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A Study of the High-Quality Development of Regional Economy Based on the Impact of Heterogeneous Environmental Regulation

Xiaoman Wang[1,*]

[1]*School of Business Administration, Jimei University, Xiamen, 361021, China*
[*]*Corresponding author*

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Abstract: As a pivotal link between economic progress and environmental preservation, green technological innovation assumes a critical role. Examining its impact and mechanisms on high-quality economic development is essential for resolving the delicate balance between economic growth and environmental conservation. Utilizing a bidirectional fixed-effects model with temporal and regional dimensions, this study empirically investigates the specific influence of green technological innovation on regional economic development in China, as well as the ramifications of environmental regulatory policies. The results indicate that green technological innovation significantly promotes high-quality economic development in China. Notably, command-and-control environmental regulations exhibit limited impact on green technological innovation, while market-driven incentives effectively propel enterprises towards engaging in green technological initiatives. To realize the vision of high-quality economic and social development, leveraging market-oriented regulatory tools, fostering enterprise enthusiasm for green technological innovation, and providing targeted policy incentives are imperative. This approach continually strengthens enterprise capabilities in green technological innovation, effectively harnessing its guiding role in driving high-quality economic development.

1. Introduction

Green technology innovation, as an emerging technology aimed at reducing energy consumption, mitigating pollution, and enhancing ecological conditions, possesses a dual advantage of achieving both economic efficiency and environmental protection. In January 2019, the Central Committee for Comprehensively Deepening Reforms deliberated and endorsed the "Guiding Opinions on Establishing a Market-Oriented Green Technology Innovation System." This initiative aligns closely with the directive outlined in the 19th National Congress of the Communist Party of China's report, which emphasizes the need to "construct a market-oriented green technology innovation system." Subsequently, in October 2020, the 5th Plenary Session of the 19th Central Committee of the Communist Party of China approved the "14th Five-Year Plan," wherein the pervasive incorporation of the core concept of "green" across various developmental sectors and aspects is evident. Green development has unequivocally become the primary developmental ideology and an indispensable approach underpinning modern economic high-quality development. Therefore, the questions arise: Can green technology innovation indeed stimulate high-quality economic development at the regional level? How should environmental regulatory policies for green technology innovation be strategically chosen? The answers to these inquiries hold significant theoretical and practical implications for sustaining continual and robust economic development and expediting progress in the journey toward high-quality development[1-3].

Presently, research on achieving high-quality economic development primarily concentrates on two facets: measurement methodologies and driving mechanisms. The assessment of high-quality economic development generally falls into two categories: one involves constructing an evaluative indicator system for high-quality economic development from diverse perspectives (Zhang, 2020), and the other centers on characterizing the quality of economic growth from a productivity viewpoint (Liu and Ling, 2020). Investigations into how to expedite high-quality economic development primarily emphasize an innovation-driven standpoint. Wang et al. (2019) employed the Weighted Slacks-Based Measure (WSBM) model based on network analysis to gauge the performance level of technology innovation-driven high-quality economic development across 30 provinces in China. Their study revealed that the overall performance level of technology innovation-driven high-quality economic development in China is relatively modest, with significant regional disparities. In a separate study, Shi (2020) found that artificial intelligence can pivot around social reproduction by innovating production modes, enhancing distribution efficiency, optimizing exchange patterns, propelling consumption upgrades, and aligning with emerging development principles such as innovation, coordination, green development, openness, and sharing. This alignment serves to address the escalating aspirations of the populace for an improved quality of life and comprehensive human development, thereby propelling high-quality economic development.

It is apparent that much of the existing research primarily centers on the interplay between environmental regulation and green technology innovation, or alternatively, the nexus between environmental regulation and high-quality economic development. The actual impact of green technology innovation on high-quality economic development has received comparatively less attention. Building on this observation, the present study takes the new development concept as its foundation to design a comprehensive evaluation indicator system for high-quality economic development. The entropy weighting method is employed to calculate its composite index, serving as a surrogate variable for high-quality economic development. Additionally, the study systematically examines the influence of heterogeneous environmental regulation on the effectiveness of green technology innovation. This endeavor aims to offer novel insights and perspectives that can contribute to advancing the level of high-quality economic development.

The primary contributions of this paper are as follows: (i) A thorough exploration of the question of whether enterprise-driven green technology innovation can indeed foster high-quality economic development at the regional level, thereby complementing existing research in the realm of the relationship between green technology innovation and high-quality economic development. (ii) The construction of a regional high-quality economic development index through the utilization of the entropy weighting method, facilitating a comprehensive and nuanced evaluation of the level of regional high-quality economic development. (iii) Origination from the standpoint of environmental regulatory policy choices for green technology innovation, the paper conducts a meticulous analysis and empirical testing of the specific impacts of command-and-control environmental regulation and incentive-based environmental regulation on green technology innovation. This endeavor aims to furnish a foundational basis for governmental formulation of effective environmental policies[4-7].

2. Research Hypothesis

2.1. Green Technology Innovation and High-Quality Economic Development

Green technology innovation is a pivotal means of achieving energy conservation and emission reduction while ensuring economic performance for enterprises. Enterprises can enhance energy utilization efficiency through innovations in green processes and technologies. Additionally, the introduction of green product innovations caters to consumer preferences for environmentally friendly products, thereby fostering green consumption. Research conducted by Peng and Li (2015) underscores that to optimize industrial structure and realize a green transformation, industries must transition from extensive to intensive growth, with pollution control shifting from high-carbon pollution to green emission reduction. The efficiency improvements and pollution reduction resulting from green technology innovation play a positive role in this transitional process. Original research by Yuan and Chen (2019) further accentuates that green technology innovation not only enhances production efficiency and reduces pollution emissions but also contributes to the improvement of energy use efficiency and sustainable development capabilities. Drawing from the analyses, the conjecture posits that the implementation of green technology innovation is instrumental in mitigating the prevalence of pollution-intensive sectors within the industrial composition. The accelerated shift toward a cleaner industrial structure is regarded as a pivotal factor contributing to the advancement of high-quality economic development within a given region. This hypothesis is formulated with an awareness of the intricate interplay between green technology innovation and the augmentation of regional economic quality.

H 1: Green technology innovation can significantly enhance the high-quality economic development of a region.

2.2. Environmental Regulation and Green Technology Innovation

Confronted with the positive role of green technology innovation in propelling the advancement of high-quality economic development at the regional level, encouraging enterprises to engage in green innovation activities and undertake green technological advancements have become imperative for sustaining continuous and robust economic development. Within the prevailing institutional framework, China's environmental regulatory policies continue to exhibit a predominant "command and control" orientation, with market incentives playing a supplementary role. Despite the stringent nature of command environmental regulations, they are amenable to decentralized goal-setting, compelling enterprises to upgrade their green technologies by intensifying pollution control efforts to comply with environmental emission standards (Xu and Cui, 2020). Tang et al. (2020) also underscore the stronger promotion effect of command environmental regulations on China's overall environmental efficiency. In contrast, market incentive-oriented environmental regulations offer greater flexibility, principally providing innovation incentives for enterprises through market-driven mechanisms such as taxes, subsidies, and pollution permits, thereby facilitating the internalization of external costs associated with environmental pollution. Grossman et al. (2018) posit that although pollution charges escalate business costs and diminish direct profits, they effectively induce managerial introspection on the deficiencies in their green development practices, subsequently promoting green innovation through internal incentive structures. Environmental regulations characterized by market mechanisms, exemplified by emission trading systems, can stimulate green innovation activities distinguished by green invention patents through the optimization of resource allocation and research and development initiatives. Consequently, relative to command environmental regulations, market incentive-based environmental regulations can effectively harness the proactive engagement of enterprises in achieving a balanced development between economic performance and environmental governance. Drawing upon these theoretical considerations, this paper posits the following hypotheses:

H 2: Throughout the course of expediting regional high-quality economic development, both command-and-control environmental regulations and market incentive-based environmental regulations demonstrate efficacy in stimulating enterprises to undertake green technology innovation, with the latter exhibiting a more pronounced impact[8-12].

3. Research Design

3.1. Baseline Model

To examine the specific impact of green technology innovation on high-quality economic development at the regional level, the baseline model in this paper is set as follows:

$$HED_{it} = a_0 + a_1 GTI_{it} + \beta Control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (1)$$

Where i and t respectively represent the province and year; HED represents the indicator for high-quality economic development at the regional level; GTI represents the indicator for green technology innovation; Control denotes the control variables; γ represents time-fixed effects, μ represents regional fixed effects, and ε represents the random error term.

3.2. Variable Definitions and Data Sources

3.2.1. Variable Definitions

(1) Dependent Variable: High-Quality Economic Development (HED)

Regarding high-quality economic development, some scholars have utilized single indicators such as total factor productivity (Sun and Lin, 2018) or labor productivity (Fan et al., 2020) for assessment. However, relying on singular metrics may lead to a partial evaluation outcome. Therefore, in alignment with the research methodology of scholars (Zheng and Ge, 2020; Ren, 2020; Wang and Tang, 2021), this paper adopts a comprehensive approach. It constructs an indicator system for high-quality economic development, centered around the five major new development concepts. A total of 17 indicators are selected for inclusion. After standardizing each measurement indicator, the entropy weighting method is employed to assess the level of high-quality economic development (HED) across 30 provinces (cities, regions) from 2010 to 2019. The specific structure of the indicator system is outlined in Table 1.

(2) Explanatory Variable: Green Technology Innovation (GTI)

Leveraging the "International Patent Green Classification List" introduced by the World Intellectual Property Organization (WIPO) in 2010, this study matches the annual count of green patent applications and grants at the provincial level. Consequently, this paper employs the number of patent applications as the primary explanatory variable, while the number of patent grants serves for robustness testing. The natural logarithm of the sum of one for both the number of patent applications and grants is computed. A higher resultant value indicates a heightened level of green technology innovation.

(3) Control Variables

To address potential bias in regression outcomes stemming from omitted variables, this study follows the approach outlined by Shangguan and Ge (2019) and Chen and Chen (2018). The model incorporates controls for urban characteristics and economically relevant variables. The key variables are summarized in Table 2.

Table 1: Comprehensive Evaluation Indicator System for High-Quality Economic Development.

One-tier Indicators	Secondary Indicators	Indicator Interpretation	Data Source
Innovative Development (A)	Proportion of research and development expenditure (A_1)	Technology spending / Local fiscal expenditure	China Statistical Yearbook
	Proportion of output in the technology market (A_2)	Technology market turnover / GDP	
	Number of patent applications (A_3)	Number of patent applications and grants	
Coordinated Development (B)	Proportion of public fiscal expenditure (B_1)	Public financial expenditure / GDP	China Statistical Yearbook
	Urban-rural structure (B_2)	Urbanization rate	
	Industrial structure (B_3)	The tertiary sector / GDP	
Green Development (C)	Public financial expenditure on environmental protection industry (C_1)	Financial expenditure on energy conservation and environmental protection industries / Total fiscal expenditure	China Statistical Yearbook
	Proportion of pollution control investment(C_2)	Investment in pollution control / GDP	
	Green coverage rate in built-up areas (C_3)	Forest coverage rate	
	Industrial pollution control (C_4)	Total investment in industrial pollution control / GDP	China Industrial Statistical Yearbook
Open Development (D)	Proportion of foreign investment (D_1)	Total foreign direct investment / GDP	China Statistical Yearbook
	Trade Dependence (D_2)	Total import and export volume / GDP	
	Tourism Openness (D_3)	Total tourism revenue / GDP	
Shared Development (E)	Education proportion ratio (E_1)	Education spending / Local fiscal expenditure	China Statistical Yearbook
	Public healthcare Expenditure (E_2)	Healthcare expenditure / Local fiscal expenditure	
	Urban-rural consumption gap (E_3)	Per capita consumption expenditure of urban residents / Per capita consumption expenditure of rural residents	
	Pension insurance coverage (E_4)	Pension insurance coverage rate	

Table 2: Variable Explanation.

	Variable	Indicator Interpretation	Data Source
Dependent Variable	Economic high-quality development (*HED*)	Entropy weighting method	(See Table 1 for details)
Independent Variable	Green technology innovation (*GTI*)	Logarithm of the number of green patent applications	National Intellectual Property Administration
Control Variable	Proportion of state-owned employees (*SOW*)	Number of state-owned employees / Total workforce	China Statistical Yearbook
	Degree of government intervention (*GOV*)	Fiscal revenue / GDP	
	Material capital investment (*R&D*)	R&D / GDP	

3.2.2. Data Sources

The sample under study in this research consists of panel data spanning the years 2012 to 2019 from 30 provinces, autonomous regions, and directly administered municipalities in China, excluding Xizang and the Hong Kong, Macao, and Taiwan regions. The data primarily derives from annual publications, including the "China Statistical Yearbook," "China Environmental Statistical Yearbook," and "China Industrial Statistical Yearbook," along with the statistical database from the China National Knowledge Infrastructure (CNKI) and CNRDS. Descriptive statistics for the key variables are presented in Table 3.

Table 3: The descriptive statistics results for the main variables.

Variable	sample size	Mean	Standard Error	Min	Max
HED	240	0.624	0.311	0.168	1.339
GTI	240	4.067	1.623	0.000	7.607
SOW	240	0.434	0.230	0.036	0.896
GOV	240	0.219	0.095	0.084	0.627
R&D	240	0.014	0.011	0.002	0.061

4. Empirical Analysis

4.1. Analysis of the benchmark regression results

This section examines the influence of green technology innovation on regional high-quality economic development. The specific regression results are presented in Table 4, where columns (1) to (3) depict fixed-effects models without time effects, and columns (2) to (4) represent two-way fixed-effects models. Following the Hausman test, we opt for a model with both time and regional fixed effects as the primary benchmark regression result. Subsequently, based on the constructed baseline model, we conduct the benchmark regression analysis. In columns (2) to (4), irrespective of the inclusion of control variables, the regression coefficient of GTI on HED is consistently positive and statistically significant at the 1% level. This implies that the implementation of green technology innovation significantly raises the level of regional high-quality economic development.

Concerning the control variables, the regression results for SOW and GOV on HED exhibit significant negative coefficients. This suggests that a higher proportion of state-owned enterprises (SOEs) and increased government intervention are adverse factors for the high-quality economic development of the region. In contrast, the regression result for R&D shows a significant positive coefficient, emphasizing the pivotal role of research and development (R&D) investment in augmenting regional high-quality economic development.

Table 4: Benchmark regression results.

Variable	Dependent Variable: *HED*			
	(1)	(2)	(3)	(4)
GTI	0.010**(0.004)	0.019**(0.009)	0.016***(0.006)	0.026***(0.006)
SOW			0.105***(0.035)	-0.100*(0.002)
GOV			0.009* (0.045)	-0.078*(0.025)
R&D			0.143** (0.035)	0.002* (0.035)
Constant	0.993***(0.009)	0.988***(0.023)	0.772***(0.108)	1.331**(0.620)
Time-fixed	NO	YES	NO	YES
Region-fixed	YES	YES	YES	YES
Sample Size	240	240	240	240
R^2	0.005	0.149	0.150	0.133

Note: "***, **, *" respectively indicate significance at the 1%, 5%, and 10% levels.

4.2. Robustness Tests

Table 5: Robustness Test.

Variable	Replace the dependent variable	Replace the independent variable	
	(1) *HED→HED1*	(2) *HED*	(3) *HED1*
GTI	0.008*** (0.005)		
GTI1		0.020*** (0.011)	0.008 *** (0.036)
SOW	-0.105*** (0.035)	-0.100* (0.062)	-0.189* (0.002)
GOV	-0.099* (0.035)	-0.079* (0.077)	-0.018* (0.135)
R&D	0.143** (0.075)	0.032* (0.011)	0.006* (0.009)
Constant	0.458** (0.054)	0.762*** (0.028)	0.346** (0.561)
Time-fixed	YES	YES	YES
Region-fixed	YES	YES	YES
Sample Size	240	240	240
R^2	0.341	0. 910	0.183

Note: "***, **, *" respectively indicate significance at the 1%, 5%, and 10% levels.

This study performs robustness tests by altering the measurement methods of the dependent and independent variables, as detailed in Table 5. In column (1), the results depict the regression outcomes when replacing the measurement method of the dependent variable. Specifically, a non-radial direction distance function is utilized to compute the green total factor productivity for each province. Following the construction method of green economic growth indicators proposed by Li and Xu et al. (2018), the growth rate of green total factor productivity is used as the new dependent variable, denoted as HED1. It is noteworthy that the regression coefficient of GTI on HED1 remains significantly positive at the 1% level. Columns (2) and (3) present the results when substituting the independent variable. Acknowledging potential biases in reflecting actual technological advancements with the use of patent applications, this paper further employs the number of patent grants (GTI1) as an alternative measure for robustness testing. Notably, regardless of whether the dependent variable is HED or HED1, an increase in GTI1 is conducive to regional high-quality economic development.

4.3. The Impact of Heterogeneous Environmental Regulation on Green Technology Innovation

The above analysis indicates that the implementation of green technology innovation can promote regional high-quality economic development. Therefore, to accelerate the process of high-quality economic development, it becomes crucial to enhance the innovation capability of enterprises in green technology. The "innovation compensation" effect of environmental regulations plays a significant role in advancing green innovation activities of enterprises. However, considering that different types of environmental regulation policies may have varying impacts on green technology innovation, this paper separately examines the effects of command-and-control environmental regulation and incentive-based environmental regulation on green technology innovation by testing their respective impacts. This analysis aims to provide a basis for the selection of environmental policies promoting green technology innovation. Furthermore, it examines the green technology innovation effects of command-and-control and market incentive environmental regulations, constructing the following model:

$$GTI_{it} = \lambda_0 + \lambda_1 CER_{it} + \pi Control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \tag{2}$$

$$GTI_{it} = \lambda_0 + \lambda_1 UER_{it} + \pi Control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \tag{3}$$

Table 6: The Impact of Heterogeneous Environmental Regulation on Green Technology Innovation.

Variable	*Command type (CER)*		*Market incentive type (UER)*	
	(1) *GTI*	(2) *GTI1*	(3) *GTI*	(4) *GTI1*
CER	0. 345 (0.036)	0.009 (0.162)		
UER			0.028* (0.125)	0.073* (0.071)
SOW	-0.035** (0.015)	-0.011* (0.022)	-0.023* (0.028)	-0.140* (0.063)
GOV	-0.090* (0.031)	-0.072* (0.072)	-0.028* (0.125)	-0.069* (0.277)
R&D	0.133** (0.025)	0.030* (0.021)	0.806* (0.009)	0.032* (0.011)
Constant	0.438** (0.051)	0.709** (0.020)	0.312** (0.061)	0.462** (0.018)
Time-fixed	YES	YES	YES	YES
Region-fixed	YES	YES	YES	YES
Sample Size	240	240	240	240
R^2	0.041	0. 110	0.163	0.761

Note: "***, **, *" respectively indicate significance at the 1%, 5%, and 10% levels.

In the specified model, CER represents command-and-control environmental regulation, quantified by the total cumulative effective quantity of local environmental laws, administrative regulations, and environmental standards restricting pollution emissions enacted by provincial People's Congress Standing Committees, People's Governments, and environmental protection agencies. UER signifies market incentive environmental regulation, measured by the logarithm of pollution fee revenue. To ensure the robustness of the outcomes, this study substitutes the dependent variable with the quantity of patented grants for empirical verification, with data sourced from the "China Environmental Statistics Yearbook." The regression outcomes are presented in Table 6, where the regression coefficient for command-and-control environmental regulation is positive but statistically insignificant. In contrast, incentive-based environmental regulation demonstrates a statistically significant positive impact on green technology innovation[13-17].

5. Conclusion

(1) Market-Oriented Approach

(2) Promotion of Market-Based Incentives. This involves increasing the market position of trading entities and stimulating the enthusiasm for quota trading. The objective is to motivate enterprises to proactively engage in energy conservation and emission reduction, thereby encouraging them to undertake green technology innovation activities.

(3) Emphasis on Collaborative Innovation. This collaborative approach aims to facilitate the mutual penetration and stimulation of human capital, technological capital, and financial capital, ultimately enhancing the conversion rate of green technology innovation outcomes.

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