AHP-CRITIC-Based Collaborative Benefit Analysis of Regional Energy and Economic Development

Shuyu Li[1, a, #], Heng Lei[1, #, *], Jiangpeng Duan[2, b, #]

[1]College of Economics and Management Changsha University of Science and Technology 410114, Changsha, China

[2]School of Economics and Finance Capital University of Economics and Business 100105, Qingdao, China

*Corresponding author: leiheng220420@163.com, [a]lishuyu2220@163.com, [b]duanjiangpeng2204@163.com

Abstract. With the rapid changes in China's external economic environment, regional energy and economic problems have become increasingly prominent, and the research on the synergy between regional energy and economy has received more and more attention. From the perspective of system analysis, this paper constructs the index system of regional energy and regional economy and uses AHP-CRITIC (Analytic hierarchy process-Criteria Importance Through Intercriteria Correlation) method to calculate the coupling weight of indicators. The ordered model of the two subsystems of regional energy and economy and a composite system synergetic degree model are constructed based on synergy theory. Taking the relevant data on energy and economic development in Shanxi Province from 2010 to 2020 as samples, this research analyzes the synergetic development of regional energy and regional economy in Shanxi Province. The results show that the order degree of regional energy and economic subsystems in Shanxi Province shows an overall upward trend, but the synergy degree of the two systems shows a fluctuating trend of alternating increase and decrease. The stability of the development synergy effect is poor, and it is vulnerable to external environmental impacts. The endogenous synergistic development mechanism has not yet been formed.

Keywords: AHP-CRITIC method; collaborative model; regional energy; regional economy; Shanxi Province.

1. Introduction

Energy is an essential material foundation for the survival and development of human society, which is related to the livelihood of people and competitiveness of national strategy and occupies a pivotal position in the development of the national economy. With the increasing complexity of the global economic environment, a correct understanding of the relationship between economy and energy is crucial to promoting energy and economic coordination and sustainable development. There is a close relationship between energy development and economic growth. On the one hand, economic growth relies on energy. Namely, energy utilization promotes rapid economic growth.

On the other hand, green and sustainable energy development is inseparable from the leading role in economic growth. Economic growth provides financial guarantees for energy development, promotes the large-scale development and utilization of energy, and promotes the efficient use of energy. The gradual depletion of non-renewable energy and the ecological environment problems in energy production and utilization seriously hinder the further development of the economy.

Scholars have conducted extensive research on the impact and linkage mechanism between energy and the economy. Ozturk et al. found a long-term cointegration relationship between energy consumption and economic growth in 51 countries worldwide from 1965 to 2005[1]. Lin et al. selected the economic and energy indicators of China's provinces from 2000 to 2019, which used the EDA method model to analyze the relationship between economic growth and energy development[2]. The results show that the economic development models in different regions have different effects on energy utilization. Based on the energy statistics from 1978 to 2015, Li et al. studied the relationship between energy consumption, economic growth, and energy structure by using the vector autoregressive model method and found that the three showed a good cointegration relationship in general, and there was only one-way causality in part, without mutual causality[3]. Mary and others, through the energy consumption and economic growth in Shanxi Province in 1978 ~ 2014 data cointegration analysis, it is concluded that there is a long-term cointegration relationship between energy use and economic growth in Shanxi Province. However, there is no Granger causality[4]. From the existing research results, there are relatively few studies on the coordinated development of regional energy and economy from the perspective of synergetic, and the overall benefits of the interaction between the two systems are often ignored.

At present, in the research on the synergy between energy and economy, the commonly used research methods include principal component analysis (PCA), grey correlation analysis (GRA), and analytic hierarchy process (AHP). Li et al. based on the data of energy and economy-related indicators in Shanxi Province from 1999 to 2017, using the 3E system comprehensive evaluation method of improved GRA method, a systematic measurement model of coordinated development level is established, and the coordinated development of energy and economy in Shanxi Province is comprehensively analyzed[5]. Cao et al., based on the energy and economic indicators of Ningbo and its counties from 2008 to 2017, combined with principal component analysis and coupling coordination degree algorithm, analyzed the energy and economic development level and coupling coordination degree of Ningbo[6]. Li takes Jiangsu Province as an example, using the coupling coordination degree model to analyze the correlation between energy, economy, and environment[7]. Li et al. used grey correlation analysis to analyze the relationship between energy consumption and economic growth in Shanxi Province. The results show that the energy structure seriously dependent on coal restricts the efficient economic growth of Shanxi Province[8]. The existing regional energy economy coordination research is mainly based on the 3E system coordination degree evaluation model. When measuring the level and coordination degree of regional energy economic development, the regional energy, and economic development evaluation system is often relatively simple and lacks a systematic and comprehensive perspective. There are limitations in the perspective of research methods: purely subjective weighting methods or objective weighting methods. There are obvious limitations in calculating weights only from a single angle, resulting in deviation of results and unable to reflect them comprehensively.

Based on this, this study comprehensively selects representative influencing factors of collaborative development and establishes an evaluation index system of regional energy and economic development. The weight assignment method coupling the subjective AHP method and the objective CRITIC method is used to analyze the order parameters of the two systems qualitatively and quantitatively. In addition, This paper adopts a collaborative model from a coupling perspective, which has not been considered in previous studies. By constructing the coordination degree measurement model, this paper analyzes the synergistic effect and trend of regional energy and economic development in Shanxi Province, reveals the internal law and relationship between coordinated development of regional energy and economy, and provides a realistic basis for macro decision-making to promote regional economic development and social progress.

2. Construction of evaluation systems

2.1 Regional energy development evaluation

According to the basic principles of scientificity, comprehensiveness, systematisms, and operability, this paper comprehensively draws on the energy development evaluation index proposed in the existing literature [6]. It selects 10 regional energy evaluation indexes, including the total energy production and consumption, energy industry investment, and energy processing conversion efficiency. The total production index reflects the scale of regional energy production, production results and development speed, and the regional energy supply level. The indicators of total consumption and per capita consumption reflect regional energy consumption level and consumption growth rate, reflecting regional energy demand. The total investment in the energy industry can comprehensively reflect the scale, speed, and proportion and use the direction of investment in the energy industry, thus reflecting the renewal and expansion of reproduction in the energy industry. Energy processing conversion efficiency can reflect the advanced level of energy processing conversion equipment and production technology in the region. Energy consumption intensity refers to the proportion of energy intensity and output, which can reflect the efficiency of energy use, consumption level, and energy saving. The energy consumption elasticity coefficient represents the relationship between economic development and energy consumption, comprehensively reflecting the efficiency of energy utilization, energy production process, and energy management level. Specific indicators are shown in Table 1.

Table 1 Regional energy evaluation index

Index layer	Pnit	Positive and negative of the index
Total energy production(X1)	Million tons of standard coal	+
Total energy consumption(X2)	Million tons of standard coal	+
Total power production(X3)	Billion kWh	+
Total electricity consumption(X4)	Billion kWh	+
Energy industry investment(X5)	Million yuan	+
Per capita energy consumption(X6)	Tons of standard coal / person	+
Energy conversion efficiency(X7)	%	+
Unit DGP energy consumption(X8)	Tons of standard coal / ten thousand yuan	-
Power consumption per unit GDP(X9)	KWh / million yuan	-
Energy consumption elasticity coefficient(X10)	—	-

2.2 Evaluation of regional economic development

This paper comprehensively draws on the economic development evaluation index proposed in the existing literature[9] and selects 10 regional economic development evaluation indexes such as the scale of three industries, GDP, and the total retail volume of social consumer goods. The output values of the three industries reflect the regional industrial structure and the coordinated development of the economy and society. GDP and per capita GDP reflect regional economic situation and development level. The total retail sales of social consumer goods reflect the development of material living standards in the region, reflecting the actual degree of purchasing power of social goods and the degree of economic prosperity. The regional resident population constitutes the social subject of the region, which is the main body of construction and the power to support economic development. The number of resident populations at the end of the year can objectively reflect the regional economic development. Import and export trade can promote the growth of total economic output and is an important force in stimulating the development of the national economy. The total import and export of foreign trade can reflect the overall scale and development level of foreign trade and reflect the openness of the region and the quality of economic development. Local fiscal revenue is the main source to support the operation of government agencies and people's livelihood expenditure, which is related to the stable operation of the economy and society. It is the concentrated reflection of the quality and efficiency of national economy operation in various places and an important symbol to test the quality of regional economic operation. The ultimate goal of regional economic development is to improve people's living standards. Per capita disposable income can reflect regional economic development results and reflect the regional per capita economic situation and consumption level. The specific indicators are shown in Table 2.

Table 2 Regional economic evaluation index

index layer	Unit	Positive and negative of the index
The output value of primary industry(Y1)	Billion yuan	+
The output value of the second industry(Y2)	Billion yuan	+
The output value of tertiary industry(Y3)	Billion yuan	+
GDP(Y4)	Billion yuan	+
Total retail sales of social consumer goods(Y5)	Billion yuan	+
The permanent population at the end of the year(Y6)	10K	+
Total import and export(Y7)	Thousand dollars K	+
Local fiscal revenue(Y8)	Billion yuan	+
GDP per capita(Y9)	Yuan	+
Per capita disposable income(Y10)	Yuan	+

3. Coupling weighting method

3.1 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a subjective weighting method. The method determines the weight value of each index through the expert group, obtains the preliminary results, and then establishes a matrix for the consistency test. If the test cannot be passed, the weight value is discussed and set again until the test is passed. This method has the advantages of a simple calculation process, reducing subjective interference and correcting inconsistent views.

The steps to determine the weight by AHP are as follows [10]:

STEP1 Build the judgment matrix. A represents the target. u_i, u_j (i.j=1,2……,n)represent factors. u_{ij} represents the relative importance value of u_i to u_j. A-U judgment matrix P is composed of u_{ij}.

$$p=\begin{bmatrix} u_{11} & u_{12} & \dots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{nn} \end{bmatrix} \tag{1}$$

STEP2 Calculate the relative weight. The feature vector ω corresponds to the maximum feature root according to the judgment matrix and $\lambda_{\max}$ is obtained. The equation is as follows:

$$p_\omega = \lambda_{\max}\omega \tag{2}$$

The feature vector ω is normalized to rank the importance of each evaluation factor, that is, weight distribution --W_{AHP}.

STEP3 Consistency test. Whether the weight distribution obtained above is reasonable requires a consistency test of the judgment matrix. Inspection formula:

$$CR = CI * RI \tag{3}$$

In the formula, CR is the random consistency ratio of the judgment matrix. CI is the general consistency index of the judgment matrix. It is given by the following:

$$CI = (\lambda_{\max} - n)/(n-1) \tag{4}$$

RI is the average random consistency index of the judgment matrix.

When the CR of the judgment matrix P < 0.1 or $\lambda_{\max} = n, \mathrm{CI} = 0$, it is considered that P has satisfactory consistency. Otherwise, the elements in P need to be adjusted to make it have satisfactory consistency.

3.2 Conflict correlation between standards

Conflict correlation between standards(CRITIC) is an objective weight weighting method, considering the influence of index variation and conflict between indexes on weight. This method uses standard deviation to represent the value gap between evaluation schemes and uses index correlation to represent the conflict of evaluation indexes, which effectively determines the objective weight of indexes.

The specific steps of CRITIC are as follows [11]:

STEP1 Calculate the standard deviation.

$$\sigma_{\mathrm{j}} = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(x_{ij} - \overline{x_j})^2} \tag{5}$$

STEP2 Construct correlation coefficient matrix.

$$r_{ij} = \frac{\sum_{i=1}^{n}(x_i - \overline{x_i})(x_j - \overline{x_j})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x_i})^2 \sum_{j=1}^{n}(x_j - \overline{x_j})^2}} \tag{6}$$

In the formula: $\overline{x_i}$ is the average value of all schemes in the index x_i ; $\overline{x_j}$ is the average value of all schemes in the indicator x_j ; r_{ij} is the correlation coefficient between index x_i and index x_j.

STEP3 Comprehensive weight of each index W_{CRI}.

$$\begin{cases} W_{CRI} = \dfrac{C_j}{\sum_{i=1}^{n} C_j} \\ C_j = \sigma_j \sum_{j=1}^{n}(1 - r_{ij}) \end{cases} \tag{7}$$

3.3 Coupling weight

From the coupling perspective, the weight calculation method is conducive to balancing the gap between subjective and objective, which avoids the influence of individual subjective factors on the results. It is also avoided the easy use of objective weight without reflecting the importance of judges on different attribute indicators.

After the subjective weight W_{AHM} and objective weight W_{CRI} are obtained, since the multiplier synthesis normalization method can effectively reflect the relative weight relationship of each index and its weight proportion in the whole, this method is used to calculate the coupling weight.

$$W = \frac{W_{AHP}W_{CRI}}{\sum_{j=1}^{n} W_{AHP}W_{CRI}} \tag{8}$$

4. Synergy model between regional energy and regional economic development

Synergetics is a recent cross-cutting discipline that can be widely used to put forward by German physicist Haken. It studies the complex system composed of many subsystems interacting in a complex way. It spontaneously forms an orderly structure of time, space, or time-space through the synergy between subsystems[12].

This paper regards the regional energy system and regional economic development as a composite system composed of regional energy subsystems with different attributes and regional economic development subsystems. There is a complex nonlinear interaction between them. Finally, the overall efficiency is greater than the sum of the simple superposition of various elements, and the order of each subsystem effectively measures its contribution to the coordinated development of the whole composite system and the tightness between subsystems.

4.1 Subsystem Order Degree Model

Consider regional energy systems and regional economic development systems as composite systems S= { S_1, S_2 }, Where S_1 is the regional energy subsystem, S_2 is the regional economic development subsystem. Consider subsystem $S_j (j \in [1,2])$. Let its order parameter be $e_j = (e_{j1}, e_{j2}, ... e_{jn})$ the critical value e_{ji} when the system is stable.

It is assumed that $(e_{j1}, e_{j2}, ..., e_{jl})$ is a positive index, and its value is positively correlated with order degree. $(e_{jl+1}, e_{jl+2}, ..., e_{jn})$ is a reverse index, and its value is negatively correlated with system order.

Then the system order degree $u_j(e_{ji})$ of the order parameter component e_{ji} of the subsystem S_j is:

$$u_j(e_{ji}) = \begin{cases} \dfrac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in [1, l] \\ \dfrac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in [l+1, n] \end{cases} \tag{9}$$

Based on synergetic theory, the contribution level of order parameters to the system can be calculated by integrating each order parameter component. In this article, the linear weighting method is used to integrate, that is, the system order of the order parameter variable is:

$$u_j(e_j) = \sum_{j=1}^{n} w_j u_j(e_{ji}), w_j \geq 0, \sum_{j=1}^{n} w_j = 1 \tag{10}$$

The formula w_j is the weight of each order parameter, which is obtained by AHP-CRITIC coupling weighting.

4.2 Synergy Model of Composite Systems

The synergy level of the regional energy system and regional economic development composite system reflects the comprehensive coordination level of regional energy and economic development, namely:

$$U_{(t)} = sig(\cdot)\sqrt{|U_1(t)-U_1(t-1)|\cdot|U_2(t)-U_2(t-1)|} \quad (11)$$

$$sig(\cdot)=\begin{cases}1, U_1(t)-U_1(t-1)\geq 0, U_2(t)-U_2(t-1)\geq 0\\ -1, \text{Else}\end{cases} \quad (12)$$

$U_1(t)$ means the orderly contribution of the regional energy subsystem at time t, $U_2(t)$ means the orderly contribution of a regional economic subsystem at time t. $U_{(t)}\in[-1,1]$, When $U_{(t)}$ tends to 1, it indicates that the greater the level of synergy between regional energy and economic development is, the more effective synergy between regional energy subsystem and regional economic subsystem or between internal factors can be developed. The smaller $U_{(t)}$ is, smaller the coordination degree between the two systems is, and the two systems will be in a state of disorderly development.

5. Calculation of synergy

In this paper, the implementation of the sample selection is in Shanxi Province. On the one hand, Shanxi Province is located in the central part of China and has rich energy, such as coal, which is consistent with the theme of this paper. On the other hand, after a simple preliminary analysis, we find that there are stages in regional energy development and economic development in Shanxi Province, which is of representative significance.

Each index is brought into Equation (9)to calculate the order degree of the regional energy and economic subsystem, respectively. Substituting the order degree results into Equation (10), the synergy degree of the energy and economical composite system in Shaanxi Province from 2010 to 2020 is obtained, as shown in Figure 1.

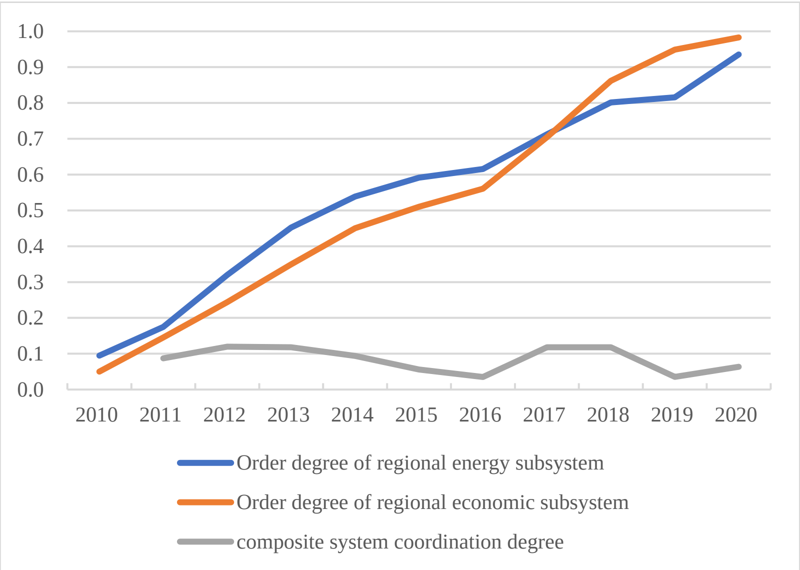

Figure 1 Changes in energy and economic order and synergy in Shaanxi Province, 2010-2020

5.1 Order analysis of subsystems

It can be seen from Figure 1 that the order degree of Shaanxi's energy and economic subsystems shows an overall upward trend. The order degree of the regional energy subsystem increases from 0.094 in 2010 to 0.935 in 2020, and the order degree of the regional economic subsystem increases from 0.051 in 2010 to 0.982 in 2020. It is indicated that the development of the energy subsystem and economic subsystem is good from 2010 to 2020, and the contribution of the two subsystems to the composite system is generally increasing.

By comparing the order degree of the two subsystems, it can be seen that the order degree of the regional energy subsystem is significantly higher than that of the regional economic subsystem from 2010 to 2017. It is indicated that the regional energy is ahead of the regional economy and has a supporting and stimulating effect on the development of the regional economy. Shaanxi Province uses resource endowment advantages, effectively converting energy advantages into economic advantages and boosting regional economic development. From 2017 to 2020, the order degree of the regional economic subsystem in Shaanxi Province exceeded that of the energy subsystem, indicating that the contribution of the development of the energy subsystem to economic growth was reduced, and it was difficult to promote economic growth by relying solely on the original logic. At this time, the economic subsystem promotes the development of the energy subsystem, and the economic growth of Shaanxi Province promotes the increase in energy consumption. It drives the optimization of regional energy structure, energy-saving, and consumption reduction. It improves energy efficiency and promotes the further development of the energy industry in Shaanxi Province.

5.2 Synergy analysis of composite system

Figure 1 shows that the synergy degree of regional energy and regional economic development in Shaanxi Province is increasing and decreasing alternately, and the overall synergy is good. The overall change of coordination degree of the composite system can be divided into the following stages :

The first stage: 2010 ~ 2013: the collaborative situation is good, collaborative degree increased steadily. The synergy degree of the composite system is rising steadily, and the order degree of the regional energy subsystem and regional economic subsystem is rising. The order degree of the energy subsystem is higher than that of the economic subsystem, and the development degree is ahead of the economic subsystem. It shows that the economic subsystem develops rapidly under the impetus of the energy subsystem, and the coordinated and orderly development of the two systems is good. As a major resource province in China, Shaanxi Province has a good resource endowment and can fully use resource advantages to transform into economic advantages. The development of the energy industry in this stage of development has brought a rapid expansion on an industrial scale and promoted rapid economic growth.

From 2014 to 2016, the coordination situation deteriorated in the second stage, and the coordination degree decreased year by year. The synergy degree of the composite system decreased, the order degree of the regional energy subsystem and the regional economic subsystem slowed down, and the growth rate of the energy subsystem decreased greatly, which slowed the development of the economic system. The synergy effect showed a decreasing trend, and the synergy degree and the growth rate of the two systems were the lowest in 2016. The long-term accumulation of industrial structural problems and energy consumption problems in Shaanxi Province still exist, and the accumulation of problems and contradictions has intensified and erupted. It is difficult to form a multi-support industrial structure, and its adjustment has entered a forced stage. Meanwhile, the prices of energy consumer goods such as coal and oil are low, the downward pressure on the economy is increasing, and the development contradictions are exposed.

In the third stage: from 2017 to 2018, the coordination situation improved, and the coordination degree ran at a high level. The synergy degree of the composite system is good, the order degree of the regional energy subsystem and regional economic subsystem increases greatly, and the synergy effect of the two systems is noticeable. The order of the regional economic subsystem exceeds the regional energy subsystem, and the momentum of economic growth is strong. Shaanxi Province promotes the implementation of an innovation-driven development strategy, which further promotes the reform of decentralization, management, and service. It introduces a new round of 21 policies and measures to promote industrial development, which effectively resolves various risks in economic operation. It ensures that the economy continues to operate reasonably and presents a good trend of overall stability, power enhancement, and quality and efficiency improvement. Furthermore, Shaanxi Province puts forward the development concept of "Three transformations," deepening the supply-side structural reform, adhering to the deep transformation of resources, and taking the lead in implementing breakthroughs in the field of the modern chemical industry, making significant progress in the energy transformation, upgrading and structural adjustment. The structural and orderly advancement of the supply-side industry and the proposal of a stable growth policy have narrowed the growth rate of Shaanxi's energy industry and stabilized it. Economic development plays an increasingly significant role in promoting energy development, playing a positive role in optimizing industrial energy structure and the development of quality and growth.

In the fourth stage: from 2019 to 2020, the synergistic effect is poor, but there are signs of stability. In this stage, the synergy degree of the composite system is low, but there is a stable trend. The growth rate of the regional energy system slows down, and the synergy effect of the two systems is relatively weak. In 2019, Shaanxi's economy was under great downward pressure. Affected by the short-term impact of the deepening of the supply-side reform and the major coal mine accidents in Shenmu, the growth rate of industrial added value in Shaanxi fell sharply, and the economic growth of the whole province slowed down. Investment, consumption, and export growth showed a downward trend in the same year, and the driving force of economic development was insufficient. In 2020, the new corona pneumonia epidemic caused a considerable impact on economic development, resulting in slow economic growth, the restricted synergistic effect of economic and energy development, and less synergistic growth. However, by adjusting the economic structure and the active layout of high-tech industries and strategic emerging industries in Shaanxi Province, new development opportunities will be brought in the future, and the synergistic effect of energy and economy will be more obvious.

6. Conclusion

In this paper, regional energy and regional economy evaluation indexes are determined from the perspective of system analysis, and the coupling weights of each index are determined based on the AHP-CRITIC weight method. Based on the synergy theory, the order degree model of regional energy and regional economic subsystem and the synergy degree model of the composite system are constructed to solve the problem of measuring the degree of coordinated development of the energy system and regional economy and the relevant data of energy and economic development in Shaanxi Province from 2010 to 2020 are used for empirical research. The conclusions are as follows:

(1)The order degree of regional energy and economic subsystems in Shaanxi Province shows a steady upward trend, and the system synergy degree shows a fluctuating trend of alternating increase and decrease.

(2)The stability of the synergistic effect of regional energy and economic development in Shaanxi Province is poor, and it is vulnerable to external environmental impacts. The endogenous synergistic development mechanism has not yet been formed. When the external development environment deteriorates, the coordinated development effect of regional energy and economy is poor. When the relevant departments implement positive policy support or take stable growth measures, the development synergy between the two is good.

The model constructed in this paper is universal and can calculate the orderly degree of regional energy and regional economic development quantitatively and the degree of synergy and development trend between the two systems. It completes the existing research on the coordinated development of regional energy and regional economy, and it can be used to dynamically monitor the degree of coordination between regional energy and economic development in China and provide a scientific basis and reference for relevant decision-making and policy formulation to promote regional energy and economic development.

References

[1] Ilhan Ozturk, Alper Aslan & Huseyin Kalyoncu. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy Policy(8), 4422-4428.

[2] Lin Shuwei & Guan Songli. (2022). Research on carbon neutrality, economic growth and its impact on energy efficiency. Journal of Beijing University of Aeronautics and Astronautics (Social Science Edition).

[3] Li Lichun. (2017). An empirical test of the relationship between energy consumption, economic growth and energy structure in China. Statistics and Decision (13), 140-143.

[4] Ma Li, & Ye Qiangqiang. (2016). An Empirical Study on the Relationship between Energy Consumption and Economic Growth: Taking Shaanxi Province as an Example. Economic Geography (6), 6. Li Jianhui, Han Erdong & Liu Xin. (2021). Energy-Economic-Environmental System Coordinated Development Level Measurement. Statistics and Decision (13), 88-91.

[5] Li Jianhui, Han Erdong & Liu Xin.(2021). Measurement of Coordinated Development Level of Energy-Economic-Environmental System. Statistics and Decision (13), 88-91.

[6] Cao Chenglong, Yin Yitong, Lin Gang, Huang Shiqi & Gao Ming.(2020). Characteristics of Coupling Coordinated Evolution of Regional Energy-Economic-Environmental Systems——Taking Ningbo City as an Example. Science and Technology Herald (11), 70-77.

[7] Li Xinxin. (2018). Analysis of Coupling Coordination Degree of Energy-Economy-Environment System——Taking Jiangsu Province as an Example. Modern Business (07), 71-73.

[8] Li Ying & Li Zilian. (2020). The Grey Correlation Analysis of Energy Consumption and Economic Growth in Shanxi——Based on the Perspective of Energy Structure Constraints. Practice and Understanding of Mathematics (05), 60-66.

[9] Wang Aihua & Li Meilian. (2021).Research on the coordinated development of energy, economy and environment in the Pearl River-Xijiang Economic Belt.Innovation (05), 105-116.

[10] Luo Rihong, & Huang Jinlin. (2021). Comprehensive evaluation of earth-rock dam safety based on improved ahp-entropy weight method and group decision-making. Guangdong Water Resources and Hydropower (4), 7.

[11] Ke Bin, Qiu Yujun, & Zhang Xiaofei. (2020). Comprehensive evaluation of railway line speed target value weighted based on critic-g1 method. Railway Standard Design, 64(3), 6.

[12] Qiu Shaolang, Wu Biao, Yin Jing & Bai Hanzhuo. (2020). Evaluation model of synergy between logistics and regional economic development in underdeveloped areas. Logistics Technology (02), 32-36, 87.