The Coupling Effect Analysis Between Economic Growth, Industrial Structure and Environmental Pollution in China

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Abstract
It is important to explore the coupling relationship between economic growth, industrial structure and environmental pollution. In numerous analysis frameworks which used for studying economic growth, industrial structure and environmental pollution, many scholars verified whether the situation of local area in accordance with the Kuznets curve, the obtained results were always diverse. Dividing China into 3 regions of eastern, central and western, the paper study the relationship between economic growth, industrial structure and environmental pollution by using coupling coordination degree model to analysis 28 provinces and cities' panel data in 2000—2016. The study found that the economic and environment development in most prefectural units are still at a lower level of coupling and coordination. There are significant disparities in coupling and coordinating degree between eastern coastal areas and western inner areas. And economic growth has a significantly positive impetus to environmental pollution while the improvement of economic growth comprehensive level leads to the deterioration of environmental conditions; China's current industrial structure is in good condition and it has crossed the inflection point of the inverted U-shaped curve into the stage industrial structure improve environment pollution; economic growth has a bigger direct positive effect on environmental pollution and it also indirectly affects environmental pollution by influencing industrial structure, technological progress and population quality.

Keywords: Economic growth, environmental pollution, industrial structure, coupling and coordinating degree

1 Introduction

Since the reform and opening up, the economic growth process in China is developing rapidly. China's economic growth rate back to the world's first has reached 6.7%by 2016, above the level of developing countries into the middle. The economic growth promotes China's economic development and improves people's living standards, but also brings the increasingly serious environmental problems. Population and industry continuously move to towns increasing environmental pollution, resulting in a significant "urban disease" problem. How to improve environmental pollution and promote ecological environment in the development of urbanization becomes the focus of the study. Industrial structure upgrading as an important means of resolving the conflicts between the two and coordinating the development of the two attracts attention. At present, the academic circle has obtained many achievements in the research of economic growth, industrial structure and environmental pollution, but they often separated the three. In this context, it has important theoretical and practical implication to explore what are the laws between the three; whether the current level of China's economic growth and industrial structure are suited to the level of ecological environment and how economic growth and industrial structure influence environmental pollution.

According to research we know that since GROSSMAN proposed the Kuznets curve (Kuznets)--the famous inverted "U" curve--to explain the relationship between economic development and environmental pollution, economic growth, industrial structure and environmental pollution problem has been the attention of scholars. In numerous analysis frameworks which used for studying economic growth, industrial structure and environmental pollution, many scholars verified whether the situation of local area in accordance with the Kuznets curve, the obtained results were always diverse.

Over the past few decades, numerous scholars have researched the mutual relationship between economic activity and eco-environment. In the 1970s, some economists explored the conditions, processes, and elements of the coordinated growth relationship between the economy and environment using economic growth theory. For instance, Yan Xinhua(2006) indicated that a few economically developed areas have Kuznets curve characteristics in terms of time. Liu et al. (2005) built a coupling model between Chinese regional urbanization and eco-environment with the grey relative degree model and analyzed the spatial characteristics of the relationship between urbanization and eco-environment at the provincial level. At present, many domestic and foreign scholars believe that there is a close relation between industrial structure change and economic growth, since domestic scholars also used the empirical analysis of China's reform and opening up the adjustment of industrial structure promotion effect to economy growth. Bao Qun (2014)using the panel data of 6 indicators for 1996-2000 waste covering over 30 provinces, then through the establishment of pollution protection equation and output equation analyses the relationship between economic development and environmental pollution. It reveals the deep-seated reasons for the continued deterioration of the ecological environment in China.

2 Methods

Coupling is a type of relationship in which one system or subsystem and another, or one subsystem and the elements in another subsystem mutually influence and affect each other. The interactive coupling relation of economy and environment is the sum of their interaction, mutual influence and nonlinear relation. The assessment of degree of coupling can be performed in four steps:

2.1 Constructing assessment indicators of economic and environmental subsystems

According to previous research methods, We chose 28 provinces in China as assessment objects, select the study sample interval is from 2000 to 2016. One reason for this choice is that these 28 provinces are somewhat independent geographically and spatially. Another reason is that they are independent economic entities. The data are come from the economic networks statistics database, Chinese Statistical Yearbook, China land resources Yearbook and the local statistical yearbook (Table 1).

System	Function	Indicator
Economic Comprehensive development index	Regional economic power	GDP per capita
		Average gross value of industrial output
		Financial revenue per capita
	Regional development potential	Gross fixed assets investment
		Financial expenditure
	Regional development vigor	Gross volume of passenger transport
		Gross volume of cargo transport
		Gross retail sales of social consumer goods
Environmental comprehensive development index	Atmospheric environment variables	SO2 emission
		Inhalable particle concentration
		Waste gas treatment rate
	Water environment variables	COD emission
		Industrial wastewater treatment rate
		Wastewater discharge
	Ecological construction	Soil erosion rate
		Forest coverage
		Urban green coverage rate
	Economic environment related variable	The proportion of environmental investment in GNP

Table 1： Indicators for evaluating the regional economic and environmental subsystems in China
source: Chinese Statistical Yearbook.

2.2 Calculating the efficiency function

The regional economy–environment coupling system is composed of an economy subsystem and an environment subsystem. Each subsystem is constituted by various indicators. Suppose there are "n" indicators in subsystem i named $x_1, x_2, \ldots x_n$. The efficacy coefficient d_{ij} of the indicator in the regional economy–environment coupling system would be expressed as:

$$d_{ij} = (x_{ij} - x_{ij}\,\min) / (x_{ij}\,\max - x_{ij}\,\min) \text{ positive indicators}$$
$$d_{ij} = (x_{ij}\,\max - x_{ij}) / (x_{ij}\,\max - x_{ij}\,\min) \text{ negative indicators} \quad (1)$$

where d_{ij} is the efficacy coefficient of indicator j in subsystem i. x_{ij} max is the maximum score of indicator j in subsystem i; xij min is the minimum score of indicator j in subsystem i; x_{ij} is the score of indicator j in subsystem i ; and $0 \le d_{ij} \le 1$. d_{ij} shows the degree of satisfaction of the goal. $d_{ij} = 0$ means the lowest degree of satisfaction, while d_{ij} $j = 1$ means the highest degree of satisfaction.

2.3 Comprehensive assessment of subsystem efficacy

The comprehensive efficacy of the subsystem is the integration of the contribution of all indicators to its subsystem, which can be achieved using the formula:

$$u_i = \Sigma w_{ij} d_{ij} \quad (2)$$
$$w_{ij} \ge 0,\ \Sigma w_{ij} = 1,\ j = 1,2,\cdots,\ n$$

where u_i is the comprehensive efficacy of subsystem i and wij is the weight of indicator j in subsystem i .

2.4 Assessment of the degree of coupling and coordination of the regional economic and environmental systems

With the concept of capacity coupling and the capacity coupling coefficient model in physics, we obtain a degree of coupling model for the mutual function of multiple ： .

$$C = \{(u_1 \times u_2 \times \cdots\cdots \times u_n)/[\Pi(u_i + u_j)/n]\}^{\wedge(I/n)} \quad (3)$$

According to formula (3), we know that $0 \le C \le 1$. The degree of coupling score is between 0 and 1. When $C = 1$, the degree of coupling is the largest, and the system has benign resonance and is working into a new orderly structure. When $C = 0$, the degree of coupling is the smallest, and one subsystem and another (or one element and another) will be uncorrelated, and the coupling system will tend to be disordered.

Coordination is the feature in which all of the elements are in harmony with each other in the process of system evolution. The model of degree of coordination can reflect the level of harmony in an economy and environment coupling relationship, and it can be calculated as follows:

$$T = (au_1 \times bu_2)^{(1/2)} \quad (4)$$
$$D = (C \times T)^{(1/2)} \quad (5)$$

where D is the degree of coordination, C is the degree of coupling, and T is the comprehensive coordinating index of economy and environment, which reflects the effect or contribution of integrated synergy of economic development and the environment. a and b are weights to be determined. Because the economy is as important as the environment, a=b=0.5.

According to the distribution of u_i, the value of the comprehensive efficacy of the subsystem, the value of the degree of coordination D is between 0 and 1. The higher the comprehensive efficacies that the economic and environmental subsystems contribute to the whole system, the higher the value of the degree of coupling and coordination will be. Additionally, the better the economic and environmental systems is, the more harmonious their relationship.

3 Conclusions and discussion

Through modeling and literature research, we can draw the following five conclusions：

First, there is an interactive coupling relationship between regional economy and environment. As two subsystems, the interaction between them exist four stages. They're low water coupling, antagonism, running-in and high level coupling. They restrict each other. Coordinating the development relationship of the two subsystems is the basis of the benign development of the large scale economic environment system.

The second, economic growth has a significantly positive impetus to environmental pollution while the improvement of economic growth comprehensive level leads to the deterioration of environmental conditions; China's current industrial structure is in good condition and it has crossed the inflection point of the inverted U-shaped curve into the stage industrial structure improve environment pollution; economic growth has a bigger direct positive effect on environmental pollution and it also indirectly affects environmental pollution by influencing industrial structure, technological progress and population quality. The coefficient of Industrial structure is the largest among the indirect path, which means industrial structure is the most effective way to improve environment pollution.

Third, the coupling degree of economic development and eco-environment is the synergy between order parameters in the interaction process of regional economy and ecological environment. It reflects the trend of the system from disorder to order. The development of the economic system will lead to the deterioration of the ecological environment. After the economic grew to a certain extent, it will also promote the environmental protection. The coupling-coupling model in this development process consists of the efficacy function, the coupling degree function and the coupling degree index system. Among them, the establishment of the upper and lower bounds of order parameter and the establishment of the coupling index system are the key to the correct application of the model.

Fourth, with the structure analysis of the industrial sectors in the four stages, it can be seen that the polluting industrial sectors accounted for the highest proportion in the running-in stage and antagonism stage. Furthermore, the dominant industrial sectors

in the antagonism stage were mainly mining and metallurgy industries with low value-added and high-pollution discharge, and should be the most important type of area for environment monitoring and regulation. China's current industrial structure is in good condition and it has crossed the inflection point of the inverted U-shaped curve into the stage industrial structure improve environment pollution; economic growth has a bigger direct positive effect on environmental pollution and it also indirectly affects environmental pollution by influencing industrial structure, technological progress and population quality. The coefficient of Industrial structure is the largest among the indirect path, which means industrial structure is the most effective way to improve environment pollution.

Final, dividing China into 3 regions of eastern, central and western, the paper study the relationship between economic growth, industrial structure and environmental pollution by using coupling coordination degree model to analysis 28 provinces and cities' panel data in 2000—2016. The study found that the economic and environment development in most prefectural units are still at a lower level of coupling and coordination. There are significant disparities in coupling and coordinating degree between eastern coastal areas and western inner areas. And economic growth has a significantly positive impetus to environmental pollution while the improvement of economic growth comprehensive level leads to the deterioration of environmental conditions. In addition empirical results suggest that the effect of economic growth to environmental pollution copes with the Environmental Kuznets Curve from the perspective of the whole nation, laying on the right downward part of the inverted-U curve. From regional perspective, there also exists inverted-U shaped curve in the eastern and middle regions while in the western region the relationship appears to be N shaped. Meanwhile, the influence of other factors displays distinct characteristics.

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