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Environmental regulation, industrial structure and low-carbon development

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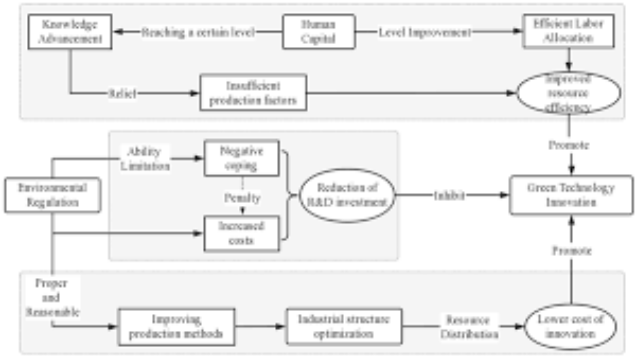
Graphical abstract



Abstract

In this paper, the provincial panel data of china from the year 2006 to 2019 are used to analyze the association among environmental regulations, industrial structure od industries and low-carbon development. The results show that regional industrial CO_2 emissions in China's east, center, and west were greatly decreased by environmental restrictions. The most significant deterrent to carbon emissions in the central region was, notably, environmental regulatory measures. By encouraging improvements in industrial structure and increasing its efficiency, the study shows that these rules helped to lower industrial carbon emissions. The examination of the sub-sample mechanism reveals significant regional variations: an advanced industrial structure was a major force behind low-carbon development in the western region, whereas high-efficiency industrial structures were critical in the eastern region. Through structural changes in the business, environmental restrictions can effectively promote low-carbon economic growth, as this study highlights. Across a range of control factors, environmental regulation considerably decreased regional industrial carbon emissions by about 0.196 to 0.033. Trade openness, urbanization, and the development of human capital all helped to reduce carbon emissions by roughly 1.057 to 4.104. The efficacy of regulatory tools was verified by endogeneity tests, which yielded coefficients varying between -0.891 and -0.156 for distinct factors. The results offering actual proof of the varying effects of environmental laws in various geographical areas and highlight the necessity of specialized policy strategies to promote sustainable development.

Keywords: environmental regulation; industrial structure; low-carbon development; provincial panel;

1. Introduction

Since the reform, the economy of chine has experienced a rapid development period. However, the years of extensive development has also caused great pressure on the environment, resulting in resource waste, environmental pollution and other serious environmental problem. In particular, frequent air pollution has become increasingly serious in recent years, causing certain damage to economic efficiency and public health. Through institutional and technological innovation, accelerating industrial transformation and upgrading, improving the rate of utilization of new energy, and reducing the consumption of fossil fuels as much as possible, it is possible to achieve a win-win situation between ecological protection of environment and socio-economic development in China, making economy a low carbon and better imprinted in the track of economic development. Therefore, adjust the structure of industries, transform the high carbon industry to low carbon industry, and give importance to the positive role of environmental regulation which is crucial to ensure high-quality and sustainable development of economy of china. Environmental regulation has a considerable role in industrial structure and in the development of economy. The industrial structure refers to the organization and composition sector within economy, which can utilize assessing the policy and economic processes effects. According to the conventional theory of growth, the division of labor, accumulation of factors and technological progress are the driving forces of economic growth, so the impact of the pollution and the environmental policy is not obvious. However, when it comes to sustainable development and development of environmental policies, economic development also obtains new acceleration power from endogenous growth theory. Some scholars have studied if environmental policies are helpful in achieving the relation between the pollution control and the development of economy according to the theoretical

concept of endogenous growth [Bovenberg and Mooij 1994].

The optimization of industrial structure and the transformation of economic development mode have become one of the important ways for the market to be flexible to the changes of environmental regulations and realize the free flow of factors. In fact, it also acts as the source and power for China to realize an economy less carbon footprints and sustainable development. Many scholars have used different theories to explain how environmental regulation affects industrial structure. One is "follow the cost theory". According to traditional neoclassical economics, the stricter regulations for environment are, the more negative externalization of production costs will be caused by enterprises, which will reduce production costs and adjust production scale through resource reallocation, resulting in industrial structure adjustment [Chen 2022]. Second, the "pollution refuge hypothesis". In the context of an open economic environment, if the government or enterprises want to evade environmental regulations or reduce environmental costs, they will certainly take relevant measures to cause differences in environmental costs among different countries, which will lead to regional migration of industries prone to cause pollution [Millimet *et al.* 2016; Sun *et al.* 2017; Solarin *et al.* 2017]. The third is "Porter hypothesis". When there are certain strict or moderate environmental regulations, enterprises will actively or passively seek to enhance the rate of utilization resources, improve environmental protection technology and strengthen enterprise innovation, so as to produce innovation compensation effect and gradually achieve Pareto improvement in the industry in which enterprises are engaged [Porter and Linde 1995; Ramanathan *et al.* 2017; Qiu *et al.* 2021]. Therefore, low-carbon economy has eventually become the direction of industrial structure alteration agreed by the academic circle, that is, to take "low-carbon economy" as the core concept, transform the industry into "low-carbon industry", and lead the industry to the development path of high income, low pollution and lesser consumption of energy [Ma and Kuo 2021]. The UK was the first to put forward the concept of "low-carbon economy" in its energy white Paper in 2003, and now all countries are gradually transforming their economy mode to "low-carbon economy" on this basis [Watson *et al.* 2021]. As a special economic development model, low-carbon economy is also affected by the level of domestic industrial structure, factor endowment, resource allocation, production and consumption patterns, etc. [Wang *et al.* 2021, Tang *et al.* 2020]. The industrial structure transformation from conventional development mode to lesser carbon emission and lesser pollution mode will be a complex and multi-dimensional change process. Under the low-carbon economic model, the optimization of industrial structure can maintain the overall productivity at a high level, but the consumption of resources will be reduced, which means that the low-carbon development model for economy is characterized by stages and low emissions, which maintains sustainability and productivity while reducing environmental impact [Wu *et al.* 2019]. Therefore, the study about these associations among environmental regulation, industrial structure and low-carbon development is of more value for China to have a deep understanding of environmental pollution and deepen the reform of economic system.

By filling a significant gap in the current research, the proposed study analyzes environmental legislation' effects on regional industrial carbon emissions in-depth. It explains the varied impacts of legislation in various parts of China by using robust regression models and performing heterogeneity tests.

This research contributes on the efficacy of different regulation strategies and provides important insights into the mechanisms via which environmental policies affect carbon emissions. The study also looks at the efficiency and progress of industrial structure as mediating factors, which deepens our understanding of the mechanisms by which laws influence emissions. Policymakers and other stakeholders need to have these information in order to create more focused and successful environmental policies. Moreover, the study's endogeneity tests strengthen the findings' methodological rigor and reliability while guaranteeing the analysis's robustness. All things considered, this study makes a substantial contribution to the subject by expanding academic understanding as well as providing useful implications for environmental governance and sustainable development initiatives.

The paper is organized as follows: Section 1 provides an overview of the research background and aims, emphasizing the need of examining how environmental rules affect low-carbon development. In Section 2, pertinent literature is reviewed, a theoretical framework is provided, and holes addressed by this study are identified. The methodology, including data sources, variable definitions, and the econometric models used for analysis, are covered in detail in Section 3. The empirical data are presented in Section 4, together with robustness checks and a discussion of how environmental rules affect carbon emissions and industry structure. In conclusion, Section 5 highlights the significance of region-specific solutions for fostering sustainable development and finishes with policy implications.

2. Literature Survey

Researches have analyzed the regulations for environment and low-carbon development on different perspectives. Since the proposal of "low-carbon economy", the concrete models such as "low-carbon agriculture", "low-carbon industry" and "low-carbon city" have emerged successively [Liu 2019; Guan *et al.* 2018; Gao 2021]. Environmental regulation will force the government to give importance to the policy formulation of low-carbon development, gradually balance the economic growth of traditional industrial structure, which lays a good foundation for ecological environmental protection [Song *et al.* 2021]. Under the criteria of environmental regulation, low-carbon economic development, as a constraint, enables the government to effectively implement the low-carbon

concept through a variety of policy tools, thus maximizing the role of environmental regulation [Yu 2018; Shi 2019], for instance adjusting the industrial structure by strengthening pollution control, and completing all-round optimization and upgrading of low-carbon industrial development from policy to practice [Zho 2018]. However, some studies have shown that there is some regional heterogeneity between environmental regulation and low-carbon development [Schaeffer *et al.* 2020; Xiao and Li 2013]. Therefore, in order to ensure the gradual shifting of structure of industries to environment-friendly and low-carbon energy saving direction, it is essential to attach importance to the mechanism of regulation of environment on this concept of low-carbon development [Stewart *et al.* 2019].

Hypothesis 1: Environmental regulation significantly reduces regional industrial carbon emissions.

Hypothesis 2: The effect of the environmental regulation on the low-carbon development varies from region to region.

Environmental regulation has a direct effect on low-carbon development, but it also has many indirect effects mechanisms via certain factors. As a variable that can affect industrial structure and even economic development, environmental regulation is considered by some scholars to have a threshold effect. When environmental regulation changes, industrial structure will also change accordingly. As a threshold variable, environmental regulation will first inhibit and then promote the change process of industrial structure [Feng et al 2022; Zheng 2016]. When environmental regulation reaches a certain inflection point, its promoting effect on the structure of industrial becomes more obvious, which is consistent with the findings of many studies that once the strength of the environmental regulation reaches a certain inflection point, the structure of industries will be continuously optimized and upgraded [Gu *et al.* 2022; Meng *et al.* 2021]. Other scholars have shown that there is a certain forcing mechanism among the regulations of environmental and the industrial structure of industries. That is, the existence and strengthening of environmental regulations will have a certain impact on the industrial structure, and even force the industrial structure to adapt to the change of regulations of environment, and the industrial structure in different regions will have different responses to environmental regulations [Han and Wu 2018; Song *et al.* 2022]. Some small and medium-sized polluting enterprises in undeveloped regions cannot pass the environmental protection costs on to consumers, so they cannot upgrade or replace the original polluting equipment [Kennedy 2010]. In contrast, developed regions have more large enterprises with strong pollution prevention and control capabilities, so the level of development of the same industry in various regions will vary.

Hypothesis 3: Environmental regulation significantly reduces carbon emissions by promoting industrial restructuring.

To summarize, the adjustment of structure of industries and economic development are never accomplished overnight, in which environmental regulation plays an indispensable role. In the background work China pays much attention to environmental governance and prevention and control of pollution, the relationship between environmental regulation and industrial structure becomes more and more close. As a global consensus, the low-carbon concept is also one of the products of environmental regulation, which is bound to get impact by the change of the structure of the industrial. Scholars have carried out relevant studies from the relation between environmental regulation and low-carbon development, as well as the relation between low-carbon development and industrial structure. However, there are few literatures on the relationship between these three aspects. Comparing to the available literature, the marginal contribution of this work is as follows: A. In terms of research data, through sorting out relevant literature, regional industrial carbon emission intensity is adopted to measure regional low-carbon development level and to explore the impact of environmental regulation on low-carbon development. At the same time, the advancement and efficiency improvement of industrial structure were measured by using the advancement and efficiency of regional industrial structure as intermediary variables, so as to measure the role of industrial structure in the impact mechanism of environmental regulation on low-carbon development more comprehensively. B. From the perspective of research, there are some studies that focus on internal mechanism of regional heterogeneity between regulation of enviornment and low-carbon development in existing literatures. From the perspective of regional heterogeneity and basic industrial structure, this work discusses the relationship and mechanism among environmental regulation, industrial structure and low-carbon development, in order to lay a good foundation for the development of the industrial structure towards a lower carbon, more optimized direction.

The analysis of the literature identifies shortcomings in the approaches that are currently in use, especially when it comes to thoroughly investigating the mediating function of industrial structure in the connection between environmental laws and low-carbon development. For generalizability and practical implications, it is imperative to address variances in industrial structure and regional variability. Panel data analysis includes drawbacks including endogeneity and omitted variable bias, despite its benefits. Nonetheless, strong techniques will be used to reduce biases and improve validity. The proposed study intends to fill these gaps and restrictions and offer important insights into how to formulate policies and develop strategies for sustainable development.

3. Empirical Analysis

3.1. Econometric model setting

According to the theoretical mechanism and research hypothesis mentioned above, this work constructs the given econometric method for empirical research:

$$\ln ei = a_0 + a_1 \ln er_{it} + a_2 X_{it} + \gamma_i + \varepsilon_t + \mu_{it} \quad (1)$$

First of all, in Formula (1), the explanatory variable ln ei_{it} denotes the intensity of industrial carbon emission of a region I in t years, that is measured by logarithm of the

emission of carbon per unit GDP of each region; the core explanatory variable $\ln ei_{it}$ is the environmental regulation intensity in region *i* in *t* years, which is represented by the logarithm of the ratio of investment of regional pollution control to the total industrial output value. γ_i represents region effect, ε_t represents year effect and μ_{it} represents error term. Secondly, Equations (2)–(5) are the mediating effect models.

$$adv_{it} = \beta_0 + \beta_1 \ln er_{it} + \beta_2 X_{it} + \gamma_i + \varepsilon_t + \mu_{it} \quad (2)$$

$$\ln ei_{it} = \delta_0 + \delta_1 adv_{it} + \delta_2 \ln er_{it} + \delta_3 X_{it} + \gamma_i + \varepsilon_t + \mu_{it} \quad (3)$$

$$eff_{it} = f_0 + f_1 \ln er_{it} + f_2 X_{it} + \gamma_i + \varepsilon_t + \mu_{it} \quad (4)$$

$$\ln ei_{it} = \lambda_0 + \lambda_1 eff_{it} + \lambda_2 \ln er_{it} + \lambda_3 X_{it} + \gamma_i + \varepsilon_t + \mu_{it} \quad (5)$$

Advancement of structure of regional industry (*adv*) and efficiency of the structure of industries (*eff*) were used as intermediate variables to measure the enhancement of structure of industry advancement and efficiency. The advancement of structure of industry is estimated by the ratio tertiary industry's added value to the secondary industry's added value. The efficiency of industrial structure is calculated by proportion of the regional GDP in the investment in social fixed assets.

X_{it} is a set of control variables: A. urbanization rate (*urban*). It is estimated by proportion of urban population in entire population of region at the end of a year. [Rubashkina *et al.* 2015] found that the improvement of urbanization rate is conducive to the development of a lesser carbon emission economy. B. The intensity of environmental protection and governance (*exp*). It is expressed by proportion of the expenditure of environmental protection of each region in the total financial expenditure of the region considering the large gap in the investment in environmental protection and governance among different regions. C. Trade openness (*trade*). Trade openness reflects the degree of trade between a region's commodity market and the international commodity market, which is measured by the proportion of the volume of total import and export in the gross domestic product of a region [Long *et al.* 2020]. D. Human capital (*edu*). Human capital is an important driving factor of innovation of technologies and upgrading of industries [Wang *et al.* 2011]. In this paper, the average educational year of a region is used to measure its human capital level. E. Financing constraints (*fin*). The level of financing constraints has a crucial effect on the development and innovation of regional industries, which is measured by ratio of the sum of deposits and regional financial institutions loans at the end of the year to the regional GDP.

3.2. Measurement of regional industrial carbon emission intensity

The emission of industrial carbon dioxide in various regions mainly comes from the consumption and release of fossil energy. Currently, there is no accurate statistics of industrial carbon emissions in official statistical reports of various regions in China. Therefore, this paper estimates regional emissions of CO_2 according to fossil energy consumption in each region that refers to measurement methods of existing studies. According to the calculation methods proposed [Liang *et al.* 2019], this paper refers to representative consumption of different energy products in China Energy Statistical Yearbook and calculates the total regional carbon emission according to the standard coefficient of coal conversion and coefficient of emission of carbon published by IPCC.

$$CO_{2i} = \sum_{j=1}^{15} E_j \cdot SC_j \cdot CF_j \quad (6)$$

Here, CO_{2i} represents total emission of carbon in region *i*, and E_j, SC_j, CF_j defines the consumption, coefficient of standard coal conversion and coefficient of emission of carbon of energy in category *j*, respectively. On this basis, the ratio of regional total carbon emission CO_{2it} to GDP_{it} is used to measure the intensity of emission of carbon per unit *GDP* of region *i* in *t-th* year (ton of standard coal/ten thousand yuan) (Table 1).

Table 1. Carbon emission coefficient and standard coal conversion coefficient of different types of energy

Energy type	Carbon emission coefficient	Standard coal conversion coefficient
Raw coal	0.755	0.714
Cleaned coal	0.755	0.900
Coke oven gas (COG)	0.354	0.614
Other gas	0.354	0.614
Other coking products	0.644	1.154
liquefied petroleum gas (LPG)	0.504	1.714
Refinery dry gas	0.460	1.571
Other petroleum products	0.585	1.310
Coke	0.855	0.971
Crude oil	0.585	1.428
Gasoline	0.553	1.471
Kerosene	0.571	1.471
Diesel	0.592	1.457
Fuel oil	0.618	1.428
Natural gas	0.448	1.214

Note: The unit of measurement of coefficient of emission of carbon is kg standard coal/kg. In the coefficient of standard coal conversion, the unit of measurement for natural gas is kg standard coal/m^3, and the unit of measurement for other energy is kg standard coal/kg. Data are gathered from the Guidelines of IPCC for 2016 National Greenhouse Gas Inventory [Arulselvan and Rajaram 2022; Li and Wang 2020; Xu 2024].

3.3. Description of data sources and descriptive statistics

This work mainly analyzes the regional data from thirty provinces (municipalities and autonomous regions) in China from the year 2006 to 2019. Data of various indicators mainly come from the Statistical Yearbook of china, China Energy Statistical Yearbook, China Industrial Statistical Yearbook published by the National Bureau of Statistics, statistical yearbook of various provinces as well as Guidelines of IPCC for 2016 National Greenhouse Gas Inventory. Tibet Autonomous Region is excluded because of missing data. Provincial statistics yearbooks were used to supplement information in circumstances where data was absent. Based on accepted procedures and prior research, the choice of input variables which included the actual capital stock, labor force, and energy consumption was rigorously justified. For example, the perpetual inventory approach was used to calculate capital stock, and a 4% depreciation rate was taken from pertinent literature. In order to guarantee consistency and comparability across locations and time periods, output variables, such as added value and carbon emissions, were carefully specified and assessed using standardized techniques advised by the 2006 IPCC Guidelines (Table 2).

Table 2. Descriptive statistics of variables

Variable	Observed value	Mean value	Variance	Minimum value	Maximum value
ln er	420	0.768	0.447	0.119	2.416
ln er	420	3.531	0.721	1.278	5.636
urban	420	0.511	0.152	0.243	0.875
exp	420	0.039	0.017	0.008	0.146
trade	420	0.192	0.333	0.012	1.827
edu	420	8.594	0.995	6.381	12.083
fin	420	2.736	0.992	1.288	7.883
adv	420	0.975	0.489	0.502	4.041
eff	420	1.928	0.804	0.676	4.668

4. Analysis of Empirical Results

4.1. 4.1 Benchmark regression analysis

Table 3 displays the baseline test results. From the regression coefficients of core explanatory variables in column (1), it is obvious that the environmental regulation (*lner*) significantly reduced regional industrial carbon emissions. Related variables of control are added in the columns (2)–(6), respectively, and regression coefficients of core explanatory variables are mainly negative at the 5% level. This shows that the environmental regulation measures on the whole significantly promoted the effective implementation of conservation of energy of industries and reduction of emission tasks in various regions and promotes steady development of regional economy with low carbon [Tan *et al.* 2024].

The improvement of urbanization rate (*urban*) is conducive to the large-scale agglomeration of labor, capital and the other factors of production, reduces the production input cost of enterprises, promotes regional industrial reform and innovation, thus realizing the significant reduction of industrial carbon emission level and contributing to rapid development of an economy with lesser carbon emission. The increase of environmental protection and governance intensity (*exp*) will inevitably make the relevant departments at all levels strengthen the environmental supervision, pollution control and comprehensive punishment of the polluting enterprises in the region, resulting in a significant increase in the "pollution cost" of enterprises. On this basis, high-pollution enterprises have to arrange their production activities in strict accordance with the emission regulations of environmental protection regulations to effectively curb the regional industrial carbon emission level. The higher the trade openness (*trade*) is, the more it will flourish an economy with lesser levels of carbon. Due to the active opening of the domestic market, foreign advanced products and technologies, high-quality human capital and efficient management experience flow into the domestic industry with international trade, which greatly promotes the progress of China's productivity and significantly minimized levels of emission of carbon of several regions in China. The enhancement of human capital (*edu*) is bound to effectively restrain regional industrial carbon emission intensity. A high level of human capital contains a high level of cultural knowledge ability and skilled production skills, which will significantly minimize the cost of production of enterprises, enhance the efficiency of the production of enterprises, and supports the smooth realization of energy conservation and emission reduction goals of enterprises. The change of financing constraint (*fin*) intensity seriously restricts the production scale adjustment and technological process upgrading of enterprises. When the level of financing constraint becomes increasingly severe, enterprises are likely to fall into a situation of cash flow shortage, which will disturb the enterprise's normal production and operations and make enterprises have no time to pay attention to their "pollution control" investment, thus leading to a significant increase in regional carbon emission level.

Table 3. Regression results of benchmark test

Variable	(1)	(2)	(3)	(4)	(5)	(6)
ln er	-0.196***(0.022)	-0.051***(0.013)	-0.044***(0.011)	-0.037***(0.010)	-0.033**(0.017)	-0.026**(0.012)
urban		-4.104***(0.195)	-2.654***(0.270)	-2.020***(0.278)	-1.057**(0.454)	-1.850***(0.396)
exp			-4.794***(0.646)	-5.912***(0.646)	-5.747***(0.645)	-3.618***(0.578)
trade				-0.369***(0.057)	-0.307***(0.061)	-0.187***(0.053)
edu					-0.122***(0.046)	-0.222***(0.040)
fin						0.321***(0.024)
Constant	0.797***(0.077)	2.770***(0.140)	1.765***(0.190)	1.362***(0.194)	1.950***(0.292)	2.547***(0.256)
Regional effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Observed value	420	420	420	420	420	420
R^2	0.132	0.523	0.568	0.599	0.604	0.706
Number of provinces	30	30	30	30	30	30

*Note: ***, ** and * denotes the significant at levels of 1%, 5% and 10%, Robust standard error is given in brackets. The same in Table 4 to 8.*

Table 4. Test results of regional heterogeneity

Variable	(1)	(2)	(3)
	Eastern region	Central region	Western region
ln er	-0.168***(0.040)	-0.313***(0.047)	-0.158***(0.028)
urban	-1.423***(0.504)	-2.764***(0.764)	-3.217***(0.721)
exp	-1.210(1.317)	-3.468***(0.833)	-3.175***(0.941)
trade	-0.185***(0.060)	-1.274(0.810)	-2.122***(0.689)
edu	-0.300***(0.058)	-0.263***(0.076)	-0.076(0.079)
fin	0.314***(0.033)	0.557***(0.054)	0.242***(0.041)
Constant	2.600***(0.348)	3.219***(0.513)	1.962***(0.499)
Regional effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Observed value	154	112	154
R^2	0.692	0.799	0.713
Number of provinces	11	8	11

4.2. Heterogeneity test

Table 4 shows the results of test of regional heterogeneity. It is found that environmental regulation measures (*Iner*) in eastern regions and western regions much inhibited regional industrial carbon emissions at the one% level, but the heterogeneity effect of regulation of environment in each region is also obvious. First of all, compared with central region, environmental regulations in regions of eastern side have an effect of weak reduction on emission of carbon. This is because the carbon emission control system in the eastern region is relatively complete, and the pollution emission level is already low. In particular, the long-term medium-high speed development of economy because of the reform and opening up are gradually adjusted and upgraded the structure of industries in eastern region, optimized the industrial scale layout, improved the internal upstream and downstream supply chain channels, and steadily improved the resource allocation efficiency of factor market and product market, as a result, the low carbon economic development level of the eastern region is naturally better than that of the regions of central and western [Yin *et al.* 2024]. Secondly, the regulation of environment measures in the central region have the strongest reduction effect on carbon emissions. This is because the central region is nearer to the eastern region that is developed economically, where the high-density transportation network reduces the transportation cost. The central region not only provides a large number of labor and natural resources for the eastern region, but also shares a part of high-pollution and industries that consumes lot of energy for the eastern region. As a result, the level of pollution in western region is relatively high, and the deployment of regulation of environment measures will significantly reduce the carbon emission level in region of west. Finally, the environmental regulation in western region has the weakest reduction effect on carbon emission. This is because the level of the development of economy in west region is comparatively backward and there is a congenital lack of large-scale industrial clusters.

4.3. Robustness test

For the purpose of exploring whether the restraining impact of environmental regulatory measures on industrial carbon emissions is reliable, robustness test was conducted according to the benchmark model and corresponding outcome are reported, as displayed in Table 5. Columns (1)–(3) successively use different environmental regulation tools to replace the core explanatory variables of the regression model. Among them, command-based regulation tools are expressed by

the logarithm of number of policies and regulations for protection of environment in each region, voluntary regulation tools are measured by the logarithm of the number of environmental protection petitions in each region, and market-based regulation tools are measured by the logarithm of the total amount of pollution discharge fees collected in each region. The results of robustness test show that all types of environmental regulation tools significantly suppressed carbon emissions at 5% level. According to the regression coefficient of core interpretation, it can be found that command-based regulatory tools have the strongest effect on low-carbon development, indicating that strict environmental policies and regulations and high-intensity supervision system are still effective tools for pollution control and low-carbon development [Li *et al.* 2024] (Table 5).

Table 5. Robustness test results

Variable	(1)	(2)	(3)
	Command-based regulation tool	**Voluntary regulation tool**	**Market-based regulation tool**
ln er	-0.055***(0.017)	-0.035**(0.016)	-0.029**(0.011)
urban	-1.940***(0.387)	-1.865***(0.392)	-1.805***(0.392)
exp	-4.099***(0.586)	-3.595***(0.589)	-3.528***(0.573)
trade	-0.172***(0.053)	-0.187***(0.055)	-0.203***(0.054)
edu	-0.189***(0.041)	-0.223***(0.040)	-0.223***(0.040)
fin	0.320***(0.023)	0.322***(0.023)	0.323***(0.023)
Constant	2.319***(0.240)	2.567***(0.236)	2.908***(0.338)
Regional effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Observed value	420	420	420
R^2	0.712	0.706	0.707
Number of provinces	30	30	30

Table 6. Test results of full-sample mediation mechanism

Variable	(1)	(2)	(3)	(4)
	adv	**lnei**	**eff**	**lnei**
adv		-0.194***(0.046)		
eff				-0.142***(0.016)
ln er	0.093***(0.013)	-0.067**(0.031)	0.070*(0.036)	-0.023**(0.011)
urban	1.190***(0.364)	-2.080***(0.394)	11.428***(0.990)	-0.225(0.414)
exp	3.312***(0.532)	-4.260***(0.590)	3.633**(1.446)	-3.102***(0.544)
trade	0.234***(0.049)	-0.142***(0.054)	0.275**(0.134)	-0.227***(0.050)
edu	0.334***(0.037)	-0.158***(0.042)	0.176*(0.100)	-0.247***(0.038)
fin	-0.066***(0.022)	0.334***(0.023)	-0.350***(0.059)	0.272***(0.023)
Constant	1.895***(0.235)	2.180***(0.267)	4.940***(0.640)	1.845***(0.252)
Regional effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Observed value	420	420	420	420
R^2	0.377	0.715	0.635	0.743
Number of provinces	30	30	30	30

4.4. Full sample mediation mechanism test

According to the theoretical mechanism analysis, it is found that regulations for environment can promote the development of an economy with low-carbon emission through the adjustment of industrial structure, but the specific transmission channel remains to be investigated. Table 6 displays the results of tests of full-sample intermediary mechanism. In columns (1)–(4), regional industrial structure advancement (adv) and high-efficiency of industrial structure (eff) are used as intermediate variables to measure the upgrading and efficiency improvement of structure of industries. The advancement of structure of industries is expressed by ratio of added value of tertiary and the secondary industries, and the high-efficient of industrial structure is measured by the proportion of the regional GDP in the investment in social fixed assets. The results show that regulations for environment significantly improved the level of advancement of the industrial structure advancement (adv) and efficiency of structure of industries(eff), resulting in a significant decrease of regional industrial carbon emissions. Where, regulations for environment plays a more prominent role in promoting low-carbon economic development through the advancement of industrial structure (adv).

4.5. Test of sub-sample mediation mechanism

From the above theoretical analysis and empirical research, regional heterogeneity is observed in impact of the environmental regulation on economy with low-carbon. Therefore, the transmission channel of regional intermediary mechanism is further verified under the consideration of regional differences. Tables 7 and 8 show the mediating

effects of advanced industrial structure (adv) and efficient industrial structure (eff) in different sample regions, respectively. The results show that environmental regulations in different regions restrain industrial carbon emissions by improving advancement of industrial structure (adv) and efficiency of industrial structure (eff), respectively. However, the change of structure of industries has a significant differentiated effect on regional low-carbon development. According to columns (2), (4) and (6) of Table 7, it can be found that environmental regulation reduces the carbon emission level most in western region through the transmission channel of industrial structure advancement (adv). According to the columns (2), (4) and (6) of Table 8, it can be known that environmental regulation has the most significant effect on carbon emissions in eastern region through the improving high-efficiency of industrial structure (eff).

Table 7. Test of sub-sample mediation mechanism (I)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Eastern region	Eastern region	Central region	Central region	Western region	Western region
adv		-0.204***(0.062)		-0.246***(0.093)		-0.430***(0.128)
ln er	0.102***(0.022)	-0.039**(0.020)	0.139***(0.030)	-0.027**(0.123)	0.131**(0.060)	-0.015**(0.007)
urban	4.502***(0.704)	-1.619**(0.667)	0.877(0.687)	-2.979***(0.752)	0.057(0.396)	-3.192***(0.702)
exp	0.604(1.494)	-1.333(1.286)	0.928**(0.436)	-1.960(1.418)	2.009***(0.517)	-4.039***(0.952)
trade	0.172*(0.092)	-0.172***(0.058)	3.205***(0.729)	-2.061**(0.847)	1.067***(0.378)	-2.581***(0.685)
edu	0.730***(0.066)	-0.151**(0.072)	0.216***(0.068)	-0.209***(0.077)	0.063(0.043)	-0.049(0.077)
fin	-0.027(0.038)	0.320***(0.033)	-0.114**(0.049)	0.585***(0.054)	-0.109***(0.022)	0.289***(0.042)
Constant	3.110***(0.395)	1.965***(0.391)	1.464***(0.461)	2.860***(0.520)	0.167(0.274)	1.890***(0.487)
Regional effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Observed value	154	154	112	112	154	154
R^2	0.605	0.709	0.361	0.808	0.288	0.729
Number of provinces	11	11	8	8	11	11

Table 8. Test of sub-sample mediation mechanism (II)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Eastern region	Eastern region	Central region	Central region	Western region	Western region
eff		-0.324**(0.039)		-0.268***(0.029)		-0.111***(0.049)
ln er	0.132**(0.059)	-0.014***(0.003)	0.071**(0.033)	-0.042***(0.009)	0.009**(0.004)	-0.002**(0.001)
urban	15.047***(1.921)	-1.594***(0.712)	7.755***(1.778)	-1.662***(0.640)	11.016***(1.155)	-0.354***(0.078)
exp	10.371**(4.078)	-0.901(1.337)	11.891***(3.364)	-0.997***(0.218)	0.394(1.508)	-3.302***(0.806)
trade	0.345*(0.185)	-0.195***(0.060)	5.004***(1.886)	-0.066(0.652)	4.226***(1.105)	-0.752(0.612)
edu	0.545***(0.179)	-0.316***(0.059)	0.336*(0.176)	-0.173***(0.060)	0.177(0.126)	-0.133*(0.068)
fin	-0.159**(0.071)	0.309***(0.034)	-0.863***(0.126)	0.326***(0.049)	-0.121*(0.065)	0.203***(0.035)
Constant	5.693***(1.078)	2.430***(0.372)	6.007***(1.193)	1.611***(0.438)	4.366***(0.800)	0.547(0.460)
Regional effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Observed value	154	154	112	112	154	154
R^2	0.532	0.695	0.826	0.877	0.776	0.791
Number of provinces	11	11	8	8	11	11

4.6. Endogeneity test

Considering that explanatory variables may be correlated with random perturbation terms, which may lead to endogeneity problems in the model, this paper adopts systematic GMM model to do endogeneity test in order to correct the endogeneity problems in the original model. In the columns (1)–(4) of Table 9, environmental regulation (lner), command-based, voluntary and market-based regulation tools as core explanatory variables are added into the system GMM model, and the lag period (L.lnei) of explained variables is also introduced according to the original model. The results show that all types of regulatory tools significantly restrained regional industrial emission of carbon at the level of 1%, and the regression coefficients of control variables were consistent with the empirical test

results. In addition, the output of the AR (1), AR (2) and Sargan test show that the original model had no autocorrelation and the choice of tool variables was reasonable, that further verifies the credibility of the results of the benchmark regression further.

5. Discussion

In this work, the analysis was conducted mainl from panel data of Chinese provincial regions from 2006 to 2019, and the mediation effect model was employed to discuss the association between factors such as environmental regulation, industrial structure and low-carbon development by using the advancement and efficaccy of regional structure of industries as the intermediary variables. The empirical outcome states that :(1) regulation for environment has reduced the carbon emissions of regional industries significantly. (2) From heterogeneity perspective, environmental regulation measures in regions of east and west significantly inhibited the emission of carbon in regional industries, but the impacts of regulations of environment varied from region to region; The inhibition impact of the regulations for environment measures on carbon emissions is the strongest in the central region, followed by inhibitory effect in the eastern region, and that the inhibitory effect in the western region is the weakest, which is further verified by the output of the robustness test. (3) The mediating impact of further mechanism test shows that environmental regulatory measures significantly reduced regional industrial carbon emissions through industrial structure advancement and improvement of efficiency of structure of industries. In particular, the promotion impact of industrial structure advancement on low-carbon development is more obvious. (4) Sub-sample test for the transmission mechanism shows that the industrial structure advancement in western region and the efficient industrial structure in eastern region are important driving factors to assure the low-carbon economy development. Looking forward, policies that improve the efficiency of the industrial structure and support low-carbon technology must be given top priority, particularly in areas with laxer regulatory frameworks. China may achieve its long-term objectives of carbon neutrality and ecological preservation by doing this, hastening the shift to a more sustainable and ecologically friendly economic model. The ability of industrial operations to provide desired results with the least amount of resource input and environmental damage is referred to as industrial efficiency. According to this study, increasing industrial efficiency results in less carbon emissions and increased sustainability by streamlining operations, cutting waste, and better utilizing resources.

Table 9. Endogeneity test results

Variable	(1)	(2)	(3)	(4)
L.lnei	-0.039***(0.011)	-0.026*(0.016)	-0.011**(0.005)	-0.014**(0.006)
ln er	-0.177***(0.048)	-0.285***(0.066)	-0.158***(0.044)	-0.156***(0.035)
urban	-0.106*(0.061)	-0.069*(0.036)	-0.155***(0.058)	-0.142**(0.065)
exp	-0.891*(0.502)	-1.089*(0.661)	-0.789*(0.422)	-0.884**(0.443)
trade	-0.127(0.089)	-0.159*(0.096)	-0.141*(0.080)	-0.116*(0.064)
edu	-0.099**(0.042)	-0.096**(0.041)	-0.114***(0.043)	-0.114***(0.040)
fin	0.037***(0.014)	0.038**(0.016)	0.046**(0.023)	0.043**(0.020)
Regional effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Observed value	300	300	300	300
AR(1)	0.001	0.005	0.002	0.001
AR(2)	0.265	0.168	0.179	0.231
Sargan	0.998	0.963	0.991	0.987

There are various possible limitations to the study. First, it is based on statistics at the provincial level, which does not account for notable intra-regional differences in industrial structures and environmental laws. Second, calculations based on fossil energy use were necessary due to the lack of government information on industrial carbon emissions, which could introduce measurement inaccuracies. Third, it's possible that the study period (2006–2019) did not adequately reflect the environmental regulations' long-term effects. Finally, even with the use of GMM models, any endogeneity problems can still affect how robust the findings are.

6. Conclusion

In conclusion, the importance of environmental laws in promoting low-carbon development in China's logistics sector is highlighted by this study. Key findings show the strong influence of regulatory measures on improving industrial efficiency and reducing carbon emissions over a 14-year period, based on an analysis of data from 30 provinces. A complete framework for evaluating the environmental performance of the logistics industry is provided by the suggested system, which incorporates a number of input and output variables, including actual capital stock, labor force, energy consumption, added value, and carbon emissions. The study notably emphasizes how important it is to increase ecological consciousness and enforce strict environmental laws in order to progress toward a high-quality economy. The research highlights the importance of incorporating low-carbon development concepts into all regions and promotes the use of policy options to hasten the shift towards a more sustainable and environmentally friendly economic model. The study tries to tackle ecological issues at their root and speed up the shift to a low-carbon, circular economy by giving priority to the optimization of industrial

and energy infrastructure. Looking ahead, future research will concentrate on improving the suggested method even further in order to boost its comprehensiveness and predictive power. In addition, efforts will be focused on investigating novel approaches to advance low-carbon development and industrial efficiency in the logistics sector. China can lead the way in making the transition from large-scale economic development to a high-quality, sustainable economy by continuing to adhere to international best practices and utilizing emerging technologies. This will help to advance global efforts towards environmental conservation and climate mitigation.

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References

Arulselvan G., Rajaram A. ," an optimised data accumulation technique using node selection in an ad hoc network for environmental monitoring," Journal of Environmental Protection and Ecology. 2022;**23(8**):3564–3573.

Bovenberg A.L., and Mooij R.A.D., "Environmental Tax Reform and Endogenous Growth," *Journal of Public Economics*, 1994, **63(2**) (February 1994): 207–237. https://doi.org/10.1016/S0047-2727(96)01596-4

Chen M., "A study of Low-Carbon Development, Urban Innovation and Industrial Structure Upgrading in China," *International Journal of Low-Carbon Technologies* 2022, **17(1)** (January 2022): 185–195. https://doi.org/10.1093/ijlct/ctab097

Feng Y.Y., Chen Y.Q., Wang Z., and Wei J., "Synthesis of Mesoporous Carbon Materials from Renewable Plant Polyphenols for Environmental and Energy Applications," *New Carbon Materials* 2022, **37**(1) (February 2022): 196–222. https://doi.org/10.1016/S1872-5805(22)60577-8

Gao H.Y., "Study of Low-Carbon Energy Development in China: the Case of Fujian Province," *IOP Conference Series Earth and Environmental Science* 2021, **781(3)** (May 2021): 032038. https://doi.org/10.1088/1755-1315/781/3/032038

Gu G., Zheng H., Tong L., and Dai Y., "Does Carbon Financial Market as an Environmental Regulation Policy Tool Promote Regional Energy Conservation and Emission Reduction? Empirical Evidence from China," *Energy Policy* 2022, **163(4)** (April 2022): 112826. https://doi.org/10.1016/j.enpol.2022.112826

Guan H.M., Liu W.X., Zhang P.Y., Lo K., Li J., and Li L.G., "Analyzing Industrial Structure Evolution of Old Industrial Cities Using Evolutionary Resilience Theory: A Case Study in Shenyang of China," *Chinese Geographical Science* 2018, **28(03)** (March 2018): 516–528. https://doi.org/CNKI:SUN:ZDKX.0.2018-03-014

Han H., and Wu S., "Structural Change and Its Impact on the Energy Intensity of Agricultural Sector in China," *Sustainabili*ty 2018, **10**(12) (December 2018): 1–23. https://doi.org/10.3390/su10124591

Kennedy A.L., "Using Community-Based Social Marketing Techniques to Enhance Environmental Regulation," *Sustainability* 2010, **2(4)** (April 2010): 1–23. https://doi.org/10.3390/su2041138

Li M., and Wang J., "Spatial-temporal distribution characteristics and driving mechanism of green total factor productivity in China's logistics industry,".\ *Polish Journal of Environmental Studies*,2020 ***30*(1)**, pp.201–213. https://doi.org/10.15244/pjoes/121046

Li, W., Zhang, Y., Xu, J., Fang, S., Li, Q., Gong, W., Wang, C. and Zhang, R., 2024. Evaluation for the effect of low-carbon city pilot policy: evidence from industry in China. *Environmental Science and Pollution Research*, pp. 1–20. https://doi.org/10.1007/s11356-023-31685-0.

Liang S., Zhao J.F., He S.M. , Xu Q.Q. , and Ma X., "Spatial econometric Analysis of Carbon Emission Intensity in Chinese Provinces from the Perspective of Innovation-Driven," Environmental Science and Pollution Research International 2019, **26**(14) (May 2019): 13878–13895. https://doi.org/10.1007/s11356-019-04131-3.

Liu L.L., "Upward Trend of Nitrogen Deposition Curbed by the Dual Force of Environmental Regulation and Social-Economic Structural Change in China," *Science Bulletin* 2019, **64(18)** (October 2019): 1300–1302. https://doi.org/CNKI:SUN:JXTW.0.2019-18-004

Long H.M. , Jiang H. , and Jiang X. , "The Spatial Effect of Financial Development on Industrial Structure Optimization," *Journal of Hunan University (Social Sciences)* 2020, **34**(02) (April 2020): 42–48. https://doi.org/10.16339/j.cnki.hdxbskb.20200403.014

Ma J., and Kuo J., "Environmental Self-Regulation for Sustainable Development: Can Internal Carbon Pricing Enhance Financial Performance?" *Business Strategy and the Environment* 2021, **30(8)**, (December 2021): 3517–3527. https://doi.org/10.1002/bse.2817

Meng X.C., Seong Y.H., and Lee M.K, "Research characteristics and development trend of global low-carbon power-based on bibliometric analysis of 1983-2021," *Energies* 2021, **14(16)** (August 2021): 4983. https://doi.org/10.3390/en14164983

Millimet D.L., Roy J., "Empirical Tests of the Pollution haven Hypothesis when Environmental Regulation is Endogenous," *Journal of Applied Econometrics* 2016, **31(4**) (February 2015): 652–677. https://doi.org/10.1002/jae.2451

Porter M.E., and Linde C.V.D., "Towards A New Conception of the environment-competitiveness relationship," *Journal of Economic Perspectives* 1995, **4(4)** (February 1995): 97–118. https://doi.org/10.1016/10.1257/jep.9.4.97

Qiu S.L., Wang Z.L., and Geng S.S., "How do Environmental Regulation and Foreign Investment Behavior Affect Green Productivity Growth in the Industrial Sector? An Empirical Test based on Chinese Provincial Panel Data," *Journal of Environmental Management* 2021, **287(1)** (June 2021): 112282. https://doi.org/10.1016/j.jenvman.2021.112282

Ramanathan R., He Q., Black A., Ghobadian A., and Gallear D., "Environmental Regulations, Innovation and Firm Performance: A Revisit of the Porter Hypothesis," *Journal of Cleaner Production* 2017, **155(2)** (July 2017): 79–92. https://doi.org/10.1016/j.jclepro.2016.08.116

Rubashkina Y., Galeotti M., and Verdolini E., :Environmental Regulation and Competitiveness: Empirical Evidence on the

Porter Hypothesis from European Manufacturing Sectors," *Energy Policy* 2015, **83(8)** (August 2015): 288–300. https://doi.org/10.1016/j.enpol.2015.02.014

Schaeffer R., Bosetti V., Kriegler E., Riahi K., and Vuuren D., "Climatic Change: CD-Links Special Issue on National Low-Carbon Development Pathways," *Climatic Change* 2020, **162(04)** (April 2020): 1779–1785. https://doi.org/10.1007/s10584-020-02890-4

Shi C.K., "Effect and Mechanism of Market-Based Environmental Tools on Economic Growth: Based on the Perspective of Industrial Structure," *Journal of Central South University* 2019, **25(02)** (February 2019): 78–88. https://doi.org/10.11817/j.issn.1672-3104.2019.02.010

Solarin A.S., Al-Mulali U., Musah L., Musah I., and Ozturk I., "Investigating the pollution haven hypothesis in ghana: an empirical investigation," *Energy* 2017, **124(1**) (April 2017): 706–719. https://doi.org/10.1016/j.energy.2017.02.089

Song Q., Liu T., and Qi Y., "Policy Innovation in Low Carbon Pilot Cities: Lessons Learned from China," *Urban Climate* 2021, **39(2)** (September 2021): 100936. https://doi.org/10.1016/j.uclim.2021.100936

Song S.X., Zhang L., and Ma Y.X., "Evaluating the Impacts of Technological Progress on Agricultural Energy Consumption and Carbon Emissions based on Multi-Scenario Analysis," *Environmental Science and Pollution Research* 2022, **30**(10) (October 2022): 16673–16686. https://doi.org/10.1007/s11356-022-23376-z

Stewart J., Anda M., and Harper R.J., "Low-carbon Development in Remote Indigenous Communities: Applying A Community-Directed Model to Support Endogenous Assets and Aspirations," *Environmental Science & Policy* 2019, **95(Suppl. S152)** (May 2019): 11–19. https://doi.org/10.1016/j.envsci.2019.01.003

Sun C., Zhang F., and Xu M., "Investigation of Pollution Haven Hypothesis for China: An Ardl Approach with Breakpoint Unit Root Tests," *Journal of Cleaner Production*, 2017, **161(sep.10)** (September 2017): 153–164. https://doi.org/10.1016/j.jclepro.2017.05.119

Tan, L., Yang, Z., Irfan, M., Ding, C.J., Hu, M. and Hu, J., 2024. Toward low-carbon sustainable development: Exploring the impact of digital economy development and industrial restructuring. *Business Strategy and the Environment*, ***33*(3)**, pp.2159–2172. https://doi.org/10.1002/bse.3584

Tang H.L., Liu J.M., and Wu J.G., "The impact of command-and-control environmental regulation on enterprise total factor productivity: A quasi-natural experiment based on China's "Two Control Zone" policy," *Journal of Cleaner Production* 2020, **254(1)** (May 2020): 120011. https://doi.org/10.1016/j.jclepro.2020.120011

Wang Y., Jian L., Hansson L., Kai Z., and Wang R., "Implementing stricter environmental regulation to enhance eco-efficiency and sustainability: a case study of Shandong Province's pulp and paper industry, China," *Journal of Cleaner Production* 2011, **19**(4) (March 2011): 303–310. https://doi.org/10.1016/j.jclepro.2010.11.006

Wang Y., Zhang F.Q., Zheng M.B., and Chang C.P., "Innovation's spillover effect in china: incorporating the role of environmental regulation," *Environmental Modeling & Assessment Volume* 2021, **26(5)** (October 2021): 695–708. https://doi.org/10.1007/s10666-021-09763-9

Watson L., Falconer L., Dale T., and Telfer T.C., "'Offshore' salmon aquaculture and identifying the needs for environmental regulation," *Aquaculture* 2021, **546(1554)** (August 2021): 737342. https://doi.org/10.1016/j.aquaculture.2021.737342

Wu L., Sun L., Qi P., Ren X., and Sun X., "Energy Endowment, Industrial Structure Upgrading, and CO2 Emissions in China: Revisiting Resource Curse in the Context of Carbon Emissions," *Resources Policy* 2019, **74(12)** (December 2021): 102329. https://doi.org/10.1016/j.resourpol.2021.102329

Xiao X.Z., and Li S.L., "Study on the Dynamic Influence of Environmental Regulation on Industrial Upgrading Path," *Economic Theory and Business Management* 2013, **33(06)** (June 2013): 102–112. https://doi.org/10.3969/j.issn.1000-596X.2013.06.010

Xu, B., 2024. Environmental regulations, technological innovation, and low carbon transformation: A case of the logistics industry in China. *Journal of Cleaner Production*, ***439***, p.140710. https://doi.org/10.1016/j.jclepro.2024.140710

Yin, K., Miao, Y. and Huang, C., 2024. Environmental regulation, technological innovation, and industrial structure upgrading. *Energy & Environment*, ***35*(1)**, pp.207–227.https://doi.org/10.1177/0958305X221125645

Yu X., "Study on the Classification Model of Low-Carbon Development in National Pilot Industrial Parks, China Population," *Resources and Environment* 2018, **217(09)** (September 2018): 35–42. https://doi.org/CNKI:SUN:ZGRZ.0.2018-09-005

Zhao B., Ouyang Z., Duffy M.C., Andersen M.A.E., and Hurley W.G., "An Improved Partially Interleaved Transformer Structure for High-Voltage High-Frequency Multiple-Output Applications," *IEEE Transactions on Industrial Electronics* 2018, **66(04)** (October 2017): 2691–2702. https://doi.org/10.1109/TIE.2018.2840499

Zheng J.L., "Environmental Regulation Competition and Industrial Structure Adjustment from the Perspective of Decentralization," *Modern Economic Science* 2016, **38**(01) (January 2016): 77–85. https://doi.org/10.3969/j.issn.1002-2848.2016.01.008