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The Impact of Air Pollution Regulations on High-Quality Economic Development

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Abstract: The pursuit of high-quality economic development is a critical challenge in the context of increasing environmental concerns, particularly air pollution. This study delves into the efficacy of environmental regulations in fostering economic growth that is both sustainable and of high quality. Utilizing the entropy weight method, an index system for high-quality economic development is established, and a comprehensive analysis of panel data from 30 provinces in China, spanning from 2008 to 2020, is conducted through a two-way fixed differential model. The study examines the regional heterogeneity in the impact of policy and explores the mediating roles of industrial structure upgrading and technological innovation in advancing high-quality economic development within regions prioritized by policy. The findings reveal that regulatory policies can indeed enhance high-quality economic development, albeit with regional disparities observed between the eastern and central regions. The paper concludes with a set of targeted recommendations for policy implementation.

Keywords: Environmental regulation; High-quality economic development; Advanced industrial structure; Technological innovation

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1. Introduction

China's economic trajectory, historically characterized by input-driven and extensive growth, has led to remarkable economic gains but concurrently exacerbated resource constraints and environmental degradation. The crux of achieving high-quality economic development lies in reconciling economic growth with ecological sustainability. The Air Pollution Prevention and Control Action Plan introduced in 2013 and the subsequent emphasis on regional joint prevention and control of air pollution in the 14th Five-Year Plan underscore the national commitment to balancing ecological imperatives with economic advancement. This study aims to assess whether environmental regulations can effectively reconcile these objectives and contribute to high-quality economic development.

2. Literature review

The extensification of economic growth has been accompanied by excessive resource consumption and environmental degradation, with air pollution emerging as a pressing issue [1]. The literature on the economic impact of environmental regulation is divided. The compliance cost theory put forward that environmental regulations impose a trade-off between economic growth and environmental quality, inhibiting production performance and industry profitability with increased regulatory intensity [2–3]. In contrast, Porter's hypothesis advocates for the promotion theory, suggesting that stringent environmental regulations can catalyze technological innovation, enhance total factor productivity, and achieve a harmonious balance between high-quality economic growth and environmental protection [4].

3. Study hypothesis

This study puts forward three hypotheses. Firstly, environmental regulations directly foster green economic development by increasing production costs and promoting optimal resource allocation. Secondly, regional heterogeneity in the impact of regulations is expected, with the eastern regions of China having a more robust legal framework for environmental protection and potentially experiencing industrial transfer due to the "pollution sanctuary" effect [5]. Lastly, the study hypothesizes a positive mediating effect of industrial upgrading and technological innovation on high-quality economic development in regions with prioritized policy implementation [6].

4. Research design

The study employs a natural experimental design, leveraging the Air Pollution Prevention and Control Action Plan as a quasi-natural experiment. The experimental group consists of a total of 12 provinces, including the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta, along with their surrounding areas, with the remaining provinces as the control group. The research constructs a high-quality economic development index system and applies a DID model with fixed effects to the panel data, focusing on innovation, coordination, green development, openness, and shared prosperity.

4.1. Model construction

4.1.1. Standard DID model

In the model as shown in **Equation 1**, *i* represents province, *t* represents time, *policy* effect is the interaction term between the degree of policy implementation treated and the time effect of implementation, and β_1 is the influence coefficient of policy on the high-quality economic development of key implementation regions. con_{it} is the five control variables and coefficient *P* is the influence degree of the control variables. The μ_i represents the individual fixed effect, λ_t is the time-fixed effect, and ε represents the random error term.

$$Eco_{it} = \beta_0 + \beta_1 policy + Pcon_{it} + \mu_i + \lambda_t + \varepsilon \tag{1}$$

4.1.2. Intermediary effect model

To study the mediating effects of industrial structure upgrading (his), and technological innovation (zl) on the high-quality economic development of regions with policy priorities, the following model is constructed.

$$Eco_{it} = \beta_0 + \beta_1 policy + \varepsilon \tag{2}$$

$$zjbl = \alpha + apolicy + \varepsilon \quad (3)$$

$$Eco_{it} = \gamma + cpolicy + bzjbl + \varepsilon \quad (4)$$

Where, *zjbl* is the intermediary variable, b, a and c are all regression coefficients.

4.2. Construction and selection of variables

The dataset utilized for analysis comprises panel data from 30 provinces excluding Tibet spanning the years 2008 to 2020, sourced from the National Bureau of Statistics (**Table 1**).

4.2.1. Explained variable

At the core of the five new development concepts, the entropy-weighted TOPSIS method is utilized to establish an indicator system for high-quality economic development (*Eco*). A total of 14 first-level indicators and 21 second-level indicators were selected.

4.2.2. Explanatory variable

In the economic analysis under consideration, the focus of the dummy variable pertains to the extent of the implementation of air pollution environmental regulatory policies. The control group, designated by the value 0, represents regions that are not prioritized as key implementation areas, whereas the experimental group, indicated by the value 1, corresponds to areas classified as key implementation zones. The variable representing time captures the impact of the duration of policy enforcement, with the years spanning from 2008 to 2013 assigned a value of 0, and the period from 2014 to 2020 given a value of 1. An interaction term, which is a combination of the policy treatment and the time variable, is introduced to signify the policy effect, labeled as "policy" with a binary value of either 0 or 1. The regulatory policy is considered to be in effect in the key areas only when this interaction term assumes a value of 1.

4.2.3. Intermediate variable

Advanced industrial structure (*his*): the ratio of the added value of the third and secondary industries. Technological innovation (*zl*): the number of domestic patent applications granted by each province.

4.2.4. Control variable

Government control (*Gov*): the proportion of general budget expenditure of local finance to GDP. Urbanization (*urban*): the proportion of the urban population in the sum of the rural population and urban population. Environmental governance capacity (*nl*): the proportion of completed investment in industrial pollution control to GDP. Education level (*lnedu*): the number of employees in the education industry by region. Industrial scale (*gygm*): the number of industrial enterprises above the designated size in each province.

4.2.5. Other variables

Rationalization of industrial structure (*tl*): the Dry Chunhui Thiel index. Research and development investment (*RD*): the proportion of local fiscal expenditure on science and technology in regional GDP.

Table 1. Descriptive statistics of variables

Variable	Minimum	Maximum	Mean	Standard Deviation	Median
Eco	0.092	0.635	0.221	0.093	0.198
his	0.527	5.244	1.253	0.703	1.106
zl	5.429	13.473	9.800	1.544	9.907
Gov	0.100	0.758	0.254	0.111	0.230
urban	0.291	0.896	0.570	0.131	0.555
nl	0.086	110.339	13.166	12.858	9.098
lnedu	11.127	14.345	13.058	0.690	13.165
gygm	5.814	11.090	8.854	1.206	8.798
lnrgdp	9.180	11.181	10.072	0.428	9.958
tl	0.008	1.511	0.542	0.300	0.516
RD	0.002	0.014	0.004	0.003	0.004

Note: $*P < 0.1$, $**P < 0.05$, $***P < 0.01$

5. Empirical analysis

5.1. Regression analysis of DID model

In the economic analysis presented, the year 2008 was selected as the baseline reference group. Interaction terms between dummy variables and treated items from the years 2009 to 2013 were crafted to form the set of explanatory variables. The interaction coefficients were found to be statistically indistinguishable from zero, aligning with the hypothesis of parallel trends. The outcomes of the difference-in-differences (DID) regression with fixed effects are detailed in **Table 2**. Column (1) displays the regression outcomes for Model 1 without the inclusion of control variables, while column (2) presents the results with the control variables incorporated into Model 1. The coefficients for the policy variable, which gauges the impact of policy implementation, exhibit a double difference value of 0.012 in both instances, achieving a level of statistical significance at the 5% threshold. This suggests that the innovation compensation effect has successfully enhanced the total factor productivity and has played a significant role in fostering high-quality economic development within the regions that have been prioritized by the policy.

Table 2. DID regression results

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	0.219*** (117.677)	-0.389 (-1.130)	-1.376* (-1.860)	0.350 (0.994)	-0.542 (-1.520)	-0.285 (-0.818)
policy	0.012** (2.109)	0.012** (2.100)	0.036*** (2.925)	0.000 (0.009)	0.011* (1.920)	0.010* (1.665)
Gov		0.141** (2.327)	0.154 (0.723)	0.085* (1.717)	0.144** (2.391)	0.133** (2.204)
urban		0.234** (2.350)	0.659*** (3.640)	-0.155 (-1.269)	0.272*** (2.658)	0.220** (2.206)
nl		0.000 (0.617)	0.001 (0.859)	-0.000 (-0.769)	0.000 (0.489)	0.000 (0.589)

Table 2 (Continued)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Lnedu		0.044 (1.631)	0.113* (1.889)	0.006 (0.192)	0.049* (1.808)	0.039 (1.434)
gygm		-0.016 (-1.548)	-0.033 (-1.322)	-0.021* (-1.662)	-0.011 (-0.997)	-0.020* (-1.910)
tl					0.037 (1.601)	
RD						2.594* (1.705)
TFE	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.011	0.039	0.085	0.227	0.024	0.026
n	390	390	156	234	390	390
F	F(1,347)=4.448 p=0.036	F(6,342)=2.545 p=0.020	F(6,126)=4.347 p=0.001	F(6,198)=2.322 p=0.034	F (7,341)=2.558, p=0.014	F (7,341)=2.609, p=0.012

5.2. Robustness test

tl and RD were added to Model 1 for regression. As shown in columns (5) and (6) of **Table 2**, the policy coefficient is still significant at the 10% level. Through the robustness test, the reliability of the conclusion that regulation promotes high-quality economic development in the regions with key implementation policies is verified.

5.3. Regional heterogeneity analysis

According to columns (3) and (4) in **Table 2**, the policy regression coefficient of samples in eastern provinces is 0.036, which is significant at the 1% level, indicating that the implementation of regulatory policies has a significant role in promoting the high-quality economic development of key implementation areas in eastern China, while the policy regression coefficient of central and western provinces is not significant, and the conclusion is vice versa. The gygm coefficient is significantly -0.021, which proves that there are still low-pollution heavy industry enterprises in the Midwest area. At the same time, there is a significant gap in the intensity of regulation compared with the eastern part of the country. Improving the intensity of environmental regulation has a positive significance for promoting high-quality regional development, which is also proved by the Gov regression coefficient of 0.085 in the central and western parts at the level of 10%.

5.4. Analysis of intermediary effect

Table 3 shows the results of the mediation effect analysis of the two variables in China. The regression coefficients of *his* and *zl* on policy are significantly positive, and the regression coefficients of *Ec*o on *his*, *zl*, and *policy* are significantly positive, that is, the upgrading of industrial structure and technological innovation play a bridging role in the high-quality economic development of the regions with key policy implementation.

Table 3. Analysis results of national mediating role

Variable	Eco	his	Eco	zl	Eco
constant	0.215*** (40.886)	1.166*** (29.828)	0.140*** (16.658)	9.382*** (124.138)	-0.015 (-0.492)
policy	0.029** (2.529)	0.406*** (4.818)	0.002 (0.233)	1.943*** (11.934)	-0.019 (-1.538)
his			0.065*** (10.796)		
zl					0.025*** (7.423)
n	390	390	390	390	390
R^2	0.016	0.056	0.244	0.269	0.139
F	F(1,388)=6.393, p=0.012	F(1,388)=23.213, p=0.000	F(2,387)=62.428, p=0.000	F(1,388)=142.423, p=0.000	F(2,387)=31.194, p=0.000

Note: $*P < 0.1$, $**P < 0.05$, $***P < 0.01$

6. Conclusions and recommendations

The study concludes that environmental regulations play a significant role in promoting high-quality economic development, particularly in the eastern regions of China. To enhance ecological efficiency, the paper recommends facilitating collective regional supervision, promoting industrial structure advancement, and stimulating technological innovation. These recommendations aim to guide policy implementation in a manner that aligns with regional characteristics and fosters sustainable economic growth.

Disclosure statement

The author declares no conflict of interest.

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