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Investigating the Relationship between Economic Growth, Institutional Environment and Sulphur Dioxide Emissions

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Abstract: In order to promote ecological sustainability, the issue of sulphur dioxide emissions is of increasing interest to researchers. Majority of the current research, however, focuses on the relationship between sulphur dioxide (SO_2) emissions, foreign direct investment (FDI), and trade, as well as the effects of trade on SO_2 emissions, thus rarely takes it into account that the greater impact of the institutional environment and economic growth on SO_2 emissions. Using the 2008–2017 provincial panel data, this paper uses a fixed effects model to empirically test the institutional environment and economic growth of sulphur dioxide (SO_2) emissions. The results show that GDP growth and SO_2 emissions had an inverted "U"-shaped relationship. The institutional environment and the higher level of government intervention in the region led to SO_2 emissions decreasing significantly, and the institutional environment and the level of government intervention on economic growth and SO_2 emissions form a negative regulatory role. In this paper, environmental governance research, specified by the regional environmental governance, and government environmental performance audit policy provide empirical evidence, thus promoting sustainable ecological and environmental development.

Keywords: statistical analysis; sustainability; institutional environment; government intervention; GDP; sulphur dioxide emissions

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1. Introduction

A system is designed by people, including regulatory, normative and cultural cognitive symbol systems, so as to restrict people's interaction. Institution is a game rule, and transaction cost is the basis of institution formation. Market transaction costs are influenced by institutional arrangements, and these arrangements undoubtedly have an impact on economic growth and performance. Different economies' protracted performance variances will be significantly impacted by the institutional development process [1]. The material living conditions of people have substantially improved due to the rapid advancement of science, technology, and industrialization, and the environmental effects of human activity are becoming more pronounced. Some areas unilaterally pursue economic expansion at the expense of the environment and natural resources [2]. The substantial threat posed by global climate change to human life and progress has drawn the attention of the international community. Restrictions on gas emissions were imposed on industrialized and developing nations, respectively, by the 1997 Kyoto Protocol and the 2009 Copenhagen climate negotiations summit [3]. Although some Chinese cities' air quality has improved recently, the country's overall air quality is still not optimal. The conventional soot pollution, which is still a severe problem, is characterized by sulphur dioxide (SO_2), nitrogen oxides, and inhalable particles. As a result of the secondary pollution issues such as ozone and fine particles, the ozone layer is destroyed, acid rain occurs, fresh water supplies are depleted, water is polluted, and biodiversity is lost. The quality of human life and of the environment in which people live has declined as a result of frequent loss, extreme climate change, and other negative effects [4].

The principal air pollutant under control at the time is sulphur dioxide (SO_2). It serves as acid rain's primary precursor. PM2.5 pollution in the area will also result from the chemical transformation of sulphate. Sulphur dioxide (SO_2) emitted from the air is very harmful, which causes scholars to carry out research on SO_2 emission, FDI, foreign trade and other aspects. The faster the industrialization process is, the faster China's economic growth is. The success of reforming and opening it up, and economic growth seem to be accompanied by obvious pollution problems. The deterioration of environmental quality is exacerbated with economic growth and trade liberalization. However, it does not grow at the same speed as economic indicators [5]. Shen and Tang [6] empirically analysed the impact of foreign trade on the emission of sulphur dioxide (SO_2) in China from 2002 to 2006. They believed that foreign trade is beneficial to reduce the emission of sulphur dioxide (SO_2) in China. They can reduce the emission of sulphur dioxide (SO_2) by changing the structure of export products and import products. Ma et al. [7] used static and dynamic panel data models to empirically find an inverted "U" relationship between per capita income and per capita sulphur dioxide (SO_2) emissions, and technological progress will inhibit sulphur dioxide (SO_2) emissions. Ma [8] analysed the impact of sulphur tax on the emission of sulphur dioxide (SO_2) and energy consumption in China, and believed that the collection of sulphur tax could not only achieve the goal of reducing the emission of sulphur dioxide (SO_2), but also have no significant negative impact on GDP. Wang et al. [9] found that excessive use of energy and excessive emission of sulphur dioxide (SO_2) and chemical oxygen demand (COD) are the main sources of environmental inefficiency. Zhang et al. [10] used a generalized spatial two-stage least squares (GS2SLS) model to explore the effect of import trade technology spillover on the intensity of industrial air pollution emissions. Zeng et al. [11] found that FDI has a significant and positive direct impact on China's economic growth and technological innovation, and can have a significant pull effect on the domestic economy through backward spillover channels, as well as a significant impact on SO_2 emissions.

By reading both the national and international literature, it can be observed that the relationship between economic growth and environmental quality has been an important direction of domestic and foreign research. However, at present, the academic research subjects mainly focus on the regions or the overall economic aggregate to reveal the changing relationship of the economic environment, and pay very little attention to the atmospheric environment of specific provinces and cities. In terms of research content, more studies focus on testing the overall change relationship between economic growth and environmental quality, the lack of follow-up institutional design, and the analysis of the path and influence between economic growth and environmental quality, especially further analysing the specific impact of institutional factors and economic growth factors on the environment.

There are many existing studies on the relationship between carbon dioxide (CO_2) emissions and economic growth [12–20]. There are few studies on SO_2 emission, economic growth and institutional environment. It is important to keep in mind that most carbon dioxide emissions into the atmosphere do not immediately injure anyone; instead, they have long-term effects that affect everyone. Compared to carbon dioxide, sulphur dioxide is far more dangerous to people. The conflict between environmental pollution and economic growth is becoming more and more acute under the light of the dire situation of tighter resource constraints, serious environmental pollution, and ecosystem degradation, which has emerged as a major obstacle to China's economy's sustained and rapid growth. How, then, do regional sulphur dioxide (SO_2) emissions respond to China's economic expansion? Should the economic growth path be responsible for the current situation of air pollution in China? How does the institutional environment affect economic growth and SO_2 emission?

What impact will government intervention have on sulphur dioxide (SO_2) emissions? In order to answer these questions, this paper uses the fixed effects model to investigate the impact of institutional environment and economic growth on regional SO_2 emissions based on the provincial panel data from 2008 to 2017.

The following are this paper's main contributions: First, there are not many studies on the connections between institutional environment, economic growth, and SO_2 emission; instead, majority of the literature focuses on the connections between SO_2 emission, FDI, and international trade, as well as the effects of foreign trade on SO_2 emission. In actuality, the institutional environment and economic expansion will have a bigger impact on SO_2 emissions. Furthermore, this article examines the institutional environment's regulatory functions in relation to economic growth and SO_2 emissions in addition to the relationship between institutional environment, economic growth, and SO_2 emissions. In addition, this study adds to the body of knowledge on SO_2 emissions and environmental governance by examining the effects of government intervention on economic growth and SO_2 emissions. This study also provides empirical support for altering the nature and mode of government incentives during the transitional economy period, as well as for defining policies on regional environmental governance and government environmental performance audit.

The remainder of this essay is structured as follows: the second part shows our theoretical analysis and research hypothesis; the third part presents the econometric model, mainly varieties and data; the fourth part presents the testing results and analysis; the fifth part comprises endogenous problems and robustness test; and the last part presents conclusions and suggestions.

2. Theoretical Analysis and Research Hypothesis

Hypothesis 1: *The relationship between economic growth (GDP) and sulfur dioxide (SO_2) emission is inverted U-shaped.*

The environmental Kuznets curve (EKC) theory [21] was proposed by Grossman and Krueger to explain how economic growth affects the environment. When the per capita GDP was low, the emission of SO_2 was in the stage of centralized growth; however, when the per capita GDP was high, the emission of SO_2 was in the stage of decline. In other words, with economic growth, the emission of sulphur dioxide (SO_2) presents an inverted "U" type of increase and then decrease. This finding was made when studying the impact of NAFTA on the environment. Seldom and Song [22] investigated the association between suspended particles, nitrogen oxides, sulphur dioxide (SO_2) and carbon monoxide (CO) and per capita GDP, and found that there was an inverted "U" relationship between the four pollutants and the per capita GDP. Since then, many scholars at home and abroad have verified that the inverted "U" relationship between economic growth and carbon emissions still exists (for example: [23–26]).

Hypothesis 2: *The higher the institutional environment is, the lower the SO_2 emission is, that is, the institutional environment has a significant negative correlation with SO_2 emission; the institutional environment plays a negative regulatory role between economic growth and SO_2 emission.*

System is a type of behavioural norm with mechanisms for incentives and restraints that gives people a choice of interests. In other words, people should weigh the costs and benefits while deciding whether to follow the rules, and only after careful deliberation should they make that decision [27]. To advance the industrialization and urbanization processes, institutional environment transformation is required. By establishing order and reducing uncertainty through the institutional structure, institutions play a fundamental and necessary role in economic progress. They also work to improve governance systems [1]. It is not difficult to identify the successes of institutional innovation and the restrictions of the institutional environment on economic growth given the acceleration of industrialization and urbanization. The better the market order and the greater the concept and awareness of environmental protection, the fewer air pollutants such as sulphur dioxide (SO_2) will be released into the atmosphere. In contrast, the lower the institutional environment, the more environmental protection and governance may be neglected in order to pursue economic growth at the expense of the environment and resources, leading to an increase in the emission of air pollutants such as sulphur d. (SO_2). The institutional context is crucial for economic development. Economic growth is supported by a favourable institutional framework [28,29]. In the process of gradual economic transition, the market development in different regions is extremely uneven [30]. The higher the institutional environment is, the higher the economic growth is, and the stronger the environmental protection and governance are. Therefore, we expect that the institutional environment and SO_2 emissions will change in the opposite direction. Since 2007, China's overall greenhouse gas emissions from fossil fuels have increased to the highest level ever. This is a natural consequence of China's lengthy period of rapid economic growth. With the acceleration of market-oriented processes, it is inevitable to objectively require a fundamental change from extensive to intensive economic growth. Institution is not simply thought of as an exogenous factor influencing economic behaviour; it is also necessary to consider how institutions develop, persist, and change. Institutions change to adapt to economic growth and regulate economic growth and emission of air pollutants such as sulphur dioxide (SO_2).

Hypothesis 3: *The higher the level of government intervention is, the lower the SO_2 emission is, that is, there is a significant negative correlation between the level of government intervention and SO_2 emission; the level of government intervention plays a negative regulatory role between economic growth and SO_2 emission.*

The environment is a typical public good, and the consumption of environment has the characteristics of being non-competitive and non-exclusive. Without government intervention, environmental consumption will lead to excessive consumption. To improve energy efficiency and reduce pollution emissions, the government needs to implement active environmental control policies [31]. China's energy conservation and emission reduction goals are under pressure from the international community, and local governments are also subject to the mandatory requirements of the central government. For the central government, it is a political and economic process related to determination to change the incentive orientation, methods and corresponding regulations. For the local government, it is an incentive-related process to change the functions of the government, from blindly pursuing GDP to sustainable growth within the political and economic behaviour [16]. The rigidity of energy demand in China's economic growth at this stage indicates that the compulsory emission reduction in sulphur dioxide (SO_2) will certainly be at the expense of economic growth and the urbanization process, but it is possible to slow down the growth of sulphur dioxide (SO_2) emissions [18]. Compared with the developed market economy countries and regions, the local governments of our country still have a lot of resources, and there are still many interventions in economic activities. At present, China's economy has changed from intensive growth to extensive growth at the expense of the environment and resources. Therefore, we believe that the higher the level of government intervention, the stronger the government's willingness to control and protect the environment, and the government uses economic means (such as tax and financial subsidies) and administrative means to intervene in the law and market mechanisms in order to affect the emission of air pollutants such as sulphur dioxide (SO_2) in the region. In the face of external system pressure and requirements, the emission of air pollutants such as sulphur dioxide (SO_2) in the region will show a downward trend. If the institutional arrangement is unreasonable, the policy making is not correct, the government's interference in the economic and environmental control is unreasonable, and the legal structure is loose, it may cause rent-seeking behaviour or even the government's deterioration, that is to say, the rent-seeking phenomenon and the government's deterioration caused by the inadequate system and low management level may cause the negative correlation between natural resources and economic growth [32]. Therefore, we expect that the level of government intervention is negatively related to SO_2 emissions, and negatively regulates the relationship between economic growth and SO_2 emissions.

Through the abovementioned assumptions, the following can be obtained: the higher the level of government intervention, the stronger the government's willingness towards environmental control and protection, which affects the emission of air pollutants such as sulphur 2 (SO_2) through tax and fiscal subsidies and administrative means such as the promulgation of systems and regulations. The institutional environment is essential to economic development; the better the institutional environment, the stronger the concept and awareness of environmental protection, and the lower the emission of air pollutants such as sulphur dioxide (SO_2). On the other hand, due to insufficient government intervention and a lack of a system, environmental protection and governance will increase the emission of sulphur dioxide (SO_2) at the expense of SO_2; this is because environmental protection and governance will increase the emission of sulphur dioxide (SO_2) at the cost of SO_2.

3. Measurement Model, Main Variables and Data

In this paper, the provincial panel data of 31 provinces in China from 2008 to 2017 are used to verify the impact of the institutional environment and economic growth on regional sulphur dioxide (SO_2) emissions and the regulatory role of the institutional environment.

Note: From the relevant research literature, there are many research data during this period, and the author should be more representative when establishing the model.

The measurement model is constructed as follows:

$$\begin{aligned} SO_{2i,t} &= \alpha_{i,t} + \beta_1 Lngdp_{i,t} + \beta_2 Lngdp^2{}_{i,t} \\ &+\beta_3 Total_{i,t} + \beta_4 Total_{i,t} \times Lngdp_{i,t} + \beta_5 Total_{i,t} \\ &\times Lngdp^2{}_{i,t} + \beta_6 Total_{i,t} \times Lngdpp_{i,t} + \beta_7 Total_{i,t} \\ &\times Lngdpp^2{}_{i,t} + \beta_8 Lnp + \sum \beta_k Year + \zeta_{i,t} \end{aligned} \tag{1}$$

In order to investigate the influence of government intervention and economic growth on SO_2 emission in the region and the regulatory role of institutional environment, the measurement model is constructed as follows:

$$\begin{aligned} SO_{2i,t} &= \alpha_{i,t} + \beta_1 Lngdp_{i,t} + \beta_2 Lngdp^2{}_{i,t} + \beta_3 Total\_G_{i,t} \\ &+\beta_4 Total\_G_{i,t} \times Lngdp_{i,t} + \beta_5 Total\_G_{i,t} \times Lngdp^2{}_{i,t} \\ &+\beta_6 Total\_G_{i,t} \times Lngdpp_{i,t} + \beta_7 Total\_G_{i,t} \times Lngdpp^2{}_{i,t} \\ &+\beta_8 Lnp + \sum \beta_k Year + \zeta_{i,t} \end{aligned} \tag{2}$$

Among them, sub-script $i(i = 1, 2, \ldots, 31)$ and $t(t = 2008, 2009, \ldots, 2017)$ represent, respectively, i th province and year t, and ζ represents the error term. The explained variable in the model (SO_2) is the regional sulphur dioxide emission; *Lngdp*, *Lngdpp* represent regional GDP and per capita GDP, respectively. In order to investigate the possible nonlinear relationship between GDP and SO_2 emission, a square term was added to the model: $Lngdp^2$, $Lngdpp^2$. *Total* and *Total_G* represent the regional institutional environment and the level of government intervention. In order to test the interaction effect, the multiplier of institutional environment, GDP and per capita GDP is added to model (1). In model (2), the multiplier of government intervention level, GDP and per capita GDP is added. In addition, we control the difference between the total population (LNP) and the year.

In order to eliminate the heteroscedasticity and obtain the elasticity of the explanatory variables directly, natural logarithm processing is carried out for variables such as SO_2 emission, GDP, per capita GDP and total population. The data of SO_2 emission, GDP and total population in the model mainly come from China Statistical Yearbook and China Environmental Yearbook. The market-oriented index is adopted for system environment and government intervention level [30]. The market index data from 2016 to 2017 are calculated using the moving average method. The specific operability definitions of variables in the model are shown in Table 1.

Table 1. Definition of variable operability.

Variable Name	Variable Definition
$Lnso_{2i,t}$	Natural logarithm of total sulphur dioxide (SO_2) emissions in *i* provinces in *t* years
$Lnso_2p_{i,t}$	Natural logarithm of sulphur dioxide (SO_2) emissions per capita in *i* provinces in *t* years
$Lngdp_{i,t}$	Natural logarithm of GDP in *i* provinces in year *t*
$Lngdp^2{}_{i,t}$	The square term of natural logarithm of GDP in *i* provinces in year *t*
$Lngdpp_{i,t}$	Natural logarithm of per capita GDP in *t* year of *i* provinces
$Lngdpp^2{}_{i,t}$	Square term of natural logarithm of per capita GDP in *i* provinces in year *t*
$Lnp_{i,t}$	Natural logarithm of population in *i* provinces in year *t*
$Total_{i,t}$	Marketization index of *i* provinces in year *t*
$Total\_G_{i,t}$	The government intervention level of *i* provinces in year *t*, expressed by the relationship index between the government and the market
$Total \times Lngdp$	The multiplier of market index and GDP
$Total \times Lngdp^2$	Market index and multiplier of the square term of GDP
$Total \times Lngdpp$	Multiplier of market index and GDP per capita
$Total \times Lngdpp^2$	Market index and multiplier of per capita GDP
$Total\_G \times Lngdp$	Government intervention level and the multiplier of GDP
$Total\_G \times Lngdp^2$	Government intervention level and the multiplier of the square term of GDP
$Total\_G \times Lngdpp$	Government intervention level and multiplier of GDP per capita
$Total\_G \times Lngdpp^2$	Government intervention level and multiplier of per capita GDP square
Year	Virtual variable of year: if it is a certain accounting year, take 1; otherwise, take 0

4. Inspection Results and Analysis

4.1. Descriptive Statistics

According to the research time period, which is 2022–2023, the following data were collected in February 2022. Table 2 provides descriptive statistics of the main variables. According to the results in Table 2, from 2008 to mid-2017, the maximum SO_2 emission is 2,003,000 tons in Shandong Province in 2011, and the minimum is 749 tons in Tibet in 2009. The average sample value is 736,500 tons. There is a significant difference in the emissions from different regions. The average GDP is CNY 899.231 billion, the maximum is CNY 5267.359 billion in Guangdong Province in 2017, the minimum is CNY 16.656 billion in the Tibet region in 2008, and the standard deviation is CNY 891.430 billion, which indicates that the economic development of each region is unbalanced and the difference is large. The average value of the market-oriented index reflecting the institutional environment of each region is 6.704, the maximum value of the market-oriented process index is 11.80 (the market-oriented process index of Zhejiang Province in 2015), and the minimum value is 0.38 (the market-oriented process index of Tibet region in 2015). The maximum value of government intervention level is 10.65 (the relationship index between government and market in Guangdong Province in 2012), the minimum value is −4.660 (the relationship index between government and market in Tibet in 2015), and the average value is 7.58, indicating that the level of government intervention in various regions is quite different.

Table 2. Descriptive statistics of variables (I = 31, T = 10, n = IT = 310).

Variable	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
SO_2	310	73.65	46.85	0.0749	200.30
gdp	310	8992.31	8914.30	166.56	52,673.59
$Lnso_2$	310	3.869	1.360	−2.592	5.300
$Lnso_2p$	310	−4.190	0.835	−8.190	−2.741
Lngdp	310	8.613	1.112	5.115	10.87
$Lngdp^2$	310	75.42	18.37	26.17	118.2
Lngdpp	310	0.554	0.670	−1.127	2.111
$Lngdpp^2$	310	0.755	0.966	0	4.458
Lnp	310	8.059	0.871	5.587	9.260
Total	310	6.704	2.189	0.380	11.80
Total_G	310	7.580	2.233	−4.660	10.65

4.2. Probability Density Function

In order to investigate the differences of sulphur dioxide (SO_2) emissions, economic growth and institutional environment among provinces, 31 provinces are divided into three regions: eastern, central and western regions, according to the sample data (Among them, the eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan; the central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Hebei, Hubei, Hunan; and the northwest region includes inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Chongqing, Tibet). The division of east and west in China is mainly based on the geographical location (including terrain, customs and characteristics) and the economic development level. The density function diagram of the main variables in Table 2 is drawn, as shown in Figures 1–4. According to Figures 1 and 2, the peak degree of SO_2 emission in the central region is the highest, the trend is relatively concentrated, and the difference in the western region is the largest. According to Figures 3 and 4, the peak degree of GDP and institutional environment in the central region is the highest, and the trend is relatively concentrated. On a whole, there are some differences in sulphur dioxide (SO_2) emissions, economic growth and institutional environment between the eastern, central and western regions, which further confirms the descriptive statistical results in Table 2.

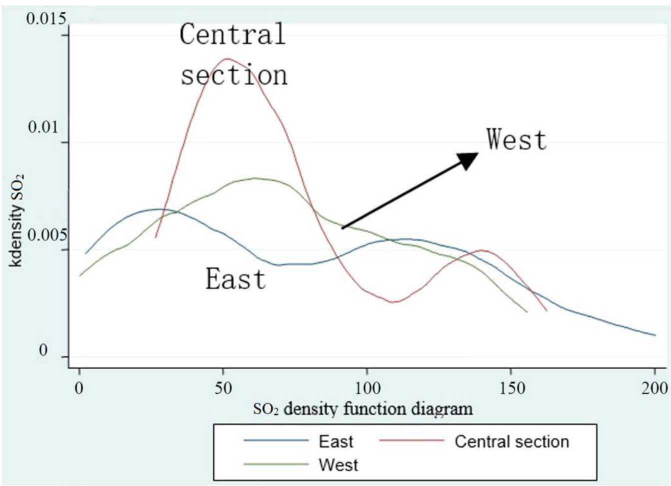

Figure 1. SO_2 density function diagram.

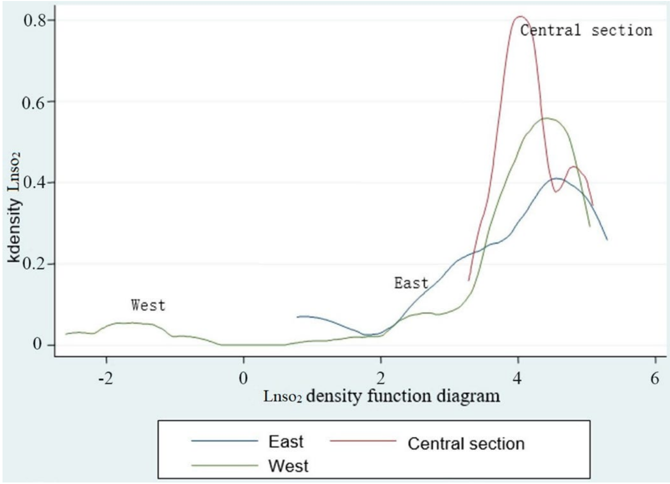

Figure 2. $Lnso_2$ density function diagram.

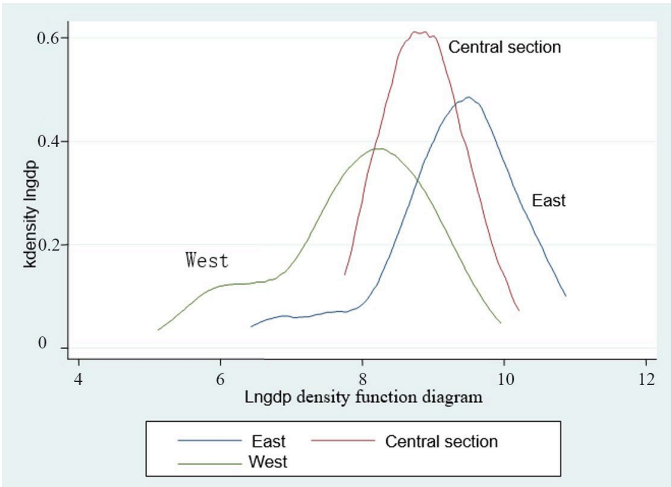

Figure 3. *Lngdp* density function diagram.

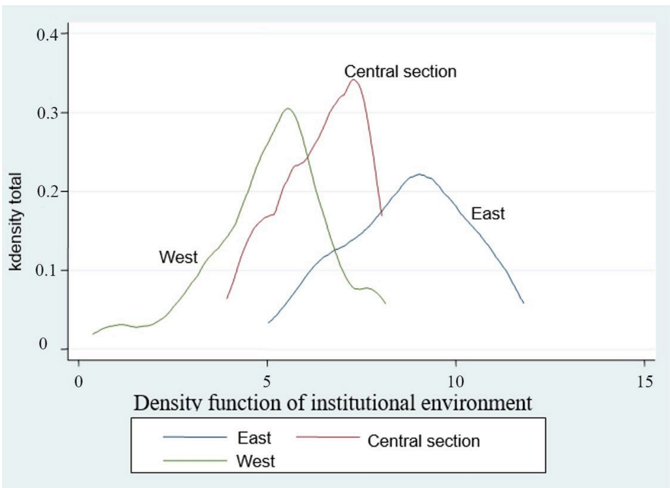

Figure 4. Density function of institutional environment.

4.3. Impact of Institutional Environment and Economic Growth on Sulfur Dioxide Emissions

Table 3 reports the regression results of model (1) and examines the impact of institutional environment and economic growth on regional sulphur dioxide (SO_2) emissions.

The fitting F value of column (1)~(6) is significant ($p < 0.01$). The regression model as a whole has passed the significance test, and the goodness of fit of the model is above 0.360, indicating that the model has a strong explanatory power. Column (1) reports the impact of GDP growth on regional sulphur dioxide (SO_2) emissions. The coefficient of LnGDP is positive and significant at the 1% significance level, and the coefficient of $lngdp^2$ is negative and significant at the 1% significance level. The results show that the effect of GDP on SO_2 emission is non-linear, but in an inverted "U" relationship, that is, with GDP growth, SO_2 emission in the region increases gradually, and when it increases to a certain extent, SO_2 emission starts to decline again. Hypothesis 1 in this paper is verified. Column (2) reports the impact of the institutional environment on SO_2 emission in the region. The total coefficient is negative and significant ($p < 0.01$), which means that the higher the institutional environment is, the more attention is paid to environmental governance, and the SO_2 emission tends to decrease. Columns (3)~(6) are put into the multiplication terms of total and *LnGDP*, $Lngdp^2$, *Lngdpp*, $Lngdpp^2$. The regression results show that the multiplier coefficients of *Total* × *LnGDP*, *Total* × $Lngdp^2$, *Total* × *Lngdpp* and *Total* × $Lngdpp^2$ are −0.045, −0.002, −0.067, −0.019. The coefficients of perspective, *Total* × *LnGDP* and *Total* × $Lngdp^2$ are significant at the 1% significance level. The coefficients of *Total* × *Lngdpp* and *Total* × $Lngdpp^2$ were significant at the 5% significance level. It shows that with the growth of GDP, the higher the market-oriented process, the more the negative growth of SO_2 emissions in the region is, that is, the institutional environment has a negative regulatory effect on economic growth and SO_2 emissions. The results show that under the condition of controlling other variables unchanged, regardless of whether GDP or per capita GDP variables are adopted, the institutional environment negatively regulates economic growth and SO_2 emission. The higher the market-oriented process is, the stronger the awareness of environmental protection and governance is, and the more willing it is to reduce SO_2 emission. Hypothesis 2 in this paper has been verified.

Table 3. Test results based on the influence of institutional environment and economic growth.

	(1)	(2)	(3)	(4)	(5)	(6)
Lngdp	1.520 ***					
	(3.16)					
$Lngdp^2$	−0.100 ***					
	(−3.70)					
Total		−0.155 ***	0.295 ***	0.088	−0.022	−0.074
		(−3.21)	(3.27)	(1.67)	(−0.40)	(−1.55)
Total × *Lngdp*			−0.045 ***			
			(−3.60)			
Total × $Lngdp^2$				−0.002 ***		
				(−3.27)		
Total × *Lngdpp*					−0.067 **	
					(−2.57)	
Total × $Lngdpp^2$						−0.019 **
						(−2.40)
Lnp	−0.690	−0.733	−0.313	−0.301	−0.179	0.700
	(−0.96)	(−1.02)	(−0.42)	(−0.40)	(−0.21)	(0.65)
$Year_{2009}$	0.167 ***	0.231 ***	0.222 ***	0.213 ***	0.209 ***	0.186 ***
	(3.64)	(5.38)	(5.48)	(5.37)	(4.76)	(3.84)

Table 3. *Cont.*

	(1)	(2)	(3)	(4)	(5)	(6)
$Year_{2010}$	0.256 **	0.393 ***	0.381 ***	0.361 ***	0.358 ***	0.299 ***
	(2.49)	(5.36)	(4.99)	(5.04)	(5.02)	(3.87)
$Year_{2011}$	0.438 **	0.644 ***	0.633 ***	0.603 ***	0.602 ***	0.513 ***
	(2.70)	(5.41)	(4.91)	(4.98)	(5.36)	(4.43)
$Year_{2012}$	0.492 **	0.731 ***	0.742 ***	0.703 ***	0.718 ***	0.580 ***
	(2.32)	(5.29)	(4.72)	(4.79)	(5.27)	(4.22)
$Year_{2013}$	0.497 *	0.762 ***	0.803 ***	0.754 ***	0.790 ***	0.599 ***
	(1.84)	(4.77)	(4.33)	(4.36)	(4.88)	(3.81)
$Year_{2014}$	0.489	0.662 ***	0.789 ***	0.735 ***	0.794 ***	0.541 ***
	(1.47)	(4.66)	(4.15)	(4.16)	(4.66)	(3.72)
$Year_{2015}$	0.479	0.651 ***	0.809 ***	0.750 ***	0.813 ***	0.532 ***
	(1.33)	(4.34)	(3.90)	(3.90)	(4.40)	(3.41)
$Year_{2016}$	0.559	0.680 ***	0.880 ***	0.819 ***	0.911 ***	0.586 ***
	(1.31)	(4.15)	(3.81)	(3.79)	(4.19)	(3.61)
$Year_{2017}$	0.636	0.685 ***	0.951 ***	0.888 ***	1.005 ***	0.645 ***
	(1.28)	(3.98)	(3.82)	(3.78)	(4.09)	(3.70)
_cons	3.495	10.27 1*	6.505	6.372	5.160	−1.604
	(0.56)	(1.78)	(1.09)	(1.05)	(0.76)	(−0.18)
R^2	0.534	0.383	0.495	0.493	0.484	0.447
Adj.R^2	0.515	0.360	0.475	0.472	0.463	0.425
F	20.450 ***	23.707 ***	53.706 ***	47.742 ***	45.458 ***	42.285 ***
N	310	310	310	310	310	310

Note: (1) ***, **, * represent the significance levels of 1%, 5% and 10%, brackets based on white heteroscedasticity robust standard error calculation T value obtained; (2) The explained variable is the natural logarithm of sulphur dioxide emissions ($Lnso_2$); (3) Columns (1)–(6) in Table 3 are regressed using the fixed effects model and random effect model after passing Hausman test, $p < 0.01$. Therefore, the random effect model is rejected and the fixed effects model is selected; in order to save space, not all regression results of random effect models are reported in the table.

4.4. The Impact of Government Intervention and Economic Growth on Sulfur Dioxide Emissions

Table 4 reports the regression results of model (2) and tests the impact of government intervention and economic growth on regional SO_2 emissions. The fitting F value of column (7)~(12) is significant ($p < 0.01$). The regression model has passed the significance test as a whole part, and the goodness of fit of the model is above 0.334, indicating that the model has strong explanatory power. Column (7) reports the impact of GDP growth on regional sulphur dioxide (SO_2) emissions, indicating that GDP and regional sulphur dioxide (SO_2) emissions show an inverted "U" relationship. Column (8) reports the impact of government intervention level on SO_2 emission in the region, with a negative and significant ($p < 0.01$) total Zug coefficient. The government intervention level has a significant negative correlation with SO_2 emission, which means that the higher the level of government intervention, the more effective the environmental governance and protection measures are. Columns (9)~(12) are put into the multiplier of Total g with *Lngdp*, $Lngdp^2$, *Lngdpp*, $Lngdpp^2$. The regression results show that the multiplier coefficients of *Total_G* × *LnGDP*, *Total_G* × $Lngdp^2$, and *Total_G* × *Lngdpp* are −0.059, −0.003, −0.096, respectively, All of them were significant at the level of 1%. The coefficient of the multiplier of *Total_G* × $Lngdpp^2$ is −0.019, significant at the 5% significance level. It shows that with the growth of GDP, the higher the level of government intervention, the more negative the growth of SO_2 emissions in the region is. That is to say, the level of government intervention has a negative regulatory effect on economic growth and SO_2 emissions. The results show that under the condition of controlling other variables unchanged, regardless of whether GDP or per capita GDP variables are adopted, the level of government intervention negatively regulates economic growth and sulphur dioxide (SO_2) emissions. The higher the level of government intervention, the stronger the local government controls and intervenes in the factor market. With the introduction of environmental performance audit and the accountability mechanism, the government departments will further strengthen environmental supervision and governance, so as to reduce regional oxidation Sulphur (SO_2) emission; thus, hypothesis 3 is verified.

Table 4. Test results based on the impact of government intervention and economic growth.

	(7)	(8)	(9)	(10)	(11)	(12)
Lngdp	1.520 ***					
	(3.16)					
Lngdp^2	−0.100 ***					
	(−3.70)					
Lnp	−0.690	−0.671	−0.678	−0.618	−1.135	0.574
	(−0.96)	(−0.86)	(−0.86)	(−0.79)	(−1.46)	(0.56)
Total_G		−0.083 *	0.424 ***	0.170 **	0.050 **	−0.035
		(−1.73)	(3.29)	(2.45)	(2.34)	(−0.92)
Total_G × *Lngdp*			−0.059 ***			
			(−3.82)			
Total_G × *Lngdp*^{2}				−0.003 ***		
				(−3.80)		
Total_G × *Lngdpp*					−0.096 ***	
					(−5.03)	
Total_G × *Lngdpp*^{2}						−0.019 **
						(−2.66)
$Year_{2009}$	0.167 ***	0.194 ***	0.241 ***	0.226 ***	0.219 ***	0.165 ***
	(3.64)	(6.24)	(5.77)	(5.79)	(6.24)	(5.26)
$Year_{2010}$	0.256 **	0.337 ***	0.441 ***	0.405 ***	0.375 ***	0.265 ***
	(2.49)	(4.90)	(4.41)	(4.26)	(6.14)	(4.51)
$Year_{2011}$	0.438 **	0.535 ***	0.703 ***	0.655 ***	0.637 ***	0.453 ***
	(2.70)	(4.87)	(4.52)	(4.36)	(6.70)	(4.78)
$Year_{2012}$	0.492 **	0.563 ***	0.804 ***	0.750 ***	0.785 ***	0.488 ***
	(2.32)	(4.93)	(4.81)	(4.64)	(6.94)	(4.89)
$Year_{2013}$	0.497 *	0.542 ***	0.871 ***	0.809 ***	0.899 ***	0.483 ***
	(1.84)	(4.41)	(4.58)	(4.41)	(6.53)	(4.32)
$Year_{2014}$	0.489	0.460 ***	0.898 ***	0.832 ***	0.981 ***	0.441 ***
	(1.47)	(4.33)	(4.30)	(4.18)	(6.02)	(4.04)
$Year_{2015}$	0.479	0.406 ***	0.890 ***	0.825 ***	1.009 ***	0.407 ***
	(1.33)	(4.06)	(4.17)	(4.06)	(5.82)	(3.77)
$Year_{2016}$	0.559	0.456 ***	1.015 ***	0.947 ***	1.173 ***	0.481 ***
	(1.31)	(3.52)	(4.08)	(3.93)	(5.57)	(3.44)
$Year_{2017}$	0.636	0.460 ***	1.109 ***	1.043 ***	1.322 ***	0.544 ***
	(1.28)	(3.43)	(4.11)	(3.99)	(5.58)	(3.44)
_cons	3.495	9.512	9.362	8.800	12.356 *	−0.745
	(0.56)	(1.52)	(1.48)	(1.40)	(1.97)	(−0.09)
R^2	0.534	0.358	0.477	0.489	0.537	0.422
Adj.R^2	0.515	0.334	0.456	0.469	0.518	0.399
F	20.450 ***	22.467 ***	26.503 ***	27.349 ***	22.893 ***	29.735 ***
N	310	310	310	310	310	310

Note: (1) ***, **, * represent the significance levels of 1%, 5% and 10%, brackets based on white heteroscedasticity robust standard error calculation T value obtained; (2) The explained variable is the natural logarithm of sulphur dioxide emissions ($Lnso_2$); (3) Columns (7)–(12) in Table 4 are regressed by fixed effect model and random effect model after passing Hausman test, $p < 0.01$. Therefore, the random effect model is rejected and the fixed effect model is selected; in order to save space, not all regression results of random effect models are reported in the table.

5. Endogenous Problems and Robustness Test

5.1. Endogenous Problems

Tables 3 and 4 carry out the regression test for model (1) and model (2). Although the test results are statistically significant, we still need to be cautious about the previous research conclusions. On the one hand, the fixed effects model can only solve the endogenous problem caused by the missing variables that do not change with time; therefore, it is impossible to make a simple presumption based on the above results; on the other hand, the panel data often have autocorrelation problems. The sample in this study only contains 310 small samples of observations; thus, it is unable to ensure the unbiased estimation results [33]. For this reason, this paper uses the lagged items of *Lngdp*, $Lngdp^2$, *Lngdpp*, $Lngdpp^2$, and Total in two–four periods and three regions in the East, the Middle and the West as instrumental variables to replace *Lngdp*, $Lngdp^2$, *Lngdpp*, $Lngdpp^2$, Total, and uses the two-stage least squares method (2SLS) to test the impact of institutional environment and economic growth on regional sulphur dioxide (SO_2) emissions in order to solve the variables' endogeneity and autocorrelation of panel data.

Table 5 reports the regression results using the tool variable 2SLS model. The explained variable of column (13)~(14) is lnso2, and the explained variable of column (15)~(16) is lnso2p. The Wald test of column (13)~(15) shows that the regression model as a whole passes the significance test ($p < 0.01$), and the Wald test of column (16) shows that the whole regression model passes the significance test ($p < 0.05$). The primary term coefficient of GDP is positive and significant (p 0.01), according to columns (13) and (15), while the secondary term coefficient is negative and significant (p 0.01). It confirms once more the earlier finding that there is an inverse "U" relationship between regional sulphur dioxide (SO_2) emissions and GDP. The institutional environment's overall coefficient was negative and statistically significant (p 0.01), which supported the earlier findings. According to columns (14) and (16), the first term of GDP per capita's coefficient is positive and statistically significant (p 0.10), but the second term fails to pass the test because it lacks statistical significance. Overall, the regression results in Table 5 have no substantial impact on the previous conclusions, indicating that the previous conclusions are stable.

Table 5. Regression results of 2SLS model.

	Explained Variable ($Lnso_2$)		**Explained Variable ($Lnso_2p$)**	
	(13)	**(14)**	**(15)**	**(16)**
Lngdp	4.797 ***		4.797 ***	
	(5.52)		(5.52)	
$Lngdp^2$	−0.235 ***		−0.235 ***	
	(−5.05)		(−5.05)	
Lngdpp		0.716 *		0.716 *
		(1.89)		(1.89)
$Lngdpp^2$		0.015		0.015
		(0.08)		(0.08)
Total	−0.179 ***	−0.198 ***	−0.179 ***	−0.198 ***
	(−2.98)	(−2.81)	(-2.98)	(−2.81)
Lnp	0.553 ***	1.443 ***	−0.447 **	0.443 ***
	(3.16)	(9.65)	(−2.55)	(2.96)
Year	Yes	Yes	Yes	Yes
_cons	−23.369 ***	−7.282 ***	−23.369 ***	−7.282 ***
	(−6.13)	(−6.16)	(−6.13)	(−6.16)

Table 5. *Cont.*

	Explained Variable ($Lnso_2$)		Explained Variable ($Lnso_2p$)	
R^2	0.742	0.661	0.312	0.097
Adj.R^2	0.729	0.644	0.277	0.051
Wald chi^2	186.91 ***	154.10 ***	63.50 ***	17.39 **
N	186	186	186	186

Note (1) ***, **, * represent at significance levels of 1%, 5% and 10%, T value in brackets; (2) The selected tool variables are the lagged items of Lngdp, $Lngdp^2$, Lngdpp, $Lngdpp^2$, Total lag period 2–4 and the three regions of East, Middle and West; (3) The length of year control variable is large, which is omitted here.

5.2. Robustness Check

First, the natural logarithm ($Lnso_2p$) of per capita sulphur dioxide (SO_2) emissions is used to replace the explained variables of models (1) and (2), and model (1) and model (2) are re-estimated. The test results are shown in Tables 6 and 7. Table 6 reports the regression results of model (1)'s re-estimation, and tests the impact of the institutional environment and economic growth on regional SO_2 emissions. The fitting F value of column (17)~(22) is significant ($p < 0.01$). The regression model has passed the significance test as a whole, and the goodness of fit of the model is above 0.377, indicating that the model has strong explanatory power. The column (17) regression findings confirm the inverted "U" link between regional GDP and sulphur dioxide (SO_2) emissions. The regression results in column (18) further support the link between SO_2 emissions and the institutional environment. The coefficient of column (19)~(22) multiplier is negative and significant, which also verifies the existence of regulatory effect of institutional environment.

Table 6. Test results based on the influence of institutional environment and economic growth.

	(17)	(18)	(19)	(20)	(21)	(22)
Lngdp	1.520 ***					
	(3.16)					
$Lngdp^2$	−0.100 ***					
	(−3.70)					
Total		−0.155 ***	0.295 ***	0.088	−0.022	−0.074
		(−3.21)	(3.27)	(1.67)	(−0.40)	(−1.55)
Total × Lngdp			−0.045 ***			
			(−3.60)			
Total × $Lngdp^2$				−0.002 ***		
				(−3.27)		
Total × Lngdpp					−0.067 **	
					(−2.57)	
Total × $Lngdpp^2$						−0.019 **
						(−2.40)
Lnp	−1.690 **	−1.733 **	−1.313 *	−1.301 *	−1.179	−0.300
	(−2.36)	(−2.41)	(−1.76)	(−1.72)	(−1.41)	(−0.28)
$Year_{2009}$	0.167 ***	0.231 ***	0.222 ***	0.213 ***	0.209 ***	0.186 ***
	(3.64)	(5.38)	(5.48)	(5.37)	(4.76)	(3.84)
$Year_{2010}$	0.256 **	0.393 ***	0.381 ***	0.361 ***	0.358 ***	0.299 ***
	(2.49)	(5.36)	(4.99)	(5.04)	(5.02)	(3.87)

Table 6. *Cont.*

	(17)	(18)	(19)	(20)	(21)	(22)
$Year_{2011}$	0.438 **	0.644 ***	0.633 ***	0.603 ***	0.602 ***	0.513 ***
	(2.70)	(5.41)	(4.91)	(4.98)	(5.36)	(4.43)
$Year_{2012}$	0.492 **	0.731 ***	0.742 ***	0.703 ***	0.718 ***	0.580 ***
	(2.32)	(5.29)	(4.72)	(4.79)	(5.27)	(4.22)
$Year_{2013}$	0.497 *	0.762 ***	0.803 ***	0.754 ***	0.790 ***	0.599 ***
	(1.84)	(4.77)	(4.33)	(4.36)	(4.88)	(3.81)
$Year_{2014}$	0.489	0.662 ***	0.789 ***	0.735 ***	0.794 ***	0.541 ***
	(1.47)	(4.66)	(4.15)	(4.16)	(4.66)	(3.72)
$Year_{2015}$	0.479	0.651 ***	0.809 ***	0.750 ***	0.813 ***	0.532 ***
	(1.33)	(4.34)	(3.90)	(3.90)	(4.40)	(3.41)
$Year_{2016}$	0.559	0.680 ***	0.880 ***	0.819 ***	0.911 ***	0.586 ***
	(1.31)	(4.15)	(3.81)	(3.79)	(4.19)	(3.61)
$Year_{2017}$	0.636	0.685 ***	0.951 ***	0.888 ***	1.005 ***	0.645 ***
	(1.28)	(3.98)	(3.82)	(3.78)	(4.09)	(3.70)
_cons	3.495	10.271 *	6.505	6.372	5.160	−1.604
	(0.56)	(1.78)	(1.09)	(1.05)	(0.76)	(−0.18)
R^2	0.546	0.399	0.509	0.506	0.498	0.462
Adj.R^2	0.528	0.377	0.489	0.486	0.477	0.440
F	22.003 ***	27.945 ***	55.180 ***	51.373 ***	47.062 ***	45.430 ***
N	310	310	310	310	310	310

Note: (1) ***, **, * represent at significance levels of 1%, 5% and 10%, brackets based on white heteroscedasticity robust standard error calculation T value obtained; (2) The explained variable is the natural logarithm of sulphur dioxide emission per capita ($Lnso_2p$); (3) Models 17–22 in Table 6 are regressed using the fixed effects model and random effect model after passing Hausman test, $p < 0.01$. Therefore, the random effect model is rejected and the fixed effect model is selected; in order to save space, not all regression results of random effect models are reported in the table.

Table 7. Test results based on the impact of government intervention and economic growth.

	(23)	(24)	(25)	(26)	(27)	(28)
lngdp	1.520 ***					
	(3.16)					
$lngdp^2$	−0.100 ***					
	(−3.70)					
Total_G		−0.083 *	0.424 ***	0.170 **	0.050 **	−0.035
		(−1.73)	(3.29)	(2.45)	(2.34)	(−0.92)
$total\_G \times Lngdp$			−0.059 ***			
			(−3.82)			
$total\_G \times Lngdp^2$				−0.003 ***		
				(−3.80)		
$total\_G \times Lngdpp$					−0.096 ***	
					(−5.03)	

Table 7. *Cont.*

	(23)	(24)	(25)	(26)	(27)	(28)
$total\_G \times Lngdpp^2$						−0.019 **
						(−2.66)
lnp	−1.690 **	−1.671 **	−1.678 **	−1.618 **	−2.135**	−0.426
	(−2.36)	(−2.13)	(−2.13)	(−2.07)	(−2.75)	(−0.41)
$year_{2009}$	0.167 ***	0.194 ***	0.241 ***	0.226 ***	0.219***	0.165 ***
	(3.64)	(6.24)	(5.77)	(5.79)	(6.24)	(5.26)
$Year_{2010}$	0.256 **	0.337 ***	0.441 ***	0.405 ***	0.375***	0.265 ***
	(2.49)	(4.90)	(4.41)	(4.26)	(6.14)	(4.51)
$Year_{2011}$	0.438 **	0.535 ***	0.703 ***	0.655 ***	0.637***	0.453 ***
	(2.70)	(4.87)	(4.52)	(4.36)	(6.70)	(4.78)
$Year_{2012}$	0.492 **	0.563 ***	0.804 ***	0.750 ***	0.785***	0.488 ***
	(2.32)	(4.93)	(4.81)	(4.64)	(6.94)	(4.89)
$Year_{2013}$	0.497 *	0.542 ***	0.871 ***	0.809 ***	0.899***	0.483 ***
	(1.84)	(4.41)	(4.58)	(4.41)	(6.53)	(4.32)
$Year_{2014}$	0.489	0.460 ***	0.898 ***	0.832 ***	0.981***	0.441 ***
	(1.47)	(4.33)	(4.30)	(4.18)	(6.02)	(4.04)
$Year_{2015}$	0.479	0.406 ***	0.890 ***	0.825 ***	1.009***	0.407 ***
	(1.33)	(4.06)	(4.17)	(4.06)	(5.82)	(3.77)
$Year_{2016}$	0.559	0.456 ***	1.015 ***	0.947 ***	1.173***	0.481 ***
	(1.31)	(3.52)	(4.08)	(3.93)	(5.57)	(3.44)
$Year_{2017}$	0.636	0.460 ***	1.109 ***	1.043 ***	1.322***	0.544 ***
	(1.28)	(3.43)	(4.11)	(3.99)	(5.58)	(3.44)
_cons	3.495	9.512	9.362	8.800	12.356**	−0.745
	(0.56)	(1.52)	(1.48)	(1.40)	(1.97)	(−0.09)
R^2	0.546	0.375	0.491	0.503	0.549	0.437
Adj.R^2	0.528	0.352	0.471	0.483	0.531	0.414
F	22.003 ***	26.772 ***	27.469 ***	29.088 ***	22.844 ***	33.973 ***
N	310	310	310	310	310	310

Note: (1) ***, **, * represent the significance levels of 1%, 5% and 10%, brackets based on white heteroscedasticity robust standard error calculation T value obtained; (2) The explained variable is the natural logarithm of sulphur dioxide emissions ($Lnso_2$); (3) Columns (23)–(28) in Table 7 are regressed using the fixed effect model and random effect model after passing Hausman test, $p < 0.01$. Therefore, the random effect model is rejected and the fixed effects model is selected; in order to save space, not all regression results of random effect models are reported in the table.

Table 7 reports the regression results of model (2)'s re-evaluation. The fitted F value of column (23)~(28) was significant ($p < 0.01$). The regression model as a whole has passed the significance test, and the goodness of fit of the model is above 0.352, indicating that the model has a strong explanatory power. The regression results of column (23)~(28) are essentially consistent with those of Table 4, and the above conclusions are further tested.

Secondly, this paper also adopts the following robustness tests: (1) retest the observed values of the main variables at the 1%, 5% and 10% levels of winsorize, and there is no significant difference in the test results; (2) carry out the robustness tests with different year combinations, such as 2008–2012, 2013–2017, and the results show that the conclusions in Tables 3 and 4 have not changed; (3) divide the samples into three parts for the eastern, central and western regions—the research results are not affected. Through the adjustment and test of the abovementioned different methods, the results have not changed significantly; therefore, the empirical results and analysis of this paper are robust.

6. Conclusions and Suggestions

Based on the provincial panel data from 2008 to 2017, this paper uses the fixed effect model to investigate the institutional environment, the level of government intervention, the impact of economic growth on regional sulphur dioxide (SO_2) emissions, and the regulatory role of institutional environment and government intervention on economic growth and regional sulphur dioxide (SO_2) emissions. It is found that when the economic growth (GDP) is at a low level, the regional sulphur dioxide (SO_2) emissions are in a centralized growth stage; however, when the economic growth (GDP) is at a high level, the sulphur dioxide (SO_2) emissions are in a declining stage, which is to say, with the economic growth (GDP), the sulphur dioxide (SO_2) emissions show an inverted "U" pattern of rising first and then falling. It was found that the higher the level of institutional environment and government intervention, the lower the SO_2 emission. Further tests show that the institutional environment plays a negative role in regulating economic growth (GDP) and sulphur dioxide (SO_2) emissions, and the level of government intervention also plays a negative role in regulating economic growth (GDP) and sulphur dioxide (SO_2) emissions. To promote sustainable development, based on the above conclusions, this paper puts forward the following policy recommendations:

(1) To limit the emission of air pollutants such sulphur dioxide, alter the energy structure and industrial structure, speed up the upgrading of industrial structure, raise technical proficiency and independent innovation capacity, and progressively phase out high energy consumption and emission industries (SO_2).

(2) The high growth of China's industry is at the expense of high energy consumption and high emissions. Improving and perfecting the environmental control system and incentive mechanism, guiding the rational consumption of energy and improving efficiency, are important ways of reducing emissions. The government cannot only guide enterprises to care about the use of resources, but should also put pressure on enterprises to innovate technology.

(3) In order to increase the strengthening of R & D of the renewable and new energy industry technology, on the one hand, the government is the "visible hand" to regulate and support new energy; on the other hand, the market "invisible hand" is used to stimulate and reallocate resources in order to reduce the emission of air pollutants such as sulphur dioxide (SO_2) as much as possible.

(4) For increasing the strengthening of R & D of the renewable and new energy industry technology, on the one hand, the government is the "visible hand" that regulates and supports new energy; on the other hand, the market "invisible hand" is used to stimulate and reallocate resources in order to reduce the emission of air pollutants such as sulphur dioxide (SO_2) as much as possible.

Due to the different development of different regions of China, there are also certain differences in the relationship between the institutional environment, economic growth and sulphur dioxide (SO_2) emissions. This study has not deeply involved the specific analysis of economic environment coordination between regions, and the lack of spatial differences in a spatial pattern. In addition, due to the many parameters of sulphur 2 (SO_2) emissions, some data and complex parameters did not flow into the estimation range; therefore, the data are not up to the date. In the next step, we can focus on the empirical research data in different regions, as well as a more comprehensive analysis of sulphur dioxide (SO_2) emissions, in order to be more comprehensively evaluate and to analyse the coordinated development relationship between the institutional environment, economic growth and sulphur dioxide (SO_2) emissions.

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