The Impact of Environmental Regulation on Development of Digital Economy:

A Perspective on Energy Endowment

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Abstract. Environmental regulations can force industries to undergo digital transformation, regulate market order, and lay a solid institutional foundation for the high-quality development of the digital economy. Based on the panel data of each province in China from 2011 to 2022, this paper uses the panel threshold model to study the relationship between environmental regulations, the digital economy, and energy endowment. The results show that the intensity of environmental regulations has a significant promoting effect on regional digital economic development; when the energy endowment reaches a certain level, the impact of environmental regulations on digital economic growth has a nonlinear characteristic of diminishing marginal effect; the influence of the intensity of environmental regulations on regional digital economic development has significant regional heterogeneity, and it is more obvious in the western regions. Therefore, in order to promote the growth of the digital economy, the government should further improve the environmental regulation system, implement differentiated regulation for different energy endowment regions, and promote regional cooperation and the development of environmentally friendly digital economy through regional experience mutual learning and certain policies towards the western regions.

Keywords: Environmental regulations, Digital economy, Energy endowment, Threshold model

1 Introduction

Sustainable development and the "dual carbon" goals are the core guiding principles for the high-quality development of China's economy. The digital economy, as a national strategy, has become a key driver for economic growth. Digitalization and green and low-carbon transformation are a mutually reinforcing unity and are the dual engines for achieving sustainable development. In the current context of significant differences in energy endowments, environmental regulations have become an important policy lever for connecting the two. To explore the sustainable growth path of the digital econ-

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omy, this paper intends to study the influence relationships among environmental regulations, the digital economy, and energy endowments and conduct empirical analysis, with the aim of proposing policy recommendations with practical guidance significance.

2 Literature Review

Domestic scholars have conducted in-depth studies. Zhang et al. [1] used panel data from 285 prefecture-level cities in China and found that environmental regulations have driven the exit of high-pollution and high-energy-consuming industries, creating space and resources for the development of the digital economy. With the deepening of research, Liu et al. [2] verified the existence of the inverted U-shaped relationship and found that when intensity of environmental regulations is low, regulations mainly eliminate backward production capacity through screening effects and promote digital economy growth; but when the intensity is too high, it will suppress the digital innovation of enterprises due to the crowding-out effect.

Regarding the impact of environmental regulations on energy endowment, on the one hand, strict environmental regulations will increase usage costs of traditional fossil energy, thereby forcing energy endowment-rich regions to accelerate transformation [3]; On the other hand, environmental regulations will also stimulate the research and application of renewable energy technologies, enabling regions with superior renewable energy endowment to gain new development advantages [4]. Lin et al. [5] found that the increase in the intensity of environmental regulations significantly reduced the economic contribution of traditional energy endowments, while improving development efficiency of renewable energy endowments; Zhang [6] also pointed out that environmental regulations, by influencing the spatial allocation of energy endowment, guide energy factors to flow to regions with higher energy utilization efficiency and wider application of digital technologies.

3 Theoretical Model and Research Hypothesis

Strict environmental standards can facilitate the transformation of traditional industries towards high-tech and low-pollution industries, promote integration and application of digital technologies. Meanwhile, by regulating market behaviors, the transaction costs can be reduced, thereby significantly promoting regional digital economy. Based on this, this paper proposes Hypothesis 1:

H1: Environmental regulations have a promoting effect on the development of regional digital economy.

The negative externalities resulting from enterprises' reliance on resource are more significant in regions with abundant energy resources. When environmental regulation corrects such externalities, due to regional differences, there will be different constraints and incentives. Hence, differentiated characteristics in promoting effect of environmental regulations will occur. Based on this, this paper proposes Hypothesis 2:

H2: The promoting effect of environmental regulations on the digital economy changes with the level of energy resources.

According to resource-based theory, different regions have significant differences in economic development levels and institutional environments, which will cause different transmission path and intensity of the promoting effect of environmental regulations. Based on this, this paper proposes Hypothesis 3:

H3: The effect of environmental regulations on the development of regional digital economy has regional heterogeneity.

4 Model Setting and Descriptive Statistics

4.1 Research Design

To demonstrate the relationship among environmental regulations and the digital economy, this paper constructs a regression model as shown in Equation (1).

$$DigEco_{it} = \beta_0 + \beta_1 ER_{it} + \beta Controls_{it} + \delta_i + \omega_t + \varepsilon_{it} \quad (1)$$

In model (1), DigEco represents the level of digital economic development, ER represents the intensity of environmental regulations, Controls represent a series of control variables, i represents the province, t represents the year, β is the coefficient to be estimated, δ_i is the province-fixed effect, ω_t is the time-fixed effect, and ε_{it} represents the random error term. To further explore the impact mechanism of environmental regulation under different levels of energy dependence, a threshold effect model was constructed as shown in Equation (2).

$$DigEco_{it} = \beta_0 + \beta_1 ER_{it} * I(Energy_{it} \le \gamma_1) + \beta_2 ER_{it} * I(Energy_{it} > \gamma_1) + \beta Controls_{it} + \delta_i + \omega_t + \varepsilon_{it} \quad (2)$$

4.2 Variable Selection

The dependent variable is the level of digital economy development, denoted as DigEco. By applying the entropy weight method, the paper fully considers the revenue of telecommunications business, the number of personnel in information transmission, computer services and software industry, the number of internet broadband access users, the number of mobile phone users and the inclusive finance index [7]. The core explanatory variable is the intensity of environmental regulation (ER), which is proportion of industrial pollution control investment to the secondary industry [8]. Energy endowment (Energy) is taken as the threshold variable (total fixed asset investment in the energy industry) [9].

Regarding the selection of control variables, this paper selects three variables: per capita GDP (nAvgGDP, the value of the regional economic total after averaging by the local total population at the end of the year), technological innovation (nrd, represented by the number of patent authorizations), and the degree of population aging (AG, the proportion of the elderly population to the total population).

4.3 Data Source and Descriptive Statistics

The data mainly come from different years' China High-tech Industry Statistical Yearbook, China Statistical Yearbook, China Environmental Statistical Yearbook and other sources. The descriptive statistics of each variable are shown in Table 1.

Table 1. Descriptive Statistics of Variables (N=360)

Variable	Mean	Std. Dev.	Min	Max
DigEco	0.177	0.129	0.006	0.870
ER	0.003	0.002	0.000	0.025
nrd	7.282	11.609	0.050	87.221
nAvgGDP	10.928	0.840	9.033	13.573
AG	11.185	2.874	5.473	20.016
Energy	0.029	0.025	0.004	0.148

5 Empirical Results

5.1 Benchmark Regression

The benchmark regression results of impact of environmental regulation intensity on digital economy development are shown in Table 2. The columns (1) to (4) in Table 2 represent the regression results after gradually adding control variables. The results show that the estimated coefficient of environmental regulation intensity is significantly positive, indicating that environmental regulation intensity has a positive promoting effect on the level of digital economy development, and Hypothesis 1 is correct.

Table 2. Baseline Regression Results (N=360)

Variable	DigEco			
	(1)	(2)	(3)	(4)
ER	5.933**(1.744)	3.257**(0.933)	3.567**(0.961)	3.205**(0.894)
nrd		0.005***(0.000)	0.005***(0.000)	0.005***(0.000)
nAvgGDP			0.077**(0.035)	0.103**(0.036)
AG				0.005**(0.002)
Time and Province Fixed	Yes			
Constant	0.059***(0.013)	0.053***(0.007)	-0.760*(0.372)	-1.072**(0.387)
R^2	0.785	0.877	0.880	0.882

Note: Robust standard errors are in parentheses; ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively, as in the table 3 below.

5.2 Robustness Tests

This paper conducts robustness tests using the following three methods. Firstly, the data for 2020 are excluded because the economy was severely impacted by the pandemic that year. Secondly, four municipalities with significant differences from other provinces (Shanghai, Beijing, Tianjin, and Chongqing) are excluded. Finally, to eliminate the influence of outliers, this paper further truncates all continuous variables at the 5% and 95% quantiles. The regression results of the three methods all indicate that the conclusion in the previous part has a certain degree of credibility.

Table 3. Robustness Test Results

Variable	(1)	(2)	(3)
	Excluding year2020 samples	Exclude municipalities directly controlled	Winsorizing
ER	2.524***(0.712)	3.578***(1.062)	3.091**(1.327)
Controls, Time and Province Fixed		Yes	
Constant	-0.937**(0.362)	-1.079**(0.421)	-0.444(0.414)
N	330	312	360
R^2	0.879	0.879	0.888

5.3 Threshold Effect Analysis

This paper first conducts threshold existence test. Considering energy endowment, the test results of the threshold value of the influence of environmental regulations on the development of the digital economy are shown in Table 4. Only a single threshold test passed. As can be seen from Table 5: it can be seen that when the energy endowment level reaches a certain threshold, the promoting effect of environmental regulations on the digital economy significantly weakens, and Hypothesis 2 holds.

Table 4. Results of Threshold Effect

Threshold	Threshold value	F-value	P-value	BS	Crit10	Crit5	Crit1
Single	0.010	19.340	0.083	300	18.406	21.029	26.435

Table 5. Regression Results of the Threshold Model

VARIABLE	Threshold value	$I(Energy_{it} \leq \gamma_1)$	$I(Energy_{it} > \gamma_1)$
ER	0.010	22.674***(5.338)	0.473(1.257)

5.4 Heterogeneous Analysis

The results of the heterogeneity regression are shown in Table 6. Environmental regulations' promoting effect is only significant in the western region. This might be due to

the fact that the eastern region has a strong economic foundation and a well-structured digital industry layout, while the western region has heavy pollution, poor regulation, and a single industrial structure, so the strengthening of environmental regulations can help accelerate digital transformation to reduce pollution emissions and improve production efficiency. Hypothesis 3 holds.

Table 6. Heterogeneity Analysis

Variable	(1)	(2)	(3)	(4)
	Eastern	Central	Western	Northeastern
ER	3.595(3.947)	-6.459(3.929)	1.708**(0.598)	0.544(2.720)
Constant	-0.614(1.536)	0.169(0.504)	-0.468(0.352)	0.451(0.467)
Controls			Yes	
Time and Province Fixed			Yes	
N	120	72	132	36
R^2	0.898	0.949	0.918	0.984

6 Conclusion and Suggestion

6.1 Conclusion

This paper conducts an empirical analysis based on data from 30 provinces in China from 2011 to 2022 to investigate the relationships among environmental regulations, digital economy, and energy endowment. The following conclusions are drawn: Firstly, environmental regulations have a promoting effect on the development of the digital economy; Secondly, as the level of energy endowment increases, the promoting effect of environmental regulations on the development of the digital economy weakens; Finally, the promoting effect of environmental regulations on the development of the digital economy is most evident in the western regions.

6.2 Recommendation

Based on this, this article puts forward the following policy suggestions: 1) Improve the environmental regulation system and empower the development of the digital economy. 2) For regions with medium or scarce energy resources, increase environmental standards to force the traditional energy industry to upgrade digitally. 3) Learn from each other and transfer experiences among regions, achieve balanced development.

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