International Journal of Allied Research in Economics
Volume.14, Number 6; November-December-2023;
ISSN: 2836-7995| Impact Factor: 5.93
https://zapjournals.com/Journals/index.php/ijare
Published By: Zendo Academic Publishing

IMPACT OF ENVIRONMENTAL REGULATION ON ECONOMIC GROWTH IN THE YANGTZE RIVER DELTA

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Article Info
Keywords: Yangtze River Delta, economic growth, high-quality development, environmental regulation, internal circulation, sustainability, policy-making, domestic demand, entropy method, multicollinearity.
DOI
10.5281/zenodo.10149029

Abstract
China's economic landscape faces significant challenges due to its detachment from the United States, resulting in a prolonged period of economic downturn. Responding to this situation, the Political Bureau of the CPC Central Committee has introduced the concept of "internal circulation," aimed at bolstering domestic demand and generating fresh impetus for economic growth. This research delves into the connection between environmental regulations and high-quality economic development. It conducts a thorough analysis of panel data spanning 18 years across 33 cities in the Yangtze River Delta region. The study employs the entropy method to construct comprehensive indices for measuring both high-quality economic growth and environmental regulation. Additionally, the research employs the variance inflation factor test to identify and address multicollinearity. The findings of this study hold substantial significance for policymakers striving to achieve economic development that is both high-quality and environmentally sustainable. The results underscore that environmental regulation can serve as a novel catalyst for high-quality economic growth, emphasizing the continued importance of reinforcing such regulations. As a recommendation, policymakers are urged to prioritize environmental protection in their decision-making processes, aiming for a harmonious balance between economic growth and environmental sustainability.

INTRODUCTION

Since the inception of reform and opening up, China has achieved remarkable economic growth (Lu et al., 2019). In comparison to 1978, China's GDP surged 310 times by 2021. However, the comprehensive improvement of living standards cannot be solely gauged by GDP. The persistent environmental issues in China have garnered increasing attention (Liu & Lin, 2019). Against this backdrop, the 19th CPC National Congress introduced the concept of high-quality economic growth, signifying a transition to the high-quality development stage for China's economy.

Simultaneously, facing the dual demands of industrial growth and carbon neutrality, traditional environmental policies encounter new challenges (Wang & Shen, 2016). With China aiming to achieve peak carbon emissions

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by 2030 and committing to carbon neutrality by 2060 (Shi et al., 2021), the central government has implemented a mandatory target responsibility system to combat haze pollution (Zhang & Wu, 2018). Consequently, air quality monitoring data in various cities has exhibited notable and sustained improvement (Tilt, 2019). According to China's National Bureau of Statistics, the total investment in environmental control amounts to 953.5 billion yuan, constituting 1.16% of nominal GDP. As emphasized by Xi Jinping, lucid waters and lush mountains are invaluable assets, and former Prime Minister Li Keqiang has asserted that economic growth at the expense of environmental degradation is unacceptable. However, divergent views exist, with some scholars suggesting that environmental regulations may compromise economic prosperity (Chong et al., 2016). Li et al. (2022) highlight that intensifying environmental regulation is significantly challenged by an increase in the economic growth target.

The Yangtze River Delta urban agglomeration, being the most developed in China, grapples with the conundrum of balancing economic growth and environmental improvement. This paper seeks to address these questions, offering new policy perspectives for achieving high-quality economic growth in the Yangtze River Delta agglomeration and providing innovative ideas for other urban agglomerations.

The subsequent sections of this paper are structured as follows: Section 2 provides a review of previous research. Section 3 outlines the methodology and empirical model employed. The results of the empirical model are presented in Section 4, and Section 5 concludes with policy suggestions.

2. Literature Review

Research about the measurement concerning high-quality economic growth often focused on economic coordination, green development, opening up, achieve sharing and innovation (Du et al., 2020). Moreover, previous research commonly used entropy method to measure the highquality economic growth (Deng et al., 2021). Albeit similar measurement, their perspectives were radically different. There have been numerous studies to investigate the nexus of highquality economic development and environmental regulation from a national view(Shangguan & Ge, 2020), or a regional view (Liu et al., 2021). However, China's urban environmental regulation efficiency exhibited regional heterogeneity (Liu et al., 2023). Given that China is a geographically vast country, these studies were overly macroscopic in nature and failed to concentrate on a particular urban agglomeration.

Researches on the environmental regulation were much more ample. From an economic point of view, the study of environmental issues is inevitable for economic research. However, previous researches often focus on the connection between specific emissions and economic development, such as carbon emissions (Wang et al., 2022) or air qualities (Zhao & Yuan, 2020), but did not build a comprehensive index which can evaluate overall environmental states. Similar to the previous researches focused on high-quality economic development, former studies mainly focused on the effect of economic growth on environmental pollution from a countrywide or multinational view, for instance, prior studies have investigated the relationship between environmental regulation and economic growth in OECD countries(Hashmi & Alam, 2019), fewer studies have focused on such connection from an intercity perspective. Some authors suggested that the concept of conventional central place is outdated(De Goei et al., 2010). Moreover, other researchers, such as Batten (1995) argued that the global economy is increasingly forming agglomerations. As the relationship between cities is tending to both competition and cooperation (Fang & Yu, 2017), such connection is becoming more and more complex.

Research from Li (2013) pointed out that environmental regulation will increase the proportion of the service sector relative to the industrial sector, thus promoting industrial restructuring, also, research from Cao et al. (2020) demonstrated that an inverted U-type relationship existed between environmental regulation and the development of GDP during the period from 2002 to 2010. Furthermore, Fu (2010) demonstrated that from 1978 to 2008, China's economic growth led to the optimization of industrial structure. However, based on Granger causality test, he argued that the optimization of industrial structure did not propel the growth of the economy (Fu, 2010). Only a few works on literature demonstrated the nexus between high-quality economic growth and environmental regulation. As GDP cannot completely evaluate the economic growth, a comprehensive index for evaluating high-quality economic development from various aspects still needs to be built.

Hence, there are three gaps in the previous research that still need to be addressed. Firstly, much of the research focus on specific emissions, rather than providing a comprehensive index that evaluates environmental regulation from various perspectives. Secondly, many studies overlook the fact that inter-city coordinated development is the primary form of urbanization in China. Finally, there has not been enough attention paid to the relationship between highquality economic growth and environmental regulation.

In summary, further research is necessary to examine the connection between high-quality economic growth and environmental regulation, especially in intercity and comprehensive prospective. To address this issue, the paper employs a panel database of Yangtze River Delta Urban Agglomeration (contains Shanghai, Jiangsu province, Zhejiang province and Anhui province), to focus the interaction between environmental regulation and high-quality economic growth.

3. Methodology and Data

3.1. Variable Selection

3.1.1. Measurement of High-Quality Economic Development

In essence, high-quality economic development is not solely defined by the increase of GDP in absolute terms, but also encompasses multiple aspects such as structure optimization, green, openness, and sharing. Based on previous research (Du et al., 2021; Li et al., 2021), and the availability of data, we selected 11 variables from 4 dimensions to evaluate the comprehensive index of high-quality economic development (Table 1).

Table 1.

Comprehensive index of high-quality economic development

Variable Type	Variable Name	Definition	Contribution
Economic structure optimization	aGDP (Per capita GDP)	Logarithm of per capita GDP	positive
	CI (Consumption index)	Ratio of total retail sales of customer goods to regional GDP (%)	positive
	SI (Service industry importance index)	Proportion of the tertiary industry in the GDP (%)	positive
Open development	FDI (Foreign direct investment)	Ratio of foreign direct investment to regional GDP (%)	positive
	FTD (Foreign trade dependence)	Ratio of imports and exports (adjusted for exchange rates) to regional GDP	positive
Sharing development	PCRA (Per capita road area)	Per capita road area (m^2)	positive
	EI (Education importance index)	Ratio of education expenditure to GDP (%)	positive

Variable Type	Variable Name	Definition	Contribution
	LMF (level of completeness of medical facility)	Logarithm of the number of hospitals	positive
	LNI (level of completeness of network infrastructure)	Logarithm of the number of Internet users	positive
Green development	PCGC (per capita green covered area)	Per capita green covered area (m^2)	positive
	PCWC (Per capita daily household water consumption)	Logarithm of per capita daily household water consumption (liter)	negative

3.1.2. Measurement of Environmental Regulation

Based on previous research and the availability of data, a comprehensive index evaluation system of environmental regulation was constructed(Zheng et al., 2021). We selected six variables (Table 2). The original data were obtained from the China Statistical Yearbook on Environment, China City Statistical Yearbook and Anhui statistical yearbook. The linear interpolation method was used to complete the missing data. Furthermore, in 2003, the sixth plenary session of 16th CPC Central Committee proposed the Scientific Development Concept, marking a brand-new phase in China's environmental protection policy. Hence, we took 2003 as the starting year of our data. Due to the availability of data, we considered the year 2020 as the terminal year of our data.

Table 2.

Comprehensive index for environmental regulation

Variable Type	Variable Name	Definition	Contribution
Environmental Regulation	water sulfur	Industrial wastewater discharge (metric tons)	negative
		Industrial sulfur dioxide emissions (metric tons)	negative
	parti	Industrial particulate matter emissions (metric tons)	negative
	houwaste	Harmless disposal rate of household waste (%)	positive
	induwaste	Comprehensive utilization rate of general industrial solid waste (%)	positive
	sewplant	Centralized treatment rate of sewage treatment plant (%)	positive

3.1.3. Control Variables Description

Based on previous research(Li et al., 2021; Liu et al., 2021; Wan et al., 2019), we selected following variables: (1) Degree of government intervention (*DGI*): we use DGI, the proportion of local general public budget expenditure in its regional GDP to represent the governmental impact to the economy. (2): Labor force (*Labor*): we use the number of employed persons to represent the labor force. (3) Population density (*Density*): we use the number of people per km^2 to signify the congestion degree of corresponding cities.

Note: To avoid heteroscedasticity, variables with large values (*Labor*, *Density*) in the model were treated by natural logarithm.

3.1.4. Data Processing

We used STATA 16.0 to process our data (Table 3).

Table 3.

Descriptive statistics of each variable

Variable	Obs	Mean	Std. Dev.	Min	Max
development	594	0.1901154	0.0707076	0.078832	0.7114472
regulation	594	0.7836128	0.112966	0.4148102	0.9546739
DGI	594	0.1296538	0.0757147	0.0490955	1.485164
lnLabor	594	4.262919	1.128493	2.158715	6.614036
lnDensity	594	7.677263	0.5705925	5.209486	9.149422

Based on the aforementioned model, we used Variance Inflation Factor (VIF) to test multicollinearity, and found that the maximum VIF is 1.29 (Table 4). According to empirical law, only when variables with a VIF higher than 10 can harm the regression(Kleinbaum et al., 2013). Therefore, we believe that there is no significant multicollinearity that would affect the regression analysis.

Table 4.

Variance Inflation Factor Test

Variable	VIF	1/VIF
regulation	1.29	0.777792
lnLabor	1.25	0.797997
lnDensity	1.11	0.899488
DGI	1.1	0.912486
Mean VIF	1.19	

In order to determine the appropriate estimator, *Hausman's test* was conducted in this study. The result indicates a strong rejection of the random effect estimator (p-value = 0.000), providing evidence that the fixed effect estimator is more suitable for this case (Table 5).

Table 5.

Result of Hausman's test

VARIABLES	FE
regulation	0.198***
	(0.027)
DGI	0.053*
	(0.031)
lnLabor	0.003
	(0.003)
lnDensity	-0.006
	(0.006)
Constant	0.065
	(0.043)
Observations	594
Number of id	33
Hausman	553

p-value	0.000

Note. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

3.1.5. The Processing of EEM

In this paper, the Entropy Evaluation Method (EEM) is used to objectively weight the indicators. The entropy method is an objective approach for weighting indicators that considers the magnitude of their information entropy. The larger the dispersion of the indicator, the smaller the information entropy, represents a greater amount of information it conveys, resulting in a higher weight being assigned. The entropy method is widely used in comprehensive evaluations.

The weight quantifies the uncertainty associated with each variable. By employing this uncertainty as a measure to assign weights, the resultant weights reflect the relative importance of each variable in calculating the comprehensive index. Moreover, utilizing the EEM (Entropy Evaluation Method) to calculate the weights can reduce subjectivity. Through the calculation of weights based on data, the entropy weight method diminishes the influence of subjective judgment on weight allocation. Consequently, it offers a relatively objective approach for determining the weights of different criteria, thereby mitigating the impact of subjective biases.

First, for positive variables, we can apply normalization using the following formula:

$xijk' = x \underline{\qquad\qquad} maxxijk, -k-xminxmin,k,k$ (1)

The negative variable is the opposite of the positive variable. x_{ijk} represents the value of the i-th indicator for the j-th year and the k-th region. There is a total of N years, P regions, and V indicators. To prevent zero values, the standardized results were shifted by 0.001.

$x_{ijk}'' = x_{ijk}' + 0.001$ (2)

Next, compute the relative entropy values (REV) for each indicator in each region and year. A high REV indicates a greater relative importance of the corresponding indicator. The value E_{ijk} represents the relative importance of an indicator in a specific region and year.

$xijk''$

$E_{ijk} = \frac{}{\sum_{j=1}^{P} \sum_{k=1}^{V} x_{ijk}''}$ (3)

Third, calculate the entropy values (EV) of each indicator. Use REV to calculate EV. EV is an indicator which measures the importance of an indicator to all year and regions.

$E_k = -\frac{1}{\ln(NP)} \sum_{i=1}^{N} \sum_{j=1}^{P} E_{ijk} \ln E_{ijk}$ (4)

Fourth, use weight formula to calculate the weight of each indicator. The weight of each indicator is inversely proportional to its entropy value, with a larger entropy value indicating a smaller weight.

$1-E^k$

$w_k = {}_V \underline{\qquad\qquad} {}_{-}\sum Vk=1\ k$ (5)

Finally, calculate comprehensive index of Environmental Regulations.

$Z_{ij} = \sum_{k=1}^{V} w_k x_{ijk}''$ (6)

$\sum_{k=1}^{V} w_k = 1$ (7)

3.2. Modeling

By previous research and preceding text, we set the following model to demonstrate the impact of environmental regulation on the high-quality economic growth:

$development_{ij} = \alpha_0 + regulation_{ij} + \alpha_1 DGI_{ij} + \alpha_2 lnLabor_{ij} + \alpha_3 lnDensity_{ij} + \varepsilon_{ij}$ (8)

In this model, i and j represent corresponding indicator in i year and j region. ε_{ij} represents the error term.

4. Results of Empirical Model

For fixed model analysis, a balanced dataset contains the changes of various indicators in 33 cities over 18 years is used. In this model, we set *development* as explained variable, *regulation* as explanatory variable, *DGI*, ln*Labor* and ln*Density* as control variables. Due to data availability, cities with missing data for more than 3 years were deleted. In this paper, we deleted 8 cities: Bozhou, Anqing, Xuancheng, Chizhou, Huainan, Chuzhou, Fuyang, LuAn.

All these cities located in Anhui province.

4.1. Empirical Result

Table 6 shows the result of regression, for Explanatory variable:

The result shows that environmental regulation has a significant positive impact on highquality economic growth, which evidences that environmental regulation can boost highquality economic growth prominently. Based on the coefficient, which shows that for every one unit increase in environmental regulation, the comprehensive index of high-quality economic development will shift in the same direction by 0.128 units.

For Control variables:

(1) *DGI*: the positive coefficient of *DGI*, coupled with a p-value< 0.05 , suggests that government expenditure has a significantly positive effect on high-quality economic development. Governments implement regional policies to exert influence on the economy. In the case of the Yangtze River Delta urban agglomeration, the result indicates that governments should prompt expenditure and leverage their regulatory role to promote high-quality economic growth.

(2) *lnlabor*: the coefficient of *lnlabor* is positive, p-value< 0.01, indicates that the number of employed persons has a significant prompting effect on high-quality economic development. Employment is the foundation and premise of social economic growth.

(3) *lnDensity*: the coefficient of *lnDensity* is negative with a p-value less than 0.01, suggesting that an increase in population density restrains economic growth. The main reason for this may lie in the fact that population growth undermines the outcomes of high-quality economic development. For instance, in a densely populated area, the supply of resources such as land, water, and air may be limited, resulting in problems such as resource overuse and environmental pollution, which may impact economic progress and people's quality of life.

Table 6.

The result of regression

VARIABLES	**development**
regulation	0.128***
	(3.168)
DGI	0.091**
	(2.397)
lnLabor	0.029***
	(8.186)
lnDensity	-0.029***
	(-5.709)
Constant	0.177***
	(3.480)
Observations	594

R-squared	0.225

Note. t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2. Robustness Test

To estimate the robustness of the model, explanatory variable and all control variables are lagged one year. The result (Table 7) shows that the coefficients and significance do not have a noticeable change, which verifies that our model is robust.

Table 7.

Robustness Test

VARIABLES	development
L.regulation	0.131***
	(3.144)
L.DGI	0.094**
	(2.371)
L.lnLabor	0.027***
	(7.331)
L.lndensity	-0.028***
	(-5.221)
Constant	0.178***
	(3.384)
Observations	561
R-squared	0.193

Note. t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

5. Conclusions

This paper uses the data of 33 cities in the Yangtze River Delta urban agglomeration during an 18-year period to demonstrate the connection between environmental regulation and highquality economic growth. Through rigorous analysis, we have successfully established a compelling connection between environmental regulation and the pursuit of high-quality economic growth in this region. We can come to the conclusion that: strengthening environmental regulation can promote high-quality economic development in Yangtze River urban agglomeration. In essence, our research underscores the indispensability of a harmonious relationship between environmental regulation and high-quality economic development. By recognizing and capitalizing on this relationship, the Yangtze River Delta urban agglomeration can chart a trajectory that transcends mere economic growth and instead embraces sustainable, resilient, and prosperous development for the benefit of current and future generations. Thus, we can give the following policy suggestions.

6. Policy Suggestions

(1) Establish a comprehensive evaluation system for economic growth. Policy makers should formulate policies based on the idea: green mountains are gold mountains. The growth of the economy should not merely be measured by the increment of GDP. Local government should not equate the GDP with people's living quality, give full play to the proactive role and ensure that the people can truly benefit from China's economic growth. Advocate comprehensive development, optimize economic structure, increase openness, share the achievement of economic growth, and propel green development.

(2) Strengthen environmental regulation. Due to the sustained global economic downturn, China's economic growth has also come under significant pressure. China needs to find new sources of economic growth. In such background, strengthening environmental regulation will inject vitality into China’s economy. Local government should adapt policies to specific conditions to prioritize sustainable economic development practices that align with environmental regulations. Create a conducive environment for the development and implementation of green technologies and practices.

(3) Based on the coefficients of controlled variables, the government should create appropriate policies to boost residents' employment rates. Effectively managing the population siphon effect and population radiation effect in the development of urban clusters to prevent population density from exceeding the city's capacity.

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