An Empirical Study of China's Environmental Economic Policy and the Effect of Industrial Green Transformation—Based on Data Envelopment Analysis Model

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Abstract—As the world's environmental problems become increasingly prominent, countries are paying more attention to the environment and energy. Under the background of the national "14th Five-Year Plan" strategy, China has successively introduced a series of environmental and economic policies aimed at key pollutant emission industries. Guide and encourage high-polluting and high-emission enterprises to develop a green economy, while various environmental and economic policies have different effects on the green transformation of enterprises in different regions. Therefore, Based on regional heterogeneity, the effects of environmental economic policies on the green transformation of the energy industry are investigated in this study. This is essential for enhancing the difference, coordination, complementarity, and pertinence of policies, contributing to comprehensively improving the promotion of environmental economic policies to the green transformation of the energy industry significance. Besides, Based on the panel data of 30 provinces in China from 2008 to 2019, this paper conducts in-depth data mining on it, filters useful information, uses data envelopment analysis (DEA) to calculate the total factor productivity of industrial green in each province, and determines the key driving factors for industrial green transformation .. Further use Stata 15.0 software to conduct regression analysis on the fixed effects of environmental economic policies on the efficiency of industrial green transformation, and build an environmental economic policy evaluation index system. The differences between the three regions of East, Middle, and West are analyzed. The results demonstrate that guiding and restricting policies have a significantly positive effect on the green transformation of the energy industry while the role-participating policy and the green tax system have a significantly negative impact. From the perspective of the regional differences of environmental economic policies to the green transition of the energy industry, guiding and restricting policies have a significant role in promoting the green transition of industries in the eastern and western regions but have a counterproductive effect on the middle region; role-participating policies have a different influence on the industrial green transformation in the western region than it has on the eastern and middle regions; the effect of the green tax system on the industrial green transformation in the three regions of the East, Middle, and West is in the same direction as the whole country, and the impact on the middle region is the most significant.

Keywords- Green economy; Environmental Economic Policy; Factor Analysis; Fixed Effects Model; Data mining

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1 Introduction

In recent years, green development has gradually become a consensus plan for all countries around the world to handle multiple challenges in resources and environments, as well as climate change. During the "13th Five-Year Plan" period, China has made remarkable achievements in the construction of ecological civilization. The pollution problem of industrial enterprises has been effectively controlled. During the "14th Five-Year Plan" period, China's ecological civilization construction will usher in new challenges. All industries will focus on cultivating the driving force of green production transformation, forming a green supply chain that promotes green production transformation, establishing an information trading platform that facilitates green production, and improving policies and standard systems that contribute to the development and growth of green markets, and combining real factors such as regional and industry heterogeneity to drive the deep transformation of green production.

The industry is not only a pillar industry of the national economy but also a key industry for pollutant emissions. The realization of the green transformation of the industry has the following benefits to China's green economic development. First, it can accelerate the resolution of the contradiction between economic development and environmental pollution and promote China's active response to global climate change. Second, it can accelerate the transformation of economic development mode following energy-saving and emission-reduction policies. Environmental economic policies based on market principles can effectively internalize external diseconomy, which is of great significance for promoting industrial green transformation. Meanwhile, the effect evaluation of environmental economic policies is a guarantee for improving the efficiency of policy implementation and the implementation effect. Most of the existing papers are based on a single environmental economic policy. For example, Hong Yuan et al. (2018) emphasized environmental fiscal policies and believed that it has a significant impact on local environmental pollution control [1]. Zhu Xiaohui et al. (2017) researched green taxation policies and proposed that the overall pollution control effect of China's current environmental taxes is not significant [2]. Our study aims to fully consider the possible interactions between different environmental and economic policies. Specifically, ten major environmental and economic policies are listed; principal component analysis is employed to construct a network of relationships between different policies; environmental policies with significant effects are selected according to the roles of the major environmental economic policies (such as the environmental compensation policy, green tax policy, environmental income policy, environmental expenditure policy, and environmental support policy) in the industrial green transformation, so as to establish a comprehensive evaluation system for environmental economic policies and conduct further research on them.

Since each region of our country is in different stages of industrial green transition, the effects of various economic policies on different regions present certain differences. Xu Donglan et al. (2009) used the eastern, middle, and western regions of China as the research area to demonstrate that the green transformation effects of the three regions are influenced by environmental policies [3]. Zhang Cheng et al. (2011) believed that the eastern and middle regions have formed a more significant "U"-shaped relationship between the intensity of environmental policies and the progress of enterprise production technology compared with the western region [4]. Besides, Wang Dong (2011), Wang Guoyin (2011), Hu Xiaozhen (2011), Zhang Hongxia (2020) and others have also researched regional heterogeneity [5-8]. Therefore, it is necessary to fully consider regional heterogeneity, truly reflect the level of industrial green transformation in different regions, and effectively accelerate the process of industrial green transformation for constructing a differentiated, coordinated, complementary, and pertinent environmental economic policy system and studying its impact on the effect of industrial green transformation.

In summary, the existing literature has the following shortcomings in studying the effects of environmental economic policies on industrial green transformation. First, existing research mainly focuses on the impact of a single environmental economic policy on industrial green transformation while ignoring the possible interactions between different environmental and economic policies, resulting in a negative impact on the accuracy and rigor of the evaluation system. On this basis, 30 provinces (except Hong Kong, Macao, Taiwan, and Tibet) are taken as the research object in this study; the availability of relevant data is considered; the period of 2008-2019 is selected; environmental and economic policies are effectively combined; input-output data of the industrial economy are collected. Meanwhile, positive products and negative products are introduced, and economic and environmental effects are comprehensively considered, so as to construct a comprehensive evaluation index system for industrial green transformation. Additionally, the DEA model is adopted to calculate the industrial green total factor productivity of each province and determine the key driving factors for the industrial green transformation. Furthermore, Stata 15.0 software is used to conduct regression analysis on the fixed effects of environmental economic policies on the efficiency of industrial green transformation, construct a quantitative model, evaluate the effects of environmental economic policies on industrial green transformation in different regions, and provide a theoretical basis for China to give full play to the role of environmental economic policies in the green transition.

2 Construction of Environmental-Economic Policy Evaluation System

2.1 Variable selection

In this study, an environmental and economic policy indicator evaluation system is constructed to comprehensively evaluate the effects of China's main environmental and economic policies on the green transformation of the energy industry. Academia usually divides environmental economic policies into formal environmental economic policies (including command and control environmental economic policies and economic incentive environmental economic policies) and informal environmental economic policies (public participation environmental economic policies). Based on Hao Chunxu's (2020)'s [9] classification of national environmental and economic policies, the current main environmental and economic policies are reclassified in this paper. Specifically, environmental economic policies are divided into restricting environmental economic policies, guiding environmental economic policies, and role-participating environmental economic policies. Restrictive environmental economic policies indicate the government's use of its administrative authority to formulate laws, regulations, administrative, and orders that directly affect polluters' pollution discharge behavior, including environmental compensation policies. Guiding environmental economic policy represents the state's use of modified market mechanisms, which promote the coordinated development of environmental protection and economic growth under the consideration of the economic development level and degree of openness and other factors, mainly including environmental income policies, environmental expenditure policies, and environmental support policies. Role-participating environmental economic policies are mainly aimed at environmental economic policies without specific policy implementation targets, such as environmental rights trading policies and environmental resource value accounting policies.

Furthermore, the PDF of sewage charges and the intensity of green tax policy GTPI are employed in this paper to measure environmental compensation policies, so as to measure specific policy tools in detail. The environmental income policy is expressed regarding urban land use tax ULUT, urban maintenance and construction tax UMCT, and resource tax AVT. The environmental expenditure policy is expressed by three indicators: environmental protection expenditure EPE, total investment in environmental pollution control TIEPC, and total industrial pollution control investment TIIPC. Environmental support policies are described by science and technology expenditure EST. Environmental rights trading policies focus on carbon emission intensity CI and per capita carbon emission CEPC. Additionally, unit energy consumption UEC is used to represent the environmental resource value accounting policy; the total environmental pollution control investment is taken to account for the proportion of GDP PGDP to represent the environmental financial policy. The index system is illustrated in Fig. 1.

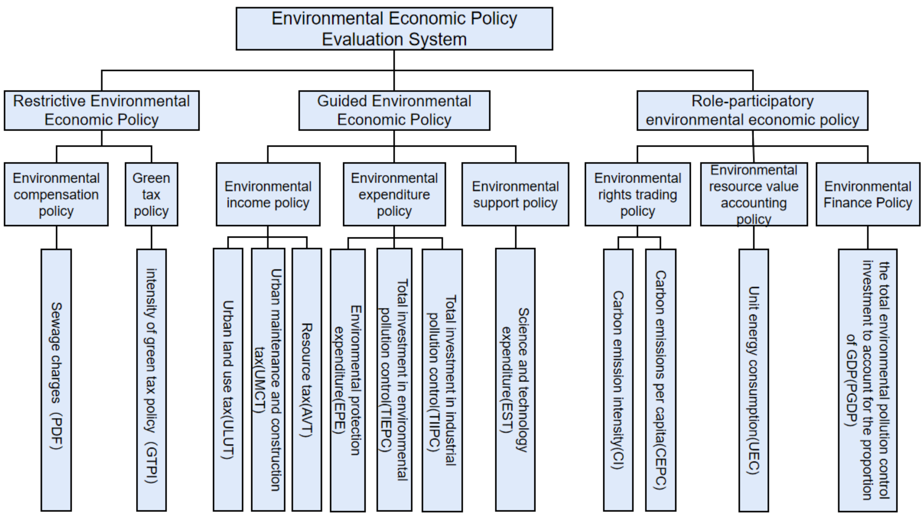

Fig.1 Environmental Economic Policy Evaluation System

The above data are collected from the "China Environmental Statistics Yearbook", "China Environmental Statistics Yearbook", "China Tax Yearbook", National Bureau of Statistics, and China Carbon Emission Database. Considering the missing data on sewage charges in some provinces in 2019, the average growth rate over the years is applied in this paper to calculate and supplement.

2.2 Model building

Factor analysis is conducted to effectively divide the relevant indicators of environmental economic policies. It can extract the key variables that can effectively explain environmental economic policies under the condition of ensuring sufficient original information to make the classification of environmental economic policies more reasonable and accurate.

The KMO test and Bartlett sphere test on the sample data are performed using IBM SPSS Statistics 24 software to determine whether the sample data is suitable for factor analysis. According to the results in Table 1, the KMO test value of the sample data is greater than 0.7, and the Bartlett sphere test is 0, which is less than the judgment standard of 0.05. Thus, it satisfies the applicability test of factor analysis.

Table 1 KMO and Bartlett test

KMO Sampling suitability measure		0.755
Bartlett sphericity test	Approximate chi-square	2918.668
	Degree of freedom	78
	Significance	0.000

Since the units of the various indicators are different and not comparable, the indicators are standardized in this paper. The principal component analysis is performed on standardized data, and 3 principal components were extracted. The cumulative contribution rate exceeded 70%, suggesting that the factor analysis result is good and meets actual requirements. Furthermore, the Caesar normalized maximum variance method is employed for factor analysis. After data processing, the cumulative contribution rate of the variance of the factors remains unchanged, and the main common factors with clear economic meanings are obtained. The results are presented in Table 2.

Table 2 Rotation component matrix

index	F1	F2	F3
Total investment in environmental pollution control	.872		
Total investment in industrial pollution control	.826		
Urban land use tax	.864		
Urban maintenance and construction tax	.719		
Resource tax	.560		
Sewage charges	.780		
Environmental protection expenditure	.737		

index	F1	F2	F3
Science and technology expenditure	.550		
Carbon emission intensity		.847	
Carbon emissions per capita		.815	
The total investment in environmental pollution control accounts for the proportion of GDP		.785	
Unit energy consumption		.607	
Strong green tax policy			.842

As observed from the rotating component matrix in Table 3, the common factor F1 scores higher on the eight indicators of TIEPC, TIIPC, ULUT, UMCT, AVT, PDF, EPE, and EST. Among them, TIEPC, TIIPC, and EPE reflect the environmental expenditure policy; ULUT, UMCT, and AVT reflect environmental income policies; PDF reflects environmental compensation policies; EST reflects environmental support policies. To a certain extent, F1 can be expressed as a guiding and restricting policy factor, namely, the country's measures to change the status quo of environmental protection. Besides, CI and CEPC represent environmental rights trading policies; PGDP represents environmental financial policies; UEC represents environmental resource value accounting policies and displays more emissions results, that is, public voluntary indicators. Therefore, F2 can be expressed as a role-participating policy factor. Additionally, GTPI denotes the intensity of green taxation policies, which is the result of considering the combined effects of seven types of green taxes and pollution discharge fees. Thus, it is used as a common factor to explain the environmental economic policy, and F3 is represented by the green tax system.

3 Measurement of Industrial Green Transformation Efficiency

3.1 Description of specimen method model

It is revealed by combing the existing literature that there are many studies on the efficiency of traditional industries with the proxy index mainly as the total factor productivity. However, the traditional total factor productivity output only considers the expected output while neglecting the impact of the environment and resources. Moreover, the research focus of industrial green transformation is "green". Hence, the green total factor productivity that incorporates environmental performance is selected as the proxy indicator of industrial green transformation in this paper.

Besides, the DEA-Malmquist index is employed to measure the green total factor productivity of 30 provinces in China. In the actual measurement process, this method only needs to determine the input and output variables and does not require price information, contributing to not only saving a lot of time but also reducing errors caused by price changes.

(1) DEA Model

Considering the issue of environmental constraints, Fare (1993) [10] constructed a model composed of traditional economic growth factors and undesired output and then modeled it through a directional distance function. In our study, 30 provinces are taken as decision-making units, and it is assumed that each region adopts M types of input factors x, that is, $x=(x_1, x_2,..., x_M)\in R+M$, which is finally transformed into N expected output indicators y and K kinds of undesired output indicators b, expressed as $y=(y_1,y_2,...,y_N)\in R+N$ and $b=(b_1,b_2,..., b_K)\in R+K$, respectively. After modeling, the formula is referenced (1):

$$p(x)=\begin{cases}(y,b):\sum_{k=1}^{K}=z_k y_{kn}\geq y_{kn}, n=1,2,3...\\ \sum_{k=1}^{K}=z_k x_{km}\leq x_{km}, m=1,2,3...\\ \sum_{k=1}^{K}=b_{ki}>0, i=1.2.3...;\sum_{i=1}^{I}b_{ki}>0, k=1,2,3...\end{cases} \tag{1}$$

(2) ML Index

The ML index proposed by Chung (1997) [11], which considers energy consumption and environmental issues, is used as a factor input and undesired output to build green total factor productivity. The base period is t, and the green total factor productivity in period t+1 is the product of the technical efficiency change index (EFFCH) and the technological progress index (TECH). For specific formulas, refer to (2) and (3):

$$ML_t^{t+1}=EFFCH_t^{t+1}\times TECH_t^{t+1} \tag{2}$$

$$ML_t^{T+1}=\left[\frac{1+S_0^t(x^t,y^t,b^t,y^t-b^t)}{1+S_0^t(x^{t+1},y^{t+1},b^{t+1},y^{t+1}-b^{t+1})}\bullet\frac{1+S_0^{t+1}(x^t,y^t,b^t,y^t-b^t)}{1+S_0^{t+1}(x^{t+1},y^{t+1},b^{t+1},y^{t+1}-b^{t+1})}\right] \tag{3}$$

Among them, technical efficiency change (EFFCH) can be expressed by the product of the pure technical efficiency change index (RECH) and scale efficiency change index (SECH). Regarding ML, EFFCH, TECH, RECH, and SECH, less than 1, equal to 1, and greater than 1 indicate the decline, change, and improvement of green total factor productivity, technical efficiency, technological progress, pure technical efficiency, and scale efficiency, respectively.

3.2 Variable selection

(1) Investment index

Labor input: Due to the lack of statistical indicators of labor time and labor quality, "the number of people employed in various provinces and cities in China (mining, manufacturing, electricity, heating, gas and water production and supply)" is taken to measure labor input.

Capital input: Industrial capital stock is used as a proxy variable. Based on the practice of Zhang Jun (2004) [12], the Perpetual Inventory Method (PIM) is utilized to perform estimation, and the industrial capital stocks of all provinces and cities from 2008 to 2019 are obtained using 2008 as the base period for price deflation.

Resource input: In this study, the physical quantity of the industrial terminal consumption in the energy balance sheet of each province and city in China is converted into ten thousand tons of standard coal according to the standard coal conversion coefficient. This is used as a proxy variable.

(2) Output indicators

Expected output: It is measured by "industrial added value". The price effects are eliminated using 2008 as the base period to ensure the accuracy of the data.

Unexpected output: It refers to the industrial pollutants produced by the enterprise during the production process. The pollutant indicators selected in this paper include industrial wastewater discharge and industrial waste gas discharge. The related missing values are filled with SPSS software and the formula y= c/x forwards the index.

The above data are collected mainly from the National Bureau of Statistics, "China Industrial Statistical Yearbook", "China Energy Statistical Yearbook", and "China Environmental Statistical Yearbook".

4 Research design and empirical analysis

4.1 Variable interpretation

(1) Explained variables and explanatory variables

The explained variables and explanatory variables in this paper are the effects of industrial green transformation and environmental economic policies, respectively. The specific evaluation system has been constructed in the previous research.

(2) Control variable

① The level of economic development. According to the Kuznets curve, environmental pollution will gradually decrease with the continuous expansion of economic aggregates, promoting industrial transformation. Besides, industrial green transformation may be hindered if economic development is only quantitative expansion without qualitative improvement.

② The level of urbanization. Urbanization accelerates the flow of production factors such as talents and information resources and brings a strong impetus to enterprise innovation, promoting green development. However, the concentration of population also accelerates resource consumption, aggravates environmental pollution, and inhibits green development to a certain extent.

③ Energy structure. The coal-based energy structure not only consumes resources but is also the main source of carbon dioxide. The degree of optimization of the industrial energy consumption structure will affect the efficiency of industrial green transformation.

④ Industrial enterprise scale. Generally, the higher the scale of the industry, the more conducive the green energy management and the realization of a green circular economy. Simultaneously, inter-industry competition can improve corporate innovation capabilities and accelerate the transformation of green industries.

A detailed description of the above-mentioned control variables is provided in Table 3.

Table 3 Variable setting table

Variable type	Variable name	Variable representation	Metrics	Data Sources
Control variable	The level of economic development	EG	The log value of the region's per capita GDP after price deflation	National Bureau of Statistics
	The level of urbanization	URB	Urban population/resident population	Provincial Statistical Yearbook
	energy structure	ES	Industrial coal consumption/total industrial energy consumption converted by standard coal	"China Energy Statistical Yearbook"
	Industrial enterprise scale	BS	Main business income of industrial enterprises above designated size/number of units of industrial enterprises above designated size	"China Industrial Statistics Yearbook"

4.2 Model design

Before the analysis of the panel data, it is necessary to judge the applicability of different models. The panel data is not tested for stationarity since the sample data is short panel data and the time limit is relatively short.

First, a mixed regression model and a fixed-effect model are constructed, and the Wald test is performed. The p-value of the F test is 0.0000. The null hypothesis "H_0: no individual effect" is strongly rejected, reflecting an individual effect. Then, the solid effect model and the random effect model are constructed to perform the Hausman test. The corresponding p-value is 0.0001. If the random effect is rejected, the fixed-effect model should be used. Finally, the time effect is considered in the fixed-effect model. As a result, the original hypothesis "no time effect" is rejected, suggesting that the time effect should be included in the model. Based on the above tests, the two-way fixed effects model (Two-way FE) was finally determined. The specific results of the model calculation are exhibited in Table 4.

Table 4 Wald test and Hausman test

Testing method	Statistics	P-value	result
Wald test	16.76	0.0000	Reject the null hypothesis, there is an individual effect
F test	15.68	0.0000	Reject the null hypothesis, there is an individual effect
Hausman test	32.11	0.0001	Reject the null hypothesis, there is an individual effect

The constructed benchmark model is equation (4):

$$ecoGTFP_{it} = \lambda_0 + \lambda_1 F_{it} + \lambda_2 Controls_{it} + \mu_i + \varphi_i + \varepsilon_{it} \quad (4)$$

Among them, i represents a province, t denotes a year, GTFPit indicates the efficiency of industrial green transformation, λ_0 is a constant term, and F refers to a core explanatory variable. Controls include four control variables that have an impact on industrial green transformation: economic development level, urbanization level, energy structure, and industrial enterprise scale. Besides, μ_i represents the individual fixed effect, ϕ_t denotes the time fixed effect, and ε is the error term.

4.3 Empirical analysis

(1) Descriptive statistics

The control variables are standardized to alleviate the heteroscedasticity problem caused by different dimensions. The descriptive statistical results of all variables are listed in Table 5:

Table 5 Descriptive statistics

VARIABLES	N	mean	sd	min	max
Province	300	15.50	8.670	1	30
year	300	12.50	2.877	8	17
GTFP	300	1.382	0.341	0.436	3.005
F1	300	6.67e-08	1.000	-1.444	4.301
F2	300	1.00e-07	1.000	-1.657	3.307
F3	300	1.33e-07	1.000	-3.521	2.896
BS	300	-2.67e-07	1.000	-1.897	3.094
URB	300	-2.67e-07	1.000	-1.939	2.641
InEG	300	3.33e-08	1.000	-2.484	2.724
ES	300	3.33e-08	1.000	-2.652	4.398

(2) The Effect of Environmental-Economic Policy on Industrial Green Transformation

The impact of environmental economic policies on industrial green transformation is examined by constructing a two-way fixed effects model. The specific results are illustrated in Table 6.

Table 6 National regression estimation results

VARIABLES	F1_w	F2_w	F3_w	BS_w	URB_w
GTFP	0.083***	-0.084***	-0.083***	0.016	-0.235**
	(-2.63)	(-3.11)	(-2.76)	(-0.55)	(-2.46)
VARIABLES	**InEG_w**	**ES_w**	**Constant**	**Prob (Fstatistic)**	
GTFP	1.129***	0.055	2.892***	0.000	
	(-6.15)	(-1.58)	(-10.22)		

[a.] (*** p<0.01, ** p<0.05, * p<0.1)

Specifically, the coefficient of F1 for the guiding and restricting policies is positive, indicating that the national policies with guiding and restricting effects have a positive impact on the green transition of industrial energy. In other words, the government links corporate environmental pollution behavior with costs and restricts corporate industrial waste discharge by levying urban maintenance and construction tax, urban land use tax, resource tax, and other taxes and fees that have guiding and restricting effects on industrial enterprises. This effectively prevents enterprises from neglecting social and environmental benefits to increase and realize economic benefits, and at the same time verifies the "Porter Hypothesis." This suggests that appropriate tax and fee policies can effectively improve environmental efficiency. Moreover, the price paid by enterprises to make up for the negative externalities caused by pollution can well promote enterprise innovation and promote enterprise transformation and upgrading.

The role-participating policy F2 and the green tax system F3 are negatively related to the effectiveness of the green transformation of industrial energy. The main indicators of the role-participating policy F2 are carbon emissions intensity, per capita carbon emissions, and unit energy consumption. The carbon emissions intensity and per capita carbon emissions indicators are calculated based on the carbon emissions of the whole society and cover all industries including industry. Unit energy consumption is an indicator representing the level of energy consumption and the status of energy conservation and consumption reduction. The total energy consumption is used as the denominator to indicate the energy consumed per 10,000 yuan of GDP. This indicator covers the entire economy and is also an explanatory indicator of broad significance. The larger the index result, the greater the per capita carbon emissions or the more the energy consumed per 10,000 yuan of GDP. This demonstrates that carbon emissions have not been effectively controlled, the energy utilization rate is low, and the effect of the green transformation of the energy industry is poor.

The impact of the green tax system F3 on the green transformation of the energy industry is significantly negative. This conclusion is consistent with Zhou Bo's (2012) [13] research results that limited by fiscal revenue functions and a single mode of regulation, taxation policies cannot play their role as an innovation driver, cannot promote the transformation and upgrading of industrial enterprises, and cannot effectively adjust the industrial structure. Additionally, the essence of green taxation policy is to fulfill government functions. From one perspective, taxation policies cannot ultimately benefit all industrial enterprises in general and cannot stimulate corporate innovation behavior. From another perspective, due to the increase in the cost of enterprises, the converse effect is beyond the scope of the enterprise's bearing, increasing the burden of the enterprise, leading to tax evasion and tax evasion, and affecting the total tax revenue. As a result, the government cannot fully perform its functions, the total investment in environmental pollution control is reduced, and the atmosphere for corporate industrial transformation is lacking. Ultimately, it is not conducive to the transformation and upgrading of energy industrial enterprises.

(3) Analysis of Regional Heterogeneity

Given the significant differences in the level of economic development among Chinese provinces and the differences in the implementation and implementation effects of various environmental and economic policies between regions, China's provinces are divided into three major regions of east, middle, and west in this paper according to the level of economic development and geographical distribution. Among them, the eastern region includes 11 provinces (cities) in Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the middle region includes10 provinces (autonomous regions) in Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi of, Henan, Hubei, Hunan, and Guangxi; the western region includes 9 provinces (autonomous regions) in Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Chongqing. A series of dual fixed-effects models in the east, middle, and west are established to discuss whether there is regional heterogeneity in the impact of environmental economic policies on industrial green transformation. The specific regression results are presented in Table 7.

Table 7 Regression estimation results for the three major regions

VARIABLES	east	central	west
F1_w	0.132***	-0.076	0.277**
	(2.87)	(-0.62)	(2.43)
F2_w	-0.013	-0.122	0.029
	(-0.17)	(-1.03)	(0.55)
F3_w	-0.036	-0.070*	-0.066
	(-0.75)	(-1.67)	(-0.72)
BS_w	0.020	0.060	-0.037
	(0.43)	(1.14)	(-0.48)
URB_w	-0.575***	-0.162	2.259***
	(-4.58)	(-1.32)	(4.12)
InEG_w	0.794***	1.612***	0.300
	(3.16)	(4.14)	(0.48)
ES_w	0.080	0.055	-0.049
	(1.62)	(1.10)	(-1.00)
Constant	1.998***	3.780***	5.541***
	(6.41)	(6.75)	(4.59)
Observations	110	100	90

R-squared	0.816	0.904	0.870
Province FE	YES	YES	YES
Year FE	YES	YES	YES
F test	0	0	0
r2_a	0.759	0.871	0.821
F	14.01	47.82	32.66

(*** p<0.01, ** p<0.05, * p<0.1)

By comparing the effects of environmental and economic policies in different regions of East, Middle, and West on the effect of industrial green transformation, it can be revealed that the estimation results of the three regions are not the same. Among them, the coefficients of F3 are all negative, in line with the whole country. Thus, the direction of F3's influence on industrial green transformation is consistent while the degree of influence is significantly different. Meanwhile, the influence of F1 and F2 on industrial green transformation is different in direction and degree. Generally, there is significant regional heterogeneity between environmental economic policies and industrial green transformation.

Firstly, the guiding and restricting policy F1 has a crucial role in promoting the green transformation of industries in the eastern and western regions. However, it has a counterproductive effect on the middle region. Concerning investment in environmental pollution control, different regions have different priorities, and policy effects vary from place to place. The eastern region focuses on "quality" development while the middle and western regions focus more on "quantity" development. Considering the unevenness of China’s economic development, the middle region mostly includes heavy industrial provinces. With the relatively insufficient economic development, many local governments have chosen to sacrifice the environment in exchange for rapid industrial growth. As a result, enterprises have overtaxed taxes, increased financial pressure, and reduced innovation space, leading to slow industrial transformation effects.

Secondly, the direction of the role-participatory policy F2's influence on the industrial green transformation in the western region is different from its influence on the eastern and middle regions due to the existence of factors such as the intensity of policy implementation, the speed of information transmission, and the adjustment of corporate strategies. Policies may not always take effect in the current period. For example, Li Shenglan et al. (2020) [14] discovered that carbon emission rights trading has an impact on regional pollution emissions. The dynamics and effects also vary with the types of pollutants. The public's awareness of environmental protection in the western region is weak, legal protection needs to be improved, and thus related policies may fail to achieve the expected results.

Thirdly, the impact of the green tax system F3 on the industrial green transformation effects of the three major regions of the east, middle, and west is consistent with that of the whole country, but only has a significant impact on the middle region. The intensity of the green tax used in this paper is the proportion of the sum of generalized green tax and pollutant discharge fee to the sum of total tax and pollutant discharge fee. According to He Wujie et al. (2020) [15], the empirical evidence demonstrated that sewage charges have not played a role in promoting the green transformation of industries. This can be explained as follows. The pollution discharge fee collection standard is low or even lower than the pollution control cost of the enterprise. As a result, the enterprise is deficient in the enthusiasm for technological innovation, and the speed of industrial green transformation is weakened. Moreover, the total amount of sewage fee income is insufficient, and it cannot be guaranteed that it will be fully invested in environmental protection. Thus, the green tax system F3 has an insignificant impact on the eastern and western regions.

4.4 Robustness test

Given the impact of the accidental events of the 2008 financial crisis, the method of excluding the data in 2008 is adopted for robustness testing to ensure the validity of the above regression results. The provincial panel data from 2009 to 2019 are used, and the estimation is performed using the fixed-effect regression models. The results[1] are compared with Tables 6 and 7. It is demonstrated that the estimated results of the impact of environmental economic policies on the green transition of the energy industry are basically the same whether it is based on national regression analysis or regional heterogeneity analysis. Therefore, the empirical analysis results in this paper are valid and robust.

5 Conclusions and suggestions

This study is based on the panel data of 30 provinces from 2008 to 2019. Factor analysis is conducted to effectively divide the environmental and economic policies. The ML index is employed to measure the degree of industrial green transformation in 30 provinces. Besides, a two-way fixed-effect model is established to empirically test the impact of environmental economic policies on industrial green transformation. The research conclusions are described as follows. First, the regression results of environmental economic policies and the national industrial green transformation suggest that different types of environmental economic policies have a significant impact on industrial green transformation. Among them, restricting and guiding policies have a significant positive role in promoting China's industrial green transformation. The role-participating policy has a phenomenon of "incomplete implementation" of the policy due to its lack of restraint and therefore has a relatively limited impact on the effect of industrial green transformation. Additionally, the level of urbanization and energy structure in the control variables also have an essential impact on industrial green transformation. Second, the panel data is further processed by spatial sub-samples according to the difference in economic development level and geographical distribution. China is divided into three regions: East, Middle, and West. The regression analysis indicates that different types of environmental and economic policies have different impacts on industrial green transformation in different regions, with significant regional heterogeneity. Among them, restricting and guiding policies can promote the efficiency of industrial green transformation in the eastern and western regions while the green tax system has a significantly negative impact on the middle region.

[1] Considering space limitations, this article does not give the estimated results of the robustness test in the main text. If you are interested, please ask the author for it.

Through research, this article can relatively objectively evaluate the effects of various environmental and economic policies on the green transformation of industries in different regions, providing a theoretical basis for China to give full play to the role of environmental and economic policies in the green transformation, and also for accelerating the process of green transformation in various regions. This is conducive to the rational formulation and application of environmental policies in various regions, improving the quality of industrial green transformation, and contributing to the overall development of my country's green economy.

Based on the above conclusions, the following feasible suggestions for the formulation and implementation of future policies are proposed.

(1) China should give full play to the synergy between various environmental and economic policies and continuously strengthen the guiding role of local governments in macro-control. Firstly, various environmental and economic policies cooperate to achieve "1+1>2" and build a policy system of "pre-defense-control during the event-governance after the event" to better play the positive role of environmental policies and promote the green development of the industry. Besides, the government has the power to make policy decisions and can lead the direction of macroeconomic development. Compared with the pursuit of "quality" development in the eastern region, the middle and western regions pay more attention to the increase in "quantity". The government cannot sacrifice the environment in exchange for economic growth. It is necessary to establish the concept of green development and give full play to the guiding role of the government.

(2) Given regional heterogeneity, an environmental and economic policy system suitable for its development should be established under the full consideration of regional characteristics. The eastern region has a relatively high level of economic development and good policy implementation. Thus, it can play a demonstrative role by combining its advantages to build bridges cooperation with neighboring regions or across regions, so as to jointly promote the implementation of the industrial green transformation strategy. For the middle and western regions, it is crucial to strengthen environmental regulations, appropriately reduce or exempt tax incentives, increase investment incentives, enhance the promotion of "green development", raise the environmental awareness of the government, enterprises, and the public, and achieve the coordinated development of the quantity and quality of the industrial industry.

(3) The government should adjust the energy consumption structure and promote industrial optimization and upgrading. If the industry wants to achieve a green transformation, from one perspective, it must change its "high consumption, high pollution, high emission" growth mode, adjust the energy consumption structure, develop clean and renewable energy, and realize low-carbon, green, and sustainable development; from another perspective, local governments should use policy measures to reasonably limit the "three highs" projects, eliminate outdated production capacity, vigorously support low-carbon, energy-saving, and environmentally-friendly industries, promote technological innovation of enterprises, reduce energy consumption for development, and ensure the rational and advanced development of the industrial structure.

On the basis of the research in this article, the following suggestions can be made for future research:

(1) The empirical research objects of this article on industrial green transformation are limited to the three regions of the whole country and the central and eastern regions. In the future, the

research objects can be shifted to comparisons among urban agglomerations such as Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta. The research time can also be appropriately extended, the spatial scope of the research object is reduced to a certain province or a certain economic zone, and the relationship between environmental economic policies and green transformation can be explored more deeply in a small area.

(2) The conclusion drawn from the municipal analysis in this article shows that guiding and restrictive policies have a significant positive effect on the green transformation of the energy industry. In the future, we can in-depth explore how guiding and restrictive policies can promote the development of green transformation of the energy industry.

(3) The index system of influencing factors still needs to be supplemented and improved. In-depth study of specific influence paths and influence mechanisms is also a possible future research direction to clarify the relationship between various variables to improve the interpretation of the model.

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