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The Role of Industrial Structure Upgrading in Moderating the Impact of Environmental Regulation on Air Pollution in China

Yu Liu [1], Chun-Ni Xie [1], Zi-Shuang Wang [1], Noure-El Houda REBAI [1] and Xiao-Min Lai [2,*]

[1] College of Management, Wuhan Institute of Technology, Wuhan, 430205 and China; lyu429@163.com (Y.L); xcn1028@163.com(C.-N.X); Rebai.noure@gmail.com (Noure-El Houda REBAI); ziwang1022@163.com(Z.-S.W.)

[2] College of Law and business, Wuhan Institute of Technology Wuhan, 430205 and China;

* Correspondence: xiaomin.lai@foxmail.com (X.-M.L); Tel: +86 15827277086

Abstract: Air pollution is an important factor affecting human health and daily life. Chinese government is making vigorous efforts to control air pollution. The upgrading of industrial structure is a problem-solving tool in environment and economic growth cases. This paper aims to explore the relationships among environmental regulation, the upgrading of industrial structure and air pollution. The PVAR (Panel Vector Auto Regression) model and moderation effect model has been used to conduct empirical analysis based on panel data of 30 provinces in China from 2004 to 2020. The results of analysis indicate (1) the environmental regulation can significantly reduce the air pollution, but the deterioration of air quality could not effectively influence environmental regulations. (2) The upgrading of industrial structure can weaken the air pollution and air pollution hinders the upgrading of industrial structure. (3) With the improvement of environmental regulation, the industrial structure is constantly upgraded, but the upgrading of the industrial structure has a negative effect on the improvement of environmental regulation. (4) The upgrading of industrial structure can positively moderate the influence of environmental regulation on air pollution.

Keywords: air pollution; environmental regulation; industrial structure; PVAR model; Moderating effect

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1. Introduction

According to the Global Environmental Performance Index (EPI) in 2020, the ranking of China's air quality is the 137th among 180 countries. Since launching its open-door policy and economic reform, China has experienced spectacular economic growth. However, the conventional path of economic growth has caused unprecedented environmental pollution and health risks [1,2]. The traditional economic growth model has caused resource exhaustion and is difficult for sustainable development [3].Frequent air pollution has a significant impact on human health [4,5]. It is showed that air pollution has serious impact on the general public and has become a major bottleneck for China's sustainable development [6]. In recent years, China's government attaches great importance on increasing the environmental investment and promoting the upgrading of the industrial structure. Recently, the discussion on the relationships among the environmental regulation, the upgrading of industrial structure and air pollution in the academic field is getting heated.

There are three viewpoints about the impact of environmental regulation on air pollution according to previous literatures. First, the environmental regulation is helpful for reducing air pollution. Using the panel data of province-level [7]and prefecture-level [8] , some studies found that environmental regulations can suppress the air pollution through technological progress, industrial structure adjustment and cost control [9]. Second, environmental regulation will cause the deterioration of air pollution [10]. Hao et al. [11] uses the first difference GMM(generalized method of moments) method to explore the relationship and finds that current environmental regulations have not achieved the goal of control pollution. Third ,there is a non-linear relationship between environmental regulations and air pollution [12].

The literature on environmental regulation and industrial structure upgrading mainly focuses on three aspects. To begin with, the "following costs" hypothesis thinks that environmental regulations will increase the additional costs of enterprises，squeeze out the profits and inhibit the upgrading of the industrial structure [13] . Then, the "innovation compensation" hypothesis finds that the environmental regulations can stimulate the vitality of innovation and promote the upgrading of the industrial structure. In the end, there is a non-linear relationship between environmental regulations and air pollution .Some literature believes that there is a non-linear U-shaped relationship between them [14,15].

A great deal of research has been done between the industrial structure upgrading and air pollution. But the influence mechanism of industrial structure upgrading on air pollution is still unclear [16].Through the construction of static and dynamic spatial econometric models, Ma et al. [17] find that the optimization and rationalization of industrial structure can significantly improve air quality. By constructing a spatial econometric model , Yang et al [18]concluded that industrial structure upgrading will reduce carbon emissions by improving green total factor productivity. But Feng et al [19] obtains the opposite conclusion. Feng tries to explore the effect of industrial structure upgrading on carbon emissions in China, using the traditional OLS (Ordinary Least Square) model, the dynamic SYS-GMM (System Generalized Method of Moments) model.

According to the previous literature, the relationships among environmental regulation, the upgrading of industrial structure and air pollution are still unclear. This study uses the panel data of 30 provinces in China from 2004 to 2020 to conduct the empirical analysis on them. The first major contribution is that the study uses the PVAR model to explore the short-term and long-term interaction relationships among the environmental regulation, the upgrading of the industrial structure and the air pollution. The second major contribution is that this study aims to explore the influence effect of environmental regulation on air pollution, focusing on moderating effects of the upgrading of industrial structure.

2. Theoretical Analysis and Research Hypothesis

This section will explore the direct effect of environmental regulation on air pollution and the moderating effect of upgrading of industrial structure, as shown in Figure 1.

The negative externalities of environmental problems and unclear environment property rights leads to the market failure in the pollution control [20], which makes the control of air pollution more dependent on the government. The environmental regulation is an effective way for government to control the air pollution. Environmental regulations can directly affect the air pollution [7]. Environmental regulations will increase the cost of the enterprise, resulting in the "cost effect", and finally reducing air pollution [21,22]. Environmental regulations can indirectly affect the air pollution through FDI [7]. Improving environmental regulation can attract multinational companies with advanced technology. The foreign companies can introduce more clean technologies and abundant capital to the host country, resulting in the "pollution halo effect", thus reducing air pollution.

The first hypothesis is proposed based on the above analysis.

H1: The improvement of the environmental regulation can effectively promote the reduction of the air pollution.

The previous literature has been conducted among the environmental regulation, the upgrading of industrial structure and air pollution. When exploring the relationship between environmental regulation and air pollution, some studies regard the upgrading of industrial structure as a control variable and find that the upgrading of the industrial structure will reduce air pollution [23]. Du and Chen [24] take the industrial concentration as a mediating variable and find that environment regulation can reduce the density of air pollution through promoting the industrial concentration.

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The upgrading of the industrial structure may play a moderating role of the impact of environmental regulation on air pollution.

The upgrading of industrial structure can make up the shortcoming of environmental regulation on air pollution. Through promoting technological innovation [25],driving the transformation of production and the upgrading of consumption [26],the upgrading of industrial structure can lead enterprises to develop in a green way.

Based on the above analysis, this paper proposes the second research hypothesis:

H2: the upgrading of the Industrial structure positively moderates the effect of environmental regulation on air pollution.

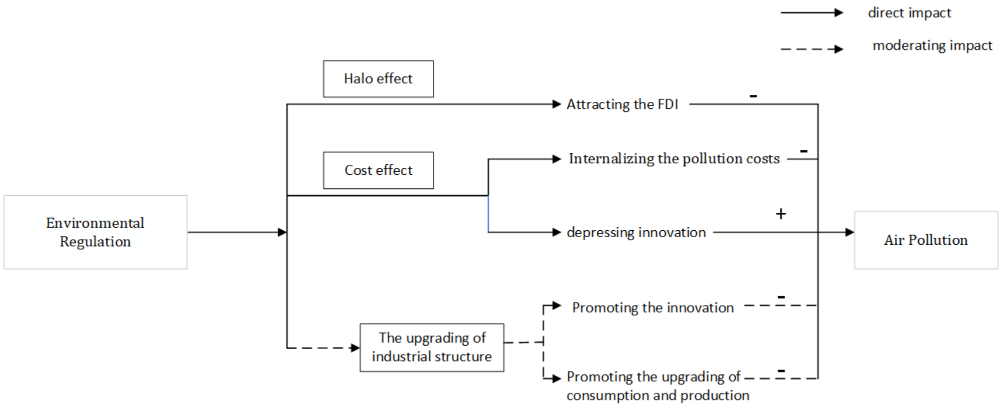

Figure 1. The impact paths of environmental regulation on air pollution.

3. Methods

3.1. Model Specifications

Time-series vector autoregression (VAR) models was regarded as an alternative to multivariate simultaneous equation models initially [27].All variables in a VAR model are treated as endogenous, which can effectively show the relationship between the variables. Newey et.al introduced VAR in panel-data setting and panel VAR models have been used in multiple applications across fields [28]. Further developed by Love and Zicchino [29], the PVAR model has been widely used in the fields of economy, policy and industrial structure.

This paper uses the moderating effect model to explore the influence effect of environmental regulation on air pollution, focusing on moderating effects of the upgrading of industrial structure.

$$Model1: Y_{it} = \alpha_0 + \sum_{n=1}^{p} \beta_n Y_{it-n} + \gamma_i + \sigma_t + \mu_{it}$$

In the model 1, where Y_{it} is a three-variable vector $[\text{pollition}_{it}\ \text{regulation}_{it}\ TS_{it}]$ of section individual i at timepoint t. Y_{it-n} is the n-order lag term of Y_{it}. $pollution_{it}$ denotes the emission of SO_2, $regulation_{it}$ denotes the tax of SO_2, TS_{it} represents the upgrading of industrial structure . α_0 is the intercept vector, i represents different provinces, t represents different years, p is the lag order, β_n is the coefficient matrix of the lagging variable, γ_i is the individual effect, σ_t is the time effect, μ_{it} is the random perturbation term.

$$Model2: \ln pollution_{it} = \alpha_0 + \beta_1 \ln control_{it} + \beta_2 \ln regulation_{it} + \varepsilon_{it}$$

$$Model3: \ln pollution_{it} = \alpha_0 + \beta_1 \ln control_{it} + \beta_2 \ln regulation_{it} + \beta_3 \ln TS_{it} + \varepsilon_{it}$$

$$Model4: \ln pollution_{it} = \alpha_0 + \beta_1 \ln control_{it} + \beta_2 \ln regulation_{it} + \beta_3 \ln TS_{it} + \beta_4 \ln regulation_{it} * \ln TS_{it} + \varepsilon_{it}$$

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In the model 2-4，where $pollution_{it}$ is the dependent variable, denoting the emission of SO_2 in the j province of the i year. $regulation_{it}$ is the key explanatory variable, denoting the tax of SO_2 in the j province of the i year. TS_{it} represents the upgrading of industrial structure in the j province of the i year. $Control_{it}$ is a vector composed of the control variables [7,8,30], it mainly includes the control variables such as development, innovation, urban, open, invest and energy. α_0 Intercept term. β is the regression coefficients of the equations. ε_{it} is the random error term.

3.2. Dependent Variables

In previous studies, scholars choose different indicators to measure air pollution including $PM_{2.5}$ [31,32], CO_2 [33], and SO_2 [34] . SO_2 is one of the main factors in the increase of $PM_{2.5}$ [35,36] and is more harming to human body [37]. Meanwhile, SO_2 is the main object of environmental regulations. Considering the availability of data, we select SO_2 emission as the dependent variables to measure the pollution. The data of SO_2 emission comes from the China Statistical Yearbook, including 30 provinces in China from 2004 to 2020. The data represents the emission of industrial SO_2. The data is calculated and reported by each province. The methods for measuring SO_2 emissions in various provinces include detection data method, material measurement method and emission coefficient method, which are different for different industries.

3.3. Independent Variables

Previous studies have selected indicators such as the number of environmental protection laws and the proportion of pollution control investment in total industrial output value GDP [38] to measure the degree of environmental regulation, but the law is constrained by the intensity of the enforcement and the proportion of treatment investment cannot reflect the regulation of every specific pollutant. As one of the most important environmental regulatory means, environmental tax can overcome the above shortcomings we select the environmental tax of SO_2 as a key indicator to measure the intensity of environmental regulations.

3.4. Moderate Variables

According to the theoretical mechanism analysis, air pollution is highly correlated with the environmental regulation, and the upgrading of industrial structure may play a moderating role. The industrial structure upgrading is the process of establishing and realizing a high-efficiency industrial structure. According to Clark's Law, some literature adopts the proportion of non-agricultural output value as the measure of industrial structure upgrading. However, after the 1970s, the information technology revolution had a great impact on the industrial structure and there was a trend of "economic service". Especially after the reform and opening up, this trend has accelerated. The traditional indicator cannot reflect the upgrading of industrial structure in China. This paper adopts the research conclusion of Gan. It takes the ratio of tertiary industry output to secondary industry output (TS) to measure the upgrading of industrial structure [39].

3.5. Control Variables

A range of factors that can affect air pollution are controlled. The previous studies [7,8,30] have shown the level of economic (development), the level of innovation (innovation), the level of urbanization (urban),the openness to trade (open),the investment scale (invest) and energy efficiency (energy) are closely related to air pollution. Therefore, we choose the above variables as control variables.

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3.6. Data Resource

On July 1 ,2003, the government promulgated the Regulations on the Administration of the Charging and Use of Pollutant Discharge Fees. It had a huge impact on Pollutant Discharge Fees for a long time. So we choose the panel data from 2004. On January 1,2018, an environmental tax system was enacted to replace the former sewage charge system. The tax rates for each pollutant were roughly the same as the former sewage charge rates. The tax rate for each pollutant before 2018 can be replaced by sewage charge rates. The data of sewage charge rates from 2004-2018 are collected from the documents of the Ministry of Finance and the Price Bureau. After 2018 the data of environmental tax are collected from provincial tax bureaus. The data of other variables are mainly collected from 2004-2020 of *China Statistical Yearbook on Environment* and *China Statistical Yearbook.* The panel data consists of 30provinces in China from 2004-2020, while Tibet, Taiwan, Hong Kong and Macau are not included due to data availability. This study uses the moving average method to supplement the missing individual data.

4. Results

4.1. Descriptive Analyses

SO_2 mainly comes from the combustion of fuels such as coal and petroleum. The average emissions of SO_2 were 506,600 tons. Pollutant emissions showed a downward trend from 2010 to 2020, and the efficiency of emission reduction has been greatly improved since 2015. The trend of SO_2 tax had a marked increase since 2015. The average regional GDP (Gross domestic product) per capita was 42,600 yuan and the average number of patents granted in the region was 37,800 pieces. The average level of urbanization is 54.0%. For trade openness, the ratio of total imports and exports to total local GDP can reach a maximum of 1.7. For the investment scale, the ratio of total fixed asset investment output to local GDP reaches a maximum of 0.09. For energy efficiency, for every 10,000 yuan increase in regional GDP, the mean consumption is 0.99 tons. The highest regional tertiary sector output as a proportion of secondary sector output was 5.3. The average tax charge per pollutant equivalent was 1.36 yuan (Table 1).

Table 1. Descriptive statistics.

	Variable	Measure	unit	Mean	S.D	Min	Max
Dependent variable	Pollution	SO_2 emissions (Ten thousand tons)	Ten thousand tons	50.06	39.68	0.09	171.50
Independent variable	Regulation	The tax of so_2	yuan	1.360	1.740	0.420	12.00
Control variable	Development	GDP per capita	Ten thousand yuan	4.265	2.840	0.422	16.48
	Innovation	the number of patents granted	Ten thousand piece	3.782	7.274	0.007	70.97
	Urban	The proportion of urban resident population in the total permanent resident population	%	54.00	14.00	25.00	98.00
	Open	The ratio of the total value of imports and exports to local GDP	%	30.0.	36.00	1.00	170.00
	Invest	The ratio of total fixed asset investment to local GDP	-	0.0100	0.0100	0	0.0900

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	Energy	The ratio of actual energy use to local GDP	-	0.990	0.650	0.190	4.190
Moderating variable	TS	The ratio of output value of tertiary industry to output value of secondary industry	-	1.150	0.600	0.530	5.300

4.2. PVAR Results

STATA software is used to run the Model 1. GMM (Generalized Method of Moment) and the impulse response function are performed to test the short-term and long-term interaction among them and the regression results are shown in Table 2 and Figure 2. In the Figure 2, the area between the first and third lines forms a 95% confidence interval. The second line represents the impulse response value

For the so_2 , the results of GMM are reported in the column 2 of Table 2. In particular the first lag of environmental regulation and the industrial structure upgrading negatively determines the current level of so_2 at the 10% and 5% level of significance. The first line of the Figure 2 reports the IRFs of so_2 .The results show that the effect of one standard deviation shock of environmental regulation and industrial structure upgrading on so_2 were negative. It indicates the environmental regulation and industrial restructure upgrading are beneficial to the pollution reduction in short and long term, which is consistent with our hypothesis H1.

For the tax rate of so_2, the results of GMM are reported in the column 3 of Table 2. The coefficient of so_2 emissions is -0.009 at the 10% level of significance. The second line of the Figure 2 reports the IRFs of environmental regulation. The effect of one standard deviation shock of so_2 on environmental regulation was negative. It shows the deterioration of air quality could not effectively influence environmental regulations. For the upgrading of industrial structure, the results of GMM are reported in the column 3 of Table 2. The coefficient of so_2 tax rate is positive in the lag 1 and the coefficient of so_2 is negative at the 10% level of significance. The third line of The Figure 2 reports the IRFs of industrial structure upgrading. The upgrading of industrial structure responds positively to the regulations, which indicate that the improvement of environmental regulation can promote the upgrading of the industrial structure.

Table 2. the short-term interaction among environmental regulation, the upgrading of industrial structure and air pollution.

VARIABLES	Pollution			Regulation			TS		
	Coefficient	95%CI	P>|z|	Coefficient	95%CI	P>|z|	Coefficient	95%CI	P>|z|
L.h_pollution	1.067	(0.944, 1.190)	0.000	-0.009	(-0.020, 0.001)	0.100	-0.001	(-0.003, 0.000)	0.078
L2.h_pollution	-0.129	(-0.253, -0.006)	0.039	0.005	(-0.007, 0.018)	0.389	0.001	(-0.000, 0.002)	0.143
L.h_regulation	-0.498	(-3.193, 2.196)	0.076	1.126	(0.408, 1.844)	0.002	0.083	(-0.004, 0 .171)	0.062
L2.h_regulation	1.721	(-0.177, 3.619)	0.060	0.151	(-0.063, 0.366)	0.168	-0.009	(-0.040, 0.022)	0.571
L.h_TS	-32.527	(-58.82, -6.226)	0.015	-1.725	(-4.757 , 1.306)	0.265	0.778	(0.236, 1.319)	0.005
L2.h_TS	25.345	(11.63, 39.05)	0.000	-0.147	(-1.185, 0.890)	0.781	-0.190	(-0.312 -0.068)	0.002
Observations	420			420			420		

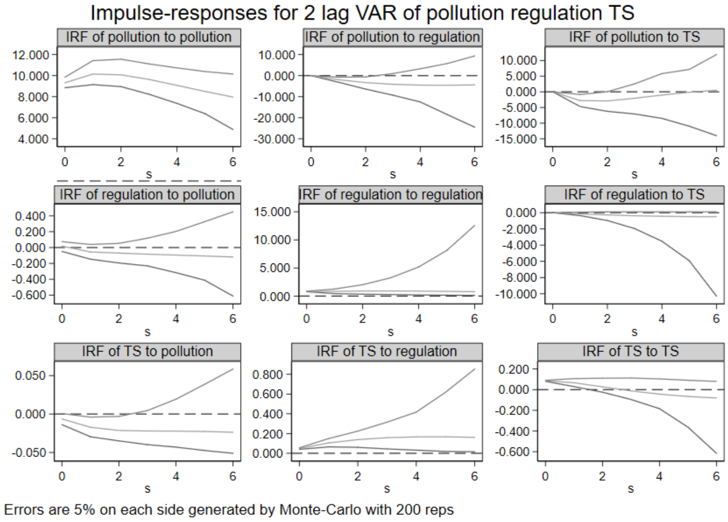

Figure 2. the long-term interaction among environmental regulation, the upgrading of industrial structure and air pollution.

4.3. Moderating Results

The STATA software is used to run the Model 2- 4, the regression results are shown in Table 3. In the Model 2, the coefficient of air pollution is -0.520 at the 1% level of significance, indicating that environmental regulation can significantly reduce air pollution. It further confirms our H1 hypothesis. The upgrading of industrial structure is added in Model 3. The coefficient of industrial structure upgrading is -0.363, indicating that the upgrading of industrial structure can reduce the air pollution. The cross term of environmental regulations and industrial structure upgrading is added in Model 4. The coefficient of the cross term is -0.349, which is significant at 1% level of significance, indicating that the moderating effect is significant. the upgrading of industrial structure can positively strengthen the reduction effect of environmental regulations on air pollution, which is Consistent with the H2. To visualize the moderating effect, an interaction diagram of the moderating effect was made and shown in Figure 3.

Table 3. The moderating effect test results.

		Model 2			Model 3			Model 4		
Dependent variable		pollution	95% CI	P value	pollution	95% CI	P value	pollution	95% CI	P value
Independent variable	regulation	-0.520	-0. 733 , -0. 308	0.000	-0.479	-0.683 , -0.275	0.000	-0.246	-0.440 , -0.051	0.013
Control variable	development	-0.058	-0. 293 , 0. 175	0.612	-0.041	-0.274 , 0. 190	0.715	0.027	-0.119 , 0.173	0.718
	Innovation	-0.040	-0.097 , 0.016	0.156	-0.038	-0.096 0.018	0.179	-0.005	-0.048 , 0.037	0.803

	Urban	0.369	-0.542, 1.281	0.414	0.319	-0.095, 2.911	0.476	-0.039	-0.440, 0.650	0.706
	open	-0.035	-0.114, 0.044	0.371	-0.028	-0.110, -0.053	0.488	-0.039	-0.108, -0.028	0.257
	invest	0.127	0.012, 0.243	0.032	0.123	0.006, 0.239	0.039	0.158	0.028, 0.287	0.372
	energy	0.285	-0.180, 0.752	0.221	0.325	0.179, 0.830	0.198	0.297	-0.093, 0.688	0.136
	TS				-0.363	-0.826, 0.100	0.120	-0.4680	-0.929, 0.007	0.142
Moderating variable	C_regulation*C_TS							-0.349	-0.493, -0.205	0.000
	_cons	14.204	4.789, 16.098	0.001	10.693	4.827, 16.558	0.001	9.508	-3.303, -1.264	0.000
	N		510			510			510	
	r2_a		0.907			0.907			0.913	
	Prob>F		0.0			0.0			0.0	

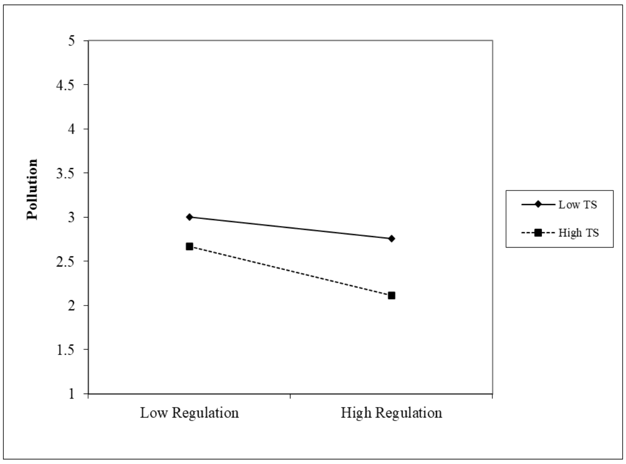

Figure 3. The effect of moderating.

5. Discussion

This study aims to explore the relationship among the environmental regulation, the upgrading of industrial structure and air pollution and examines whether the upgrading of industrial structure can positively moderate the impact of the environmental regulation on air pollution.

One of the key points of this study is to clarify the dynamic relationship among the air pollution, environmental regulation and the upgrading of industrial structure. Firstly, the results show that environmental regulations can significantly reduce emissions which is consistent with previous research [3–5], but the deterioration of the air could not obviously influence environmental regulations. Teng Wang et al. [23] found that the environmental regulation in 2020 had a significant negative effect on air pollution, and the coefficient was -0.123 based on panel data for the period 2003-2016. The coefficient in our study is -0.52. It is proved that the intensity of the environmental regulation has been strengthened in recent 5 years. Zhang [40] concluded that there was a nonlinear relationship between command-and-control environmental regulation and air pollution. It can be concluded that since the 18th Party Congress of China, Chinese environmental regulation has become more and more effective in air pollution control. Environmental tax is one of the means of environmental regulation and lower than the cost of governance and the optimal tax rate, so the environmental regulation is difficult influenced by the pollutant emission.

Secondly, air pollution hinders the upgrading of industrial structure and industrial structure upgrading has a long-term negative effect on the emission of air pollutants, which is consistent with previous research [13,28,29]. It is concluded that air pollution is not conducive to technological innovation, thus inhabiting the upgrading of industrial structure. The upgrading of industrial structure can help to reduce the fossil fuels and reduce the air pollution.

Thirdly, the environmental regulation promotes the upgrading of the industrial structure. Environmental regulation can influence the flow of resources and capital by the price mechanism, which will accelerate the elimination and merger in market and the upgrading of industrial structure.

The other critical finding of this study is that the upgrading of industrial structure has a positive moderating effect on the influence of the environmental regulations on air pollution. With the upgrading of industrial structure, the moderating effect gets stronger. Specifically, environmental regulation has a greater negative impact on air pollution in high level of industrial structure areas than in the baseline areas. Yang Song [23] thought the environmental regulation has a negative effect on air pollution, the coefficient is -0.339. After adding the variable of the upgrading of industrial structure, the coefficient is -3.53. It showed that the upgrading of industrial structure will strengthen the negative impact of environmental regulation on air pollution. The underlying mechanisms remain unclear but could be twofold. It is proved that the upgrading of industrial structure can promote the innovation, which in turn leads to decreased negative impact on air pollution. On the other hand, the upgrading of industrial structure can lead the consumption and production in a green way.

6. Conclusion and implication

Since launching its open-door policy and economic reform, China has experienced spectacular economic growth. Meanwhile, China has caused unprecedented environmental pollution [1,2]. Although China has enacted numerous measures to protect the air, the effect of the environmental regulation has not formed a unit view. To objectively evaluate the effect of these polices and provide empirical evidence and useful reference for the government, a benchmark analysis is performed. Two key conclusions are obtained. Firstly, the environmental regulation can significantly reduce the air pollution. Secondly, the upgrading of industrial structure can reduce the air pollution and may play a moderating role. The upgrading of industrial structure can positively moderate the impact of environmental regulation on air pollution.

The main policy implications of this study are summarized as follows. Firstly, the government should actively promote the upgrading of industrial structure and regard it as an important supplement to environmental regulation. Secondly, due to the economic growth, the environmental tax is set at a very low level for a long time. the deterioration of air could not obviously influence the environmental regulations. In order to make full use of environmental tax, the government should reform the tax rate and make it adapt to the actual pollution situation and economic development

7. Limitation

This study still has some limitations. We only use the emissions of SO_2 to measure the pollution. In the future research, we will add nitrogen oxide data from 30 provinces in China except Tibet to enhance the validity of the experimental results. For the impact of environmental regulation on the industrial structure we do some reasonable explanations as much as possible, but the underlying mechanism remains unclear.

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