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Using Statistical Methods to Study the Mechanisms of Environmental Regulation and Energy Consumption on Economic Development: Based on the Provincial Panel Data of China

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Abstract:

The issue of environmental regulation and energy consumption in China, which is developing rapidly today, has gained the attention of many scholars. In this regard, this paper analyzed the relationship between environmental regulation and energy consumption, and economic development in China using panel data of 30 provincial-level administrative regions across China from 2001 to 2019. Unlike previous studies, this paper uses statistical methods to consider the effects of both environmental regulation and energy consumption on economic development. In the empirical study, the data were analyzed by the mediation model and the threshold effect model. The statistical results show that environmental regulation has a significant positive effect on economic growth, and energy consumption has a non-linear relationship on economic growth. Based on this, the paper mainly proposed three measures. First, the indicators of urban ecological construction should be closely related to economic indicators. Second, it is needed to strengthen the management of sewage discharge. Third, rational planning of energy allocation and promotion of clean energy are required to effectively achieve green and sustainable economic and social development.

Keywords: *Environmental regulation, Energy consumption, Economic growth, Mediation, Threshold model*

I. INTRODUCTION

The Bulletin on China's Ecological and Environmental Status (2018) published by the Ministry of Ecology and Environment of the People's Republic of China shows that in 2018, only 121 of the 338 prefecture-level cities and above met the ambient air quality standards, accounting for 35.8% of all cities. Although this figure continues to grow steadily, there are still more serious environmental problems in China at this stage [1]. From the view of energy, CNPC Economics & Technology Research Institute (ETRI) believes that in the next 30 years, China's energy demand will continue to grow. However, with the industrial transformation, it is expected that energy intensity will decrease by 50% compared to 2015, and

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energy consumption will decrease by 2% annually. Meanwhile, the growth rate of primary energy demand will be much lower than the economic growth rate in the same period [2]. The research on the relationship between energy consumption and economic development in China started late, but the results achieved in recent years are considerable [3]. Wang found that China's energy consumption was basically decoupled from economic development between 1990 and 2007 [4]. Yang et al. stated that there is a two-way causal relationship between energy consumption and economic growth in China during the period 1952-2008 [5]. In September 2020 at the 75th General Assembly of the United Nations, China pledged to peak CO_2 emissions by 2030 and strive to achieve carbon neutrality by 2060 [6]. While ensuring the positive effect of environmental regulation and energy use on economic development, it is conducive to formulate reasonable environmental protection and energy use policies to accelerate economic transformation and better economic development.

For decades, studies on environmental regulation and economic development have proliferated [7-11]. Moreover, recent studies have focused more on regionalized environmental economic development patterns. For example, a panel data study of two provinces in the Taihu Lake Basin proved the role of environmental regulations in promoting economic growth in the region [7,12]. Traditionally, economists believe that the initial purpose of environmental protection is bound to be contrary to economic development, while Porter's hypothesis argues that appropriate and reasonable environmental regulation can achieve economic development while protecting the environment through technological upgrading of enterprises [13-17]. Studies by foreign scholars on the relationship between the environment and the economy show that when per capita income reaches a certain level, the environment will improve with the increase in per capita income [13,18]. At the same time, studies in China have also verified that energy mix and energy intensity drive economic development in the long run [8,9,19].

This paper mainly explored the mediating and threshold effects between energy use, environmental regulation and economic development. The aim of this paper is to explore the promotion of healthy and stable economic development through reasonable environmental regulation and energy use policies. In this paper, the panel data from 2001-2019 were analyzed for 30 provincial-level administrative regions in China (Hong Kong, Macao, Taiwan and Tibet excluded).

The innovations of this paper are as follows. First, the study is no longer limited to a specific region, and the analysis is conducted in two directions: environmental regulation and energy use. Second, in the empirical study, we guaranteed the reliability of the results by applying the mediating effect as well as the panel threshold model in this paper. From the analysis of the mediating effect results, we concluded that the parkland area per capita itself has a significant positive effect on the growth of GDP, and the freshwater resources per capita is positively related to the share of primary industry. As for the As for the the threshold model, we found that when energy structure is taken as the threshold variable, energy structure, energy intensity, and the share of environmental protection capital investment have a significant dichotomous threshold effect on the share of secondary industry; and a significant triple threshold effect on GDP. Third, we analyzed the model results and made policy proposals for two aspects (environmental regulation as well as energy use) to ensure the effectiveness and relevance of the policy. One is that we should

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strengthen the guidance of green space construction through policies and laws & regulations, and improve the coordination of land planning and so forth. Another one is that the government should vigorously promote the concept of new circular economy, increase investment in order to study the purification and recycling of wastewater resources, combine freshwater resources per capita and other relevant indicators with green GDP, and strictly limit water pollution and other behaviors. The last one is that the government should fully understand the current situation of energy utilization and predict the future trend of energy consumption with reasonable models, and on this basis, formulate a rational energy utilization plan to continuously promote the efficient and clean extraction and utilization of fossil energy.

The paper is structured as follows. Part II presents the literature review; Part III introduces the data and its sources; Part IV describes the mediating effects and the threshold model, and Part V discusses the empirical model results; Part VI draws the paper's conclusions and gives relevant policy proposals.

II. LITERATURE REVIEW

In recent years, the research on environment and economy has always been popular, and environmental regulation and green economy are still hot topics for discussion. While at the same time, with the emergence of a series of problems such as energy shortage, there are also a great deal of discussions on energy use and economic development [20-23]. As for the relationship between environmental regulation and economic growth, the research views of domestic and foreign scholars are quite different. Foreign scholars generally believed that China has a high level of environmental pollution, yet the proportion of pollution control investment is very low, and the proportion of investment in environmental pollution control to GDP in China has been low. [13-17]. Chinese scholars thought much more differently. They argued that reasonable environmental regulations, based on the current stage of enterprise development on the environmental impact, can help promote high-quality economic development [12,24,25,26]. Regarding the relationship between energy use and economic development, both groups have pointed out that the high proportion of coal consumption in total resource consumption is the main cause of environmental degradation [27-31].

Studies on the relationship between environment and economy began earlier overseas. In 1993, Panayotou proposed the first environmental Kuznets curve (EKC) on the relationship between environmental quality and per capita income, using the inverted U-shaped curve proposed by Kuznets in 1955 to define the relationship between per capita income and income inequality. The EKC shows that environmental quality decreases with the increase of per capita income and improves with the increase of income when the level of per capita income reaches a certain level. In other words, the relationship between environmental quality and income is inverted U-shaped. According to statistics, environmental pollution is effectively controlled when the pollution control investment in developed countries reaches about 3% of GDP. In contrast, China has a high level of environmental pollution while the proportion of pollution control investment is low. It was found that the proportion of 338 cities above prefecture level in China with substandard ambient air quality was 75.1% in 2016. At the same time, the proportion of investment in environmental pollution control to GDP in China has fluctuated around 1.5% for many years. Robert N. Stavins (2007) considered that a coordinated development of environmental economy should be

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achieved by setting specific goals and targets, especially through the Kaldor-Hicks principle and the analysis of cost-benefit [13]. While traditional environmentalists have based their study of the environment on the relationship between humans and nature, Andrew's environmental justice proposal took social relationships into account [15]. Mariana (2017) suggested that it is necessary to study the content related to procedural justice in order to truly protect the environment and achieve environmental justice, thus helping policy makers to develop more effective policies and measures to advance sustainable development [17]. Environmental change affects human production and economic development in various ways, so the study of environmental economics is particularly important.

Currently, domestic research tends to focus on the technological adjustment of related industries, the impact of innovation and upgrading on environmental improvement and hence on economic development, and more detailed regionalized environmental and economic development patterns. In the following, we summarized the domestic and foreign research on the impact of environmental regulation and energy use on economic development.

It is generally agreed in Chinese research that reasonable environmental regulations contribute to economic growth [25, 32]. For the first time since the first United Nations Conference on the Human Environment in 1972, Chinese delegates discussed the balance between human development and environmental protection with the rest of the world. Traditionally, economists have argued that protecting the environment will inevitably have a negative impact on economic development, as the enactment of environmental protection policies will inevitably lead to increased production costs for enterprises, some of which will be restricted by environmental requirements and others will face increased economic costs that will affect their development [7,10].

However, Porter's hypothesis suggested that appropriate environmental regulation could stimulate technological innovation. Not only would it compensate for the additional cost of environmental protection to firms, but it would also increase their productivity and enhance market competitiveness [13, 24]. According to externality theory, Zhao et al. (2007) stated that the solution to the environmental pollution problem is fundamentally a comparison of costs and benefits. Only when the social benefits obtained from the implementation of environmental regulation policy are greater than the social costs will the government's regulation policy be efficient [24,25]. It has been shown that Chinese industrial environmental regulation policies have a certain role in promoting technological innovation in industries, and thus can indirectly improve industrial performance through innovation compensation effects [25]. According to Yuan (2015), environmental regulation significantly contributes to the growth of industrial green total factor productivity, which verifies the validity of Porter's hypothesis from the perspective of productivity [32].

Regarding the role of environmental regulation, Cheng and Li (2017) verified through a dynamic spatial panel model that environmental regulation has a significant contribution to the upgrading of urban industrial structure [34]. Recently, Guo et al. (2021) employed a DID model to assess the impact of strengthening regional environmental controls on the quality of economic development in two provinces of the Taihu Lake basin using panel data at the prefecture level and above [7]. The results showed that

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environmental control significantly reduced environmental pollution in the whole region and in the meantime improved the industrial structure and boosted the economic level of the cities [6-7]. However, there is heterogeneity in the effects on cities with different levels of development, with positive effects on large and medium-sized cities and negative effects on small-sized cities [7]. Also, it has been found that green finance can help promote high-quality economic development. Furthermore, there are some mediating effects in green finance on high-quality economic development, among which the greatest mediating effects are found in promoting high-quality economic development through guiding residents' green consumption [12].

Studies in China on the impact of energy on the economy focused more on energy intensity and energy consumption. Chen et al. (2015) raised that with the development of China's economy, the rapid growth of energy consumption in the transportation industry, if uncontrolled, will inevitably generate an energy crisis and even threaten human existence [38]. Li (2017) found that the use of green mining technologies, efficient and clean conversion and utilization technologies, and qualitative grading of coal by using multi-generation technologies, which realize the coordinated development of energy use and economy, is the trend of energy use. Through the assessment of energy efficiency as well as environmental efficiency in different countries and regions, Du (2018) presented that in the numerous literature studying energy efficiency, most of them use radial measures, leading to overestimation of China's energy efficiency [28], but in fact, the efficiency of energy use in China is probably lower than the perceived situation. Through the compilation of data on global primary energy consumption, Yang et al. (2020) concluded that in terms of energy consumption structure, the world is undergoing a systemic transition of progressively cleaner and lower carbon energy structure [29]. Feng (2017) noted that providing a full range of integrated energy services to customers through centralized and rational distribution of available energy, while also reducing costs through a centralized function, will be the basic pattern of future economic development driven by energy consumption.

Energy consumption is important in supporting economic growth, and energy consumption plays a part in mediating the effect of industrial upgrading on economic growth [8]. The energy structure not only significantly affects the energy economic efficiency of the region, but also affects the energy economic efficiency of the surrounding areas through spatial spillover effects, and reasonable control of energy efficiency can promote economic development through energy use [9]. By adjusting the existing energy structure, the bottleneck of energy to the medium and high speed of economic development can be avoided to a certain extent [19].

The majority of previous studies have examined the relationship between environmental regulation or energy and the economy. Whether there is a relationship among environmental regulation, energy and economic development is unknown [33]. The impact of pollutant emissions under environmental regulation, and the impact of energy mix and energy intensity on economic development under energy use are also unknown [35-37]. Therefore, this paper combined these variable factors and analyzed the relationship among environmental regulation and energy use and economic development using panel data of 30 Chinese provinces for the past 20 years, and gave related suggestions.

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III. DATA SOURCE

Among the 34 provincial administrative regions in China, data from Taiwan, Hong Kong, Macao, and Lhasa were excluded because of the large lack of statistical data and the large differences in national policies towards local areas. Therefore, this paper mainly adopted the annual statistics of energy use, environmental regulation, and economic development related variables from 2001-2019 for 30 provincial administrative regions across China. Among them, the data on economic development, factors related to energy use, and energy use were obtained from the China Statistical Yearbook, China Energy Statistical Yearbook, and China Environmental Statistical Yearbook for each year. For the missing data, they are mainly supplemented by other relevant statistical yearbooks of each province. For the data that are still missing, the interpolation method was used to calculate the values at the missing places, and then the data were winsorized to prevent the influence of outliers on the results [40-41]. There are two main factors to consider when using data from 2001-2019. First, a large number of data were missing before 2001, which greatly affected the subsequent data processing and the analysis results. Second, since the establishment of the State Environmental Protection Administration and the Ministry of Ecology and Environment in 1998, the data after 2001 are more reliable and more informative for the study of environmental regulation on economic development [42-43]. Finally, we selected a total of 6 environmental variables, 10 energy use variables, and 11 economic development variables, a total of 27 variables, and the statistical characteristics of the variables are shown in Table I.

Table I. Statistical characteristics of the variables

Variables	Number of samples	Mean	SD	MAX	MIN
Air quality rate (%)	176	0.82	0.19	0.98	0.53
Parkland area per capita (m^2)	551	10.33	3.98	20.38	2.90
Sulfur dioxide emission compliance rate (%)	96	1.01	0.33	0.98	0.51
Freshwater resources per capita (m^3/person)	570	2100	2500	16176.90	36.50
Environmental protection capital investment (per 100 million yuan)	570	76.40	100	747.40	5.30
GDP (per 100 million yuan)	570	15000	16000	99631.50	300.1
Environmental protection capital investment ratio (%)	570	0.01	0.01	0.26	0.00
Amount of soot emissions (per 10,000 tons)	532	39.18	48.86	151.60	0.90
Industrial wastewater discharge (per 10,000 tons)	570	81000	78000	383503.90	401
Industrial solid waste emissions (per 10,000 tons)	551	22000	130000	236424.5	75
Sulfur dioxide emissions (per 10,000	570	64.34	42.23	200.30	1.9

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tons)					
Population (10,000)	570	4400	2700	12489	523
Per capita energy consumption (10,000 tons/person)	570	2.92	1.72	11.39	0.00
Energy intensity (10,000 tons / 10,000 yuan)	570	1.17	0.90	4.47	0.00
Coal consumption (10,000 tons)	570	8500	6700	28048.10	142.10
Total energy consumption (10,000 tons of standard coal)	570	12000	8200	41390	520.40
Energy structure (%)	570	0.74	0.24	1.00	0.00
Number of domestic patent applications received	570	53000	100000	807700	124
Number of research and experimental development staff	570	64000	97000	2424872	475
R&D expenditure of industrial enterprises above the scale (10,000 yuan)	570	1900000	3300000	23148566	8768
Percentage of primary industry (%)	551	0.12	0.06	0.35	0.00
Percentage of secondary industry (%)	551	0.45	0.08	0.60	0.16
Urbanization rate of household population (%)	551	0.52	0.16	0.89	0.24
Urban Engel's Coefficient	551	0.35	0.07	0.48	-0.26
Rural Engel's Coefficient	551	0.39	0.10	0.60	0.26
Total industrial output (100 million yuan)	551	21000	30000	164195.1	243.5
Labor productivity (yuan/person, year)	570	240000	260000	724422	10721

In particular, the statistics scopes for monitoring data between emissions, wastewater & concentrations of solid waste, and air pollutants emitted in industrial production in China are different [44]. The former counts the emissions in all areas within the province, while the latter mainly monitors the concentrations of various air pollutants in municipal administrative districts [12]. In this paper, all the statistical data of all regions within the province were used in analyzing the relevant data [45-46].

In the mediation model studied in this paper, there are two major concerns: the ultimate effect of the energy use variable of soot emissions on economic development through the mediating effect on the environmental regulation variable [47-48]; and the final effect of environmental regulation variables on economic development through the mediating effect on energy use variables [49-51].

In the threshold regression model, the main focus is on the effect of energy intensity and the share of environmental protection capital investment on economic development (here, mainly the share of GDP and secondary industry output) when energy structure is used as a threshold variable.

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IV. SELECTION OF EMPIRICAL MODEL AND VARIABLES

4.1 Mediation Model

4.1.1 Model setting

The mediating effect is a doctrine in the development of organic molecular structure theory, which refers to the effect of X on Y through M, i.e., M is a function of X and Y is a function of M. Considering the effect of the independent variable X on the dependent variable Y, if X affects the variable Y through M, M is said to be a mediating effect [52].

In this study, the actual or theoretical relationship among each environmental regulation variable on economic development variables is obtained by examining the effect of environmental regulation on economic development [54-55]. To further explore the internal mechanism and rationale between the two, this paper referred to Judd and Kenny's stepwise test regression coefficient method [28] to explore the mediating effect of energy intensity as a mediating variable [53].

The mediation model is constructed as follows.

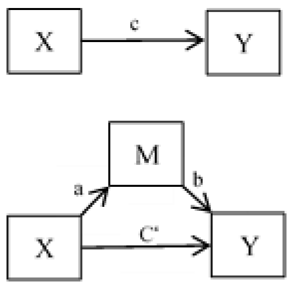

Figure 1 Mediation model

The model can be divided into two parts. In the first picture, the variable X is called the causal variable and the variable that it causes or Y is called the outcome. Path *c* in the above model is called the total effect since there is not a third variable involved. In the second picture, a process or mediating variable M in added, and the variable X may still affect Y. Path *a* represents the effect of the independent variable X acting on the mediating variable M, and the path *b* represents the effect of the mediating variable M acting on the dependent variable Y. This process constitutes an indirect effect between the independent variable X and the dependent variable Y. The coefficient c' represents the direct effect of the independent variable X acting on the dependent variable Y when the indirect effect is considered, i.e., c = ab + c'.

This paper mainly explores the effect of environmental regulation on economic development when energy intensity is a mediating variable and the effect of energy intensity on economic development when environmental regulation is a mediating variable [56-58].

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The process of exploring mediating effects through stepwise tests of regression coefficients is divided into three steps. In the first step, the total effect of the independent variable and the dependent variable is tested. The second step examines the relationship between the independent variable X and the mediating variable M. In the third step, after controlling for the mediating variable M, the total effect between the independent variable X and the dependent variable Y and the relationship between the mediating variable M and the dependent variable Y are examined.

4.1.2 Description of variables

4.1.2.1 Explained variable

The explained variable is the economic development condition. The GDP, primary industry share, and secondary industry share of each province from 2001-2019 are used to represent the level of economic development. When the variables are brought into the calculation as mediating effects model, the ratio of the primary industry output value of each province to the GDP in that year is used as the primary industry share to be substituted into the model. The units of GDP and primary industry output value are controlled to be consistent when calculating the ratio, and the secondary industry share is measured in the same way.

4.1.2.2 Explanatory variables

The explanatory variables are the variables explored in this paper that may have an impact on the development with the economy, which are divided into two categories: environmental regulation and energy intensity [59-61]. The details are as follows.

The main areas of environmental regulation include air pollution, water pollution toxic substances, etc [62]. Different emission policies are designed to transform environmental pollution into private costs borne by the polluting subjects themselves. In order to quantitatively measure the environmental regulation, the variables used in this paper to represent environmental regulation are: parkland area per capita and freshwater resource concentration per capita [64-65]. Since the increase of parkland area per capita and freshwater resources per capita are direct expressions of the effect of environmental regulation in a certain economic environment, this paper expresses the intensity of environmental regulation in a certain period [66].

Energy intensity refers to the ratio of energy consumption to output, which can reflect to a certain extent the dependence of an economy on energy for economic development. Aiming to refine the energy intensity variables here, soot emissions, industrial wastewater emissions and energy mix, are used to represent energy intensity, all reflecting to some extent the level of industrial development of the economy under study.

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4.1.3 Data description

$$x' = x - \mu \tag{1}$$

To avoid the data from affecting the test results due to different orders of magnitude in the calculation process, all variables were centered before the calculation by formula (1), in which, x denotes the original data, x' denotes the data after centering, and μ denotes the mean value of the original data so that the mean value of the centered data is zero to avoid unnecessary errors.

4.2 Threshold Model

To prevent endogeneity problems and ensure the robustness and rigorousness of the results, this paper used a panel threshold model to analyze the existing main sample data and further explore the impact of energy utilization on economic development. Since this paper focuses on the impact mechanism of energy use on economic development, we added environmental protection capital investment ratio, energy intensity and energy structure as control variables based on Hansen's panel threshold regression model, and set the energy variables to be explored as threshold variables to construct a double threshold model of environmental regulation on economic development.

$$\ln API_{it} = \sigma_0 + \sigma_{11} EI_{it} I(EI_{it} \leq \phi_1) + \sigma_{12} EI_{it} I(\phi_1 < EI_{it} \leq \phi_2) + \sigma_{13} EI_{it} I(EI_{it} > \phi_2) + \sigma_2 X_{it} + \varepsilon_{it} + V_i$$

X stands for the set of control variables, $X_{it} = (ISIA_{it}, IGDP_{it}, IEA_{it}, EI_{it}, ES_{it})$ and $\sigma_0 \sim \sigma_2$ are the parameter to be estimated. $\sigma_{11} \sim \sigma_{13}$ are the different impact coefficients on economic development in the interval of the threshold values; ϕ_1 the first threshold value, ϕ_2 the second. When $\phi_1 = \phi_2$, it is a single threshold model; $I(\cdot)$an indicative function. When the conditions in brackets are met, $I(\cdot)$ is valued as 1, and if not, 0. ε is a random disturbance term. According to the sign of the coefficients corresponding to each threshold interval, we can judge the basic trend of the non-linear relationship between energy use and economic development. When two adjacent intervals have significant coefficients with opposite signs, the threshold value corresponding to the surface is an inflection point. For example, when $\sigma_{11} > 0$, $\sigma_{12} < 0$ and σ_{13} is not significant, there is an inverted "U" shaped relationship between energy use and economic development, and vice versa. When $\sigma_{11} > 0$, $\sigma_{12} < 0$ and $\sigma_{13} > 0$, there may be an "N-shaped" curve relationship between the two, and vice versa, there may be an inverted "N" curve relationship. According to the actual situation of this research, when $\sigma_{11} > 0$, $\sigma_{12} > 0$ and $\sigma_{13} > 0$, there may be a fluctuating upward curve relationship between energy use and economic development, and vice versa.

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V. RESULTS AND DISCUSSION

5.1 Results Analysis of Mediation Effect

First, the environmental regulation is studied as the independent variable, energy intensity as the mediating variable, and economic development as the dependent variable.

When green space per capita was used as the independent variable X, soot emissions as the mediating variable M, and GDP as the dependent variable Y, the regression coefficient c=0.884, which showed that green space per capita was significantly related to GDP. The results demonstrate that an increase in parkland area per capita significantly reduces soot emissions with a coefficient of a=0.202. For the next test, the significant relationship between parkland per capita and GDP does not change after adding soot emissions again, but the coefficient decreases from c=0.884 to c'=0.863. The coefficient between soot emissions and GDP b = 0.102, and the mediating effect is 2.3% of the total effect. This indicates that soot emissions only play a minor mediating role between park green space per capita and GDP. The specific results are shown in Table II.

Table II. Mediation Model Result (1)

Independent variable X (parkland area per capita, or green space per capita)	GSP
Dependent variable Y (annual gross product)	GDP
Mediating variable M (energy structure)	ES
c	0.884***
c'	0.262**
a	0.202*
b	0.065*

When freshwater resources per capita is taken as the independent variable X, soot emission as the mediating variable M, and the share of primary industry as the dependent variable Y, the regression coefficient c=0.898, and the results indicate that freshwater resources per capita emission is significantly correlated with the share of primary industry. After adding the mediating variables, the correlation coefficient between freshwater resources per capita and soot emissions a=0.424, and the correlation coefficient between soot emissions and the share of primary industry b=0.065, with the mediating effect accounting for about 3.0%, indicating that the mediating effect is not significant in the share of freshwater resources per capita and the share of primary industry, and the correlation coefficient is reduced to c'=0.870. The specific results are shown in Table III.

TableIII. Mediation Model Result (2)

Independent variable X (freshwater resources per capita)	FRP
Dependent variable Y (percentage of output value of	FIA

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primary industry)	
Mediating variable M (soot emissions)	SE
c	0.898***
c'	0.870***
a	0.424**
b	0.065*

When the green space per capita is the independent variable X, GDP the dependent variable Y, and industrial wastewater discharge the mediating variable, the regression coefficient c = 0.884. The correlation coefficient between the green space per capita and industrial wastewater discharge a= 0.249; the correlation coefficient between industrial wastewater discharge and GDP b= 0.119; the mediating variable accounts for 3.3% and the correlation coefficient c decreases to c '=0.854. The specific results are shown in Table IV.

Table IV. Mediation Model Result (3)

Independent variable X (green space per capita)	GSP
Dependent variable Y (annual gross product)	GDP
Mediating variable M (wastewater discharge)	DIW
c	0.884***
c'	0.854***
a	0.249*
b	0.119*

The further study used energy intensity as the independent variable, environmental regulation as the mediating variable, and economic development as the dependent variable.

The independent variable is energy structure, the mediating variable is freshwater resources per capita, and the dependent variable is the share of primary industry, with regression coefficient c=0.345. The results show that energy structure is significantly related to freshwater resources per capita with coefficient a=0.487. freshwater resources per capita is significantly related to the share of primary industry. After adding the mediating variable, there is no significant change in the relationship between energy structure and the share of primary industry, the coefficient c=0.345 decreases to c'=0.223. The coefficient of the relationship between freshwater resources per capita and the share of primary industry b=0.250, the mediating effect accounts for 35.3%. The specific results are shown in Table V.

Table V. Mediation Model Result (4)

Independent variable X (energy structure)	ES
Dependent variable Y (percentage of output value of primary industry)	FIA
Mediating variable M (freshwater resources per capita)	FRP
c	0.345**
c'	0.223*

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a	0.487**
b	0.250**

5.2 Analysis of Threshold Model Results

Table VI shows the empirical results of the threshold model 1. The test results show that there is a significant dichotomous threshold of energy structure on the share of secondary industry, and the triple threshold is not significant. It can therefore be seen that there is a non-linear relationship between the energy structure and the share of secondary industry, and the results of the robustness test are basically consistent with the estimation results of the original model indicating the reasonableness of the model set in this paper.

From the results of the parameter estimation in Table VI it is clear that there is an inverted U-shaped relationship between energy structure and the share of secondary industry. That is, as the energy structure increases, the effect of energy structure on the share of secondary industry changes from positive to negative, which means that when the energy intensity is less than 52.6%, a 1% decrease in energy structure will cause a 7.26% decrease in the share of secondary industry, and when the energy structure is greater than 84.2%, a 1% decrease in energy structure will cause the secondary industry to increase by 0.72%. Combined with the actual situation of regional development, this may be attributed to the fact that when the coal energy structure is under 52.6%, with the increase of coal energy utilization, along with the industrial structure adjustment and the continuous development of technology, the proportion of secondary industry, including manufacturing industry, keeps increasing. Instead, when the coal energy structure increases to 84.2%, the continuous increase of coal input, due to the constraints of technology, production capacity and other realistic factors will lead to the decrease of the secondary industry output value.

In addition, Table VI shows that other environmental variables also have an impact on the share of secondary industry. Among them, the share of environmental capital investment will have a negative impact on the share of secondary industry, namely, a 1% increase in the share of environmental capital investment will cause a 4.56% decrease in the share of secondary industry, indicating that most of the current development of secondary industry is still a development at the cost of polluting the environment [67-68]. The increase in energy intensity will have a positive impact on the share of secondary industry: a 1% increase in energy intensity will cause a 7.16% increase in the share of secondary industry which is in line with the current stage of energy use and development cognition, with the increase in the share of energy input, the corresponding secondary industry will also be developed.

Table VI. Threshold Model Result (1)

	Model 1	Robustness test
Energy structure $(ES)(ES \leq \varphi_1)$	-1.32 (-5.06)	-0.061^{**} (-2.68)
Energy structure $(ES)(\varphi_1 \leq ES < \varphi_2)$	0.073^{***} (2.89)	0.065 (1.97)

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Energy structure $(ES)(ES > \varphi_2)$		0.007 (0.26)	-0.023 (-1.33)
Percentage of investment in environmental protection funds		-0.046^{***} (-7.59)	-0.034^{***} (-3.17)
Energy intensity		0.072^{***} (9.46)	0.083^{***} (4.20)
Constant		0.360^{***} (22.16)	0.322^{***} (15.51)
R^2		0.395	0.395
N		390.000	390.000
F		46.453	46.453
Threshold estimates	Single threshold	0.842	0.842
	Dichotomous threshold	0.526 0.842	0.526 0.842
	Triple Threshold	0.909	0.909
Threshold effect test (P value)	Single threshold	0.033^{**}	0.033^{**}
	Dichotomous threshold	0.007^{***}	0.007^{***}
	Triple Threshold	0.013^{**}	0.013^{**}

Table VII shows the empirical results of the threshold model 2, and the test results show that there is a significant triple threshold for the energy structure. It is evident that there is a non-linear relationship between energy structure and GDP, and the results of the robustness test are basically consistent with the estimation results of the original model indicating the reasonableness of this model.

The results of parameter estimation in Table VII show that there is an inverted U-shaped relationship between energy structure and GDP, that is, as the energy structure increases, the effect of energy structure on GDP changes from positive to negative, that is, when the energy intensity is less than 57.5%, a 1% decrease in energy intensity will cause a 28.2% decrease in GDP, and when the energy intensity is greater than 86.8%, a 1% increase in energy intensity will instead cause a decrease in GDP 74.8%. Combined with the actual situation, it can be considered that when the coal energy structure is under 57.5%, increasing coal input can promote GDP growth, and when the coal energy structure is above 86.8%, increasing coal input can not. It indicates that the development of industrial and other environmental polluting enterprises can promote GDP growth to a certain extent, and it will have the opposite effect after reaching the threshold value.

In addition, it can be obtained from Table VII that other environmental variables also have an impact on GDP. Among them, the percentage of investment in environmental protection funds and energy intensity both have a negative impact on GDP, indicating that GDP growth at this stage is still inseparable at the cost of environmental pollution.

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Table VII. Threshold Model Result (2)

		Model 2	Robustness test
Energy structure $(ES)(ES \le \varphi_1)$		-1.817^{***} (-6.37)	0.282 (1.53)
Energy structure $(ES)(\varphi_1 \le ES < \varphi_2)$		-1.505^{***} -8.76	-1.414^{***} -9.29
Energy structure $(ES)(\varphi_2 \le ES < \varphi_3)$		-1.426^{***} (-10.01)	-0.748^{***} (-2.78)
Energy structure $(ES)(ES > \varphi_3)$		-0.945^{***} (-8.14)	0.044 (1.03)
Percentage of investment in environmental protection funds		-0.341^{***} (-6.49)	-0.128 (-0.95)
Energy intensity		-0.899^{***} (-15.97)	-1.086^{***} (-6.90)
Constant		1.930^{***} (15.54)	1.752^{***} (8.07)
R^2		0.582	0.582
N		393.000	393.000
F		99.891	99.891
Threshold estimates	Single threshold	0.675	0.675
	Dichotomous threshold	0.575 0.868	0.575 0.868
	Triple Threshold	0.891	0.891
Threshold effect test (P value)	Single threshold	0.007^{***}	0.007^{***}
	Dichotomous threshold	0.000^{***}	0.000^{***}
	Triple Threshold	0.000^{***}	0.000^{***}

VI. CONCLUSION AND POLICY PROPOSALS

This paper has collected panel data on a total of 27 environmental planning variables, energy use variables, and economic development variables from 2001-2019 for 30 provincial-level administrative regions across China (except those of Hong Kong, Macao, Taiwan, and Tibet). The data are analyzed by mediating effects and threshold models to identify the effects of environmental regulations and energy use on economic development, so as to give corresponding policy proposals.

The results of the mediating effects show that there is a significant positive effect of parkland area per capita on GDP, while the mediating effect with energy structure is not significant. Also, parkland area per capita has an effect on GDP through the mediating effect on industrial wastewater emissions, but the mediating effect is not significant. From the above results, it is clear that the green space per capita itself has a significant positive effect on the growth of GDP. Freshwater resources per capita has a significant positive effect on the share of primary industry, whereas the mediating effect of freshwater resources per capita on soot emissions is not significant. Energy structure has a significant and positive mediating effect

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with freshwater resources per capita. It indicates that the improvement of freshwater resources per capita can be achieved by improving the energy structure.

The results of the threshold model show that when the energy structure is used as the threshold variable, the energy structure, energy intensity and the share of capital investment in environmental protection have a significant dichotomous threshold effect on the share of the secondary industry; when the energy structure is also adopted as the threshold variable, the energy structure, energy intensity and the share of capital investment in environmental protection have a significant triple threshold effect on GDP. Combining the results of the dichotomous and triple thresholds, the share of coal consumption in total energy consumption should be controlled to ensure a positive effect on the share of the secondary industry and GDP.

By incorporating the findings of the empirical analysis in this paper, the following policy proposals are put forward. Firstly, the area of urban green space should be reasonably planned. In recent years, there are still large differences among different cities in China, so it presents an overall disordered development status [39]. It is necessary to improve the guidance of green space construction through policies and laws and regulations, and all places should start from the perspective of urban planning, based on the coordinated development of green space area, and strengthen the planning and coordination, such as clearly connecting urban green space area with GDP and other related indicators. Therefore, the cities with serious shortage of park green space per capita should take compulsory measures to guarantee green land first in urban planning. Secondly, the management of sewage discharge should be strengthened to save water resources. Managing water resources pollution and improving water resources environment is a favorable means to promote economic development [40]. The government should vigorously promote the concept of new circular economy, increase investment to research wastewater resource purification and recycling, and combine relevant indicators such as freshwater resources per capita with green GDP to link it to local economic development [69-71]. Finally, a reasonable energy utilization policy should be formulated. The relevant departments should fully understand the current situation of energy utilization and adopt a reasonable model to predict the future energy consumption trend, and on this basis, formulate a reasonable energy utilization plan, allocate energy, continuously promote the efficient and clean extraction and utilization of fossil energy, and give appropriate subsidies to the research in the direction of alternative clean energy, so as to realize the reasonable utilization of energy and the rapid development of economy and society.

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