as an important control variable; this indicator can better reflect the degree of technological innovation. Firstly, because the improvement of green TFP is inseparable from the personnel training, the investment in scientific research and

innovation, therefore the paper took the data from the number of students in each region. Secondly, the overall economic development level (GDP_{kt}) is chosen for the fact that the economic development of each region directly affects the technological innovation of enterprises, which is conducive to the improvement of green TFP. Finally, foreign direct investment (FDI) is also an important factor, which can not only inject a large amount of capital into enterprises, but also bring advanced technology and experience support, so it is conducive to the improvement of green TFP. The data comes from *China Statistical Yearbook*.

3.3. Descriptive Statistics. Before the empirical study, the descriptive statistical analyses of various variables are shown in Table 1. The measured mean of the explained variable green TFP is 0.869, the mean of fiscal expenditure on energy conservation and environmental protection is about 10.8, the mean of pollution punishment is about 15.69, and the mean of R&D investment, economic development, and foreign direct investment is 4.62, 7.547, and 6.648, respectively.

3.4. Results of Unit Root Test. The unit root test is carried out to avoid false regression. The results of all variables are stable as shown in Table 2, which proves that there is no false regression. An empirical regression analysis of panel data will be carried out in the next step.

4. Empirical Research and Discussion of Results

4.1. Spatial Correlation Test. Moran's I index is generally used for the test of global spatial correlation. Moran's I value of the green total factor productivity index was calculated according to the green total factor productivity index of 30 provinces from 2003 to 2017, and the results are shown in Table 3.

As shown in Table 3, the Moran of total factor productivity index in China is greater than zero from 2003 to 2017, and the p value of the Moran index test passed the test of 10% significance. Therefore, under a significant test level of 10%, the total factor productivity of 30 provinces and cities in China is not completely randomly distributed, but they are correlated spatially. Therefore, the spatial correlation of variables should be considered when studying the influencing factors of green total factor productivity of 30 provinces and cities in China.

From the perspective of the time change, during the whole observation period from 2003 to 2017, the value of Moran showed a rising tendency from 2003 to 2010 due to the relevant economic policies issued in 2010 to cope with the pressure of economic downturn, producing a great impact on energy consumption. From 2010 to 2017, the value of Moran has been around 0.18. Since 2010, China has frequently introduced relevant energy-saving and emission reduction policies. For example, in 2012, China issued The 12th Five-Year Plan for Air Pollution Prevention and Control in Key Areas. After that, the Moran of green total factor productivity in China kept in a relatively stable state.

4.2. Static Panel Analysis. Based on the models of established benchmark regression and the mediating effect, the system GMM method is used for empirical analysis on the influence mechanism of environmental regulation on the green TFP and the mediating effect of energy factor price. The results of direct effect and mediating effect are shown in Table 4.

Table 4 shows that model (1), environmental regulation, has a significant effect on improving green TFP of enterprises at the 1% level. Environmental regulation significantly promotes the improvement of enterprises' green TFP, and the two tools have different impact effects. If the government expenditure on energy conservation and environmental protection of each region increases by 1%, the green TFP of enterprises will increase by about 33%. If the amount of expenses on pollution discharge in each region increases by 1%, the green TFP of enterprises will increase by about 5.4%. Hypothesis 1 is true. This result is consistent with economic theory. According to "Porter Hypothesis," environmental regulation plays a positive role in promoting enterprises' green TFP in the long term. The theory holds that short-term government environmental regulation will increase the production costs and innovation costs of enterprises, which is consistent with the traditional economic theory that environmental regulation will lead to increased production costs of enterprises. However, in the long term, government environmental regulation would bring technological progress to enterprises, and the compensation benefit of innovation forced by technological progress would offset or even exceed the costs of environmental compliance, so environmental regulation is conducive to improving enterprises' green TFP. This is the more innovative content of "Porter Hypothesis" theory than the traditional economic theory. When enterprises suffer the pressure of increased costs of environmental regulations for a long time, in order to maintain the current production level, they have to internalize the costs produced by environmental regulation. As a result, to realize the improvement of green TFP, these enterprises must increase investment in technological innovation and promote technological progress. Of the two tools, government financial expenditure on energy conservation and environmental protection has a greater impact on green TFP.

Model (2) mainly analyzes the impact of environmental regulation on energy factor prices. Table 3 shows that the influence direction of the two environmental regulation tools on energy prices is different. The impact of energy conservation and environmental protection policies on energy prices is significantly negative at 1% level ($\beta = -1.307$), with a strong degree of influence. However, the impact of pollutant discharge fee levy policies on energy prices is significantly positive at 1% level ($\beta = 0.27$); that is, the increase of pollutant discharge fee levy will increase energy factor price, which proves that Hypothesis 2 is true. Energy resources are an important input factor and a key consumption resource of China's industry. The problem of pollution and resource waste produced in the production process of energy-consuming industries is becoming more and more serious, while environmental regulation aims at saving energy and protecting the ecological environment.

TABLE 1: Descriptive statistics of variables.

Variable	Name	Mean value	Standard deviation	Minimum value	Maximum value
GTFP	Green total factor productivity	0.869	0.856	0.562	1.039
TI	Financial expenditure on energy conservation and environmental protection	10.802	0.586	8.706	12.553
SC	Pollution punishment	15.694	0.789	12.949	17.423
PE	Energy price distortion	7.9032	0.7464	5.3368	10.5536
GS	R&D investment	4.62	1.573	0.554	6.808
GDP	Economic development level	7.547	0.729	5.345	9.042
FDI	FDI (foreign direct investment)	6.648	1.238	3.143	9.108

TABLE 2: Results of unit root test.

Variable	Statistics				Result
	LLC	IPS test	Fisher-ADF	Fisher-PP	
LnGTFP	-8.716***	-4204***	111.09***	148.534***	Stable
LnTI	-10.826***	-4.661***	124.226*	159.244***	Stable
LnSC	-12.179***	-5.330***	131.122***	169.568***	Stable
PE	-32.054***	-16.294***	293.884***	451.853***	Stable
LnGS	-372.932***	-51.084***	195.942***	283.870***	Stable
LnGDP	-7.002***	-1.167***	61.140***	61.850***	Stable
LnFDI	-7.026***	-2.958***	105.958***	152.574***	Stable

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

TABLE 3: Moran's I statistics of green total factor productivity in China from 2003 to 2017.

Year	Moran's I value
2003	0.1347***
2004	0.1212**
2005	0.1332*
2006	0.1408**
2007	0.1502**
2008	0.1612***
2009	0.1782*
2010	0.1824***
2011	0.2032**
2012	0.1844**
2013	0.1662***
2014	0.1863*
2015	0.2102**
2016	0.2043***
2017	0.1824***
Average	0.1665***

Note: ***, ** and * represent the significance level of 1%, 5%, and 10%, respectively.

Because of China's special institutional arrangements, the government's environmental regulation policies have a profound impact on the formation of energy factor prices in China. However, different environmental regulation tools have both positive and negative effects on energy prices. Based on the empirical results, if the government increases the expenditure on energy conservation and environmental protection, it will not increase the price of energy factors but will have the opposite effect. Only by raising energy prices can environmental protection and economic development be taken into account when increasing pollutant discharges.

Model (3) verifies the validity of Hypothesis 3. First of all, as shown in Table 3, the energy factor price has a significantly positive promotion effect on green TFP at 5% level, showing that Hypothesis 3 is true. Secondly, compared with model (1), the significance statistics of environmental regulation tools for green TFP are all reduced, which indicates that the energy factor price plays a significant mediating role in the process that environmental regulation affects green TFP, indicating that Hypothesis 3 is true. Under the general background of ecological priority, industrial structure upgrading, and green economic development, environmental regulation has become the only way for the green and healthy development of China's economy. Our government's environmental regulation policies have a positive acceleration on the improvement of the ecological environment and a great impact on the input of energy factors. The increase and decrease of energy factor prices can effectively regulate the input and use of energy and resources. Industries with higher energy consumption are faced with serious environmental pollution problems, while those with low energy consumption have fewer problems. Therefore, the input of energy and resources directly affects ecological environmental protection, thus affecting the development level of green TFP. Besides, faced with rising energy prices, in order to maintain original production and solve the problem of scarce energy resources, enterprises are forced to reduce energy input to improve energy efficiency or seek alternative resources to accelerate their energy transformation, which is conducive to the improvement of green TFP. In this paper, 30 provinces in China are selected for empirical analysis, and the results are consistent with the theoretical mechanism analysis; that is, energy factor prices play a significant intermediary role in the process that environmental regulation affects enterprises' green TFP.

TABLE 4: Empirical results.

Variable	GTFP		TI	SC	GTFP
	Model (1) GTFP	Model (2) GTFP	Model (3) TI	Model (4) SC	Model (3) GTFP
L.LnGTFP	0.336*** (8.912)	0.330*** (5.784)			0.029 (0.736)
LnTI		1.307*** (-15.304)			0.351*** (5.256)
LnSC		0.270*** (8.544)			0.022*** (3.568)
L.PE	-0.054*** (3.720)		0.062*** (5.760)	0.270*** (8.544)	0.270*** (8.544)
PE					0.018** (2.30)
LnGS	-0.029** (-1.59)	0.263*** (7.384)	0.263*** (7.384)	0.263*** (7.384)	-0.010* (-0.472)
LnGDP	0.298*** (2.984)	-0.820*** (-6.936)	-0.820*** (-6.936)	-0.820*** (-6.936)	0.545*** (4.464)
LnFDI	-0.178*** (-5.072)	0.098 (1.208)	0.098 (1.208)	0.098 (1.208)	-0.194*** (-5.664)
AR (1)	[0.001]	[0.016]	[0.016]	[0.016]	[0.097]
AR (2)	[0.263]	[0.258]	[0.258]	[0.258]	[0.374]
Sargan test	[0.558]	[0.378]	[0.378]	[0.378]	[0.315]

Note: ***, ** and * represent the significance level of 1%, 5%, and 10%, respectively, with z values in parentheses and p values in square brackets.

TABLE 5: Spatial effect estimation results of green total factor efficiency under static model.

Variable Name	Spatial lag model	Spatial error model	Spatial Durbin model
LnTI	0.0845** (2.32)	0.0889* (2.03)	0.0935* (2.06)
LnSC	0.483*** (3.23)	0.377** (2.51)	0.323** (2.39)
L.PE	-0.259*** (-3.47)	-0.256** (-2.23)	-0.214*** (-3.25)
LnGS	0.765** (2.58)	0.658** (2.36)	0.673** (2.64)
LnGDP	0.0277 (1.54)	0.00302 (1.25)	0.02672 (1.52)
LnFDI	0.567** (2.67)	0.599** (2.44)	0.0437** (2.38)
Spatial rho	0.202*** (3.85)		0.276*** (3.18)
Lambda		0.0467 (0.573)	0.672** (2.34)
Variance sigma2_e	0.00934*** (8.022)	0.00937*** (9.043)	0.00962*** (9.657)

Note: ***, ** and * represent the significance level of 1%, 5%, and 10%, respectively.

4.3. Spatial Econometric Analysis. According to the static spatial econometric model theory, all variables are logarithmically processed, as shown in Table 5.

With the coefficient λ of the spatial Durbin model being positive, the model has passed the significance test at 5% level as a general form of spatial lag and spatial error. Therefore, this paper mainly analyzes the results of the spatial Durbin model. Based on the regression test results, the influence coefficient of the spatial Durbin model passed the significance test at 1% level, showing that the green total factor efficiency of China's 30 provinces really has an obvious spatial interaction effect. The positive coefficient indicates that the higher the green total factor efficiency in the adjacent area of the sample is, the higher the green total factor efficiency in the region will be, so there are positive spatial spillover effects.

The regression result shown in spatial Durbin Model indicates that environmental regulation passed the significance testing at a 10% level, while the government environmental regulation passed the significance testing at a 5% level. This demonstrates that the government's positive role in green total factor regulation can promote enterprises' energy conservation and emissions reduction. The strict green total factor policies formulated by the government can urge the enterprises to improve the technological content of products and increase investment in technology and management, forming internal virtuous cycle and reducing the consumption of energy, especially high-carbon energy.

Consequently, environmental regulation is conducive to the improvement of green total factor efficiency to a certain extent by way of improving green total factor productivity, reducing green total factor of the unit product, and enhancing the competitiveness of the products in the market. The energy price distortion passed the significance test at the level of 10%, indicating that the energy price distortion is not conducive to improving green total factor efficiency, and there is a close relationship between the energy price distortion and green total factor efficiency. China's regional economic development is unbalanced, and some provinces are still in the industrialization stage. The higher the proportion of high-energy-consuming and high-polluting industries in the national economy is, the higher the pollution intensity will be, and accordingly the lower the green total factor efficiency will be. Technological progress also passed the significance test at the level of 1%, showing that technological progress can reduce enterprise cost and create more value with less energy input, which also indicates that technological progress greatly decreases the cost of clean energy and the amount of green total factor of unit output. At the same time, technological progress continuously promotes the optimization and upgrading of the industrial structure, reducing the strength of the green total factor. Foreign trade and investment passed the significance test at the level of 5%, which indicates that foreign trade and investment have positive spillover effects on the ecological environment in our country. Compared with the domestic

enterprises, international advanced enterprises have a higher technical and management level and more advantages in energy efficiency. Therefore, through digesting and absorbing experience in technology and management of foreign advanced enterprises, domestic enterprises can improve energy efficiency and reduce the amount of green total factor.

The influence coefficient of per capita GDP on green total factor efficiency is positive, but not observable, because there is no evidence showing rapid economic growth that can improve green total factor efficiency. With the continuous advancement of the supply side reform, the economy of the Midwest provinces grows rapidly, yet the quality is not high for energy-intensive, heavy industry, and other industrial sectors in some provinces still occupy a larger proportion in the national economy. That may be the reason why the coefficient is not significant. However, the overall green total factor quantity and green total factor intensity decline, which is the reason why the influence coefficient is positive. Therefore, it is necessary to accelerate the upgrading of industrial structures, reduce the proportion of high-carbon energy consumption structures, and improve energy utilization efficiency.

5. Conclusions and Prospects

The key to achieving economic and environmental win-win is to improve China's green TFP. It is critical for enterprises to make a proactive promotion of green TFP in the severe situation of resource shortage and ecological environment destruction. Among a number of factors influencing the green TFP of Chinese enterprises, environmental regulation occupies a prominent position. Based on the special economic system arrangement in China, enterprises' green investment and green activities by improving green TFP cannot be separated from the intervention of government environmental regulation policies. Under the macro-control of the government, the prices of energy factors and other resource factors will fluctuate to a certain extent, and the price fluctuations will be transmitted to the upper, middle, and lower sections of the production of enterprises, which will change the production costs and have a great impact on green development. There are two major innovations in this paper. For one thing, an empirical analysis is carried out on the impact mechanism of government environmental regulation on Chinese enterprises' green TFP; for another, the energy factor prices are regarded as the medium that environmental regulation affects green TFP of enterprises, and its mediating effect is empirically discussed in order to enrich the mechanism of influencing factors of green TFP.

The major conclusions are as follows: firstly, environmental regulation can affect the level of green total factor productivity to a certain extent. By increasing the energy consumption costs and reducing the energy consumption, the implementation of environmental regulation encourages enterprises to innovate and improve the output level and the green total factor productivity of the whole society. Secondly, energy price plays an intermediary role between

environmental regulation and green behavior of enterprises as the source of pollution emission.

Through the dynamic change of energy price, the implementation effect of environmental regulation can be observed. Meanwhile, the change of energy price will have a direct impact on enterprise cost. Therefore, it is an important measure for China's high-quality economic development to rationalize the energy price management system in further.

This paper focuses on the impact mechanism of environmental regulation on enterprises' green TFP (including the impact effect of different regulatory tools) as well as the mediating effect of energy factor prices. According to the analysis of empirical results, four countermeasures and suggestions are proposed to provide a reference for introducing reasonable and effective environmental regulation policies and improving green TFP in China.

- (1) As for the problem of whether the proposed environmental regulation policies affect reasonably and effectively the improvement of production and environment, it is advised to rapidly construct an environmental regulation impact assessment system to evaluate and forecast the relevant regulatory measures. Because of the insufficient investment motivation of enterprises in green development, it is suggested that environmental regulation policies should be adjusted into more strict measures, such as strengthening the punishment for violating environmental regulation policies and speeding up the improvement of environmental laws and regulations.
- (2) The study finds that the government fiscal expenditure on environmental protection and energy conservation of each region has a great impact on green TFP, so the government's expenditure on environmental protection and energy conservation should be increased. And taking the government's fiscal expenditure as orientation simultaneously, the management of the market-based environmental regulation tools should be further expanded, such as user fees, resource use taxes, and emissions trading, and other financing methods should be actively explored, such as environmental funds and debt financing.
- (3) Accelerating the marketization reform of energy prices is recommended, because energy factor prices have very important mediating effects. As the prices can closely reflect the actual energy supply and demand situation as well as the scarcity of energy resources, this reform is conducive to the high-quality and healthy development of China's overall economy by accelerating the energy transformation and improving energy utilization efficiency for the enterprises with severe energy consumption.
- (4) To improve the level of enterprise green TFP, it is suggested that multilevel and differentiated environmental regulation should be implemented. Because the current imbalanced economic

development in the country, the ecological environment, and economic development level of each region are not the same, therefore, it is necessary to implement environmental regulation according to local conditions and characteristics of regional economic and social development. For example, the eastern region has a high economic development and industrialization level, so the strength of environmental regulation should be enhanced, which is conducive to improving enterprises' consciousness of innovation, reducing energy consumption, and promoting high-quality economic development. However, the economic development level of the vast western region is significantly different from that of the central and eastern regions, and the western region is rich in energy and resources. Therefore, the corresponding environmental regulation measures should be taken by comprehensively considering the characteristics of economic development and resource endowment.

- (5) For provinces with low energy market distortions and mature and improved energy market development, due to the current high degree of energy marketization, the policy orientation can be appropriately inclined to promote technological innovation and increase investment in research and development funds, improve the technical level of energy resources used in production, research and develop advanced equipment, technology, and management related to energy utilization, and earnestly play the leading role of technological progress in improving energy efficiency.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

- [1] V. Suri and D. Chapman, "Economic growth, trade and energy: implications for the environmental Kuznets curve," *Ecological Economics*, vol. 25, no. 2, pp. 195–208, 1998.
- [2] J. P. H. Poon, C. Irene, and H. Canfei, "The impact of energy, transport, and trade on air pollution in China," *Eurasian Geography and Economics*, vol. 47, pp. 1–17, 2006.
- [3] D. I. Stern, "The rise and fall of the environmental Kuznets curve," *World Development*, vol. 32, no. 8, pp. 1419–1439, 2004.
- [4] D. Maradan and A. Vassiliev, "Marginal costs of carbon dioxide abatement: empirical evidence from cross-country analysis," *Swiss Journal of Economics and Statistics*, vol. 141, no. 3, pp. 377–410, 2005.
- [5] G. Li, J. Jiang, and C. Zhou, "Analysis of the influence factors of environmental pollution in China's transition period: based on the perspective of total factor energy efficiency," *Journal of Shanxi University of Finance and Economics*, vol. 12, pp. 32–39, 2009.
- [6] X. Yuan, B. Zhang, and W. Yang, "Research on total factor energy efficiency in China based on environmental pollution," *China Industrial Economics*, vol. 2, pp. 76–86, 2009.
- [7] D. Wang, "An empirical study on labor substitution effect of energy tax collection - a trial calculation based on CGE model of shanghai air pollution in 2002," *Journal of Finance and Economics*, vol. 2, pp. 98–105, 2006.
- [8] W. Zhang and Y. Pan, "An empirical study on the impact of energy tax on international trade and environmental pollution," *Nankai Economic Research*, vol. 3, pp. 32–46, 2007.
- [9] J. Zhang, X. Zhou, and Y. Li, "Does factor market distortion restrain R&D of Chinese enterprises," *Economic Research Journal*, vol. 8, pp. 78–91, 2011.