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Endogenous Study on Economic Development, Environmental Investment, and Green Development Based on the Panel Data Analysis of 11 Provinces in the Yangtze River Economic Belt

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ABSTRACT

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Chinese President Xi pointed out that the green development of the Yangtze River Economic Belt is a national development strategy promoting the coordinated development of the economy and green development in the Yangtze River Economic Belt and the building of the national green development demonstration zone as the only way to break the environmental bottleneck of economic development. This study selects 11 provinces and cities in the Yangtze River Economic Belt between 2006 and 2017 and makes an empirical study on the relationship among green development, environmental investment, and green development by using a panel vector autoregression (PVAR) model. The results of this study found that investment in environmental governance has no significant effect on economic development and green development; that in the past, the provinces and cities in the Yangtze River Economic Belt had an unsustainable behavior of exchanging the environment for economic development; and that economic development can significantly promote green development. According to the empirical results and conclusions, this study puts forward the following suggestions to improve the level of green development and sustainable and healthy economic development: establish and improve the mechanism of environmental protection investment, optimize the structure of environmental protection investment, and gradually increase the intensity of environmental protection; actively introduce social capital into the field of environmental protection; and continue to optimize the industrial structure and increase the proportion of green industries.

ADDITIONAL INDEX WORDS: *Economic development, environmental investment, green development, PVAR.*

INTRODUCTION

With the rapid development of the Chinese economy and the seriousness of environmental pollution, green development has gradually become a crucial measure to ensure the sustainable development of economy and environment. In the 18th National Congress of the Communist Party of China, President Xi declared that "clear water and green hills are gold and silver mountains." In February 2019, President Xi proposed that "unswervingly accelerating green development is great power of China to participate in global governance and build a community of human destiny" (Xi, 2019). As the important tool to realize the coordinated development of green development and the economy, environmental investment can facilitate the sustainable development of the economy while alleviating environmental pressure. In February 2018, the National Development and Reform Commission issued Interim Provisions on the Investment Management of the Central Government in the Green Development of the Yangtze River Economic Belt. Environmental investment is a blend between economic development and green development and includes some aspects of environment protection investment, environment technology research investment, environment management investment, and so on. To deal with the problem of uncoordinated environmental and economic development in China, the investment of environmental protection by the government at all levels shows a trend of increasing year by year and has achieved certain results in antipollution and in emission reduction and has a certain effect on economic development.

Motivation

The Yangtze River economy spans the eastern, central, and western parts of China, and it is an important population cluster that plays a significant role in the national economic system. Since reform and opening up, the Yangtze River Economic Belt represents more than 40% of the country's gross domestic product (GDP) with 20% of the land area. With rapid economic development, environmental pressure on the Yangtze River Economic Belt has influenced development of the regional economy with issues such as accumulation of heavy

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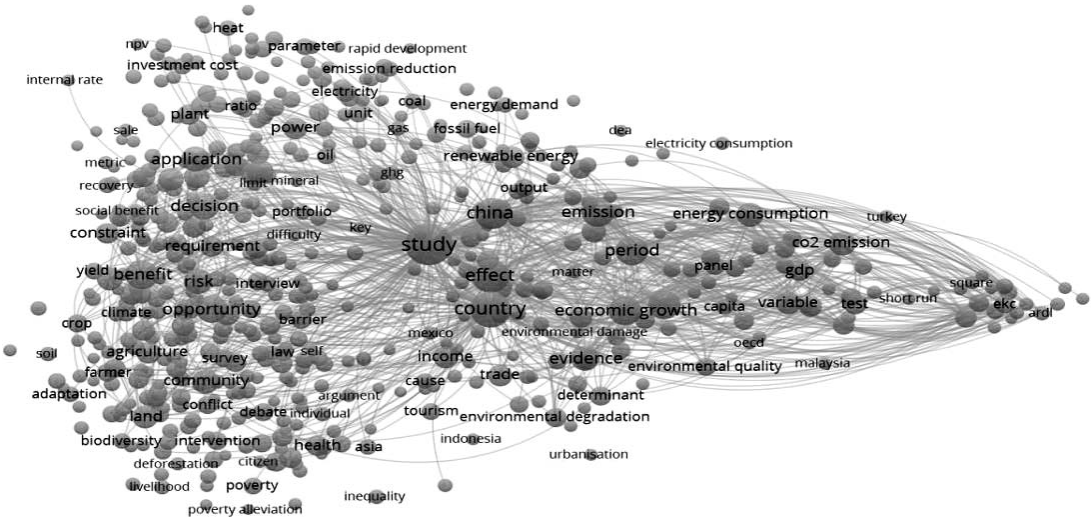

Figure 1. Clustering analysis from the literature.

industry, large population density, and so on. The "Government Work Report" in 2018 proposed "to promote the development of the Yangtze River Economic Belt with ecological priority and green development"; the 19th National Congress of the Communist Party of China also raised guidelines that focus on protection, no big development, and establishing the basic direction of the Yangtze River Economic Belt construction. Green development has become the basic requirement for development in the Yangtze River Economic Belt—and even for the national economy. At the same time, for a sustainable development of the environment and economy, green development of the Yangtze River Economic Belt is proposed by scholars from different fields. This study selects 11 provinces and cities in the Yangtze River Economic Belt for the study of a mutual connection between economic development, environmental investment, and green development by a panel vector autoregression (PVAR) model and comes up with related recommendations.

Literature Review

Foreign Literature Review

To research the overall trend of related studies abroad, this study screens out related online articles of science with the key words "economic development" and "environmental investment" and conducts the clustering analysis of 1476 articles selected from 2004 to 2018 by VOSviewer software. The results are shown in Figure 1.

As can be seen, the results of the VOSviewer clustering analysis can be divided into three sections: the green shows social benefit, investment cost, emission reduction, and so on; the red shows opportunity, benefit, risk, intervention, law, and the like; the blue shows consequences, including energy consumption, CO_2 emission, environmental degradation, environmental damages, and the like. The main research is in China because it is in a critical period of economic restructuring and involves a great deal of interaction between the economy and the environment, attracting the focus of many experts and scholars.

According to the above results, scholars from various countries have focused more on research on green intervention and the economic effects of environmental investment than on government intervention, energy conservation and emission reduction, environmental benefits, and so on. Pitkänen *et al*. (2016) concluded that the supply of cash on deposit, government intervention, and introduction of social capital play crucial roles in realizing a green economy by comparing 10 cases in five European countries. Hafezi and Zolfagharinia (2018) pointed out that government departments are supposed to supervise businesses prudently to avoid pursuing benefits while harming the environment and that the function of governmental supervision and guidance should be used to promote enterprises to innovate products. Van der Ploeg and Withagen (2013) pointed that the combination of green technology research and development (R&D) subsidies and reducing the pollution brought about by economic development can effectively alleviate environmental stress and promote the development of a green economy. He *et al*. (2019), by empirically analyzing 150 listed enterprises in China, believed that improving the structure of fiscal expenditures can effectively improve environmental issues.

Domestic Literature Review

At present, Chinese scholars mainly focus on the effect of environmental investment on pollution and its effect on economic development. In terms of the effect of environmental pollution, Li and Sun (2018) concluded that government investment guaranteed regional green development by setting up a system dynamics model to analyze the path of industrial green growth in the Beijing-Tianjin-Hebei region. Zhang, Yuan, and Du (2016) concluded that industrial environmental investment efficiency is high in the middle and low in the central and western regions by using data envelopment analysis to analyze provincial panel data in China. The Yang

and Tian (2017) study was aimed at foreign investment and pollution emissions between 1991 and 2011. They pointed out that environmental investment has no0 significant effect on pollution emission. However, Yu (2019) used the DEMETER (development of a European multimodel ensemble system for seasonal to interannual) prediction model to evaluate environmental investment issues, arguing that with the increase in environmental investment, pollution emission can be controlled effectively. In terms of an economic development affect, Wang and Sun (2018) considered that green investment plays a positive role in green GDP by analyzing provincial panel data empirically in China from 2005 to 2014, whereas Zhou, Chen, and Lu (2018) used an MS-VAR model to analyze empirically China's environmental data. They figured out that the relationship between environmental protection investment and economic development is a dynamic nonlinear relationship between the two regions, and they proposed that the contraction between economic development and environment protection belongs to adjustable contraction.

Literature Summary

As can be seen from the above analysis, scholars at home and abroad have fully affirmed a relationship between economic development and green development, but the difference is that the scholars abroad pay more attention to qualitative research on how to achieve a green economy, whereas scholars at home are more inclined to quantitative research of relationships between environmental investment, green development, and economic development. The influence of domestic scholars on the interaction between environmental investment, green development, and economic development is also divided into three points of view. First, environmental investment can prominently improve the economic and green development levels. Second, environmental investment has no significant effect on green and economic development. Third, environmental investment has different effects on green and economic development according to different regions. Therefore, on the basis of the Yangtze River Economic Belt, this study constructs a mutual influence system of economic development, environmental investment, and green development; defines environmental investment as environmental government investment; studies closely the interrelationship between environmental government investment, economic development, and green investment; and provides related policy recommendations according to research conclusions.

METHODS

On the basis of a theoretical analysis and research hypotheses, this section empirically analyzes relationships by PVAR and other models.

Theoretical Analysis and Research Hypotheses

Green development is the theme of world development today, and green development in the Yangtze River Economic Belt is a strategic policy in China. As can be seen from statistical data, environmental government investment in various regions of the Yangtze River Economic Belt is increasing year by year. As a whole, investment in the environmental management of the Yangtze River Economic Belt has increased from 90.85 billion yuan in 2006 to 369.26 billion yuan in 2017, up 306.45% and rising by nearly 25.54% per year on average. Therefore, the first hypothesis is proposed:

H1. Environmental government investment can improve the level of green development.

China is at a critical period of economic reconstruction and green development. The Yangtze River Economic Belt, as the engine and center of economic development, actively promotes, with the transformation of "two highs and one surplus" industry, environmental pollution control as an inevitable requirement for sustainable development. It will also promote economic development in the long term, but the transformation of a large number of traditional industries and the elimination of traditional high energy–consuming industries may also inhibit the growth of the economy in the short term. Therefore, the second hypothesis is proposed:

H2. Green development will restrain the growth of the economy in the short term.

With continuous economic growth, green development has become a hot topic for scholars from all walks of life. President Xi proposed in a symposium on promoting the development of the Yangtze River Economic Belt held in Chongqing in January 2016 that "the promotion of the Yangtze River Economic Belt must be considered from the long-term interests of the Chinese nation, taking ecological priority and the path of green development." With the attention of government departments, financial support from a good economy, and the inevitable requirements of sustainable economic development, the speed of green development will be improved significantly. Therefore, the third hypothesis is proposed:

H3. Economic development will promote the process of green development.

Model Construction

This study conducts research on the correlation between economic development, environmental investment, and green development in 11 cities of the Yangtze River Economic Belt by analyzing panel data with the PVAR model proposed by Holtz-Eakin and Rosen (1988) and later completed by Love and Zicchino (2006). The model has become crucial in analyzing panel data. Therefore, this study sets up the following three PVAR models and operates with the PVAR2 program proposed by Lian (2009):

$$\ln x_{it} = \alpha_{it} + \beta_1 \ln x_{it-1} + \beta_2 \ln y_{it-1} + \beta_3 \ln z_{it-1} + \mu_{it} \quad (1)$$

$$\ln y_{it} = \alpha_{it} + \beta_1 \ln x_{it-1} + \beta_2 \ln y_{it-1} + \beta_3 \ln z_{it-1} + \mu_{it} \quad (2)$$

$$\ln z_{it} = \alpha_{it} + \beta_1 \ln x_{it-1} + \beta_2 \ln y_{it-1} + \beta_3 \ln z_{it-1} + \mu_{it} \quad (3)$$

where, the subscript i indicates provinces (municipalities), the subscript t is the year, μ is a random error term, x is economic development, y expresses environmental investment, and z stands for green development.

Variation Set and Data Resources

This study selects the data of 11 provinces and cities in the Yangtze River Economic Belt from 2006 to 2017 and sorts and

Table 1. *Descriptive statistics.*

Variation	Minimum Value	Maximum Value	Average Value	Standard Deviation
ln x	7.76	11.36	9.67	0.73
ln y	3.95	5.57	4.67	0.36
ln z	−0.50	6.44	3.59	1.06

screens the data in Excel. All data are transformed logarithmically to guarantee smoothness before checking and analyzing the panel data empirically by Statal 4.0 software. The data are from the statistical yearbooks of various provinces and cities (China YearBooks, 201X) and the China Environmental Statistics Yearbook (National Bureau of Statistics of China and Ministry of Ecology and Environment, 201X).

Economic Development

Economic level is the basis for a government to carry out other functions. GDP is still a main factor to measure regional economic development, so the real GDP of each of the various provinces and cities in the Yangtze River Economic Belt was used to measure their economic development level (variable x in the equations).

Environmental Investment

Environmental investment includes environmental protection investment, environmental management investment, environmental technology R&D investment, and so on. Considering the availability of data, environmental investment per 100 million yuan GDP each of the various provinces and cities in the Yangtze River Economic Belt was used to measure the environmental investment level (variable y in the equations).

Green Development

The main reverse indicator of green development is the environmental pollution level from air pollution, which diffuses is so easily that it has a large effect on economic social development. Therefore, SO_2 discharge was selected from the main sources of air pollution in various provinces and cities to measure green development level and will be confirmed As SO_2 discharge per 100 million yuan GDP (variable z in the equations).

RESULTS

Descriptive Statistical Analysis of Samples

This study is a statistical analysis in Excel after dealing with basic data, as shown in Table 1 and Figure 2.

During the sample statistical period, ln x showed a steady upward trend, indicating that both GDP and environmental management investment showed an upward trend with time; ln y had a small fluctuation, but overall showed an upward trend; ln z showed a downward trend as a whole, indicating that green development had been paid more and more attention by people and gradually achieved the goal of reducing SO_2 discharge; therefore, GDP and SO_2 discharge have a probable correlation.

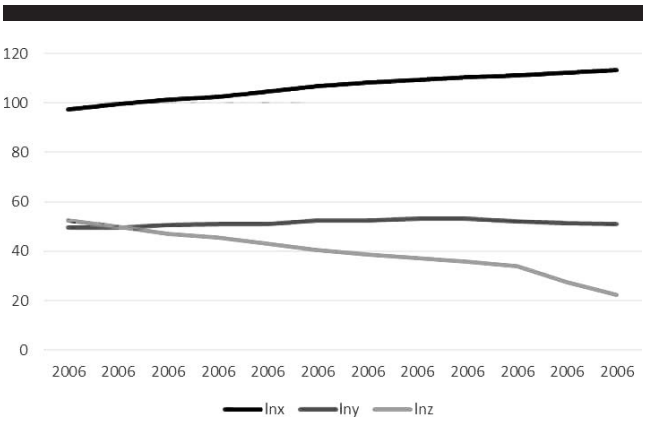

Figure 2. Time trend of ln x, ln y, and ln z.

During the statistical period, the standard deviation of ln x and ln y was <1, with a small fluctuation; the standard deviation of ln z was >1, with a large fluctuation.

Smoothness Examination

Before conducting an empirical analysis, it is necessary to test the smoothness of data to avoid a spurious or false regression. The study conducted three tests in Statal 4.0: LLC, IPS, and PP-Fisher. From the test results (Table 2), ln x and ln z in the horizontal sequence values could not pass the smoothness test, so first-order differential processing was performed on the original data; the test results all passed the smoothness test, which is a stationary sequence.

Select Lag Orders

To prevent the inaccuracy and loss of freedom in the estimation results, the PVAR model needed to select the appropriate lag orders. This study used the Akaike (AIC), Bayesian (BIC), and Hannan-Quinn information criteria (HQIC) to judge lag orders (Table 3). Finally, the lag order in this study was selected to the first order.

Relationship between Variables

The data are shown to be stable after the smoothness test, so the relationship between economic development, environmental investment, and green development was further analyzed by generalized method of moments (GMM), the impulse response function analysis, and variance decomposition.

Table 2. *Smoothness examination.*

	Horizontal Sequence Value			First Difference Sequence Value		
Variation	LLC	IPS	PP-Fisher	LLC	IPS	PP-Fisher
ln x	−4.073*** (0.0056)	−1.371 (0.689)	105.7120*** (0.000)	−6.005*** (0.0029)	−1.965* (0.060)	34.7989** (0.0407)
ln y	−6.678*** (0.000)	−2.054** (0.031)	45.5292*** (0.0023)	−12.877*** (0.000)	−3.557*** (0.000)	171.4729*** (0.000)
ln z	−2.018 (0.9258)	−0.632 (0.999)	0.490 (1.000)	−8.996*** (0.000)	−2.549*** (0.000)	45.5993*** (0.0022)

Table 3. *Lag orders.*

Lag	AIC	BIC	HQIC
1	−4.07958*	−3.04848*	−3.66136*
2	−3.5389	−2.20202	−2.998
3	−3.12499	−1.4359	−2.4445

GMM Estimation

The GMM estimated results are shown in Table 4. When GDP was set as the explanatory variable, the effect of GDP and SO_2 discharge in the first period was significantly positive for the current GDP. The specific coefficients were 0.9216 and 0.0609, whereas the environmental management investment in the first lag period had no effect on current GDP. Therefore, the economic development of various provinces and cities in the Yangtze River Economic Belt can be judged to depend mainly on sustaining previous development (still with some situations in which the environment is exchanged for development), while the investment in environmental management has not played a significant positive role in GDP.

When environmental management investment was regarded as an explanatory variable, the GDP, environmental management investment, and SO_2 discharge in the first lag period played a significantly positive role in current environmental management investment. It can be seen that when GDP grows, the government will be more willing to invest more funds for environmental management. At the same time, the more serious the environmental pollution, the more willing the government will be to invest in environmental management.

When SO_2 was regarded as an explanatory variable, the GDP in the first lag period played a significantly negative role in current SO_2 discharge, while environmental management investment in the first lag period had no significant effect on current SO_2 discharge. It can be seen that the Yangtze River Economic Belt achieved certain results in current green development and promoted green development while developing the economy, but the increase of environmental management investment cannot improve green development level prominently and solve the radical problems in green development.

Table 4. *Estimated results in GMM.*

	ln *x*		ln *y*		ln *z*	
	b_GMM	se_GMM	b_GMM	se_GMM	b_GMM	se_GMM
L.H_lnx	0.9216***	0.0262	0.3065*	0.1764	−0.3059***	0.1078
L.H_lny	0.0356	0.0229	0.4659***	0.1402	0.0317	0.0666
L.H_lnz	0.0609***	0.0127	0.1592*	0.0893	0.7010***	0.0642

Impulse Response Function Analysis

The direct relationship between variables was analyzed by GMM above, but the dynamic relationship between variables still needed to be tested by the impulse response function analysis. This study tested three variables by the Monte Carlo simulation method at a confidence interval of 95% and a simulation frequency of 1000 times. The results are shown in Figure 3.

When GDP was shocked, it produced a positive shock reaction. The initial value was about 0.04, decreasing with time, and tended to zero in the 10th period. As seen from the impulse response graph of GDP to environmental management investments, the initial response value of environmental management investment was 0, increasing gradually with time and reaching a maximum of 0.015 in the fourth period. As seen from the impulse response graph of GDP to SO_2 discharge, the initial response value of SO2 was 0, increasing gradually, reaching a maximum of 0.023 in the second phase, and finally decreasing to 0.

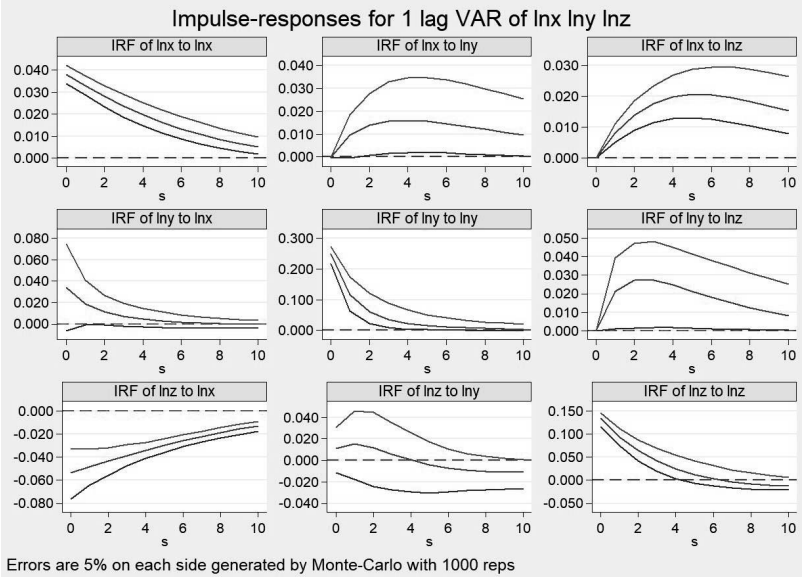

Figure 3. Results of the impulse response.

Table 5. *Results of variance decomposition.*

Variable	Period	ln x	ln y	ln z
lnx	1	1	0	0
lny	1	0.018	0.982	0
lnz	1	0.139	0.006	0.855
lnx	2	0.942	0.034	0.024
lny	2	0.019	0.975	0.006
lnz	2	0.163	0.011	0.826
lnx	3	0.86	0.073	0.067
lny	3	0.02	0.966	0.015
lnz	3	0.186	0.013	0.801
lnx	4	0.779	0.106	0.115
lny	4	0.02	0.957	0.023
lnz	4	0.207	0.013	0.78
lnx	5	0.71	0.13	0.16
lny	5	0.02	0.95	0.03
lnz	5	0.226	0.012	0.762
lnx	6	0.653	0.147	0.2
lny	6	0.02	0.945	0.035
lnz	6	0.241	0.012	0.747
lnx	7	0.608	0.16	0.233
lny	7	0.02	0.941	0.039
lnz	7	0.252	0.013	0.735
lnx	8	0.572	0.168	0.26
lny	8	0.02	0.939	0.041
lnz	8	0.259	0.015	0.726
lnx	9	0.545	0.174	0.281
lny	9	0.02	0.937	0.043
lnz	9	0.264	0.017	0.719
lnx	10	0.524	0.178	0.298
lny	10	0.02	0.936	0.044
lnz	10	0.266	0.019	0.714

When SO_2 discharge was shocked, GDP produced a negative shock response first, the initial value was about –0.06, increasing to 0 with time. As seen from the impulse response chart of SO_2 to environmental management investment, the environmental management investment produced a positive shock response value and gradually reached the maximum of 0.018 in the first period, decreasing to the minimum of –0.01 in the eighth period, finally rising to 0. As seen from the impulse response chart of SO_2 to itself, SO_2 produced a positive response value, decreasing to –0.02 in the ninth phase, and finally slowly rising to 0.

Variance Decomposition

To further analyze the degree of interaction between GDP, environmental management investment, and SO_2 discharge, this study decomposed the variance of data (Table 5). The change in GDP was 52% from its own effect, 18% from environmental management investment, and 30% from SO_2 discharge. The change in environmental management investment was 94% from its own effect, 2% from the GDP effect, and 4% from SO_2 emissions. The change in SO_2 emissions was 71% from its own effect, 27% from GDP, and 2% from environmental management investment.

CONCLUSIONS

This study empirically tested the endogenous relationship between GDP, environmental management investment, and SO_2 emissions in 11 provinces and cities in the Yangtze River Economic Belt.

Research Conclusions

Environmental management investment had no significant effect on SO_2 discharge and regional GDP. Although the investment in environmental management in the Yangtze River Economic Belt has shown a gradual increase in recent years, from the empirical results, this has not played a significant role in economic development and green development because of the large harm to the environment from previous development, which resulted in more environmental investment at the current stage for environmental improvement instead of for forming green industries.

There is still an extensive economic growth model in the Yangtze River Economic Belt that does not count environmental consequences. As seen from the GMM estimated results, SO_2 discharge in the lag period played a certain stimulative role in current GDP, whereas the results of variance decomposition showed that the change in regional GDP could be explained by the fluctuation of 30% SO_2 discharge. Therefore, it can be judged that no sustainable strategy in the Yangtze River Economic Belt realizes green development completely.

Economic development promoted green development. From the GMM estimation results, the regional GDP in the first lag period played a predominantly negative role in current SO_2 discharge, with a –0.31 coefficient of action, indicating that with the development of the economy, more focus was put on sustainable development of the economy and environment, more resources were put into protecting the environment, and certain results were achieved.

Policy Recommendations

In response to the above empirical results and conclusions, this study proposes the following policy recommendations to improve the level of green development and sustainable healthy development of the economy:

Establish a wholesome environmental investment mechanism, optimize the environmental investment structure, and strengthen environmental protection step by step. Although regional SO_2 emissions is in a state of decline with the development of economy, the increase of environmental investment cannot solve the problem with green development and does not have a significant effect on SO_2 discharge. Therefore, departments at all levels still need to improve investment of environmental protection funds while increasing environmental management investment, such as environmental protection publicity, environmental infrastructure construction, environmental technology R&D, and other traditional models that do not pollute and postgovern.

Actively introduce social capital into the field of environmental protection. The leading role of government capital setting tax incentive, low loan rates, environmental protection pollution prevention practices, and so is needed to attract the investment of social capital and ensure that green development succeeds with sufficient funds.

Continue to introduce optimized industrial structures and increase the proportion of green industry. For traditional high-energy consumption and high-pollution industries, transformation and upgrading of the industry should be carried out gradually, led by enterprises and government departments as

the facilitators and supervisors, while actively developing and increasing the proportion of green industry.

Introduce corresponding laws and regulations to provide legal protection for green development. In view of current economic development in which there is still development at the expense of the environment, government departments should introduce corresponding laws, strictly control the pollution discharge of such industries, reject any behaviors in exchange for environmental development, establish a sound accountability mechanism, and control pollution from the source.

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