A Study on Coupling and Decoupling Among Economy, Energy, Environment, and Technology for Coordinated Development of Northeast China

Yu Yang[a], Tan Li [b]*
[a]e-mail: 18500510@qq.com ,* Corresponding author: [b]e-mail: 348013764@qq.com

Changchun Humanities and Sciences College Changchun, China

Abstract— It is of great importance to understand the current economic and social development of Northeast China for further implementation of the Northeast Revitalization Strategy. In this paper, the types of "coupling" and "decoupling" among economy, energy, environment, and technology in Northeast China were studied by establishing a relevant assessment index system. It is found that the "coupling degree" is not high, and the "types of coupling degree" and "types of decoupling states" are not satisfactory in Northeast China. It is due to the "short board" of the "development degree" of the quaternion system rather than the "coordination degree" of that system. Finally, the measures to coordinate the development of the economy-energy-environment-technology relationship in Northeast China are put forward as a reference for revitalizing Northeast China.

Keywords-Northeast China; Economy; energy; environment; technology; Coupling; Decoupling

1 INTRODUCTION

With the emergence of a series of problems such as energy exhaustion, climate warming and environmental deterioration, countries and regions around the world are looking for a path of "green development" suitable for their own countries or regions. Therefore, many scholars have studied the relationship among economy, energy and environment (EEE) systems, this relationship include two types (“coupling” and “decoupling”). The “coupling” relationship was often used by scholars. For example, some scholars [1-9] have studied this "coupling" relationships in China and its administrative divisions such as Henan Province, Tianjin Municipality, the Yangtze River Delta, Liupanshui City, iron and steel industries, the Yellow River Basin, and Ningbo City. However, research on "decoupling relationship" is mainly focused on the dual systems between economy and carbon emission, and between economy and environmental pollution. In the 21st century, technology has become the direct driving force of the economic and social development. Previous studies on the EEE system can no longer fully reflect the development of the provinces(regions). So it is necessary to introduce "technology subsystem" to form a new "economy-energy-environment-technology (EEET)" quaternary system. At present, the author of this paper [9,10] has studied the "coupling relationship" of the quaternary system among provinces, cities and the eastern regions of the belt and road in China [11]. However, there is no literatures about "decoupling relationship" the among the quaternary system.

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With the deepening of the reform, the institutional and structural contradictions in Northeast China have caused many problems in its economic and social development. After more than 10 years of efforts, the revitalization strategy of Northeast China has achieved initial results. Now, how is the economic and social development of Northeast China? To answer this question, we can not make measurements by single economic indices. In this paper. the coupling and decoupling relationship for EEET system in Northeast China (Inner Mongolia Autonomous Region, Liaoning, Jilin and Heilongjiang Provinces) were studied in order to provide reference for improving the coordination development relationship of the quaternary system in Northeast China.

2 ASSESSMENT INDEX SYSTEMS

Table 1 gives an assessment index system for economy, energy, environment and technology in northeast China [11]

Table 1. The Assessment Indices for EEET

Systems	**Primary Indices**	**Secondary Indexes**
Economy Subsystems (X)	Total quantity indices	Gross regional product (GRP); Per capital GRP
	Structure indices	AGDP; Added value of 2nd industry; Added value of the tertiary industry
Energy subsystem (Y)	Energy production	Coal production; Coke production; Total oil production; gas production; electric energy production
	Energy consumption	Total energy consumed (Converted to standard coal)
Environment subsystem （Z）	Environmental disruption	discharge amount of wastewater; Sulfur dioxide emission; General industrial solid waste emissions
	Environmental improvement	Environmental protection expenditure; Comprehensive utilization rate of general industrial solid waste
Technology subsystem (T)	Technological input	Local expenditure on technology; Number of R&D
	Technology output	Number of authorized patents; Technology market volume of transaction

Given X, Y, Z, T stand for the value of economy, energy, environment and technology subsystem in EEET system, respectively. C' and G stand for coordination degree and development degree, respectively.

$$C' = \frac{8(XY + XZ + XT + YZ + YT + ZT)}{3(X + Y + Z + T)^2} \tag{1}$$

$$G(X, Y, Z, T) = \alpha X + \beta Y + \gamma Z + \lambda T \tag{2}$$

Of them α, β, γ. λ are undetermined coefficients. As economy, energy, environment, and technology are equally important, therefore:

$$\alpha = \beta = \gamma = \lambda = 1/4 \tag{3}$$

Given D stand for the "coupling degree" of the EEET system, which is closely related to coordination degree and development degree, as expressed in the equation:

$$D(X,Y,Z,T) = \sqrt{C'(X,Y,Z,T) \times G(X,Y,Z,T)} \tag{4}$$

Decoupling is also called Delinking. In 1966, the decoupling theory was formally introduced into the socio-economic field. In 2005, Tapio introduced the "decoupling elasticity index model" for the first time to study the relationship between economy and transportation development in Europe. Since then, this model has been widely used in studying the relationship between economy and environment.

Given the variable rate of the development degree in a particular period is $\Delta G'$, while the variable rate of the coordination degree is $\Delta C'$, then the decoupling elasticity index (e), can be defined as：

$$e = \frac{\Delta C'}{C'} \Big/ \frac{\Delta G}{G} \tag{5}$$

Therefore, the decoupling elasticity index can be used to study the decoupling relationship between development degree and coordination degree.

When assessing the subsystems of economy, energy, environment and technology in the model in Table 1, the relationship between total amount and structure and that between input and output is taken into full consideration. Each subsystem contains two secondary indices which, in turn, contain different numbers of tertiary indices in their respective cases.

There are positive and inverse indexes among secondary indexes in Figure 1. The larger the positive index is, the better, while, on the other hand, the smaller the inverse index is, the better. The first step is to standardize the data. Then, each index at the secondary level should be assigned a weight [11]. The standardized indexes multiply their own weights and are added together to form the primary index, respectively.

As the dimensions of each secondary index in this paper may be different from one another, therefore, the weight assignment method based on coefficient of variation is adopted in this paper. These data processing methods are found in other articles by the author [11].

3 RESULTS AND DISCUSSIONS

3.1 Coupling Analysis

Figure 1 is a coupling degree Radar chart of the EEET system in Northeast China, from which it can be seen that Heilongjiang province is on the far side of the Radar almost every year. Liaoning is basically on the inner side of Heilongjiang, but it's very close to Heilongjiang. The Inner Mongolia Autonomous Region is at the inner most of the Radar map for most of the years,

especially in 2014-2018. The results show that Heilongjiang province has the best coupling degree of the EEET quadruple system in northeast China. Liaoning is a little bit worse. Then comes Jilin, and the Inner Mongolia is the worst. It can also be found that the coupling degree is 0.7 for Heilongjiang province which is the highest in Northeast China. It can be concluded that the coupling degree of coordination development of the EEET system in the four provinces of northeast China is not high.

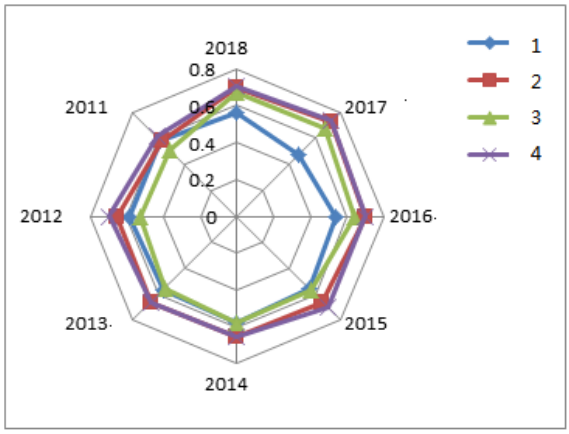

Figure1. The Coupling Degree Radar Chart of the EEET System in Northeast China for some Years (1-Inner Mongolia; 2-Liaoning, 3- Jilin, 4- Heilongjiang)

Table 2 gives the different types of coupling relationship of the provinces in northeast China in 2011-2018. In general, the Inner Mongolia autonomous region and Jilin province are types of "far-fetched". Liaoning and Heilongjiang are the type in primary coordinated development. Currently, no province is "well coordinated type" or other higher types.

Table 2 Coupling types determined by the value of coupling degree of the quaternary system in Northeast China

	Province			
	Inner M.	**Liao Ning**	**Ji Lin**	**Heilongjiang**
Types of Coupling degree (2018)	Far-fetched develop	Moderate coordination develop	Primary coordination develop	Moderate coordination develop
Types of Coupling degree (2017)	Almost disordered, recession develop	Primary coordination develop	Primary coordination develop	Moderate coordination develop
Types of Coupling degree (2016)	Far-fetched develop	Primary coordination develop	Primary coordination develop	Moderate coordination develop
Types of Coupling	Far-fetched develop	Primary coordination	Far-fetched develop	Primary coordination

degree (2015)		develop		develop
Types of Coupling degree (2014)	Far-fetched develop	Primary coordination develop	Far-fetched develop	Primary coordination develop
Types of Coupling degree (2013)	Far-fetched develop	Primary coordination develop	Far-fetched develop	Primary coordination develop
Types of Coupling degree (2012)	Far-fetched develop	Primary coordination develop	Far-fetched develop	Primary coordination develop
Types of Coupling degree (2011)	Far-fetched develop	Far-fetched develop	Far-fetched develop	Far-fetched develop

3.2 Decoupling Analysis

In Formula (5), it can be seen from that the biggest difference between decoupling elasticity index and coupling degree is that the decoupling elasticity index can be negative. Moreover, even the same value of the decoupling elasticity index can present different "decoupling states". It is due to that "a decoupling state" depends not only on the specific value, but also on the plus or minus sign of the independent variables, In order to give a more visual analysis, the decoupling types are represented in Figure 2.

3.3 Decoupling Analysis

The whole coordinate axis is divided into four quadrants and eight regions as seen in Figure 3.

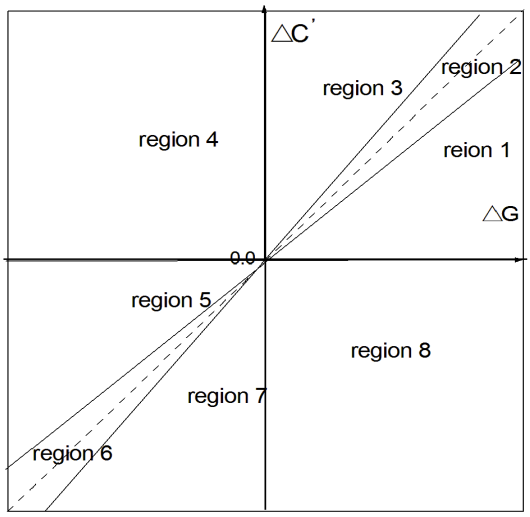

Figure 2. Classification of Decoupling Types

The horizontal axis represents variable amount of the development degree (△G), while the vertical axis represents variable amount of coordination degree (△C '). the 1-8 regions represents " weak decoupling", "growth link", "Expansion negative decoupling", "Strong negative decoupling", "weak negative decoupling", "recession link", "recession decoupling", and "strong decoupling", respectively. The dotted line is a slope of 45 degrees.

Figure 3 shows the distribution of the decoupling types of the EEET quaternary system of the four provinces in Northeast China.

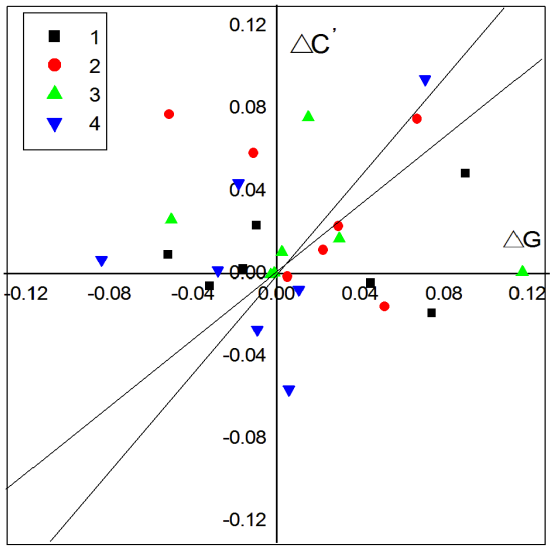

Figure 3. Distribution of the four-element decoupling types in the four provinces of Northeast China (1-Heilongjiang, 2-Jilin, 3-Liaoning, 4-Inner Mongolia)

According to the decoupling theory, if the decoupling index of the quaternary system is in the first quadrant of Figure 2, it is a good state, especially those in the region 2. The index in the fourth quadrant suggests the worst state, showing that the coordination degree and development degree deteriorate year by year. Being in the second and fourth quadrants indicates that the degree of development or that of coordination deteriorate year by year. As can be seen from Figure 3, Inner Mongolia was for one year in the "expansion negative decoupling" area in the first quadrant. The province was for three years in the second quadrant of the "strong negative decoupling" area, one year in the third quadrant of the "recession decoupling" area, and two years in the fourth quadrant of the "strong decoupling" area. Liaoning was in the first quadrant for 4 years, including 2 years in the "weak decoupling" and another 2 years in the "expansion negative decoupling". A province was for two years in the "strong negative decoupling" area of the second quadrant and one year in the "weak negative decoupling" area of the third quadrant. Jilin was in the first quadrant for 3 years, including 1 year in the second area, 2 years in the first area, 2 years in the "strong negative decoupling" area of the second quadrant, and 2 years in the "strong decoupling" area of the fourth quadrant. Heilongjiang was one year in the "weak decoupling" area of the first quadrant, for three years in the "strong negative decoupling" area

of the second quadrant, another year in the "weak negative decoupling" area of the third quadrant, and two years in the "strong decoupling" area of the fourth quadrant. In addition, according to Figure 3, if the number of data points in the first and second quadrants of a province (region) is more than those in the first and fourth quadrants, the indication is that the development and change trend of the coordination degree of the province (region) is better than that of the development degree. Therefore, the development trend of coordination degree is generally better than that of development degree in the four provinces (region) in northeast China. Therefore, seen from another aspect, the "development degree" of Northeast China has become a "bottleneck" that obstructs coupling and decoupling of the four-element EEET system.

4 CONCLUSIONS

(1) The coupling degree of coordinated development of the EEET system in Northeast China is not high. Heilongjiang province is the best, followed by Liaoning and Jilin, and Inner Mongolia is worst. The coupling type of Heilongjiang province is basically the "intermediate coordinated development" or "primary coordinated development". While Inner Mongolia is basically of the type of "far-fetched coordinated development", or even the type of "on the verge of imbalance or decline".

(2) The decoupling of coordinated development of the EEET system in northeast China is also not optimistic. Jilin province is the best, followed by Liaoning and Heilongjiang provinces, and Inner Mongolia is the worst.

(3) The development and change trend of "coordination degree" of the EEET system in Northeast China is better than that of "development degree". The problems of "development" rather than "coordination" are the "bottleneck" that prevent the coordinated development of the EEET system in Northeast China.

To deal with the problems arising from the coordination-oriented development concerning the EEET system in Northeast China, this paper puts forward the following measures and suggestions:

(1) As a Chinese saying goes, "Development is the absolute principle". At present, Northeast China is focusing on solving the "weak link" problems in the EEET-related development of the economy. However, we do not need a “blind development”. We must stick to "coordination", which is a road of green development. The "Northeast Revitalization" strategy should be aligned with the "Belt and Road" strategy.

(2) Green development is inseparable from the development of technology, relying on technology to correctly handle the relationship between economic growth, energy consumption and environmental protection.

(3) Science and technology are people-oriented. We must overcome some bad ideas such as “self-satisfaction, being lazy and unorganized”, We must also give up the philosophies such as “sitting idle, doing nothing and relying on others”. We must emphasize the policy of combining originality and innovation with introduction. On the one hand, we should stress R&D of the key technological programs of the individual regions, and on the other hand, we should introduce

advanced technological products from both home and abroad to transform traditional industries and promote the upgrading of traditional industries.

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