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How Environmental Regulations Impact Carbon Emissions

-- A based on Structure Upgrading

Fengling Zhang *

College of Finance, Anhui University of Finance and Economics, Anhui, 233000, China
* **Corresponding author**: Fengling Zhang (Email: zhangfengling2022@163.com)

Abstract: Achieving the "dual carbon" goals is crucial for China's sustainable development. From the perspective of industrial structure upgrading, using panel data from 279 prefecture-level and above cities nationwide from 2007 to 2021, this study empirically examines the effect of environmental regulations on carbon emissions and their underlying mechanisms. The research findings are as follows: (1) Environmental regulations significantly suppress carbon emissions, a conclusion robust across various sensitivity analyses; (2) From the viewpoint of industrial structure upgrading, utilizing panel data from 279 prefecture-level and above cities nationwide from 2007 to 2021, this study empirically examines the effect of environmental regulations on carbon emissions and their underlying mechanisms. The research findings are as follows: (1) Environmental regulations significantly suppress carbon emissions, a conclusion that remains robust after rigorous testing; (2) The mediating effect indicates that environmental regulations influence carbon emissions through promoting industrial structure upgrading; (3) Heterogeneity analysis reveals that the carbon emission reduction effects of environmental regulations are more pronounced in western region cities, resource-based cities, and non-resource-based cities. From the perspective of industrial structure upgrading, this study provides new empirical evidence and detailed transmission mechanisms regarding the causal relationship between environmental regulations and carbon emissions.

Keywords: Environmental regulations, Carbon emissions, Industrial, Upgrading.

1. Introduction

Against the backdrop of global climate change, both the natural environment and living environment are facing significant threats, mainly stemming from the excessive emission of carbon dioxide. According to data from the International Energy Agency (IEA), China's carbon emissions reached 10.649 billion tons in 2021, accounting for 31.72% of global carbon emissions. Faced with the severe climate situation, the Chinese government announced at the United Nations General Assembly in 2020 that it aims to peak carbon emissions before 2030 and strive to achieve carbon neutrality by 2060 to actively address global climate change. Since the reform and opening up, China's per capita GDP has increased from $275 in 1979 to $12,551 in 2021, achieving remarkable economic progress. However, the extensive economic development model has led to increasingly prominent environmental pollution issues (Cai Fang et al., 2008). In the context of unbalanced and insufficient development, the more severe environmental problems seem to overshadow some of the radiance emitted by economic development achievements. With the exacerbation of the "global warming" issue, carbon reduction has become a daunting task facing high-quality development worldwide. At the global level, the Kyoto Protocol established by the United Nations in 1997 demonstrated the world's concern for greenhouse gas emissions. The widely supported "Paris Agreement" in 2016 requires contracting parties to gradually increase their voluntary contributions and actively transition to a green and sustainable growth model. In addressing carbon emissions, China set reduction targets for energy consumption and carbon intensity in the "Eleventh Five-Year Plan" and "Twelfth Five-Year Plan," and announced the "30·60" dual-carbon goals in September 2020. This aims to peak carbon dioxide emissions before 2030 and strive to achieve carbon neutrality by 2060. This fully demonstrates China's firm determination to actively address climate change and pursue a path of green and low-carbon development. Carbon emissions, as a negative externality, are one of the main causes of market failure. Environmental policies enacted by governments are effective measures to address this market failure. However, many scholars have questioned the necessity and effectiveness of environmental regulations, giving rise to the concept of the "green paradox." Under the "green paradox" idea, it is argued that environmental regulations are long-term and continuous activities that become stricter as environmental awareness increases. Therefore, after the implementation of environmental regulations, in anticipation of even stricter future requirements, current carbon emissions may increase, leading to more severe environmental issues (Sinn, 2008).

On one hand, some scholars argue that the existence of the "green paradox" is debatable and its effects may be exaggerated (van der Ploeg and Withagen, 2012). On the other hand, structural reforms on the supply side may accelerate energy consumption and carbon emissions by encouraging early exploitation of energy resources (Gerlagh, 2011; Maria Elisa Belfiori, 2021). Thus, Van der Werf and DiMaria (2012) pointed out that imperfect implementation of environmental policies under the "green paradox" effect may increase carbon emissions in the short term and the net present value of climate change in the long term.

Meanwhile, against the backdrop of continuous economic growth in China, environmental pollution has been a widespread concern in society. In response to environmental pollution, concepts of green and sustainable development have been solidly promoted in China, leading to some improvement in ecological conditions. Since 2012, China's carbon intensity (i.e., carbon dioxide emissions per unit of GDP) have cumulatively decreased by 34%. China ranks first globally in wind power and other green electricity installation capacities, as well as in the production of new energy vehicles. By the end of 2021, the balance of green loans had grown to 1.59 billion yuan, and the role of green financial policies and taxes has been steadily advancing.

However, the existence of the "green paradox" phenomenon in China depends on various factors. Research by Yu et al. (2019) found that there is a "resource curse" relationship between energy endowment in energy-rich areas and mid-term economic development and carbon emissions, which environmental regulations can alleviate. Research by Li and Shao (2017) suggests that a single carbon tax policy does not necessarily lead to the "green paradox" and can reduce carbon emissions when combined with subsidies for research and development funds. However, the potential for the "green paradox" increases significantly when considering capital market supply-side reforms.

In light of this, this study focuses on the impact of environmental regulations on carbon emissions, using data from 279 Chinese cities at or above the prefecture level from 2007 to 2021, employing a two-way fixed-effects model to explore the effects of environmental regulations on carbon dioxide emissions.

2. Theory Analysis and Research Hypothesis

2.1. Environmental Regulations and Carbon Emissions

The impact of environmental regulations on carbon emissions operates through multiple channels, which this paper categorizes into direct and indirect pathways for analysis.

2.1.1. The Direct Pathway Through Which Influence Carbon Emissions

Pollution has negative externalities, therefore, the adopts control-type, such as taxes and pollution rights trading, to address the negative externalities of pollution. In this process, there may be two possible results. The first is from the demand, can reduce carbon emissions. On the one hand, based on corporate social, companies are by a series of by the, thereby the carbon emissions of energy-consuming. On the other hand, the taxes levied on companies by the increase costs, leading companies to increase the use of clean energy and reduce the use of energy-consuming resources, thereby reducing carbon emissions. The second is from the supply, may increase carbon emissions in the short term. This is because when are very strict, energy suppliers are concerned about the loss of future supply channels and therefore increase current energy supply. At this time, an increase in energy supply leads to a drop in energy prices, hence, carbon emissions may increase in the short term.

2.1.2. The Indirect Pathway Through Which Influence Carbon Emissions

Factors such as energy structure, structure, and foreign can all have an impact on carbon emissions. The specific pathways of influence are as follows.

The influence of energy consumption structure under government environmental constraints is manifested in the following aspects: On the one hand, the implementation of policies such as corporate social responsibility, taxation, and clean energy incentives can reduce energy consumption. On the other hand, increased intensity of environmental regulations may amplify energy suppliers' provision of energy, leading to increased energy consumption. Therefore, the stringency of environmental regulations affects the energy consumption structure, which in turn impacts carbon emissions in two ways: When energy consumption decreases, carbon emissions decrease accordingly; when energy consumption increases, carbon emissions increase as well.

The economic development model is closely related to the industrial structure. Currently, China's industrial development is predominantly in the secondary sector. Environmental regulations are aimed at environmental protection, which will inevitably lead to optimization of energy-intensive industrial structures. Specifically, there are three aspects to consider:

Firstly, environmental regulations increase production costs for energy-intensive enterprises, making it more difficult for them to survive and develop. The barriers to entry for new enterprises also rise (Zhou Yaxiong and Huang Jie, 2022). Secondly, environmentally friendly industries receive policy support. Against a backdrop of deepening environmental protection efforts and heightened public awareness, green products can capture significant market share, thereby reducing carbon emissions. Lastly, from the perspective of foreign investment, increased foreign investment can bring advanced environmental technologies to promote technological innovation and the production of clean energy. However, foreign investments may also introduce outdated industries and technologies, potentially increasing local carbon emissions.

The impact of environmental regulations on companies' technological innovation activities carries a certain degree of uncertainty. When environmental regulations are appropriately stringent, they can promote companies' technological innovation activities (Li Shibin and Guo Yanli, 2021). However, technological innovation activities are characterized by long cycles, high risks, and significant capital investment requirements, which can strain a company's resources. In comparison, government subsidies and research and development (R&D) investments may be insufficient, leading to adverse effects on production efficiency and R&D activities, which are not conducive to reducing carbon emissions.

Based on the above analysis, this paper proposes Hypothesis 1:

Hypothesis 1: Environmental regulation promotes carbon reduction, that is, when the level of environmental regulation is stringent, carbon emissions will decrease.

2.2. The Mechanism of The Role of Structure Upgrading in The Between and Carbon Emissions

Based on the literature review, there are two main perspectives regarding the impact of industrial structural upgrading on carbon emissions: the promotion theory and the inhibition theory. The promotion theory argues that industrial structural upgrading significantly reduces carbon emissions. For example, Yuan (2010) emphasizes the importance of industrial structural upgrading for reducing carbon emissions and achieving sustainable economic development in China. Li (2014) utilizes dynamic panel smooth transition models to demonstrate that upgrading industrial structure is an effective approach to reducing carbon emissions. Zhou et al. (2016) find through provincial panel data analysis that industrial structural changes have a greater impact on carbon emission performance than indigenous innovation.

On the other hand, the inhibition theory suggests that technological progress and the use of alternative energy sources play a more significant role in reducing carbon emissions than industrial structural upgrading. Gu et al. (2016) analyze energy balance data from 1980 to 2010 and conclude that technological progress contributes more to the decline in carbon intensity in China, whereas the contribution of industrial structural adjustment is relatively minor. Zhao and Long (2010) quantitatively analyze the impact of economic scale, industrial structure, technological progress, and energy consumption structure on carbon emissions in Jiangsu Province, finding that technological progress and energy consumption structure play decisive roles in carbon reduction, while the influence of industrial structural changes is weaker.

Schipper (2001) decomposes manufacturing carbon emissions in 13 IEA countries and suggests that energy consumption structure primarily determines carbon emissions changes, with industrial structure playing a minimal role. Casler and Rose (1998) analyze U.S. carbon emissions and attribute the reduction mainly to the use of alternative energy sources.

In summary, while there is support for both theories, the literature generally suggests that while industrial structural upgrading can contribute to reducing carbon emissions, its impact may be overshadowed by technological advancements and shifts in energy consumption patterns in some contexts.

In discussing the relationship between carbon emissions and industrial structure, many scholars argue that industrial structure is a primary factor influencing carbon emissions. Researchers such as Brannlund, Jeong and Kim, Lu, Zhang Wei, and Cheng Yeqing have employed methods like the Logarithmic Mean Divisia Index (LMDI) and the Kaya Identity to analyze the relationship between industrial structure and carbon emissions. They have found that optimizing and adjusting industrial structure can change China's energy consumption patterns and efficiency, thereby effectively controlling or even reducing CO2 emissions.

Regarding the relationship between carbon emissions and environmental regulations, numerous studies have explored the impact of environmental regulations on carbon emissions. For instance, Zhu, Huang Jianhuan, Chen Liming, among others, have used Tobit models to study the correlation between environmental regulations in China and CO2 emissions and ecological efficiency, finding that environmental regulations play a positive role in energy saving and pollution reduction.

In terms of the relationship between industrial structure and environmental regulation, traditional views suggest that increasing environmental regulation intensity may compress enterprises' production inputs and even increase production costs, thereby affecting companies to some extent.

Research on industrial structure and carbon emissions focuses primarily on several aspects: First, studying their interactive relationship, mostly using panel vector autoregressive models. Generally, it is believed that the added value of the secondary industry is positively correlated with carbon emission intensity, while the proportion of the tertiary industry in GDP is negatively correlated with carbon emission intensity. National and eastern regional carbon emissions are decreasing, while those in central and western regions are increasing, showing significant regional differences in the impact of industrial structure upgrades on CO2 emissions. Secondly, analyzing their connection from a coupling perspective. Nationally, China's industrial structure coupling degree and carbon emission efficiency are relatively low, but carbon emission efficiency is much higher than the renewal rate of industrial structure. Regionally, their coupling degree is moderate. Thirdly, industrial structure indirectly affects total CO2 emissions by influencing energy consumption intensity. There are differences in carbon emission efficiency between regions due to differences in industrial structure.

Based on the literature, it is evident that there have been numerous studies on the relationships between carbon emissions, industrial structure, and environmental regulations. However, research into the mutual interactions and mechanisms among these three factors remains relatively scarce. Carbon dioxide emissions are influenced by both industrial structure and environmental regulations. Therefore, emission reduction policies inevitably lead to changes in related policies, thereby impacting industrial structure and environmental regulations. These changes, in turn, affect production and daily life, ultimately resulting in variations in carbon dioxide emissions.

Based on the above analysis, this paper proposes Hypothesis 2:

Hypothesis 2: The upgrading of industrial structure plays a mediating role in the relationship between environmental regulations and carbon emissions. The more the industrial structure tends towards sophistication, the stronger the carbon reduction effect of environmental regulations becomes.

3. Sample Selection and Research Design

3.1. Sample Selection

The focus of this study is on the carbon emissions, environmental regulations, and industrial structure upgrading in 279 cities in China. Therefore, data from 2007 to 2021 were selected for the 279 cities in China. Due to incomparable statistical calibers and substantial missing data in the indicators for the Hong Kong, Macao, and Taiwan regions, cities from these areas are not included in the sample of this study. The primary sources of the data are from various statistical yearbooks and relevant statistical materials. Specifically, energy consumption data by energy variety and sector are obtained from the "China Energy Statistical Yearbook" and various statistical yearbooks. Industrial process and product usage data are collected from the "China Industrial Statistical Yearbook" and various statistical yearbooks. Data on agricultural, forestry, and other land use activities are sourced from the "China Agriculture Statistical Yearbook," "China Animal Husbandry Yearbook," "China Forestry and Grassland Statistical Yearbook," and various statistical yearbooks. Waste disposal data are obtained from the "China Environmental Statistical Yearbook" and various statistical yearbooks. Data on purchased electricity, heating, and cooling are derived from the "China Urban Statistical Yearbook," "China Energy Statistical Yearbook," and various statistical yearbooks. Emission factors are based on officially published relevant data, including the "Provincial Greenhouse Gas Emission Inventory Guidelines (Trial)," and carbon emission inventory guidelines released by various levels of government. In cases of missing data, the IPCC Emission

Factor Database is used for supplementation.

3.2. Variable Description

3.2.1. Dependent Variable: Carbon Emissions (Car)

This passage refers to the study by Jianhui et al. (2014), which calculates the carbon dioxide emissions of 279 Chinese cities from 2007 to 2021 using the three-scope method. Scope 1 refers to all direct emissions within the city, mainly including emissions from transportation, building and industrial production processes, changes in agriculture and forestry, and greenhouse gas emissions from waste disposal activities. Scope 2 refers to indirect emissions related to energy consumption that occur outside the city boundaries, mainly from the purchase of electricity, heating, and/or cooling to meet the city's consumption. Scope 3 refers to emissions caused by internal city activities occurring outside the city boundaries, excluding other indirect emissions not included in Scope 3, including greenhouse gas emissions from the production, transportation, use, and disposal of all goods purchased by the city from outside the city boundaries. Total carbon emissions = Scope 1 emissions + Scope 2 emissions + Scope 3 emissions. Since environmental regulations mainly affect various industrial production processes, this study uses the carbon dioxide emissions calculated from Scope 1 as the dependent variable.

3.2.2. Independent Variable: Environmental Regulations (Er)

This passage refers to the practice of Chen, et al. (2018), which uses the ratio of the frequency of environmental vocabulary to the frequency of words in the government work reports of prefecture-level cities as a measure of environmental regulation. The higher the value of this index, the stronger the environmental regulation.

3.2.3. Mediating Variable: Industrial Upgrading (S)

This article draws on the approach of Wang et al. (2019) to define this indicator as: $s = a_1 \times 1 + a_2 \times 2 + a_3 \times 3$. Where, a_1, a_2, a_3 respectively represent the share of the primary, secondary, and tertiary industries in GDP.

3.2.4. Control Variable

The control variables selected in this article are: government intervention level, measured by the ratio of general government expenditure to regional GDP, denoted as gov; urbanization level, measured by the ratio of urban permanent population to total permanent population, denoted as tow; population density, measured by the ratio of regional permanent population to urban area and then taking the logarithm, denoted as pop; level of openness to the outside world, measured by the ratio of actual utilization of foreign capital converted into RMB to regional GDP, denoted as ope; level of economic development, measured by GDP per capita and then taking the logarithm, denoted as eco.

The descriptive statistics of each variable are shown in Table 1.

Table 1. Decriptive statistics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
year	4,170	2,014	4.321	2,007	2,021
car	4,170	2,044	672.6	348.0	4,204
er	4,135	0.00333	0.00142	0	0.0124
s	4,145	2.279	0.142	1.831	2.760
gov	4,170	0.192	0.127	0.0426	2.349
town	4,115	0.527	0.157	0.115	1
pop	4,170	5.712	0.943	-0.446	7.882
ope	4,170	0.0177	0.0189	0	0.229
eco	4,170	10.53	0.679	4.595	13.06
city	4,170	139.5	80.26	1	278

3.3. Model Construction

Based on the theoretical analysis above, to examine the direct impact of environmental regulations on carbon dioxide emissions, the following econometric model is constructed:

$$car_{i,t} = \alpha_0 + \alpha_1 er_{i,t} + \alpha_2 con_{i,t} + m_i + l_t + e_{i,t} \quad (1)$$

Where i represents the city, t represents the year. The variables are defined as follows: $car_{i,t}$ is the carbon emissions; α_o is the constant term; $er_{i,t}$ is the coefficient of environmental regulations; $con_{i,t}$ is the control variable; m_i and l_t represent city fixed effects and year fixed effects, $e_{i,t}$ is the random error term.

To further examine the potential mediating effect of industrial structure upgrading, based on the method proposed by Wen Zhonglin et al. (2004) for testing the mediating effect of industrial structure upgrading, the model is constructed as follows:

$$s_{i,t} = \beta_0 + \beta_1 er_{i,t} + \beta_2 con_{i,t} + m_i + l_t + e_{i,t} \quad (2)$$

$$car_{i,t} = \gamma_0 + \gamma_1 er_{i,t} + \gamma_2 s_{i,t} + \gamma_3 con_{i,t} + m_i + l_t + e_{i,t} \quad (3)$$

4. Empirical Results Analysis

4.1. Base Regression Analysis

The main model regression results are shown in Table 2.

Table 2. Decriptive statistics

Dependent Variable: car				
VARIABLES	(1)	(2)	(3)	(4)
er	-0.018*** (0.005)	-0.018*** (0.005)	-0.016*** (0.005)	-0.016*** (0.005)
Constant	-0.628*** (0.055)	-0.626*** (0.016)	-0.604*** (0.057)	-0.601*** (0.030)
Control Variables	NO	NO	YES	YES
Observations	4,135	4,135	4,081	4,081
Number of cities	278	278	278	278

Note: *, **, *** correspond to significance at the 10%, 5%, and 1% levels, respectively.

Table 2 shows the baseline regression results of environmental regulations and carbon emissions. From column (1), it can be seen that environmental regulations are significantly negatively correlated with carbon emissions at the 1% level under fixed year effects, indicating that the development of environmental regulations will significantly reduce carbon emissions. Columns (2) and (3) add city fixed effects and control variables on top of column (1), and both still show significant negative correlations at the 1% level. Column (4), after controlling for control variables, city fixed effects, and year fixed effects, shows that environmental regulations and carbon emissions remain significantly negatively correlated at the 1% level. All of the above results indicate that environmental regulations significantly reduce carbon emissions, confirming hypothesis 1.

4.2. Robustness Test

To verify the reliability of the conclusions drawn in this study regarding the relationship between environmental regulations and carbon emissions, robustness tests were conducted as follows.

4.2.1. Substitute the Dependent Variable

In this study, the scope 1 carbon emissions were used as the baseline regression. For robustness testing, the total carbon dioxide emissions, which aggregate scope 1, scope 2, and scope 3 emissions, were included in Model (1). The results obtained are shown in the first column of Table 3, where the regression coefficient for environmental regulations remains significantly negative. This indicates that the baseline regression results are quite robust.

4.2.2. Exclude Outliers

To mitigate the influence of outliers on the regression results, the original data were cleaned to a certain extent before conducting the econometric analysis. As shown in the second column of Table 3, after conducting a 1% winsorization, it was observed that all regression results remained essentially unchanged. This suggests that the above conclusion is quite robust.

4.2.3. Considering Lagged Effects

Considering the potential lagged effects of environmental regulations on carbon emission reductions, a lag of one period was applied to the environmental regulation's variable. After this lag adjustment, the significance of the regression coefficient for environmental regulations did not change noticeably, as detailed in the third column of Table 3. These tests indicate that the empirical results of this study are robust to different specifications, demonstrating consistent findings regarding the impact of environmental regulations on carbon emissions.

4.2.4. Excluding Cities in Major Energy-Producing Provinces (Autonomous Regions)

To mitigate potential biases from the influence of regional energy structures on carbon intensity, apart from industrial structure, six major energy-producing provinces (autonomous regions), namely Shanxi, Shaanxi, Inner Mongolia, Gansu, Ningxia, and Xinjiang, were excluded from the urban sample for re-examination. The retest, presented in the fourth column of Table 3, showed that the significance of environmental regulations remained unchanged. This further confirms the robustness of the study's conclusions despite the exclusion, indicating that environmental regulations continue to play a significant role in reducing carbon emissions intensity.

Table 3. Robustness Test

Variables	substitute the dependent variable	exclude outliers	considering lagged effects	excluding cities in major energy-producing provinces
	(1)	(2)	(3)	(4)
er	-0.013*** (0.004)	-0.014*** (0.005)	-0.017*** (0.005)	-0.014** (0.006)
gov	0.023* (0.012)	0.049*** (0.013)	0.038** (0.015)	0.024 (0.015)
town	0.005 (0.013)	0.003 (0.015)	0.004 (0.017)	-0.009 (0.017)
pop	0.037** (0.016)	0.078*** (0.028)	0.095*** (0.023)	0.026 (0.021)
ope	-0.022*** (0.006)	-0.035*** (0.007)	-0.024*** (0.007)	-0.030*** (0.008)
eco	-0.019 (0.015)	0.040** (0.020)	0.002 (0.019)	-0.066*** (0.020)
Constant	-0.619*** (0.026)	-0.531*** (0.033)	-0.527*** (0.027)	-0.763*** (0.035)
Yearfix	YES	YES	YES	YES
City fix	YES	YES	YES	YES
N	4,081	4,081	3,809	3,402
R^2	0.761	0.695	0.676	0.722

Note: *, **, *** correspond to significance at the 10%, 5%, and 1% levels, respectively.

4.3. Mediation Analysis

Table 4 presents the results of the mediation analysis. In the first column (1), the effect of environmental regulations on carbon emissions is tested. In the second column (2), the effect of environmental regulations on industrial structure upgrading is examined. The third column (3) tests the effect of industrial structure upgrading on carbon emissions. Firstly, the mediation effect of industrial structure upgrading is analyzed.

The regression coefficient of environmental regulations in column (2) is significantly positively correlated at the 1% level, indicating that higher environmental regulation intensity promotes industrial structure upgrading. In the baseline regression in column (1), after adding the intermediate variable of industrial structure upgrading in the third column generated, the regression coefficients of environmental regulations and industrial structure upgrading are both significantly negative. This suggests that with higher levels of industrial structure upgrading, carbon emissions decrease in the comprehensive effect.

In column (3), the negative regression coefficient of environmental regulations (-0.016) and the product of the regression coefficient of environmental regulations in column (2) (0.014) with the regression coefficient of industrial upgrading in column (3) (-0.055) are negative. The same sign indicates that the intermediate variable of industrial structure upgrading has a mediating effect, validating hypothesis 2.

In conclusion, environmental regulations suppress carbon emissions through industrial structure upgrading, thereby ultimately leading to a reduction in carbon emissions.

Table 4. Mediation analysis

	(1)	(2)	(3)
Variables	car	s	car
er	-0.016*** (0.005)	0.014** (0.006)	-0.016*** (0.005)
s			-0.055*** (0.014)
gov	0.033** (0.014)	-0.053*** (0.016)	0.0380** (0.014)
town	-0.004 (0.015)	0.0053*** (0.015)	0.004 (0.017)
pop	0.037** (0.016)	0.078*** (0.018)	0.000 (0.015)
ope	-0.024*** (0.007)	-0.025*** (0.008)	-0.023*** (0.007)
eco	-0.004 (0.018)	0.040** (0.020)	0.001 (0.018)
Constant	-0.601*** (0.030)	-0.531*** (0.033)	-0.619*** (0.031)
Yearfix	YES	YES	YES
Cityfix	YES	YES	YES
N	4,081	4,057	3,809
R^2	0.699	0.693	0.699

Note: *, **, *** correspond to significance at the 10%, 5%, and 1% levels, respectively.

4.4. Analysis of Heterogeneity

4.4.1. Regional Heterogeneity Analysis

Based on the information provided, here's how the analysis of regional heterogeneity regarding the impact of environmental regulations on carbon emissions across 279 cities is described:

"To further analyze the impact of carbon emission reduction effects of environmental regulations on different cities, we conducted regional heterogeneity tests by dividing the 279 cities into three groups: Eastern, Central, and Western regions. The regression results in columns (1) to (3) of Table 5 indicate that the influence of environmental regulations on carbon emissions in Eastern and Central cities is not statistically significant, with negative coefficients suggesting a weak inhibitory effect on carbon emissions. However, in Western cities, environmental regulations show a significant negative correlation with carbon emissions at the 1% significance level." This analysis suggests that the effectiveness of environmental regulations in reducing carbon emissions varies significantly across different regions, with Western cities demonstrating a more pronounced regulatory impact compared to Eastern and Central cities.

Resource-based city heterogeneity analysis

The State Council's 2013 issuance of the "National Sustainable Development Plan for Resource-based Cities (2013-2020)" specifically designated 126 cities as resource-based cities, marking them as significant drivers for effectively controlling greenhouse gas emissions and promoting ecological civilization. Resource-based cities primarily rely on resources such as iron, petroleum, and coal, which in extraction, refining, combustion, and transportation processes generate substantial greenhouse gases. Consequently, they may respond differently to environmental regulations aimed at carbon emission reductions. Existing studies indicate that renewable and mature resource-based cities exhibit higher carbon emission efficiencies (Zhang Mingdou et al., 2023), yet there is scarce literature on whether digital economies within resource-based cities can also contribute to carbon emission reductions.Next, this paper divides the entire sample into resource-based and non-resource-based groups to analyze the carbon emission reduction effects of environmental regulations among different types of resource-based cities. According to columns (4) and (5) in Table 5, environmental regulations demonstrate a significant negative correlation with carbon emissions in both resource-based and non-resource-based cities.

Table 5. Analysis of heterogeneity

	Eastern region	Central region	Western region	Resource-based cities	non-resource-based cities
	(1)	(2)	(3)	(4)	(5)
er	-0.014 (0.014)	-0.002 (0.010)	-0.019** (0.008)	-0.024*** (0.008)	-0.009 (0.007)
gov	-0.013 (0.020)	0.073*** (0.021)	0.116*** (0.033)	0.101*** (0.020)	-0.007 (0.020)
town	0.008 (0.039)	-0.039 (0.026)	0.024 (0.029)	-0.054** (0.021)	-0.047* (0.021)
pop	0.081** (0.040)	0.007 (0.031)	0.036 (0.033)	0.041 (0.029)	0.063*** (0.025)
ope	-0.015 (0.018)	-0.003 (0.031)	0.024** (0.011)	-0.013 (0.012)	-0.022** (0.009)
eco	0.035 (0.047)	0.095** (0.039)	0.088*** (0.028)	0.022 (0.024)	-0.024 (0.027)
Constant	-1.245*** (0.077)	-0.538*** (0.070)	-0.261*** (0.054)	-0.465*** (0.046)	-0.698*** (0.041)
Yearfix	YES	YES	YES	YES	YES
Cityfix	YES	YES	YES	YES	YES
N	1440	1470	1171	1642	2439
R^2	0.791	0.699	0.063	0.669	0.725

Note: *, **, *** correspond to significance at the 10%, 5%, and 1% levels, respectively.

5. Conclusions and Policy Recommendations

Achieving the "dual-carbon" goal is a major strategic priority for China. Based on panel data from 279 cities in China from 2007 to 2021, this study empirically examines the direct impact of environmental regulations on carbon emissions and their indirect transmission mechanisms using a two-way fixed effects model. The following conclusions are drawn: First, the intensity of environmental regulations has a significant inhibitory effect on carbon emissions. Second, considering regional heterogeneity, this effect is more pronounced in western cities, resource-based cities, and non-resource-based cities. Third, in the process of reducing carbon emissions due to environmental regulations, industrial structural upgrading plays a partial mediating role. Based on these conclusions; in order to further enhance the role of environmental regulations in urban carbon reduction, this study proposes the following recommendations:

Firstly, implement stricter environmental regulatory policies to guide and demonstrate their effectiveness. This study found that environmental regulations contribute to local industrial restructuring. Therefore, it is necessary to maximize the demonstrative impact of environmental regulations on industrial upgrading and encourage local governments to competitively enhance their environmental regulations. Implementing stricter environmental regulatory policies should be a priority. Additionally, the adjustment of industrial structure through environmental regulations should proceed gradually, increasing regulatory measures based on the local enterprises' capacity to bear them. Avoid blindly intensifying environmental regulations to prevent widespread relocation or closure of local businesses.

Secondly, implement differentiated environmental regulatory strategies based on local pollution conditions. The intensity of industrial pollution influences local government's choices regarding environmental regulations. In areas where pollution is relatively light and stringent regulations might have unintended consequences, local governments should carefully consider local industrial pollution characteristics. They should avoid blindly increasing regulatory intensity and, when necessary, consider relaxing regulations to allow the market's "invisible hand" to adjust industrial structure. In contrast, in areas with more severe pollution where strict environmental regulations have proven effective, local governments should firmly utilize environmental regulations as a crucial tool. They should adjust regulatory intensity according to pollution levels, thereby better serving industrial restructuring efforts. Therefore, local governments must fully consider local pollution characteristics when formulating environmental regulatory policies.

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