Research on the Impact of Environmental Regulation and Technology Innovation on the Quality of Economic Growth

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Abstract: This paper uses the balanced panel data from 29 provinces (autonomous regions and municipalities) in China for a total of 17 years from 2000 to 2016 as a research sample, and establishes an empirical model to examine the impact of environmental regulations and technological innovation on the quality of economic growth. Then this paper test technological innovation as a threshold variable, in which play a regulatory role. Taking the provincial balanced panel data as a research sample, a fixed effect model, a system GMM model, and a panel threshold model were established for empirical testing and the robustness test. Based on the empirical results, this article draws the following conclusions: from a national perspective, environmental regulations and technological innovation can significantly promote the quality of economic growth; from a regional perspective, there are regional differences in impact effects. Under the constraints of environmental regulations, the promotion effect of technological innovation on the quality of economic growth will be reduced; the impact of environmental regulation on the quality of economic growth will have a "threshold effect", and environmental regulation can significantly promote the quality of economic growth only after crossing the threshold and the threshold of technological innovation.

Key words: Quality of economic growth, environmental regulation, technological innovation

1. Introduction

Environmental issues have been a hot issue in economic and social development. After more than 40 years of reform and opening up, China's economic level has been continuously improved, and it has now become one of the most important and dynamic economies in the world. With the rapid economic growth, various environmental problems in the process of industrialization have emerged in China, and environmental protection problems have become increasingly prominent. The "Thirteenth Five-Year Plan" period of China is an important period for the reform of the management of the ecological environment and the ecological protection system. The demands of the public for high-quality environmental quality are constantly rising, and the public is increasingly concerned about environmental protection issues. In order to deepen the concept of green development and meet the demands of the public for environmental protection, the government has increasingly strengthened environmental regulations for enterprises. Environmental regulation is a policy tool to correct market failures, which can improve the environmental quality to a certain extent, and then promote the green transformation of enterprises and the upgrading of industrial structure. On the one hand, the existing research on the impact of environmental regulation on the economy focuses on the impact of environmental regulation on the amount of economic growth, and relatively few studies on the impact of environmental regulation on the quality of economic growth. Therefore, the establishment of a multi-dimensional evaluation system that includes economic growth efficiency, economic growth structure optimization, economic stability, and ecological resource utilization to test the impact of environmental regulation on the quality of economic growth is meaningful to understand the impact of environmental regulation on the economy. On the other hand, both environmental regulation and technological innovation have an effect on the quality of economic growth. In the model, the level of technological innovation can be regarded as a variable that affects the boundary point of the effect of environmental regulation, making the theory on the relationship between environmental regulation and the quality of economic growth more abundant, which can also provide theoretical support for policy development.

The issue of environmental regulation has been the focus of academic research in recent years. Discussing the impact of environmental regulation and technological innovation on the quality of economic growth cannot only help focus on the costs paid by regulated entities, but examine the overall economic response to policy implementation.

2. Literature Review

2.1 Research on the Impact of Environmental Regulations on Economic Growth

There is a large amount of research on the impact of environmental regulation on the amount of economic growth in academia. By sorting out the early literature, it can be summarized into two types of viewpoints: one is the "follow the cost theory", which believes that under the pressure of the government's environmental regulations and policies, companies as market entities will increase environmental protection investment to meet policy requirements. This market behavior, to a certain extent, increases the production cost of the enterprise and thus hinders the improvement of corporate performance, which has a negative impact on economic growth. Gray and Shadbegian (2003) validated this hypothesis with empirical research on the US paper industry. Olga and Grzegorz (2006) also found based on empirical results that the government's policy of

restricting pollution gas emissions has significantly inhibited economic growth. Another view is the "innovation compensation theory". This hypothesis was proposed by Porter (1995). He believes that the design of scientific environmental regulation policies can force companies to innovate and can partially or even completely offset the costs of environmental regulations and improve corporate performance. Promote economic growth, this is the content of the "Porter Hypothesis". Research by Hamamoto (2006), Mazzanti and Zoboli (2009), and Zhao Hong (2008) found that government environmental regulations and policies forced companies to innovate technological innovations, reducing corporate costs and improving corporate performance, and empirically tested the "Porter hypothesis".

Based on the above two basic viewpoints, different scholars have explained the impact of environmental regulation on economic growth from different perspectives. Zhang Hongfeng et al. (2009) compared Shandong region in China with the whole country as a sample, and used mathematical statistics and relevant empirical tests to conclude that Shandong's environmental regulations are stronger than the country and have achieved certain results in environmental protection and economic performance. It is concluded that the implementation of a systematic and scientific environmental regulation policy can change the relationship between environmental quality and economic growth from reverse to co-direction. Xiong Yan (2011) obtained a positive U-shaped relationship between environmental regulation and economic growth through an empirical study of panel models, rather than a direct linear relationship. Xie Juan, Li Yushuang, and Han Feng (2012) constructed a simultaneous equation model between environmental regulation and economic growth, the empirical test results show that there are different causal relationships between environmental regulation and economic growth in different regions. Yuan Yijun and Liu Liu (2013) classified environmental regulations and conducted empirical tests on a panel data. The research results show that cost-based environmental regulations have no significant impact on economic growth, while investment-based environmental regulations can significantly promote economic growth. Shi Beibei et al. (2017) used the double difference method to examine the impact of environmental regulations on the economic growth of prefecture-level cities in China. The research results show that environmental regulation significantly promotes the economic growth of cities, and it is found that the longer the implementation of environmental regulation policies, the stronger the effect. The research results also show that there is a positive relationship between the effect of environmental regulation on economic growth and the size of the city. Wang Hongqing (2016) added the relevant mechanism of human capital to the analysis and put forward the assumption of the threshold effect of environmental regulation on economic growth. The empirical test results on the panel data show that there are significant differences in the impact of environmental regulations on economic growth, depending on the intensity of environmental regulations.

2.2 Study on the Impact of Environmental Regulations and Technological Innovation on the Quality of Economic Growth

There is limited literature in relation to the impact of environmental regulation and technological innovation on the quality of economic growth, and the mainstream research conclusion is that both regulation and innovation have promoted the improvement of the quality of economic growth. Hanguo (2018) took technological innovation as a moderating variable and incorporated it into the research framework of the economic impact of environmental regulation. When examining the economic impact of environmental regulation, it establishes an empirical model with

environmental regulation as its own threshold variable and technological innovation as its threshold variable. The panel threshold method was used to investigate the different impacts of environmental regulations on capacity utilization in different variable values. The impact of environmental regulation on production capacity utilization, with the continuous improvement of technological innovation, a mutation that first inhibits and then promotes occurs. The existence of an inflection point indicates the existence of a threshold effect of technological innovation. The improvement of technological innovation is conducive to promoting the positive effect of environmental regulation and the improvement of the quality of economic growth.

Zhang Cheng et al. (2010) used data envelopment analysis to calculate the total factor productivity (TFP) of each year in the industrial sector. Through mathematical model reasoning and empirical tests, it was concluded that innovation stimulated by environmental regulations can not only make up for costs, but also improve corporate competitiveness and productivity. In the long run, this positive promotion is even more significant. Sun Yingjie and Lin Chun (2018) used provincial panel data and systematic GMM estimation methods and found that, from a nationwide perspective, environmental regulations first suppressed and then promoted the quality of economic growth, showing an inverted U-shaped relationship. At present, the average level of environmental regulation intensity is on the left of the inflection point. Strengthening environmental regulation will help promote the improvement of the quality of economic growth. Using the comprehensive indicator system method, He Xingbang (2018) constructed an economic growth quality evaluation system covering six aspects of economic growth efficiency, social welfare, and resource utilization. Based on this economic growth quality indicator, he examined the impact of environmental regulations on the quality of economic growth. The results show that environmental regulation significantly promotes the improvement of the quality of economic growth. In addition, Huang Qinghuang and Gao Ming (2016) adopted a simultaneous equations model from the perspective of the quantity and quality of economic growth. The empirical results show that environmental regulation inhibits the amount of economic growth and promotes the quality of economic growth, and the system of environmental decentralization promotes the quality of economic growth. Environmental regulation has a positive effect on the quality of economic growth, and further expands the negative impact on the amount of economic growth.

Shi Zili (2013) selected regional research samples and constructed a VAR model to conduct an empirical test on the effects of the quality of economic growth represented by the total factor productivity growth rate of the Central Plains Economic Zone and various types of "innovation capabilities". The empirical results show that the ability of the innovation system can significantly improve the quality of regional economic growth in the short term, and increasing the strength of innovation human capital and innovation investment has a significant impact on promoting the quality of regional economic growth in the long term. Wang Zhujun (2014) analyzed and found that due to insufficient technological innovation and development in the current period, the structure of economic growth was uncoordinated and the stability of economic growth was poor, which led to the impact of technological innovation on improving the quality of economic growth. Tang Weibing et al. (2014) applied the GMM estimation of dynamic panel-data model lead to different conclusions: technological innovation is inversely related to the level of intensive economic growth.

3. Theoretical Mechanism

3.1 Mechanism of Environmental Regulation on Economic Growth

Environmental regulation policies restrict the development of highly polluting industries and promote their transformation and improvement through taxation, fines, and order suspensions. However, this compulsory measure has hindered the development of a considerable number of heavy industries and affected, for example, the refining industry and the building materials industry and the policy environment for the development of industries with high pollution and large economic volume, such as the chemical and pharmaceutical industries, has a restraining effect on the improvement of economic growth efficiency. In addition, the promulgation and implementation of environmental regulatory policies are authoritative and compulsory. The “one-size-fits-all” policy of local governments makes it impossible for economic entities in the market to optimize resource allocation through market mechanisms and to achieve optimal economic solutions. It also means economic Loss of growth efficiency. From another perspective, although environmental regulations increase the production costs of enterprises, they can force enterprises to improve management efficiency and maximize the use of capital, manpower, capital and other production factors, thereby improving the efficiency of production processes. In addition, environmental regulation policies can force production enterprises to carry out technological innovation by increasing pollution emission standards, improve production efficiency, and then increase economic growth efficiency and promote economic growth efficiency.

3.2 Mechanism of Environmental Regulation on Advanced Industrial Structure

An important measure of environmental regulatory policies is to limit the reduction of the output value or output of traditional industries such as high energy consumption and high pollution, and reduce the proportion of traditional industries through government industrial policies, compulsory measures, and incentives, or through the use of new technologies and methods. New business formats and new models promote the emergence and development of emerging industries, increasing the proportion of emerging industries, high-tech industries, and new model industries, and promoting the upgrading of the industrial structure. However, the cost effect of environmental regulation will reduce corporate performance and reduce corporate profits. It is difficult to maintain normal production and operation under the constraints of high-intensity environmental regulations. In the case of limited resources, the ability and willingness to choose to transfer to emerging industries through transformation Will reduce, thereby hindering the development of the highly polluting traditional industry to the advanced level of the industrial structure and inhibiting the advanced level of the industrial structure.

3.3 Analysis of the Synergy between the Impact of Environmental Regulation and Technology Innovation on the Quality of Economic Growth

On the one hand, environmental regulations and technological innovation will affect the cost of enterprises. Environmental regulation essentially transfers the externalities of environmental pollution to the inside of the company, incorporates the cost of pollution into the operating costs of the company, and forces the company to transform and upgrade through market mechanisms. Costs of resource-intensive companies. Although environmental regulation and technological innovation may have a positive impact on the quality of economic growth, due to the limited cost of the company, the technical transformation that was originally used to improve product quality

may be forced to be suspended due to environmental regulations. Environmental regulations and policies can only be faced directly, either by paying huge sewage charges, or by shutting down production and production, and even the technological transformation that has been made can no longer be industrialized. Under the circumstance of environmental regulatory constraints, with the increase of regulatory intensity, the impact of technological innovation on the quality of economic growth will decrease, and environmental regulatory companies will turn to economic rational measures such as “peak production” and “avoid inspection”. From this perspective, the impact of environmental regulation and technological innovation on the quality of economic growth is not synergistic.

On the other hand, environmental regulations can force companies to carry out technological innovations in order to adapt to the increasingly tight environmental protection policies of the government. The "Porter Hypothesis" proposed by Porter in 1991 systematically illustrates this view: "Scientifically designed environmental regulation policies can guide companies to carry out technological innovations, and the compensation effects brought by such technological innovations can offset related costs, thereby Enterprises are more competitive in the market. "Porter's theory of" cost compensation effect "is also increasingly supported and demonstrated by scholars at home and abroad. Then the impact of environmental regulation on economic growth can be explained as, as the intensity of technological innovation increases, technological innovation will promote the economic growth effect of environmental regulation: the level of technological innovation is low, and the positive impact of the economic quality of environmental regulation will weaken; technology After the level of innovation is raised to a certain level, the positive impact of the economic quality of environmental regulations will become more significant. From this perspective, environmental regulation and technological innovation can jointly promote the improvement of the quality of economic growth, and the impact of environmental regulation and technological innovation on the quality of economic growth is synergistic.

3.4 Measurement of the Comprehensive Quality Index of Economic Growth

When talking about the indicators and methods for measuring the quality of economic growth, existing research has sorted out the connotation, connection and difference between the quantity, speed of economic growth and the quality of economic growth from a theoretical point of view, and defined the extension of the quality of economic growth. In empirical research, Chao Xiaojing, Ren Baoping (2011) selected 28 basic indicators to measure the quality of economic growth. Wei Jie, Ren Baoping (2012) proceeded from the analysis framework of the quality of economic growth, by constructing six dimensions of connotation. The Economic Growth Quality Index (QEGI) measures and ranks the quality of economic growth in China's provinces and regions in 2010.

By sorting out relevant literature and applying the method of establishing a comprehensive index system, it has gradually become the mainstream in academic research in recent years. Although the academic community has not reached a completely unified conclusion on the construction of the quality indicator system for economic growth, in the overall logic, mainstream research is based on the speed, structure, efficiency, and stability of economic growth. Research on economic indicators and data.

On the basis of existing research and combining some prominent structural problems that emerged after the Chinese economy entered a new stage, this article has designed a plan that

includes efficient economic growth, advanced industrial structure, stable economic development, rational use of resources, and welfare. A measurement system of 20 basic indicators in five dimensions of change and fairness of distribution (see Table 4-1 for specific indicators).

Table 4-1 Construction of Quality Indicator System for Economic Growth

Dimension	Basic indicator	Calculation formula	Unit	Index attribute
Efficient economic growth (Effi)	TFP	--	--	+
	Labor productivity	Real GDP / Labour Employment		+
	Capital productivity	Real GDP / Total Investment in Fixed Assets	--	+
Advanced industrial structure (Stru)	Advance	Tertiary Industry Value Added / GDP	--	+
	Economic extraversion	Total import and export trade / GDP	--	+
	Investment rate	Gross capital formation / GDP	--	-
Economic development stability (Stab)	Economic growth volatility	(GDP growth rate of the year-GDP growth rate of last year) / GDP growth rate of last year	--	-
	Price volatility	Consumer price index	--	-
	Employment volatility	Urban registered unemployment rate	--	-
Reasonable use of resources (Reas)	Energy consumption per unit of GDP	Coal consumption / real GDP	--	-
	Power consumption per unit of GDP	Electricity consumption / real GDP	--	-
	Industrial wastewater discharge per unit of GDP	Industrial wastewater discharge / real GDP	--	-
	Industrial exhaust emissions per unit of GDP	Industrial exhaust emissions / real GDP	--	-
	Industrial solid waste emissions per unit of GDP	Industrial solid waste emissions / real GDP	--	-
Welfare changes and distribution equity (Fair)	GDP per capita	Real GDP per capita	RMB	+
	Engel coefficient of urban residents	--	--	-
	Engel coefficient	--	--	-

	of rural residents			
	Urban per capita greening area	Urban park area / urban population	Ha/10,000	+
	Ratio of rural residents 'net income to urban and rural residents' disposable income	Rural residents 'net income / urban and rural residents' disposable income ratio	--	+
	Labor compensation as a percentage of GDP	Labor compensation / GDP	--	+

The sample selected in this article is 17 years of panel data from 29 provinces (municipalities and autonomous regions), and a total of 493 observations were obtained. The data used are from the website of the National Bureau of Statistics, the provincial statistical yearbook, the China Labor and Employment Statistical Yearbook, China Statistical Yearbook of Science and Technology, China Tax Yearbook, China Financial Yearbook, EPS Macro Database, etc. For a few missing values, interpolation or average increase rate method is used to complete. For basic indicators, it can be obtained by simply calculating the factors of division, deflation, and elimination of nominal variables through the original data.

After establishing the basic index system for the quality of economic growth, this paper uses the principal component analysis method to reduce the dimension of the basic index. Before the dimensionality reduction process, pre-process the original indicators involved in Table 4-1, and take the inverse of the reverse indicator to ensure that the effect of the reverse indicator and the quality of economic growth are in the same direction. Use the averaging method for dimensionless processing.

After the basic indicators are pre-processed, principal components analysis based on the covariance matrix is performed on the normalized data. The principal components are selected based on the basic principle that the eigenvalue is greater than 1. The first three principal components are selected in this paper, and the comprehensive information amount reaches 82.11% of the original information. According to the calculation, the economic growth quality index of each province is obtained. Due to the large amount of data, the measured index results for some years from 2000 to 2016 are reported (see the appendix for detailed data over the years), as shown in Table 4-2 below.

Table 4-2 Measurement results of the economic growth quality index of provinces from 2000 to 2016 (in some years)

Province \ year	2000	2004	2008	2012	2016
Anhui	-0.619	-0.742	-0.804	-0.822	-0.444
Beijing	1.490	1.237	1.754	2.514	4.544
Fujian	1.092	0.661	0.510	0.679	1.471
Gansu	-0.907	-0.775	-0.693	-0.660	-0.429
Guangdong	0.600	0.873	0.965	1.136	1.725
Guangxi	-0.693	-0.732	-0.765	-0.584	-0.060
Guizhou	-1.023	-0.922	-0.804	-0.790	-0.712
Hainan	0.578	0.482	0.683	0.617	1.224
Hebei	-0.431	-0.375	-0.575	-0.480	-0.175
Henan	-0.634	-0.589	-0.602	-0.403	0.045
Heilongjiang	-0.092	0.000	0.096	0.400	0.823
Hubei	-0.634	-0.589	-0.602	-0.403	0.045
Hunan	-0.286	-0.261	-0.289	-0.160	0.420
Jilin	-0.428	-0.337	-0.259	0.123	0.459
Jiangsu	0.321	0.617	0.758	0.894	1.291
Jiangxi	-0.170	-0.364	-0.353	-0.170	0.002
Liaoning	-0.030	0.011	-0.150	0.138	0.489
Neimeng	-0.597	-0.778	-0.576	-0.432	0.120
Ningxia	-0.854	-0.880	-0.714	-0.437	-0.343
Qinghai	-0.922	-0.739	-0.939	-0.945	-0.658
Shandong	-0.062	-0.007	-0.078	0.269	0.533
Shanxi	-0.723	-0.641	-0.800	-0.648	-0.519
Shanxi	-0.765	-0.620	-0.625	-0.421	-0.277
shanghai	0.961	1.459	1.489	2.380	3.185
Sichuan	-0.586	-0.449	-0.447	-0.044	0.492
Tianjin	0.553	0.808	0.706	1.314	2.487
Yunnan	-0.659	-0.739	-0.620	-0.623	-0.387
Zhejiang	0.163	0.300	0.503	0.827	1.265
chongqing	-0.601	-0.609	-0.352	0.172	0.770

4. Variable Description and Data Source

4.1 Variable Generation

The interpreted variable in this paper is the comprehensive index of quality of economic growth (Qual). The 20 basic indicators are obtained by dimensionality reduction of the principal component analysis method. The related calculation process has been explained in the following sections.

Core explanatory variable: the strength of environmental regulation. The researchers do not have a complete consensus on the indicators that reflect the intensity of environmental regulations,

because it is difficult to obtain data that directly describe and reflect the intensity of environmental regulations, or the selection of unique indicators cannot systematically reflect the objective level of the intensity of environmental regulations. However, comprehensive existing research in China mainly reflects the strength of environmental regulations by selecting the following four types of proxy indicators: the first is to select the ratio of pollutant emissions to output value, or to construct a comprehensive indicator to measure the degree of pollution caused by unit GDP to measure the environment Regulatory intensity. The greater the amount of pollutant emissions per unit output value, the lower the intensity of environmental regulations; the smaller the amount of pollutant emissions per unit output value, the higher the intensity of environmental regulations. The second category is from the perspective of the government, using the number of environmental protection laws, regulations, regulations, and policies to measure the strength of environmental regulations. The greater the number of relevant environmental protection policies, the stronger the environmental regulation; the smaller the number of environmental protection policies, the lower the environmental regulation. The third category uses the level of economic development as a proxy indicator to measure the intensity of environmental regulations. For example, Lu Yang (2009) used GDP per capita as an indicator to measure the intensity of environmental regulations. The fourth category is the use of industrial pollution treatment investment as a measurement index. Zhang Cheng et al. (2011) obtained the investment in environmental pollution control per unit output value and used the ratio of industrial pollution control investment to industrial added value in each region as a measurement index. Shen Neng and Liu Fengchao (2012) divided the investment in industrial pollution control by the total industrial output value of each region as a measure: the greater the investment in industrial pollution control per unit of output value, the greater the intensity of environmental regulations, the smaller the investment in industrial pollution control per unit of output value, indicating the environment The smaller the regulatory intensity. Taking into account the objective rationality and data availability of the above-mentioned measurement indicators, the measurement indicators for environmental regulation in this paper draw on Zhang Cheng et al. (2011), and use the industrial pollution treatment investment in each region divided by the industrial added value of each region to obtain the environment for the unit industrial output value. Investment in pollution control is used as an indicator of the strength of environmental regulations.

Explanatory variable: technological innovation. Measuring the level of technological innovation can be cut from two perspectives. One is to measure the level of technological innovation input. For example, Tang Weibing and Fu Yuanhai (2014) used the ratio of R & D expenditure to GDP and the ratio of scientific research expenditure to GDP as indicators to measure technological innovation investment. The greater the technological innovation input in a certain area, the higher the level of technological innovation; the smaller the innovation input, the lower the level of technological innovation. The second is to measure the output of technological innovation, that is, the results of technological innovation. Domestic scholars generally use the amount of patent authorization as an index to measure the level of technological innovation in various regions. Patents can be divided into utility model patents, design patents and invention patents. Compared with invention patents, the other two patents are less difficult to implement, and as the domestic intellectual property system is becoming more and more complete, researchers and research institutions attach more and more importance to the protection of invention patents. Therefore, invention patents can best represent The level of technological

innovation in a region can be used as an effective measure. In addition, this article selects the amount of invention patents granted in each region, because the amount of invention patents granted is a valid recognition of relevant patents after inspection and evaluation by the competent authority, and can show the true level of technological innovation in the region to the greatest extent. Based on this, the measure of technological innovation choice in this article is the amount of invention patents granted by each province.

Control variables. The control variables used are: population dependency ratio (Depe), urbanization rate (Urba), fiscal expenditure as a proportion of GDP (Publ), and nationalization rate (Stat). Among them, the urbanization rate is calculated by the ratio of the urban population to the total population, which is used to control the impact of the level of urbanization of each province on the quality of economic growth; the proportion of fiscal expenditure to GDP is used to control the impact of the scale of government expenditure on the quality of economic growth; The population dependency ratio is equal to the sum of the dependency ratio of the elderly over 65 years old and the population dependency ratio of the children between 0 and 14 years of age to control the effect of the demographic structure on the quality of economic growth; the nationalization rate is calculated by the state-owned enterprise employees compared with the total urban employed population. It is used to control the influence of the degree of nationalization of each province (autonomous region, municipality) on the quality of economic growth.

Based on the availability of data and the timeliness of empirical results, the research object selected in this article is panel data of 29 provincial administrative units in China from 2000 to 2016. The original data mainly come from the National Bureau of Statistics, the EPS statistical database, the China Economic Network macro database, the "China Statistical Yearbook", "China Environmental Statistics Yearbook", "China Science and Technology Statistics Yearbook", "China Labor Statistics Yearbook", "China Industry" Statistical Yearbook, etc., using the average increase rate method to complete missing data in individual years. Table 5-1 is the symbolic representation of the explained variables, explanatory variables, and control variables, as well as descriptive statistics of logarithmic variables.

Table 5-1 Symbolic representation and descriptive statistics of the main variables

Variable	Variable meaning	mean	Standard deviation	Minimum	Max
Qual	Economic Growth Quality Index	0	1	-1.260	8.140
ERI	Natural logarithm of environmental regulation	2.590	0.750	-0.400	4.600
Inno	Natural logarithm of technological innovation	8.680	1.660	4.250	12.510
ERI_Inno	Natural logarithm of the cross term between environmental regulation and technological innovation	21.980	6.130	-4.200	35.850
Depe	Natural logarithm of population dependency ratio	3.600	0.200	2.960	4.050
Urba	Natural log of urbanization rate	-0.750	0.310	-1.460	-0.110
Publ	Natural logarithm of fiscal expenditure to GDP	-1.740	0.410	-2.670	-0.470
Stat	Natural logarithm of nationalization rate	-2.370	0.400	-3.700	-0.780

4.2 Model Settings

In order to empirically test the research hypothesis proposed above and analyze the impact of environmental regulation and technological innovation on the quality of economic growth from a quantitative perspective, the following basic regression model is established in this paper:

$$Qual_{it} = \alpha_0 + \alpha_1 ERI_{it} + \alpha_2 Inno_{it} + \alpha_3 Inno_{it} * ERI_{it} + \lambda Z_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Among them, $Qual_{it}$ is the quality index of economic growth in area i for t years, ERI_{it} is the intensity of environmental regulations in area i for t years, $Inno_{it}$ is the intensity of technological innovation in area i for t years, $Inno_{it} * ERI_{it}$ is the crossover term, Z_{it} is the control variable that affects the dependent variable in the model, μ_i is the unobservable region fixed effect, and ε_{it} is the unobservable error term.

In order to further examine the relationship between environmental regulation, technological innovation, and the quality of economic growth, this paper introduces a lagging period of the quality of economic growth, establishes a dynamic panel, and improves the efficiency and robustness of estimation.

This article establishes the following dynamic panel models:

$$Qual_{it} = \alpha_0 + \beta Qual_{it-1} + \alpha_1 ERI_{it} + \alpha_2 Inno_{it} + \alpha_3 Inno_{it} * ERI_{it} + \lambda Z_{it} + \mu_i + \varepsilon_{it}$$

Among them, $Qual_{it}$ is a lagging quality indicator of economic growth and represents the inertia trend of the quality of economic growth. μ_i is the unobservable regional fixed effect; ε_{it}

is the error term that obeys the same and independent distribution.

5. Analysis of empirical results

5.1 Data Stationarity Test

Due to the "false regression" problem caused by the non-stationarity of the panel data, the panel data also includes the time factor, so the paper conducts a data stability test. This paper uses panel data from 29 provinces in China. The common panel unit root test method is used to test the unit root for each variable. The test results are shown in Table 5-2.

Table 5-2 Unit root test of main variables

Variable	Fisher	LLC	Levinlin	Result
Qual	319.487***	-4.254***	-9.275***	Steady
ln ERI	115.761***	-8.168***	-12.931***	Steady
ln Inno	319.929***	-13.112***	-7.277**	Steady
lnERI_Inno	178.565***	-18.650***	-10.323***	Steady
ln Depe	380.716***	-7.952*	-7.227**	Steady
ln Urba	129.477***	-9.836***	-5.860**	Steady
ln Publ	140.782***	-5.946***	-8.008***	Steady
ln Stat	237.143***	-14.806***	-6.300**	Steady

Note: *, **, *** respectively represent that the estimation results are significant at the confidence level of 10%, 5%, and 1%

It can be obtained from Table 5-2 that each variable passes the unit root test at a significance level of 5%, which indicates that the panel data used here is a stable sequence, and the econometric model can be estimated in turn.

5.2 Analysis of Regression Results

Given that this article uses the balance panel data from 2000 to 2016 in 29 provinces in China as the research sample, before performing regression analysis, this article conducted the necessary model tests. To avoid losing too many degrees of freedom, this paper uses time trend variables to control time effects. In addition, we also conducted empirical tests of the random effect model and the fixed effect model. By analyzing the results of the Hausman test, the choice of the fixed effect model in this study is better than the random effect model.

Based on the above analysis, this article controls the individual effect by adding the dummy variables of the province and the time effect by adding the time trend variable. Using provincial balance panel data for a total of 17 years as a sample, the regression estimation is performed by a fixed effect model., and Table 5-3 lists the regression results for the national sample including the eastern region, the central region, and the western region:

Table 5-3 Impact of environmental regulations on the quality of economic growth: national and provincial regression results

	(1)	(2)	(3)	(4)
Variable	Whole	Eastern	Mid	West
ERI	0.634*** (0.164)	0.997*** (0.306)	0.700** (0.287)	-0.006 (0.139)
Inno	0.460*** (0.060)	0.589*** (0.115)	0.669*** (0.106)	0.187*** (0.051)
ERI_Inno	-0.087*** (0.019)	-0.119*** (0.034)	-0.094*** (0.032)	-0.0140 (0.017)
Depe	1.016*** (0.246)	1.566*** (0.421)	2.394*** (0.484)	0.683** (0.271)
Urba	-0.965*** (0.195)	-2.611*** (0.381)	-3.465*** (0.516)	0.250* (0.139)
Publ	0.339 (0.207)	1.539*** (0.422)	0.306 (0.376)	-0.070 (0.152)
Stat	-1.095*** (0.136)	-1.876*** (0.278)	-2.261*** (0.279)	-0.248** (0.103)
Cons	-10.110*** (1.328)	-12.940*** (2.764)	-21.108*** (2.300)	-4.445*** (1.144)
Time effect	Control	Control	Control	Control
Individual effect	Control	Control	Control	Control
Number of observations	493	187	136	170
R-squared	0.482	0.707	0.614	0.498
Hausman test	113.94***	320.45***	171.74***	63.45***

According to the regression results in Table 5-3, from the national level, environmental regulations and technological innovation have a significant positive impact on the quality of economic growth. For every 1% increase in the intensity of environmental regulations, the quality index of economic growth increases by 0.634; technological innovation For every 1% increase, the quality index of economic growth increases by 0.46; the symbol of the cross term between environmental regulation and technological innovation is negative, which means that under the constraints of environmental regulation, enterprises continue to increase their environmental governance investment in response to environmental protection standards stipulated by environmental regulation policies to achieve Environmental standards. Due to the limited cost of the enterprise, the technical transformation that was originally applied to improve product quality may be forced to be suspended due to environmental regulations, thereby inhibiting the promotion of technological innovation on the quality of economic growth.

In terms of different regions, the environmental regulations in the eastern region have a positive impact on the quality of economic growth, and the promotion of the quality of economic growth is greater than the national level. However, the western region has a negative impact on the

quality of economic growth, and the environmental regulations in the western region have a negative impact on the quality of economic growth. The impact of the quality of economic growth is not significant. What is the reason for this result? This paper believes that the reason for this result may be the threshold effect of the impact of environmental regulation on economic growth. The first is the threshold effect of the intensity of environmental regulation and the second is the threshold effect of technological innovation. The mechanism can be analyzed as follows: Due to the large differences in the economic development levels of the east, central, and western regions, the intensity of environmental regulations also varies greatly.

Generally speaking, in the eastern region where economic development is relatively high, the intensity of industrial structure adjustment, government environmental protection requirements, and public environmental awareness are relatively stronger than those in the central and western regions. Because the impact of environmental regulation on the quality of economic growth has a threshold effect, after the intensity of environmental regulation crosses a certain threshold, the impact on the quality of economic growth is greater, so the degree of impact on environmental regulation in the eastern region is positive. The central and western regions have relatively low environmental regulations and do not cross the threshold of environmental regulations. Therefore, they have a negative impact on the quality of economic growth, and the empirical results in the western region have failed the test at a significance level of 10%. The existence of the threshold effect remains to be discussed further.

5.3 Robustness Test

5.3.1 Transforming explained variables

Although this paper uses a fixed effect model to empirically analyze the impact of environmental regulation and technological innovation on the quality of economic growth, the results of empirical research are also explained and explained at the theoretical level. This kind of econometric model transforms the explanatory variables into a comprehensive index of the rationality of resource utilization and performs regression estimation.

Considering that the economic growth quality index is synthesized by 20 basic indicators through the PCA method, there is a certain amount of information loss during the process of dimensionality reduction. Therefore, this paper selects the dimension of resource utilization rationality, and combines the unit GDP energy consumption, unit the five basic indicators of GDP power consumption, industrial wastewater discharge per unit of GDP, industrial waste gas per unit of GDP, and industrial solid waste per unit of GDP were obtained to replace the comprehensive index of economic growth quality, and a robustness test was performed on empirical results. The comparison is as follows (Table 5-4):

Table 5-4 Robustness test (transformed explanatory variables)

	(1)	(2)
Variable	Quality of economic growth	Reasonable use of resources
ERI	0.634*** (0.164)	1.249*** (0.316)
Inno	0.460*** (0.060)	1.029*** (0.116)
ERI_Inno	-0.087*** (0.019)	-0.179*** (0.036)
Depe	1.016*** (0.246)	2.664*** (0.474)
Urba	-0.965*** (0.195)	-2.033*** (0.376)
Publ	0.339 (0.207)	-0.098 (0.399)
Stat	-1.095*** (0.136)	-2.262*** (0.262)
Cons	-10.110*** (1.328)	-24.880*** (2.559)
Time effect	Control	Control
Individual effect	Control	Control
Number of observations	493	493
R-squared	0.482	0.467
Number of id	29	29

Based on the empirical regression results in Table 5-4, we find that after transforming the explanatory variables (replacing the comprehensive index of economic growth quality with the comprehensive index of rationality in the use of resources), nationwide, environmental regulations and technological innovation have positive effects on the rational use of resources Influence, and the influence coefficient is greater. This empirical result further validates the empirical conclusions in the previous article, and the positive promotion effect of environmental regulation on the dimension of resource use rationality is more obvious.

5.3.2 Endogenous problems——systematic GMM model

Missing variables, measurement errors, and mutual causality often lead to endogenous problems. This paper selects the four control variables that have the closest impact on the problem in theory, but there is still the possibility of missing important control variables. This paper demonstrates that the 17-year balance panel data of 29 regions can partially alleviate the problem of missing variables. Second, there will be a certain gap between environmental regulations and technological innovation and real values, which will cause measurement errors. In addition, there may be mutual causality between environmental regulation and the quality of economic growth, and between technological innovation and the quality of economic growth.

To this end, this paper introduces a lagging period of the quality of economic growth, constructs a dynamic panel model, and uses the system GMM method for empirical testing. The

regression results are seen in Table 5-5:

Table 5-5 System GMM model regression results

Variable	The Quality of Economy Growth				
	model(1)	model (2)	model (3)	model (4)	model (5)
L.Qual	1.081*** (0.052)	1.080*** (0.057)	1.079*** (0.056)	1.079*** (0.056)	1.080*** (0.056)
ERI	0.0837** (0.034)	0.0834** (0.034)	0.0744** (0.035)	0.113*** (0.038)	0.114*** (0.037)
ERI_Inno	-0.009* (0.005)	-0.009* (0.005)	-0.008 (0.005)	-0.013*** (0.005)	-0.013*** (0.005)
Inno	0.064*** (0.016)	0.062*** (0.012)	0.057*** (0.011)	0.074*** (0.013)	0.070*** (0.015)
Urba		0.021 (0.095)	-0.022 (0.083)	0.121** (0.057)	0.133** (0.058)
Publ			0.097*** (0.019)	0.081*** (0.029)	0.075** (0.031)
Depe				0.381*** (0.118)	0.378*** (0.121)
Stat					-0.025* (0.046)
Cons	-0.494*** (0.108)	-0.459*** (0.152)	-0.278** (0.126)	-1.714*** (0.515)	-1.729*** (0.506)
Individual effect	Control	Control	Control	Control	Control
Observations	464	464	464	464	464
Number of id	29	29	29	29	29
AR (1)	0.004	0.004	0.005	0.005	0.005
AR (2)	0.534	0.530	0.517	0.458	0.459
Hansen	0.097	0.109	0.093	0.087	0.080

The regression results show that environmental regulation and technological innovation have a positive effect on the quality of economic growth. The coefficient of the crossover term is negative and passes the empirical test at a significance level of 1%. The empirical conclusions are consistent, further confirming the robustness of the aforementioned empirical results.

Threshold effect test

In the foregoing, it has been deduced from theory that there may be a non-linear relationship between environmental regulation and the quality of economic growth, and the intensity of technological innovation may affect the role of environmental regulation on the quality of economic growth. There are differences in the intensity of environmental regulation and the degree of technological innovation in various regions. This paper establishes a non-linear model of environmental regulation and the quality of economic growth. Using environmental regulation and technological innovation as threshold variables, the threshold panel model is used to further investigate the quality of environmental regulation and economic growth Threshold effect.

The principle of the "threshold effect" model is to divide the intensity of environmental regulation into several intervals and examine the different effects of environmental regulation on the quality

of economic growth in different intervals, similar to a piecewise function. Before Hansen proposed the panel threshold regression model, the treatment of similar problems was usually tested by grouping, but subjective groupings were usually not accurate and there was no uniform standard. Moreover, the group test cannot solve the problem of significance test of "threshold effect". The panel threshold model proposed by Hansen in 1999 can well solve the grouping problem.

Therefore, this paper adopts a panel threshold model to examine the impact of environmental regulation intensity on the quality of economic growth in each province, establish a model with environmental regulation intensity as the threshold variable (3), and establish a model with technological innovation level as the threshold variable (4), as shown below:

Model (3): (Take environmental regulation as threshold variable)

$$\text{Qual}_{ijt} = \alpha_0 + \alpha_{11}\text{ERI} \times I(\text{ERI} \leq v_1) + \alpha_{12}\text{ERI} \times I(v_1 < \text{ERI} \leq v_2) + \dots \\ + \alpha_{1n}\text{ERI} \times I(v_{n-1} < \text{ERI} \leq v_n) + \alpha_{1(n+1)}\text{ERI} \times I(\text{ERI} > v_n) + \alpha_2\text{Inno} + \lambda Z + \varepsilon_{it}$$

Model (4): (Take technological innovation as threshold variable)

$$\text{Qual}_{ijt} = \beta_0 + \beta_{11}\text{ERI} \times I(\text{inno} \leq \omega_1) + \beta_{12}\text{ERI} \times I(\omega_1 < \text{inno} \leq \omega_2) + \dots \\ + \beta_{1n}\text{ERI} \times I(\omega_{n-1} < \text{inno} \leq \omega_n) + \beta_{1(n+1)}\text{ERI} \times I(\text{inno} > \omega_n) + \beta_2\text{Inno} + \lambda Z \\ + \mu_{it}$$

5.3.3 Analysis of empirical results

(1) Take environmental regulations as threshold variables:

The existence of threshold effect is the premise of threshold model estimation. The threshold effect test of the results obtained by using the "Bootstrap" repeated sampling 500 times is as follows in Table 5-6:

Table 5-6 Panel Threshold Effect Test (Taking Environmental Regulations as Threshold Variables)

Model	F value	P value	BS Times	Critical value			Threshold	95% confidence interval
				1%	5%	10%		
Single threshold	28.559***	0.003	500	23.287	15.298	10.519	1.427 2.554	(1.393,1.469)
Double threshold	6.790	0.200	500	25.348	10.335	6.388		(1.554 ,4.162)

As can be seen from the table above, the P value with a single threshold is 0.003, and the P value with a double threshold is 0.2. At a significance level of 10%, only a single panel threshold model can be accepted. In addition, the panel threshold effect test also gives a single threshold estimate of 1.427 and a 95% confidence interval of (1.393, 1.469). After determining the threshold value, you can use the static panel model to estimate and get the regression results in the following Table 5-7:

Table 5-7 Panel threshold model estimation results using environmental regulation intensity as the threshold variable

Variable	Regression coefficients	Standard error	T value	P value	5% confidence interval
Inno	0.256***	0.047	5.46	0.000	(0.164, 0.349)
Urba	-0.986***	0.191	-5.16	0.000	(-1.363, -0.611)
Publ	0.308	0.203	1.51	0.131	(-0.092, 0.707)
Stat	-1.051***	0.134	-7.85	0.000	(-1.315, -0.788)
Depe	0.838***	0.245	3.43	0.001	(0.357, 1.319)
ERI_1 (ERI $\leq \nu$)	-0.038	0.160	-0.24	0.812	(-0.353, 0.276)
ERI_2 (ERI $> \nu$)	0.417***	0.135	3.09	0.002	(0.152, 0.683)
Cons	-7.631***	1.282	-5.95	0.000	(-10.150, -5.112)

The estimation results show that when the intensity of environmental regulation is lower than 1.427, the index of environmental regulation intensity increases by 1%, the comprehensive index of quality of economic growth decreases by 0.038%, and the P value is 0.017, indicating that environmental regulation has a significant impact on the quality of economic growth at a significance level of 5%. The impact is negative. However, when the intensity of environmental regulation is higher than 1.427, the impact of the intensity of environmental regulation on the comprehensive index of quality of economic growth is 0.417, and the level of P value is significant. This regression coefficient is acceptable at the 5% significance level. In this interval, The impact of environmental regulation on the quality of economic growth is a positive promotion effect. This result indicates that the effect of environmental regulation intensity on the quality of economic growth does have a threshold effect. After the intensity of environmental regulation exceeds a certain threshold value, the impact of environmental regulation on the quality of economic growth changes from inhibition to a significant promotion effect.

(2) Take technological innovation as the threshold variable:

From the theoretical mechanism in Section 3.2 and the empirical results in Chapter 5, it can be seen that technological innovation has a significant impact on the quality of economic growth, and the level of technological innovation will also affect the promotion effect of environmental regulations on the quality of economic growth. Therefore, this article further Establish the threshold value of technological innovation level, and examine the impact of environmental regulations on the quality of economic growth in different technological innovation levels seen in Table 5-8:

Table 5-8 Panel threshold effect test (with technological innovation as the threshold variable)

Model	F value	P value	BS Times	Critical value			Threshold	95% confidence interval
				1%	5%	10%		
Single threshold	62.035***	0.003	500	36.918	21.596	16.342	8.326 11.035	(8.132, 8.423) (10.788, 11.046)
Double threshold	31.509**	0.017	500	43.194	15.469	8.750		
Triple threshold	6.790	0.167	500	23.356	13.495	9.336		

The panel threshold effect test results show that at the 5% significance level, it can be determined that there are two threshold values for the model, 8.326 and 11.035, both of which are within the 95% confidence interval.

On the basis of the above threshold value and threshold number tests, this article establishes a panel threshold model again to empirically test the relationship between environmental regulation and the quality of economic growth as shown in Table 5-9.

Table 5-9 Panel Threshold Model Estimation Results with Technological Innovation Level as Threshold Variable

Variable	Regression coefficients	Standard error	T value	P value	5% confidence interval
Inno	0.180***	0.053	3.40	0.001	(0.076, 0.284)
Urba	-0.957***	0.181	-5.29	0.000	(-1.313, -0.601)
Publ	0.581***	0.199	2.93	0.004	(0.191, 0.971)
Stat	-1.158***	0.127	-9.10	0.000	(-1.408, -0.908)
Depe	0.819***	0.231	3.54	0.000	(0.364, 1.273)
ERI_1 ($Inno \leq \omega_1$)	-0.172***	0.037	-4.70	0.000	(-0.244, -.100)
ERI_2 ($\omega_1 < Inno \leq \omega_2$)	-0.080	0.052	-1.55	0.121	(-0.182, 0.021)
ERI_3 ($Inno > \omega_2$)	0.129***	0.064	2.03	0.000	(0.004, 0.256)
Cons	-6.724***	1.282	-5.24	0.000	(-9.243, -4.204)

The estimation results show that when the level of technological innovation is not high, the impact of environmental regulation on the quality of economic growth is negative. As the level of technological innovation improves, the side effects of environmental regulation on the quality of economic growth gradually decrease, and after the level of technological innovation crosses 11.035 Environmental regulations have significantly promoted the quality of economic growth. When technological innovation is at a low level, the added value of products produced by enterprises is relatively small, there are fewer opportunities to create excess profits, and limited profit margins. Increasing the intensity of environmental regulations means that manufacturing companies need to purchase pollution control equipment or supporting purification devices. The purchase or update of equipment and equipment is an important part of corporate environmental governance costs. Dealing with environmental protection costs has increased the production costs of enterprises. This will further reduce the profit margin of enterprises that had limited profits. After the level of technological innovation is higher than the threshold of 11.035 and the level of technological innovation improves, the role of environmental regulations in promoting the quality of economic growth is also significantly enhanced. In general, the environment brings cost pressure to all manufacturing-type polluting enterprises. If the company's own environmental protection standards are to be met and the market has a leading edge, the company will necessarily carry out technological innovation, or introduce new technologies, or the original Technological transformation to ensure the reduction of intermediate emissions during the production process, research and development of green and environmentally-friendly finished products, and then gain more market share, to achieve the "compensation effect" of environmental regulations, expand the production scale of enterprises, enhance their competitiveness, and enhance their development and stability And thus promote high-quality economic growth. With the continuous improvement of technological innovation level, the "innovation compensation effect" of environmental regulation

will offset the "follow the cost" effect. This conclusion is also an important basis for government regulatory agencies to use administrative coercive measures to implement environmental regulation.

6. Main Conclusions and Policy Implications

This paper discusses the mechanism of environmental regulation and technological innovation on the quality of economic growth through theoretical analysis and the establishment of an empirical model. Firstly, the relationship between the three was theoretically sorted out, combined with the establishment of a comprehensive evaluation index system to clarify the connotation of the quality of economic growth, and the comprehensive index of the quality of economic growth was measured. Then by establishing a fixed-effects model, we empirically test how environmental regulation and technological innovation affect the quality of economic growth, and test the national, eastern, central, and western samples respectively. In addition, in the empirical test, by using data from 29 provincial panels in China from 2000 to 2016, a systematic GMM method was used to obtain robust empirical results for endogenous problems, consistent with the aforementioned model. Finally, this paper establishes a panel threshold model to empirically test the "threshold effect" of the impact of environmental regulation on the quality of economic growth. Through theoretical deduction and analysis of empirical results, this article draws the following main conclusions:

(1) From a national perspective, environmental regulations can significantly promote the quality of economic growth. However, from a regional perspective, there are differences in the impact of environmental regulations on the quality of economic growth. In the eastern region where environmental regulation is stronger, environmental regulation has a significant positive impact on the quality of economic growth. In the central and western regions, environmental regulation has a negative impact on the quality of economic growth. This shows that implementing a certain degree of environmental regulatory policies can effectively promote the quality of economic growth and promote high-quality economic growth. It also affirmed the rationality and necessity of the government's implementation of environmental regulatory policies to a certain extent. This shows that implementing a certain intensity of environmental regulatory policies can effectively promote the quality of economic growth and promote high-quality economic growth.

(2) Technological innovation has significantly promoted the quality of economic growth. The regression results based on the sample data show that technological innovation can promote the improvement of the quality of economic growth. If the level of technological innovation in a region is higher, the quality of economic growth in the region will be better.

(3) Under the constraints of environmental regulations, the promotion effect of technological innovation on the quality of economic growth will be reduced. The empirical results show that the crossover terms of environmental regulation and technological innovation are both negative in regression. This shows that with the strengthening of environmental regulations, companies have to take temporary measures to deal with "one-size-fits-all" regulatory policies. This behavior of enterprises will occupy a certain cost and inhibit the investment and promotion of new technologies and new production lines. It has an inhibitory effect on the improvement of the overall production technology level, hinders the upgrading of industrial structure, affects the stable development of enterprises, increases the volatility of economic growth, and then

suppresses the promotion effect of technological innovation on economic growth.

(4) There is a "threshold effect" on the impact of environmental regulations on the quality of economic growth. Firstly, the impact of environmental regulation on the quality of economic growth is promoted after the environmental regulation crosses a certain threshold. If this threshold is not exceeded, environmental regulation will inhibit the quality of economic growth. Secondly, environmental regulation will have a positive effect on the quality of economic growth. It must be established on the premise that the level of technological innovation crosses certain thresholds. In areas with low technological levels, it is mainly engaged in industries with high energy consumption, high pollution, and low added value. Environmental regulations have a greater impact on the region's economic growth, to a certain extent. It will undermine the stability of economic growth and negatively affect the quality of economic growth. In areas with high technological level, enterprises have the ability to resist policy risks and carry out environmental protection technological transformation on their own. The impact of environmental regulatory policies has instead promoted the improvement of the quality of economic growth.

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