ENVIRONMENTAL REGULATION, ENTREPRENEURSHIP AND ECONOMIC GROWTH: AN EMPIRICAL STUDY BASED ON THRESHOLD EFFECT TEST IN CHINA*

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Abstract

Based on panel data from 2000 to 2017 on 30 provinces in China, we analyse the threshold effect of environmental regulation on the quality improvement of economic growth in Eastern, Central, and Western China using a threshold regression model with entrepreneurship as the threshold variable. The conclusions are as follows: (1) With a low entrepreneurship index, environmental regulation inhibits the quality of regional economic growth. When the entrepreneurship index is at a middle level, the effect changes from an original adverse impact to a favourable impact, which is very significant in Eastern and Western China, but not significant in Central China. When entrepreneurship is highly active, environmental regulation is beneficial to economic growth quality in all regions, and environmental regulation can bring into play the function of “reversed mechanism” to promote economic growth quality. (2) The differences in entrepreneurship level in the three regions lead to regional heterogeneity of the threshold effect between environmental regulation and economic growth quality. Eastern China realizes a double dividend of environmental improvement and economic growth. The entrepreneurial activity in the Central and Western regions is a little far away from their threshold values, at which environmental regulation can produce a significant incentive effect. In conclusion, we put forward three suggestions to improve the entrepreneurial activity and fully realize the double dividend of environmental improvement and economic growth.

Keywords: Environmental regulation, entrepreneurship total factor productivity, threshold effect test

JEL Classification: O47

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1. Introduction

After 40 years of reform and opening up, China's economy has achieved rapid growth and has become an important engine of the world's economic growth. However, the environmental pollution problem appears prominent with input factors as the driving force. Without a strict environmental regulation¹ policy, it would have a great impact on economic growth quality. High-quality economic development does not only mean high quality of macro-economic development, but also emphasizes the concept of "high quality" of economic entities, high quality of technology and high quality of products from microeconomic activities. Innovation-driven development has recently become the most important feature of high-quality economic development (Santos, 2020). Many scholars are also using the total factor productivity (TFP) contribution rate to measure quality of economic growth (Wang, 2016; Sun, 2018). We also apply the TFP contribution rate to measure quality of economic growth. Innovation-driven economic development cannot be separated from talent support. Entrepreneurs are undoubtedly the "key" component of innovation-driven economic development, and entrepreneurship² has become an important driving force for high-quality economic development (Zeng *et al.*, 2015). By cultivating entrepreneurship capital, stimulating entrepreneurs' innovative behaviour, and optimizing the allocation of capital, labour, technology, and policy, it can continuously promote economic efficiency and the contribution of total factor productivity (TFP) to economic growth. On the other hand, improvement in economic efficiency and optimization of the growth power structure can gradually reduce the depletion of resources and the damage to the environment. Giving full play to entrepreneurship has become the key to high-quality economic growth (Audretsch, 2003). However, to promote the construction of ecological civilization means increasing the operating costs of enterprises. Thus, enterprises must carry forward excellent entrepreneurship, promote technological innovation, and give full play to the effect of "learning by doing" to maximize profits and cut down costs. Environmental regulation can encourage enterprises to optimize production behaviour and improve technical efficiency by means of formulating pollution emission standards. And at the same time, it can motivate enterprises to internalize environmental costs and prevent depletion of resources. Finally, a new economic growth model compatible with environmental protection incentives is acquired. In addition, there is a complex

1 Environmental regulation is a policy design implemented by the government to improve the quality of economic growth and control environmental pollution within a certain range.

2 From different angles, entrepreneurship has different connotations, but innovation and enterprising spirit are the main dimensions of entrepreneurship, and this paper focuses on the two dimensions.

non-linear relationship among environmental regulation, entrepreneurship and economic growth quality. Entrepreneurship is regionally heterogeneous. Differences in its activities will have an impact on the formulation of environmental policies, and then on economic growth quality. Therefore, it is of great practical significance to study how environmental regulation and entrepreneurship affect improvements in economic growth quality.

2. Literature Review

At present, the academic research on relationships among environmental regulation, entrepreneurship and economic growth mainly focuses on the following aspects.

The first aspect is the relationship between environmental regulation and economic growth. For a long time, scholars have made in-depth studies on the relationship and mechanism between environmental regulation and economic growth. Some scholars have found that there are a “cost-following effect” (Jaffe and Palmer, 1997; Ederington and Minier, 2003; Zhao, 2014) and an “innovation compensation effect” (Porter, 1995; Yang, 2014). The cost-following effect shows that boosting the intensity of environmental regulation may increase production costs, thus weakening competitiveness of enterprises. The innovation compensation effect means that enhancements in the intensity of environmental regulation will have a “reverse” effect on the mode of economic growth, stimulating enterprises to increase investment in innovation and improving technological innovation ability, thus boosting economic growth. These two effects have simultaneous impacts on economic growth, resulting in a non-linear relationship between environmental regulation and economic growth. Zhang (2011) explored the relationship between environmental regulation and technological progress of enterprises in China and found that, in Eastern and Central regions, there was a U-shaped relationship between environmental regulation intensity and technological progress of enterprises, that is, low environmental regulation intensity was not conducive to technological progress of enterprises, but that improvement in environmental regulation intensity could promote technological progress of enterprises. There was no significant relationship between environmental regulation intensity and technological progress of enterprises in Western regions, but his conclusion did not provide a “threshold” of hindering or promoting the technological progress of enterprises. Wang (2016) analysed the threshold effect of environmental regulation on economic growth from the perspective of human capital, pointing out that the impact of environmental regulation on economic growth through human capital channels is inverse. However, he did not take into consideration the impact of regional heterogeneity on environmental regulation and economic growth, which reduces the applicability of research conclusions. Chen (2018) used panel data of three northeastern provinces from 1990 to 2015 to calculate the comprehensive evaluation index of environmental regulation

through the value of entropy, and established a threshold regression model to explore the significant threshold effect between the intensity of environmental regulation and economic growth. When the intensity of environmental regulation exceeds the threshold, the restrictive effect of enhancement in the intensity of regulation on economic growth tends to weaken gradually. Therefore, regional heterogeneity makes the non-linear relationship between environmental regulation and economic growth more complex, and discussing the relationship between them has become a hot topic.

The second aspect is the relationship between entrepreneurship and economic growth. In recent years, scholars have conducted a lot of theoretical and empirical research into this, and have achieved plenty of results³. Baumol (1990) distinguished entrepreneurs' functions into productive activities, non-productive activities, and destructive activities. He emphasized that the reward structure entrepreneurs face, affecting the allocation direction of entrepreneurial functions, is the key to understand the contribution of entrepreneurs' productive activities to economic growth. Studies by McMillan and Woodruff (2002) and by Gries (2010) on economic transformation in developed countries showed that transformation of the economic growth mode was mainly the result of a recombination of technological innovation and a recombination of production factors, driven by entrepreneurship. Ferreira *et al.* (2017) believed that entrepreneurship was the basis of enterprise competition and innovation, as well as the foundation of national economy. In order to create a more active environment for entrepreneurship, corresponding incentives must be given to improve production efficiency and entrepreneurial innovation. Li (2019) believed that we must rely on the intermediary role of entrepreneurship between technological innovation and high-quality economic development, so that R&D investment can promote high-quality economic development. Therefore, entrepreneurship plays an integral and "central" role in promoting high-quality economic development.

Unfortunately, although scholars have studied the impact of environmental regulation and entrepreneurship on economic growth, the conclusions are not convergent. One possible reason is that the methods for measuring environmental regulation intensity, entrepreneurship index and economic growth quality are inaccurate. However, there are few studies on the quality of economic growth from the perspective of environmental regulation. And there are even fewer studies which have incorporated environmental regulation and entrepreneurship into a research model to explore their mechanisms for promoting economic growth quality. So, is there a threshold effect among environmental regulation, entrepreneurship and the quality of economic growth? Are there regional heterogeneity differences in their mechanism of high-quality economic development

3 Wennekers and Thurik (1999), Jiang (2015) and Zeng (2015) made a detailed literature review.

in Eastern, Central, and Western regions⁴? Can environmental regulation bring into play the function of “reversed mechanism” to promote economic growth quality?

To this end, we analyse the impact of environmental regulation and entrepreneurship on economic growth quality. Based on panel data for 30 provinces (Tibet and Taiwan are not included) from 2000 to 2017, the environmental regulation and entrepreneurship indices are calculated using the entropy method and the factor analysis method, and the panel regression method is used to analyse the relationship of variables. This empirical paper analyses the threshold effect for economic growth quality with entrepreneurship as the main threshold variable, calculates the threshold value and then explores the relationship among the variables to provide suggestions for choosing appropriate environmental regulation intensity and entrepreneurship level to promote economic growth quality.

3. Econometric Model and Data Explanation

3.1 Data sources

The research data are mainly derived from statistical databases such as “China Statistical Yearbook”, “China Environmental Yearbook”, “China Science and Technology Statistical Yearbook”, “China Labour Statistics Yearbook”, *etc.* Some missing data are complemented by means of provincial statistical yearbooks, social development communiqués and the Wind database. To ensure the accuracy of the data and reduce the impact of price factors on regression results, we take 2000 as the base year.

3.2 Index design

Quality of economic growth. We use the contribution rate of TFP to economic growth (TEGP) as the main index to measure the quality of economic growth. The specific methods are as follows: in order to reduce the impact of the unobservable regional heterogeneity on the measurement results, we apply the cross-logarithmic stochastic frontier production function from a heterogeneity perspective by Yu (2017) and Kumbhakar (2000). To improve the accuracy of total factor productivity, we use the depreciation rate of 9.6% in Zhang’s (2004) algorithm to calculate the capital stock of each province respectively with 2000 as the base year; then the TFP growth rate is decomposed into the production efficiency growth rate (TEC), the technological progress rate (TP), and the scale efficiency

4 The Eastern region includes nine provinces: Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Guangzhou, Fujian and Hainan. The Central region includes eleven provinces: Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, Henan, Anhui, Jiangxi, Hunan, Hubei and Inner Mongolia. The West includes ten provinces: Guangxi, Sichuan, Chongqing, Guizhou, Yunnan, Shanxi, Gansu, Qinghai, Ningxia and Xinjiang.

(SE); finally, the ratio of the TFP growth rate to economic growth rate is used to measure the TEGP. According to the time-varying stochastic frontier production function model by Battese (1992), the initial economic growth model is set as follows:

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_t t + 1/2 \beta_{KK} (\ln K_{it})^2 + 1/2 \beta_{LL} (\ln L_{it})^2 + \beta_{KL} (\ln K_{it})(\ln L_{it}) \\ &+ \beta_{Kt} (\ln K_{it})t + \beta_{Lt} (\ln L_{it})t + 1/2 \beta_{tt} t^2 + v_{it} - u_{it} \\ u_{it} &= u_i \exp[-\eta(t-T)] \sim iidN^+(\mu, \sigma_\mu^2)\end{aligned}\quad (1)$$

where Y_{it} represents the economic output in the year t of the province i , K and L the input of capital and labour respectively, β the parameter to be estimated and η the time-varying parameter of technical efficiency, $v_{it} - u_{it}$ the synthetic error term ε_{it} , v_{it} the random interference term, which is used to measure the degree of inefficiency of the system and obeys the standard normal distribution; and u_{it} is the technical loss error term, which reflects the degree of technical inefficiency and obeys the zero truncated semi-normal distribution. On the basis of estimating the stochastic frontier production function model and referring to Kumbhakar's (2000) method for calculating and decomposing the TFP growth rate, the production function derives the time t . For simplicity, the subscript it is omitted.

$$\dot{Y} = \frac{\partial \ln f(Y)}{\partial t} = \frac{\partial \ln f(X, t)}{\partial t} + \sum_j \frac{\partial \ln f(X, t)}{\partial \ln X_j} \frac{\partial \ln X_j}{\partial X_j} \frac{dX_j}{dt} - \frac{\partial U}{\partial t} \quad (2)$$

$$\dot{TFP} = \dot{TEC} + TP + SE \quad (3)$$

$$TP_{it} = \frac{\partial \ln Y_{it}}{\partial t} = \beta_t + \beta_{it} t + \beta_{Lt} \ln L_{it} + \beta_{Kt} \ln K_{it} \quad (4)$$

$$TEC_{it} = E \left[\exp(-u_i) | (v_i - u_i) \right] \quad (5)$$

$$SE = (E - 1) \sum_j \frac{E_j}{E} \dot{X}_{ij} \quad \text{where } j = K, L \quad (6)$$

$$E_K = \beta_K + \beta_{KK} \ln K + \beta_{KL} \ln L + \beta_{Kt} t \quad (7)$$

$$E_L = \beta_L + \beta_{LL} \ln L + \beta_{KL} \ln K + \beta_{Lt} t \quad (8)$$

In the above formulas, $\dot{TFP}$, $\dot{TEC}$, TP and represent, respectively, the growth rate of TFP , the change rate of production efficiency, the rate of technological progress, and the improvement in scale efficiency. $\dot{X}_{ij}$ represents the growth rate of the input j of the province i and j is K or L . E represents elasticity of scale, $E = E_K + E_L$.

When time changes from t to $t+1$, the economic growth can be approximately decomposed into:

$$\frac{f(X_{i,t+1}) - f(X_{i,t})}{f(X_{i,t})} \approx \sum_{i=1}^n \frac{f(X_{i,t+1}) - f(X_{i,t})}{f(X_{i,t})} + \frac{TFP_{t+1} - TFP_t}{TFP_t} \quad (9)$$

Setting $TEGP_{i,t+1}$ as the contribution rate of TFP to economic growth in the period $t+1$, the percentage form is shown in Equation 10:

$$TEGP_{i,t+1} = \left(\frac{TFP_{t+1} - TFP_t}{TFP_t} \right) \left/ \left(\sum_{i=1}^n \frac{f(X_{i,t+1}) - f(X_{i,t})}{f(X_{i,t})} + \frac{TFP_{t+1} - TFP_t}{TFP_t} \right) \right. \times 100 \quad (10)$$

Environmental regulation (ER). At present, considering the heterogeneity of regional economic structure and the availability of data, we use Sun's (2019) research program to synthesize the environmental regulation index from the perspective of investments and costs. To build environmental regulation indicators from the perspective of investments, environmental regulation indicators are measured by the proportion of investments of each province in environmental pollution control to the GDP of each province and the proportion of investments of the whole country in environmental pollution to the GDP of the whole country. From the perspective of costs, environmental regulation indicators are based on the proportion of sewage discharge fees of each province to the GDP of each province and the proportion of sewage discharge fees of the whole country to the GDP of the whole country. The average value of environmental regulation intensity calculated from the two perspectives is taken as the final EV value of the region. The specific calculation methods are as follows:

$$EV_{it} = \frac{ER_{it}/GDP_{it}}{ER_t/GDP_t} \quad (11)$$

where EV_{it} is the location entropy index of environmental regulation in the period t in the province i ; the molecule is the amount of investment in environmental pollution control to the GDP or the proportion of sewage discharge fee in the period t ; and the denominator is the amount of investment in environmental pollution control in the period t or the proportion of sewage discharge fee in the period t to the GDP in the whole country. If $EV > 1$, it indicates that the level of environmental regulation in this province is higher; if $EV < 1$, it indicates that the level of environmental regulation in this province is lower.

Entrepreneurship (ENT). We use the research program of Zeng *et al.* (2015) for reference, and measures the comprehensive index of entrepreneurship from nine sub-indicators of innovation and enterprising spirit. In the factor analysis, the authors evaluate the principal component whose characteristic root is greater than 1, take the proportion

of the variance contribution rate of each principal component to the total variance contribution rate of the extracting factor as the weight, and finally obtain the comprehensive factor score of entrepreneurship. See Table 1 for specific index design.

Table 1: Evaluation index system of entrepreneurship

First-level indices	Second-level indices	Third-level indices	Calculation formula and explanation	Unit
Innovation	Enterprise innovation investment	R&D investment intensity	R&D investment/GDP	%
		Number of R&D personnel per 10,000	Number of R&D personnel/resident population	Number of R&D personnel/10,000 people
	Enterprise innovation output	Authorized number of invention patents per 10,000	Authorized number/resident population	Pieces/10,000 people
		Output value rate of new products	Output value of new products of industrial enterprises above designated size/total output value of industries above designated size	%
		Proportion of export value of high-tech enterprises to income	Total export/sales revenue of high-tech enterprises	%
Enterprising spirit	Amount of private enterprises	Number of private enterprises/total population	Number of private enterprises per 10,000 people	Number of private enterprises/10,000 people
	Number of individual enterprises	Number of individual enterprises/total population	Number of individual enterprises per 10,000 people	Number of individual enterprises/10,000 people
	Self-employment rate of private enterprises	Number of employees employed by private enterprises/total employed	The self-employment ratio is the proportion of senior managers in all employees in private enterprises	Number of senior managers/10,000 people
	Self-employment rate of individual enterprises	Number of individuals employed/total employed	The self-employment ratio is the proportion of senior managers in all employees in individual enterprises	Number of senior managers/10,000 people

Sources: Zeng *et al.* (2015) China Statistical Yearbook, China Science and Technology Statistics Yearbook and Statistical Communiqué

Table2: Statistical description of variables

Variable	Variable specification	Eastern				Central				Western			
		Average	Standard deviation	Minimum	Maximum	Average	Standard deviation	Minimum	Maximum	Average	Standard deviation	Minimum	Maximum
InTEGP	Contribution rate of TFP to economic growth	3.9093	0.0827	3.7734	4.1786	3.6520	0.0550	3.2961	4.0122	3.3822	0.1107	3.2678	3.6231
InEV	Environmental regulation intensity index	-0.1336	0.0410	-0.1889	-0.08262	0.0548	0.0875	-0.1487	0.1877	-0.0406	0.0430	-0.1006	0.0452
InENT	Comprehensive evaluation index of entrepreneurship	-2.8894	0.0324	-3.1701	-2.0162	-3.2427	0.1051	-3.7187	-2.4939	-3.8683	0.1804	-4.1914	-3.1818
InPK	Per capita physical capital	11.7627	0.6207	11.4593	13.7343	11.3937	0.1733	11.1958	11.7347	11.1145	0.0507	11.0570	11.2285
InSTRU	Industrial structure	0.1554	0.2145	-0.0283	0.5752	-0.1165	0.1830	-0.2839	0.2295	-0.4429	0.1953	-0.6940	0.0404
InOPEN	Opening-up level	-1.2302	0.1103	-1.4040	-1.034	-1.6150	0.1712	-1.9250	-1.3693	-2.2486	0.0879	-2.1070	-1.7423
InHR	Human capital level	2.2125	0.0389	2.1505	2.5982	2.1301	0.0892	2.0263	2.3468	2.0409	0.1005	1.8058	2.2129
InUL	Urbanization level	-0.5540	0.0870	-0.6383	-0.2389	-0.7434	0.0840	-0.7796	-0.5062	-0.8956	0.2694	-1.5876	-0.5281
InML	Marketization level	-1.0433	0.1064	-1.1950	-0.7497	-0.7570	0.0463	-0.9216	-0.7134	-0.8212	0.0651	-0.9032	-0.7362

Data sources: China Statistical Yearbook, China Statistical Yearbook on Environment, China Science and Technology Statistics Yearbook and Statistical Communiqué. Some data, such as InTEGP and InEV, were calculated by the authors.

Control variables. This paper also studies the impact of other control variables on economic growth quality, such as physical capital (*PK*), which is expressed by the logarithm of per capita physical capital; the ratio of physical capital stock to the number of employees at the end of the year in this region is calculated using a 9.6% depreciation rate as per capita physical capital; industrial structure (*STRU*) is measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry in each province; we use total exports (converted at the current exchange rate) as a percentage of GDP to measure the level of opening-up (*OPEN*). The level of human capital (*HR*) is measured using the average years of education, which is calculated as $(6a+9b+12c+15d)/L1$, of which *a*, *b*, *c*, and *d* are the number of primary school graduates, junior high school graduates, high school graduates, and higher education graduates respectively, and *L1* is the total number of the educated. The urbanization level (*UL*) is measured using the ratio of the urban population to the total population of the region; the market level (*ML*) is measured using the proportion of the state-owned unit employment to the urban employment, which is used as the reverse agency index to measure the impact of the market level on the quality of economic growth. All the variables are logarithmically processed, and then the model is effectively estimated. The descriptive statistics of variables are shown in Table 2.

3.3 Panel model construction

This paper focuses on the impact of environmental regulation and entrepreneurship on economic development quality. The model is as follows:

$$\ln TEGP_{i,t} = C_{i,t} + \gamma \ln EV_{i,t} + \delta \ln ENT_{i,t} + \sum_{n=1}^k \eta_n \ln X_{i,t,n} + \varepsilon_{i,t} \quad (12)$$

In Equation 12, $C_{i,t}$ is a constant; $EV_{i,t}$ is the comprehensive index of environmental regulation intensity of the province *i* in the period *t*; $ENT_{i,t}$ is the entrepreneurship index of the province *i* in the period *t*; *X* is a group of control variables, including physical capital, industrial structure, opening-up level, human capital level, urbanization level, and marketization level. γ , δ and η represent the elastic values of each explanatory variable.

4. Empirical Results and Analysis

4.1 Regression analysis of panel data

Stability test of panel data. In this paper, the LLC test and the ADF-FKher test are used to check the unit root of panel data in order to avoid the “pseudo-regression” problem and to ensure stability of the test results. From the results, the LC and ADF-FKher test probabilities of the original sequence of each variable are less than 10%. The panel data are stable and pass the data stability test.

Multiple collinearity test of variables. Due to spatial restrictions, this study omits the table of correlation coefficients of explanatory variables. Test results show that the correlation coefficients between variables are not more than 0.5. Among the eight explanatory variables, the entrepreneurship index ENT has the highest correlation with human capital HR. The absolute value is 0.3662, followed by the correlation coefficient between physical capital PK and urbanization level UL, which is 0.3217.

The authors analyse results of the VIF test for the variance expansion factor of the 8 explanatory variables, and find the maximum VIF value to be 3.65, which is much less than 10. Therefore, the correlation coefficient analysis and variance inflation factor analysis of composite variables show that there exists no multi-collinearity among the explanatory variables.

Regression analysis of panel data. We use Stata 15.0 to get the Davidson-Mackinnon test statistic of 0.0122 and the corresponding P value of 0.9874. It accepts the original hypothesis and shows that there is no endogenous error in Model 12. In order to judge whether the research model should adopt a mixed OLS effects model or a random effects model or a fixed effects model, we use Stata 15.0 to conduct an F test, an LW test, and a Hausman test respectively to make a comprehensive judgment. Finally, we choose the fixed effects model to make the regression analysis. The results are shown in Table 3.

Table 3: Model selection and regression results among variables

	Eastern		Central		Western	
Variable	Parameter	T value	Parameter	T value	Parameter	T value
Model setting	FE model		FE model		FE model	
lnEV	0.1047***	5.6803	0.1883***	11.1227	0.0921*	1.9011
lnENT	0.2615***	10.8165	0.1201***	8.4412	0.1152***	5.1396
lnPK	0.1360**	2.1754	0.1860***	10.9519	0.2160***	8.0237
lnSTRU	0.0705***	3.2322	0.0651**	2.3068	0.0505*	1.7467
lnOPEN	0.0621**	2.2265	0.0492*	1.8260	0.0322	1.0588
lnHR	0.1255***	6.7467	0.0735**	2.2321	0.1672***	6.6323
lnUL	-0.2537***	-6.5078	-0.1200**	-2.4882	-0.1050*	-1.7770
lnML	-0.0926***	4.5632	-0.0526***	3.5641	0.0262*	-1.8518
F test (P value)	76.09 (0.0000)		76.09 (0.0000)		76.09 (0.0000)	
LM test (P value)	685.28(0.0000)		685.28(0.0000)		685.28(0.0000)	
Hausman test (P value)	623.57(0.0000)		623.57(0.0000)		623.57(0.0000)	

Note: *, **, *** are significant at the 10%, 5% and 1% levels, respectively, with T values in parentheses.

Source: Authors' own calculation.

Table 3 shows that the regression coefficients of $\ln EV$ and $\ln ENT$ are positive, which means that both environmental regulation and entrepreneurship have positive effects on high-quality development. The control factors except $\ln OPEN$ in the Western region have a very significant impact on high-quality economic development, as they are significant at least at the 10% level.

4.2 Panel threshold regression model results

The results of the panel regression analysis show that environmental regulation and entrepreneurship have a significant linear impact on the level of high-quality economic development. However, the impact of environmental regulation and entrepreneurship on high-quality economic development is multidimensional, and it may show different characteristics in different regions and periods; that is to say, there may be a significant non-linear relationship among the variables. In this paper, the threshold regression model (Hansen, 1999) is used to test the non-linear relationship, and the estimation results of the panel threshold model parameters are explored to draw more accurate conclusions. Thus, on the basis of a single threshold regression model, we can construct a case where there are two thresholds. The specific model is as follows:

$$\ln TEGP = \phi_0 + \phi_1 \ln EV \cdot 1(\ln ENT \leq \gamma_1) + \phi_2 \ln EV \cdot 1(\gamma_1 < \ln ENT \leq \gamma_2) + \phi_3 \ln EV \cdot 1(\ln ENT > \gamma_2) + \eta \ln X + e_1 \quad (13)$$

In this equation, $1(\cdot)$ is a demonstrative function. When the parentheses are true, the value is 1; otherwise, the value is 0. Based on the value of entrepreneurship $\ln ENT$, larger or smaller than the threshold value of γ_1 or γ_2 , ($\gamma_1 < \gamma_2$), the whole sample interval is divided into three zones, which correspond to the different slopes of the three groups, namely, ϕ_1 , ϕ_2 and ϕ_3 . The calculation process of the two threshold models is similar to that of a single threshold. The first threshold needs to be fixed and then the second threshold needs to be estimated.

Threshold effect test and threshold estimation. When $\ln TEGP$ is the explanatory variable of high-quality economic development, we estimate a single threshold, a double threshold and a triple threshold of entrepreneurship in the 30 provinces respectively. The results are shown in the table below.

Table 4: Threshold effect test results

Region	Threshold	F value	P value	Critical value			Threshold value (ENT Corresponding value)	95% Confidence interval
				10%	5%	1%		
Eastern	single threshold	18.9605***	0.0000	2.3475	3.7080	5.3554	−3.3269 (0.0359)	(−4.2350 −2.8425)
	double threshold	12.1915***	0.0000	2.6067	3.5179	5.9204	−2.0141 (0.1333)	(−2.6478 −1.2530)
	triple threshold	2.3216	0.1500	2.5926	4.6814	6.6636	—	—
Central	single threshold	9.5894***	0.0000	3.8787	4.7041	7.5723	−3.4003 (0.0333)	(−5.2093 −2.2215)
	double threshold	6.1682**	0.0400	3.1850	5.9119	7.0208	−2.5325 (0.0794)	(−4.2285 −2.0392)
	triple threshold	0.9104	0.2500	3.6512	5.6250	6.1115	—	—
Western	single threshold	6.0104**	0.0300	3.0098	5.8091	6.8598	−3.7274 (0.0240)	(−5.2053 −3.2176)
	double threshold	7.9947***	0.0000	3.2652	5.9140	7.9155	−2.2360 (0.1068)	(−3.5062 −2.1423)
	triple threshold	1.7295	0.1500	3.0635	5.2880	7.3053	—	—

Note: *, **, *** are significant at the 10%, 5% and 1% levels, respectively, with T values in parentheses.

Source: Authors' own calculation.

From Table 4, we can see that the single threshold and double threshold of entrepreneurship are significant at least at the 5% level. After that, the threshold estimates are calculated and tested. The two thresholds and the corresponding 95% confidence intervals are detailed in Table 4, which shows that the estimated entrepreneurship thresholds are −3.3269 and −2.0141 in the Eastern region, −3.4003 and −2.5325 in the Central region, and −3.7274 and −2.2360 in the Western region. However, the triple threshold of entrepreneurship is not significant at least at the 10% level, which it is not necessary to calculate; thus, we do not present the corresponding 95% confidence intervals.

Panel threshold model parameter estimation. The entrepreneurship index is used as the threshold variable to examine the threshold effect of environmental regulation on the quality of economic growth.

Table 5: Estimation of variable threshold model parameters of environmental regulation

Eastern		Central		Western	
Variable	Regression coefficient t value	Variable	Regression coefficient t value	Variable	Regression coefficient t value
lnPK	0.1109*** 6.2432	lnPK	0.1324*** 8.6178	lnPK	0.1660*** 8.3035
lnSTRU	0.0952** 5.3248	lnSTRU	0.0550** 2.1410	lnSTRU	0.0451* 1.7770
lnOPEN	0.0552*** 4.6178	lnOPEN	0.0352* 1.8178	lnOPEN	0.0183 1.0178
lnHR	0.1547*** 10.1890	lnHR	0.0920*** 6.9538	lnHR	0.1079*** 6.3537
lnUL	-0.1617*** -6.3312	lnUL	-0.0247* 1.7260	lnUL	-0.1286*** -5.7582
lnML	-0.0830*** -7.2583	lnML	-0.0782*** -3.7537	lnML	0.0111 1.0254
lnEV × 1(lnENT ≤ -3.3269)	-0.0135*** -2.9163	lnEV × 1(lnENT ≤ -3.4003)	-0.1746** -2.3007	lnEV × 1(lnENT ≤ -3.7274)	-0.0184 -1.1907
lnEV × 1(-3.3269 < lnENT ≤ -2.0141)	0.0511*** 4.2785	lnEV × 1(-3.4003 < lnENT ≤ -2.5325)	0.0122 0.9705	lnEV × 1(-3.7274 < lnENT ≤ -2.2360)	0.0442* 1.7552
lnEV × 1(lnENT > -2.0141)	0.3242*** 17.5245	lnEV × 1(lnENT > -2.5325)	0.2257*** 13.0501	lnEV × 1(lnENT > -2.2360)	0.1475*** 7.0996

Note: *, **, *** are significant at the 10%, 5% and 1% levels, respectively, with T values in parentheses.
Source: Authors' own calculation.

Regression results in Eastern China. As Table 5 shows, when $\ln ENT \leq -3.3269$, the regression coefficient of environmental regulation on the quality of economic growth is -0.0135 . When $-3.3269 < \ln ENT \leq -2.0141$, the influence of $\ln EV$ on $\ln TEGP$ changes from negative to positive, and the regression coefficient is 0.0511 . When $\ln ENT > -2.0141$, the regression coefficient is 0.3242 . The three above coefficients are significant at the 1% level. In summary, when the comprehensive index of entrepreneurship in Eastern China is in three different intervals, the impact of environmental regulation on high-quality economic development is quite different. When the index of entrepreneurship is low, improvement in environmental regulation intensity will have a negative impact on improvement in economic growth quality. As the level of entrepreneurship continues to improve above

the threshold value of -3.3269 , stricter environmental regulation will lead to better quality of economic growth. This incentive effect will then increase significantly. The reason is that the quality of macro-economic growth depends on micro-enterprise behaviour. A low degree of entrepreneurial activity means that the effective supply of real enterprises and entrepreneurs aiming at profits on the market is insufficient, which leads to a lack of motivation and a low level entrepreneurial innovation and activities. The increased intensity of environmental regulation will make the social benefits of enterprise innovation insufficient to offset the increased costs, which leads to an increase in production costs and a decrease in market competitiveness and economic growth. However, with the deepening reform and opening-up, the activity of private economy in the Eastern region is increasing. Through innovative and entrepreneurial activities, such as “introducing new products, developing new technologies, discovering new raw materials, exploiting new markets and forming new organizational forms”, entrepreneurs have been promoting the movement of the production boundary, improving the resource allocation efficiency, production efficiency and technological progress, stimulating entrepreneurs’ enthusiasm for innovation and entrepreneurship. Especially when the entrepreneurship index exceeds the threshold value of -2.0141 , the severity of environmental regulation will further enhance the “innovation compensation effect”, promote optimization of the supply-side structure, improve the level of total factor productivity, and ultimately achieve the win-win situation of economic growth quality and environmental protection. At present, the entrepreneurship index of the Eastern region is -2.0058 , and environmental regulation has a significant incentive effect on improvement in economic growth quality, which helps the realization of the double dividend of environmental improvement and high-quality improvement of economic growth.

Regression results in the Central region. When the entrepreneurship index is relatively low ($\ln ENT \leq -3.4003$), the regression coefficient of $\ln EV$ to $\ln TEGP$ is -0.1746 , which is significant at the 5% level. When the entrepreneurship is moderately active ($-3.4003 < \ln ENT \leq -2.5325$), the regression coefficient of $\ln EV$ to $\ln TEGP$ does not pass the significance test. When the entrepreneurship index is above the threshold value of -2.5325 , the regression coefficient is 0.2257 , which is significant at the 1% level. The reason is that the Central region, as the core area of China’s heavy industry, has mostly a medium to low level of manufacturing industry. Enterprises make profits by arbitrage and produce products by simple imitation, which is at the high cost of environment pollution. When the entrepreneurship is at a low level, improvement in environmental regulation intensity will lead to the “innovation compensation effect”, which is not enough to offset the “follow-cost effect” and thus is not conducive to high-quality economic growth. Only when the entrepreneurship index breaks through -2.5325 ,

will improvement in environmental regulation severity force entrepreneurs to transform from simple arbitrageurs and imitators to entrepreneurs in the sense of Schumpeter, so as to improve the quality of economic growth supported by excellent entrepreneurship in terms of technological innovation and recombination of production factors. At present, the average value of the entrepreneurship index in Central China is -2.5875 . Environmental regulation has a positive effect on improvement in economic growth quality, but has not reached the level of a significant incentive superposition effect.

Regression results in the Western region. When the entrepreneurship index is relatively low ($\ln ENT \leq -3.7274$), the influence coefficient of $\ln EV$ on $\ln TEGP$ is -0.0184 , but it does not pass the significance test. When the entrepreneurship index is at a medium level ($-3.7274 < \ln ENT \leq -2.2360$), the regression coefficient is 0.0442 , which is significant at the 10% level. When $\ln ENT > -2.2360$, the regression coefficient is 0.1475 , which is significant at the 1% level. In summary, only when the degree of entrepreneurial activity breaks through the threshold value of -3.7274 , can improvement in environmental regulation severity promote the economic development quality remarkably. The reasons are as follows: the economic foundation of the Western region is relatively weak; the dependence of the industry on resources is high; the opportunity costs for enterprises to produce at the cost of the environment are low; the economic growth quality cannot be improved effectively without a high level of entrepreneurship. Only by vigorously promoting enterprise with innovation and entrepreneurship as its core characteristics, can improvement in environmental regulation stimulate enterprises to pursue technological innovation activities, improve innovation ability, enhance the level of total factor productivity, and then realize the effective transformation of economic development from “extensive” to “quality”. At present, the average value of the entrepreneurship index in Western China is -2.7847 . Although environmental regulation has a significant positive effect on improvement in economic growth quality, the influence coefficient is still relatively small. Therefore, for the Central and Western regions, if environmental regulation wants to get rid of the dilemma of a small incentive coefficient, improving the activity of entrepreneurship will become the main breakthrough.

In addition, other factors have a very significant impact on high-quality economic development. Physical capital $\ln PK$, industrial structure $\ln STRU$, and human capital $\ln HR$ have significant positive effects on high-quality development of regional economy, which is consistent with conclusions of most scholars in this field (Wang, 2016; Sun, 2019; Li, 2018). This is in line with the fact that the current government attaches more importance to physical capital-driven economic growth in the Central and Western regions. The government implements the promotion of industrial structure upgrading, adopts an advanced policy, and offsets the “demographic dividend” with a human capital

dividend to impact on high-quality economic development (Lucas, 1988; Wang, 2016). What is worth special attention is that by comparing the human capital coefficient with the physical capital coefficient, we can find that the human capital in the Eastern region plays a more important role in high-quality economic development than the physical capital, while the human capital in the Central and Western regions plays a smaller role than the physical capital. The possible reason is that the marginal effect of the human capital dividend in the Eastern region is higher than that in the Central and Western regions. This shows that the economic growth in the Eastern region depends more on contribution of human capital and factor productivity. The economic growth in the Central and Western regions depends more on capital inputs. The driving force of human capital is weaker, and the quality of economic development needs to be further improved. The urbanization level $\ln UL$ has a significant inhibitory effect on the quality of economic growth in all the regions. The market-oriented level $\ln ML$ has a significant role in promoting the quality of economic development in the Central and Western regions, and it is not conducive to quality of economic development in the Western region.

5. Conclusions and Suggestions

5.1 Conclusions and discussion

This paper takes entrepreneurship as the threshold variable, and finds that there exist double threshold effects between environmental regulation and economic growth quality in Eastern, Central and Western China. Because of the differences in entrepreneurial activity in the different regions, environmental regulation plays a significantly different role in improving the economic growth quality. When the entrepreneurship index does not exceed the low threshold value, environmental regulation has an adverse effect on the improvement of economic growth quality, which is very significant in the Eastern and Central regions, but not significant in the Western region. When the entrepreneurship index crosses the low threshold, the effect changes from the original adverse impact to a favourable impact, which is very significant in the Eastern and Western regions, but not significant in the Central region. When entrepreneurial activity exceeds the high threshold, the impact of environmental regulation shows a significant incentive effect on economic growth quality, and environmental regulation can bring into play the function of “reversed mechanism” to promote economic growth quality, which is consistent with conclusions of most scholars in this field (Yang, 2014; Chen, 2018).

The differences in entrepreneurship levels in different regions lead to a regional heterogeneity of the threshold effect between environmental regulation and economic growth quality. The Eastern region has a higher index of entrepreneurship, and can

realize a double dividend of environmental improvement and economic growth quality improvement. The entrepreneurship indices of the Central and Western regions are at a medium level, and the entrepreneurial activity is a little far away from the threshold value at which environmental regulation can produce a significant incentive effect. Therefore, to give full play to the reciprocal effect of environmental regulation on high-quality economic growth, the key point is to improve the level of entrepreneurship in various regions.

5.2 Suggestions

Research shows that entrepreneurship has become an important driving force for China's high-quality growth of economy. We need not merely to adopt appropriate environmental regulation intensity, but also to take into account the level of entrepreneurial activity and economic development, industrial structure, level of opening-up, human capital and marketization level, so as to give full play to the mechanism of environmental regulation to drive high-quality economic growth.

Firstly, we should vigorously improve the level of entrepreneurship and expand effective supply of leading entrepreneurship, and should give full play to the organizational and leadership ability of entrepreneurs in resource allocation, innovation and realization of social value. By focusing on the screening of strategic industrial opportunities, technological innovation, industrial organization innovation and industrial structure optimization, and improving the competitive incentive mechanism, entrepreneurs can physically participate in industrial upgrading, and actively lead and drive the quality of economic growth by giving full play to entrepreneurship.

Secondly, we should take into account the spatial heterogeneity of entrepreneurial spirit and adopt appropriate promotion strategies. The Eastern region has a strong economic foundation. In order to cultivate the entrepreneurial spirit of the new era, we should make full use of the forward-looking strategic vision of entrepreneurs, carry out pioneering innovation activities in the fourth industrial revolution tide, improve the TFP contribution rate, and achieve high-quality economic development. For the Central and Western regions, we should change the incentive structure, improve the level of human capital, and break through constraints, and cultivate a large number of entrepreneurs in the sense of Schumpeter.

Lastly, we should strengthen policy coordination and improve the system effect so that excellent entrepreneurship can be fully promoted. We should establish a strong property rights protection system, strictly protect property rights according to the law, reduce the harm brought by opportunism, and "escort" entrepreneurs' rights and interests, so that entrepreneurs who create social wealth have stable psychological expectations

for the future. It is necessary to adopt macro-industrial policies and regulatory standards to guide enterprises or industries to upgrade, to reduce unnecessary government intervention in enterprises, especially when the government makes requests on operators in safety management, R&D investment and environmental regulation by means of the “visible hand”. If they do not violate rules, regulations and standards, we should not interfere with entrepreneurs in how to eliminate backward production capacity and in when to produce according to market supply and demand situation. We should abolish all practices and regulations that hinder fair competition on the market, improve the institutional environment so that it promotes fair competition, and give all types of enterprises the right to acquire factors of production and participate in fair competition in accordance with the law.

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