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Interactive Relations Among Environmental Pollution, Energy Consumption and Economic Growth in Jilin Province, China

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ABSTRACT

As the material base of modern civilization, energy sources influence economic development considerably. While large energy consumption facilitates rapid economic growth, it also results in increasing environmental pollution and severe disequilibrium of the ecosystem. These troublesome outcomes are caused by high energy consumption, great wastes and unreasonable demand structure. Spatial autocorrelation of environmental pollution in nine prefecture-level cities in Jilin Province of China from 2005 to 2016 was measured by Moran's index based on collected panel data firstly. Subsequently, the dynamic relationship among energy consumption, environmental pollution, and economic growth was estimated by the spatial error model. Results demonstrate that energy consumption and environmental pollution in nine prefecture-level cities in Jilin Province of China present certain characteristics of spatial agglomeration from 2005 to 2016, as well as an annual rise in COD. Besides, significant positive correlations exist between environmental pollution and regional economic growth. Such correlations are significantly stronger than the correlation between energy consumption and economic growth. The dual goals of reasonable saving and utilization of energy sources and ecological environmental protection while maintaining high economic growth rate can be realized by optimizing the industrial and energy consumption structures, establishing sustainable environmental development strategy, and implementing differentiated environmental protection policies. Research conclusions can provide Jilin Province of China with some references in formulating energy and environmental development strategies, determining of emission-reduction goal, and choosing low-carbon, high-efficiency, and sustainable development path.

INTRODUCTION

Energy consumption increases dramatically as a response to the national economic development in China. China has become the largest energy consumption country in the world. Energy sources, which are the material base of modern civilization, influence economic development in China considerably. The large energy consumption facilitates the rapid economic growth in China, but introduces serious environmental pollution problems. The high energy consumption and economic growth are accompanied with serious environmental problems, such as pollution and ecological imbalance. Although energy consumption promotes economic growth, the consumption of polluted energy sources causes environmental damages and is the primary cause of environmental pollution. Problems of unreasonable energy demand structure, such as high energy consumption, great energy waste, and serious pollution, are extremely prominent in China. The conflicts among energy consumption, economic growth, and environmental protection become increasingly prominent and have become the bottleneck against China's sustainable development. Maintaining a harmonious development among preserving the high economic growth, saving and using energy sources reasonably, and protecting the environment has become a problem that has to be solved urgently in China.

Jilin Province, which is an economically underdeveloped region in China, is in the early stage of industrialization and has dual pressures of both economic development and environmental protection. As shown in Fig. 1, Jilin Province consumes a great amount of energy sources, and its environmental pollution caused by energy consumption is closely related to economic growth. Facilitating the sustainable development of economy, energy source, and environment, reducing energy consumption, and improving environmental quality while protecting the increasing energy demands for economic development have become major problems worldwide. Jilin Province is still applying the extensive economic growth model that focuses on the rapid growth of energy-consuming industries. The construction of high-energy consumption and high-pollution projects

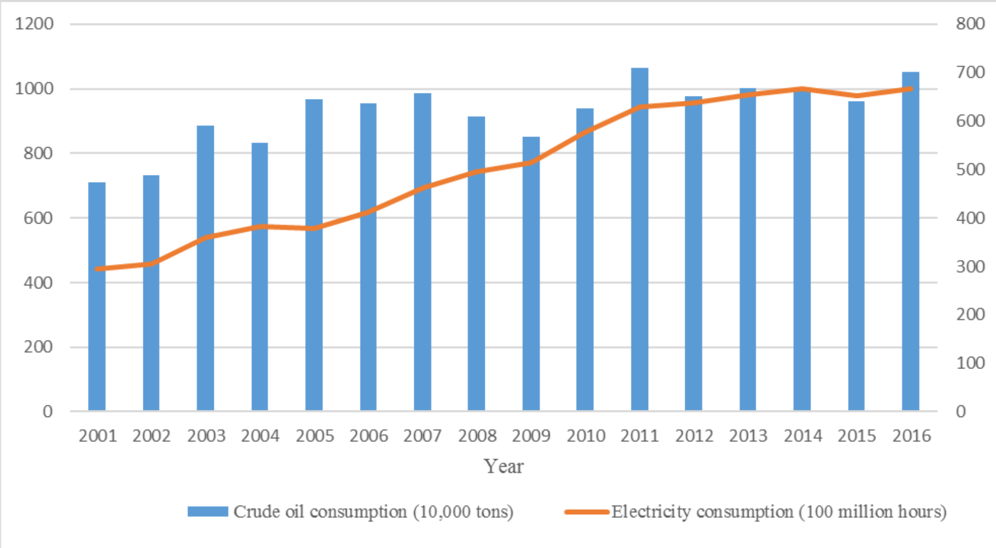

Fig. 1: Crude oil and electricity consumption in Jilin Province from 2001 to 2016.

are continuing, and this situation has brought considerable pressures to energy conservation and emission reduction. Economic growth evidently causes large energy consumption, which contributes to economic growth and environmental pollution in turn. Environmental pollution introduces substantial economic input to solve the negative effects caused by environmental pollution. Therefore, analysing interactive relations among energy sources, environmental pollution, and economic development based on relevant understanding and studies on influencing factors of energy consumption and environmental pollution in Jilin Province will provide a theoretical guidance and practical relevance to formulate economic development strategies and policies.

EARLIER STUDIES

Scholars in developed countries have been studying the relationships among environmental pollution, energy source, and economic development since 1970s. In particular, some scholars have focused on the relationship between economic growth and environmental pollution by combining endogenous economic growth model with climatic changes and sustainable development to address increasingly serious environmental pollution problems caused by energy sources. The relationships among environmental pollution, energy consumption, and economic growth have been widely explored. Kraft et al. (1978) quantitatively analysed the causal relationship between economic growth and energy consumption in America. Stern (1993) analysed the causal relationship between GDP and energy use in America from 1947 to 1990 and found a causal relationship between energy utilization and economic growth. Hawdon et al. (1995) discussed the complicated relations among energy source, environment, and economic growth. Cheng et al. (1997) examined the long-term equilibrium relationship between energy consumption and economic growth in Taiwan and found no causal relationship between GDP and energy consumption. Asafu-Adjaye (2000) estimated the causal relationship between energy consumption and income in India, Indonesia, Philippines, and Thailand. Aqeel et al. (2001) analysed the causal relationship between economic growth and energy consumption in Pakistan and believed that economic growth causes a continuous growth of energy consumption. Hondroyiannis et al. (2002) pointed out a long-term relationship among energy consumption, actual GDP, and price development in Greece. Ang (2008) explored the long-term relationships among economic growth, pollutant emission, and energy consumption in Malaysia from 1971 to 1999 and concluded positive correlations among the three variables in the short and long run. Kukla-Gryz (2009) disclosed that economic growth imposes different influences on atmospheric pollution strength in developing and developed countries. Zhang et al. (2009) studied the Granger causality among economic growth, energy consumption, and carbon emission in China. They found a one-way Granger causality between GDP and energy consumption and between energy consumption and carbon emission. Ozturk et al. (2010) investigated the long-term relationships and causal relations among economic growth, carbon emission, energy consumption, and employment rate in Turkey. Kivyiro et al. (2014) estimated the causal relations among CO_2 emission, energy consumption, economic development, and foreign direct investment in six sub-Saharan African countries and found significant differences in causal relations among these variables in six countries. No universal policies and suggestions can be offered. Alam et al. (2016) pointed out that CO_2 emission increases considerably with the increase in income and energy consumption in India, Indonesia, China, and Brazil. Bildirici et al. (2017) analysed the relationship among environmental pollution, economic growth, and hydroelectric energy consumption in the Group of Seven from 1961 to 2013. Analysis results supported the Grange causality between CO_2 emission and economic growth. Özokcu et al. (2017) examined the relations among financial stability, economic growth, energy consumption, and CO_2 emission of South Asian countries from 1980 to 2012. He found that financial stability is conducive to improve environmental quality, and economic growth and increase in energy consumption and population density are disadvantageous to environmental quality in the long run. Baloch (2018) studied the dynamic relationships among economic growth, energy consumption from road traffic, and environmental quality in Pakistan. He discovered that road infrastructure and urbanization hinder improvement in environmental quality, accelerate emission of SO_2 in atmosphere, and reduce negative influences of economic growth on total SO_2 emission. In summary, existing studies on the relations between energy consumption and economic growth have mainly focused on econometric analysis of relevant data, and research conclusions are highly sensitive to studying countries, studying period, and quantitative methods. In this study, the dynamic spatial correlations among environmental pollution, energy consumption, and economic growth in Jilin Province were studied to provide theoretical references for optimization of local industrial structure and reduction in environmental pollution.

BRIEF INTRODUCTION TO THE MODEL AND DATA PROCESSING

Brief Introduction of Model

Existing analysis methods of relations among environmental pollution, energy consumption, and economic growth mainly focus on time data or panel data. Different cities in Jilin Province have evident spatial differences. Traditional analysis based on total time series data may cover such evident spatial differences. Considering the spatial difference, time series regression method or panel data are unsuitable to explain the complicated relations among economic growth, energy consumption, and environmental pollution and have difficulties in reflecting practical analysis conclusions. Therefore, spatial statistical analysis method has to be introduced properly when processing regional data. On this basis, a Douglas production function model involving energy consumption and environmental pollution was constructed. As a result, spatial variables were introduced into this model, and a spatial econometric model was established to analyse spatial autocorrelations of energy consumption and environmental pollution and influences of agglomeration form of economic growth rate, energy consumption, and environmental pollution on regional economic growth.

Classical Douglas production function: Energy consumption and environmental pollution were considered as input elements. The production function of Jilin Province is expressed as Eq. (1):

$$Y = AK^{\alpha} L^{\beta} (Eco)^{\gamma} E^{\theta} \quad ...(1)$$

Where, Y is the total economic output, A is the total factor productivity, K is the input of physical capital stock, L is the labour input, Eco is the environmental input, and E is the energy input. α, β, γ, and θ are elasticity coefficients. The logarithmic expression of Eq. (2) is

$$\ln Y_{it} = A_i + \alpha_i \ln K_{it} + \beta_i \ln L_{it} + \gamma_i \ln(Eco)_{it} + \theta_i \ln E_{it} \quad ...(2)$$

Where, i refers to the region and t refers to time.

Construction of the spatial model: Spatial autocorrelation was verified using statistical variables in spatial statistics in this study. Through the spatial effect analysis of economic growth, the relations among economic growth, energy consumption, and environmental pollution in all cities of Jilin Province were studied by the spatial econometric model proposed by Anselin (2002). The expression of *Moran's I* is:

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(Y_i - \bar{Y})(Y_j - \bar{Y})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \quad ...(3)$$

Where, $S^2 = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y})$, $\bar{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i$, Y_i is the observation value of city i, and n is the total number of cities. W_{ij} denotes the approximate spatial weight matrix of binary system. After the spatial correlation was tested by *Moran's I*, Eq. (2) was expanded with the above-mentioned theoretical model with full consideration to the first-order lag variables and a new spatial error model based on panel data could be gained. It is expressed as Eq. (4):

$$\ln Y_{it} = C + \tau \ln Y_{it-1} + \alpha_i \ln K_{it} + \beta_i \ln L_{it} + \gamma_i \ln(Eco)_{it} + \theta_i \ln E_{it} + \mu + \psi_t$$
$$\psi_t = \delta W \psi_t + \varepsilon_t \quad ...(4)$$

Where, $\ln K_{it}$, $\ln L_{it}$, $\ln (ECO)_{it}$, and $\ln E_{it}$ are explanatory variables and $\ln Y_{it}$ is explained variable. τ, α_i, β_i, γ_i and θ_i are regression coefficients of variables. μ is the random interference term. δ is the spatial autocorrelation coefficient. W is the spatial adjacent weight matrix.

Data Source

Annual data from 2005 to 2016 were applied in this study. Panel data of nine prefecture-level cities in Jilin Province (Changchun, Jilin, Siping, Liaoyuan, Tonghua, Baishan, Songyuan, Baicheng, and Yanbian Korea Autonomous Prefecture) were used as the empirical analysis samples. On the basis of the model constructed above, GDP (unit: 100 million RMB) represents the explained variable (Y), whereas capital input (unit: 100 million RMB), labour input (unit: 100 million population), environmental input (unit: 100 million tons), and energy input (unit: 10,000 tons of standard coal) represent explanatory variables (K, L, Eco, and E). Logarithms of all data were calculated first. lnY, lnK, lnL, $ln(Eco)$, and lnE were used to express logarithms of GDP, capital stock, quantity of employment, COD, and energy consumption, respectively. The above-mentioned data were collected from Jilin Statistics Yearbook of previous years, and environmental data came from the China Environmental Statistical Yearbook.

EMPIRICAL ANALYSIS AND RESULTS

Spatial Autocorrelation Verification of Energy Consumption and Environmental Pollution

Spatial autocorrelations of energy consumption and environmental pollution in Jilin Province were verified by the global spatial correlation index *Moran's I*. It was calculated by the software of GeoDa (version 0.9.5-i). Table 1 shows that energy consumption and environmental pollution from 2005 to 2016 presented certain spatial agglomeration among nine prefecture-level cities. In other words, cities with high energy consumption and environmental pollution prefer to be adjacent to cities with high energy consumption and environmental pollution. In particular, the *Moran's I* of COD, which is an environmental pollution indicator, increased annually, thereby showing an evident agglomeration trend.

SEM Panel Analysis

Eq. (4) was estimated using Matlab2012b software and spatial module (downloaded from https://www.paneldatatoolbox.com/). Table 2 shows the results.

Table 2 shows that the regression coefficients of relevant statistical variables are significantly positive, which indicates that the spatial correlation of the spatial econometric model is significant and can be measured. Viewed from fitting effect, the goodness-of-fit of Model 2 is better than those of other models, and estimation coefficients of all four models pass through the significance test.

Table 1: Statistics of energy consumption and COD in Jilin Province.

Year	Moran's I of Energy consumption	Moran's I of COD
2005	0.0715	0.0314
2006	0.1021	0.0419
2007	0.0812	0.0784
2008	0.0654	0.0654
2009	0.0584	0.0845
2010	0.0521	0.1041
2011	0.0551	0.1098
2012	0.0576	0.1125
2013	0.0684	0.1254
2014	0.0754	0.1125
2015	0.0564	0.1241
2016	0.0598	0.1058

P-value of δ in all four models passes through the 10% significance test, and regression coefficients are positive. This finding reveals the significantly positive spatial correlation of economic growth among nine prefecture-level cities in Jilin Province, and economic growth of one region depends on the economic growth with similar spatial characteristics to some extent. Songyuan and Baicheng in Jilin Province bear small environmental protection pressure due to the rich energy sources. Moreover, the improvement in infrastructure further increases the economic growth rate in these regions. This situation reflects that economic growth between adjacent cities has significant overflow effect. All four input elements make different positive contributions to economic growth. The regression coefficient of capital is higher than those of other variables, which indicates the high dependence of economic growth in Jilin Province on investment pulling in recent years. The regression coefficient of COD is positive and passes through the 5% significance test. This finding fully proves the significantly positive correlation between environmental pollution input elements and regional economic growth in Jilin Province. This correlation is also stronger than the correlation between energy consumption and economic growth.

POLICY SUGGESTIONS

Optimize the Industrial Structure and Increase the Proportion of the Tertiary Industry

Jilin Province has low energy utilization and serious environmental pollution due to unreasonable industry structure. Therefore, the province must optimize industrial structure and promote industrial upgrade to achieve harmonious development of energy, environment, and economy. Optimization of industrial structure refers to the adjustment in industrial structure. Given the high proportion of heavy industry in Jilin Province, government sectors should adjust proportion distribution of light and heavy industries, de-

Table 2: Regression results of SEM panel.

Variable	Model 1		Model 2		Model 3		Model 4	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
	0.201	0.041	-	-	-	-	-	-
	0.422	0.001	0.664	0.005	0.425	0.005	0.414	0.001
	0.283	0.002	0.215	0.015	0.249	0.014	0.115	0.015
	0.144	0.011	0.048	0.044	0.170	0.042	0.083	0.356
	0.294	0.022	0.095	0.079	0.165	0.000	0.042	0.042
	0.552	0.019	0.586	0.063	0.447	0.024	0.440	0.047
	0.941	-	0.968	-	0.923	-	0.878	-
	0.024	-	0.009	-	0.035	-	0.007	-

(Note: Model 1 has no fixed effect, Model 2 only has space fixed effect, Model 3 only has time fixed effect, and Model 4 has space and time fixed effect)

velop the tertiary industry and light industry vigorously, and control the development of energy-consuming industries to reduce energy consumption. In addition, the government should encourage and guide development of the tertiary industry from multiple aspects through investment and policies, pay key attention to the development of tourism, labour-intensive and modern service industries. Moreover, the government should adjust and update the industrial structure of Jilin Province towards heavy, high-processing, and technical-intensive industries. While focusing on the pillar and advantageous industries, attention should be paid to optimize element configuration, increase input on technology, and adjust industrial structure toward industries with less pollution. Meanwhile, some industries with serious pollution issues shall be updated and reorganized continuously and increasing internal pollution management and technological reconstruction should be carried out to reduce pollutant production and emission.

Optimize the Energy Consumption Structure and Reduce Unreasonable Energy Consumption

The energy consumption pattern centered at coal in Jilin Province will not change considerably in the coming years due to the limitation of resource conditions. Coal consumption not only brings huge environmental and transportation pressure, but also is against the increase in energy utilization. In energy consumption structure, Jilin Province should increase consumption proportions of high-quality energy sources including hydropower, oil, and gas and reduce proportion of low-carbon energy sources. Meanwhile, Jilin Province should increase technological innovation and government support to develop and promote new technologies positively, such as clean coal, coal gasification, and coal liquefaction technologies. Utilization of renewable energy sources should be enhanced. Key attention should be paid to the development and utilization of solar energy, geothermal energy, hydropower, and biomass energy and reduction in energy consumption by increasing energy utilization. The resource advantages should be developed fully to reduce consumption of raw materials and energy consumption and realize the goal of small input, high output, and low pollution. This condition is conducive to reduce and recycle waste materials, thereby realizing the harmonious unification of economic, social, and environmental benefits.

Strengthen Environmental Protection and Establish Sustainable Environmental Development Strategies

Use of clean energy sources should be increased by developing and promoting new generations of clean high-efficiency coal processing technologies. Apart from maintaining economic and social development, Jilin Province should also reduce energy consumption per unit of industry production and relieve environmental pollution caused by combustion of large quantity of coals to provide people with a good environment for living and social production. A harmonious relationship between sustainable energy development and environmental protection is recommended. Moreover, Jilin Province should accelerate structural adjustment, technical improvement, and industrial upgrade. The province should also adjust energy consumption structure and energy product structure, increase utilization of energy sources, accelerate research and development of new energy sources, and relieve environmental pressure and effects from energy consumption fluctuations on the economy. The final goal is to realize the harmonious sustainable development of social economy, energy source, and environmental protection while realizing the strategic goal of economic and social development.

Implement Differentiated Environmental Protection Policies and Improve Regional Environment

Enterprises with high pollution and energy consumption should take steps to eliminate outdated production capacity, improve protection technologies to increase output efficiency and reduce pollution emission. The industry entry threshold should be controlled strictly, and newly enrolled enterprises should be guided to low energy consumption and low-carbon environmental protection. Accordingly, positive interaction and harmonious development among economy, energy sources, and environment protection can be realized. Regional economic growth priority should be fostered to drive peripheral economic growth and realize win-win cooperation. Considering the spatial agglomeration features of regional economic development, the government should take the following initiatives: promote industrial restructuring; accelerate the training of strategic emerging industries with regional characteristics; support technological development and innovation activities in new energy sources, energy conservation, and environmental protection; implement key energy-saving projects (e.g., energy-saving technological transformation and contract energy management); and form a new green industrial cluster.

CONCLUSIONS

Energy consumption facilitates economic development. Consumption of polluted energies causes environmental damages and is the main cause of environmental pollution. Unreasonable energy demand structural problems, such as high energy consumption, vast energy waste, and serious pollution, are extremely prominent in China. The conflict among energy consumption, economic growth, and environmental protection becomes increasingly prominent, which becomes the bottleneck against China's sustainable development. A case study based on Jilin Province of China is presented in this paper. Spatial autocorrelation of environmental pollution is estimated by the Moran's index. The dynamic relations among energy consumption, environmental pollution, and economic growth are estimated by spatial error model. The results demonstrate that energy consumption and environmental pollution in nine prefecture-level cities in Jilin Province present certain characteristics of spatial agglomeration from 2005 to 2016 and continuous annual increase in COD. Significant positive correlations exist between environmental pollution elements and regional economic growth. Such correlations are significantly stronger than the correlation between energy consumption and economic growth. Further studies should be made on estimation of spatial correlation of industrial structure and environmental pollution, environmental protection cooperation across administrative regions, quantitative relationship between energy consumption of a specific industry and environmental pollution and influencing factors of energy consumption and environmental pollution.

REFERENCES

Asafu-Adjaye, J. 2000. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics, 22(6): 615-625.

Aqeel, A. and Butt, M. S. 2001. The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal, 8(2): 101-110.

Alam, M.M., Murad, M.W., Noman, A.H.M. and Ozturk, I. 2016. Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecological Indicators, 70: 466-479.

Ang, J. B. 2008. Economic development, pollutant emissions and energy consumption in Malaysia. Journal of Policy Modeling, 30(2): 271-278.

Anselin, L. 2002. Under the hood issues in the specification and interpretation of spatial regression models. Agricultural Economics, 27(3): 247-267.

Baloch, M. A. 2018. Dynamic linkages between road transport energy consumption, economic growth, and environmental quality: evidence from Pakistan. Environmental Science and Pollution Research, 25(8): 7541-7552.

Bildirici, M. E., and Gökmenoðlu, S. M. 2017. Environmental pollution, hydropower energy consumption and economic growth: Evidence from G7 countries. Renewable and Sustainable Energy Reviews, 75: 68-85.

Cheng, B. S. and Lai, T. W. 1997. An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. Energy Economics, 19(4): 435-444.

Hawdon, D. and Pearson, P. 1995. Input-output simulations of energy, environment, economy interactions in the UK. Energy Economics, 17(1): 73-86.

Hondroyiannis, G., Lolos, S. and Papapetrou, E. 2002. Energy consumption and economic growth: Assessing the evidence from Greece. Energy Economics, 24(4): 319-336.

Kraft, J. and Kraft, A. 1978. On the relationship between energy and GNP. The Journal of Energy and Development, pp. 401-403.

Kukla-Gryz, A. 2009. Economic growth, international trade and air pollution: A decomposition analysis. Ecological Economics, 68(5): 1329-1339.

Kivyiro, P. and Arminen, H. 2014. Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. Energy, 74: 595-606.

Ozturk, I. and Acaravci, A. 2010. CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews, 14(9): 3220-3225.

Özokcu, S. and Özdemir, Ö. 2017. Economic growth, energy, and environmental Kuznets curve. Renewable and Sustainable Energy Reviews, 72: 639-647.

Stern, D. I. 1993. Energy and economic growth in the USA: A multivariate approach. Energy Economics, 15(2): 137-150.

Zhang, X. P. and Cheng, X. M. 2009. Energy consumption, carbon emissions, and economic growth in China. Ecological Economics, 68(10): 2706-2712.