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Sustainable Development of Business Economy Based on Big Data Algorithm under the Background of Low-Carbon Economy

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Abstract: After the low-carbon economy (LCE) was proposed, countries all over the world examined their national economic structures and found the necessity for developing a LCE. Therefore, it is necessary to vigorously develop low-carbon technologies and improve technological and policy innovation capabilities. From the perspective of promoting the coordinated development of the low-carbon economic system and regional sustainable development, this paper conducted an in-depth analysis of the coordinated development of the low-carbon economic system and regional environmental issues by using the relevant theories of sustainable development, low-carbon economics, and environmental economics. The index system of the low-carbon economic system and regional sustainable development was constructed, and the coupling degree model and regional coupling coordination degree model suitable for the development of the low-carbon economic system and regional sustainable development were established. On the basis of analyzing the status quo of a LCE and the environment in a coastal area, it was finally concluded that in the next five years, the value of the coupling coordination degree of the LCE and its sustainable system development would continue to approach 1 and grow steadily.

Keywords: low-carbon economy; big data algorithm; business economy; sustainable development

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1. Introduction

In recent years, studies have shown that the increase in global surface temperature would lead to huge changes in the natural environment. For example, the melting of glaciers caused by global warming, the submersion of some island countries caused by the rise of sea level, the sharp drop in food production, and the acceleration of the emergence and spread of various diseases and other disasters have brought fatal threats to human production and life. Therefore, all countries in the world have realized the importance of restraining the process of global warming, and have adopted different methods to control global warming. The proposal of the LCE is of great significance, and extensive practical explorations have been carried out around the world, but the concept of "LCE" has not yet been unified. However, the basic characteristics of the LCE are summarized in the same way: first, the LCE takes the sustainable development of human society as the primary task; secondly, the LCE is created in order to improve the utilization rate of energy by means of using low-carbon technology development and management model reform; and thirdly, the LCE has strict restrictions on the emission of carbon dioxide and other greenhouse gases.

Business economics is an important subject within economics. From a strategic position between producers and final consumers, the services sector can play an important role in the transition to a circular economy. Heyes G addressed this issue by analyzing the possibilities for information and communication technology service companies to develop and implement circular economy business models [1]. Mendicino C investigated the impact of risk disruption in a small open economy with tradable and non-tradable sectors of manufacturing [2]. Chen KJ incorporated national production into a small-scale business model to explain the different patterns between developed and developing market economies [3].

Kumar V took a balanced approach to understand the dynamics of this three-way business model–two-way customer relationship, in order to maintain the rapid growth rate in this emerging market [4]. These scholars have conducted research experiments on the business economy, but there has been no specific experimental procedure.

Big data algorithm is a widely used algorithm. In order to address the problem of evolutionary algorithms, Sabar NR proposed a heterogeneous framework that combined evolutionary methods of cooperative organizations with different types of modulo algorithms [5]. Big data applications suffer from unpredictable and unacceptably long pauses due to garbage collection. Bruno R believed that in latency-sensitive applications, these stalls affected the latency requirements of the entire application stack due to the aggressiveness of the application [6]. Big data promises to improve government decision-making by being more relevant to actual policy needs and outcomes. Hgvdv A presented a qualitative study applying these and other policy-oriented approaches in the context of big data [7]. With the volume of data growing at an unprecedented rate, the acquisition of big data insights is a new challenge. In order to solve this problem, Qian J built the granularity of information in different hierarchical decision tables. In order to illustrate the relationship between these granularity conditions and granularity decisions, he further discussed changes in quantitative indicators such as support, confidence, and coverage associated with hierarchical decision rules [8]. Although these scholars have used big data algorithms for experimental analysis, they still lack pertinence.

Previous studies on coupling analysis of the LCE and sustainable development systems are limited to qualitative or quantitative methods to describe the relationship between them, and cannot describe the characteristics of this complex system as a whole. Therefore, this paper regarded sustainable development as the core of the subject and established an influential set of indicators of the LCE and sustainable system development. A function model suitable for the coupled development of the LCE and a sustainable system was selected to reflect the changing laws and characteristics of the LCE and sustainable system development.

2. CA of Big Data Algorithms

Cluster analysis (CA) refers to the process of dividing physical or abstract objects into similar groups, and the technique is widely used in different fields. The specific steps are shown in Figure 1.

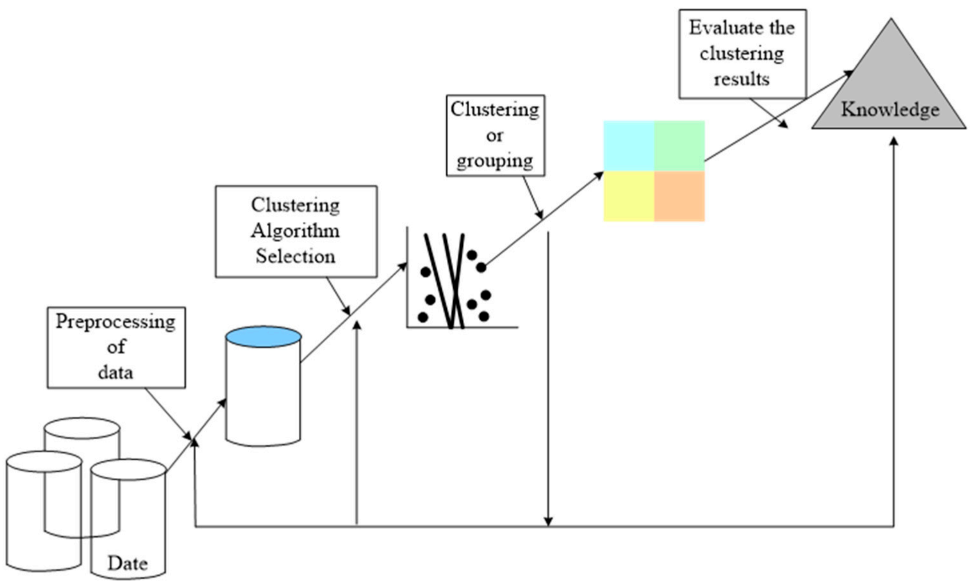


Figure 1. The four steps of cluster analysis.

Cluster analysis technology can deal with some complex data structures and help people dig out some valuable information from complex data sets. In these fields, cluster analysis technology is also constantly improving, promoting the progress and development of various fields [9].

2.1. Similarity Measure between Objects

There are many metrics for similarity. Even for the same algorithm, the results of clustering may be different if the similarity measurement method is different.

2.1.1. Distance Metric

According to the characteristics of data distribution and different solutions, it can be divided into the Euclidean distance metric, the Chebyshev distance metric, the standardized distance metric, the Manhattan distance metric, and other metric methods.

The Euclidean distance is the most commonly used measurement in clustering algorithms. The similarity is represented by the absolute distance between two objects in the calculated data space, and the calculation expression is shown in Formula (1):

$$dist(A,B) = \sqrt{\sum_{m=1}^{m} (a_j - b_j)^2} \tag{1}$$

The calculation expression of the Chebyshev distance is:

$$dist(A,B) = \lim_{q\to\infty} (\sum_{j=1}^{m} |a_j - b_j|^q)^{1/q} = \max|a_j - b_j| \tag{2}$$

The Manhattan distance is the sum of the distances between objects in a multidimensional coordinate space. When the value of q is 1, the Manhattan distance can be obtained by substituting it into the calculation formula of the Minkowski distance. The calculation expression is shown in Formula (3):

$$dist(A,B) = \sum_{j=1}^{m} |a_j - b_j| \tag{3}$$

The formula for calculating the Minkowski distance is:

$$dist(A,B) = (\sum_{j=1}^{m} |a_j - b_j|^q)^{1/q} \tag{4}$$

2.1.2. Similarity Measurement

In order to judge the correlation between two objects, in the research of clustering algorithms, similarity is generally used as the scale of measurement. The smaller the similarity value between objects, the greater the difference between them, which is just the opposite of the distance measurement method [10]. Similarity measurement indicators mainly include the Jaccard coefficient, the Pearson coefficient, and the cosine similarity.

The cosine similarity is mainly judged from the direction, and the distance similarity is judged from the length. The calculation of the cosine similarity is shown in Formula (5):

$$sim(A,B) = \cos\alpha = \frac{\vec{a} \cdot \vec{b}}{a \cdot b} \tag{5}$$

The Pearson coefficient is obtained by estimating the ratio of the covariance to the variance of the two objects in space. The value is between −1 and 1. The larger the value, the stronger the correlation. The calculation is shown in Formula (6):

$$t(a,b) = \frac{m\sum ab - \sum a \sum b}{\sqrt{m\sum a^2 - (\sum a)^2} \cdot \sqrt{m\sum b^2 - (\sum b)^2}} \tag{6}$$

When comparing the two objects A and B, only pay attention to the M attributes contained in A and the N attributes contained in B, then the formula for calculating the ratio of the number of common attributes contained in both to the total number of attributes is as shown in Formula (7):

$$Jaccard(A, B) = \frac{A \cap B}{A \cup B} \tag{7}$$

In the clustering algorithm, according to the similarity between objects, the cosine similarity distance and the Euclidean distance are often used. One is the measurement from the direction, and the other is the measurement from the distance. According to the characteristics of these two division methods and data distribution, the appropriate measurement method is selected [11].

2.2. Hierarchical Clustering

Clustering is performed in two stages. In the first stage, the dataset is constructed into a K-nearest neighbor graph to form a large cluster. Then, the graph of K-nearest neighbors is divided into many subgraphs, and each subgraph represents a small cluster. In the second stage, the similarity between these small clusters is calculated to merge and classify, iteratively iterate, and, finally, achieve the effect of clustering. The specific processing steps are shown in Figure 2.

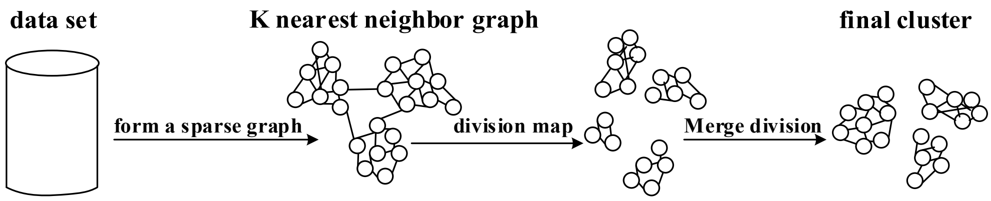


Figure 2. The processing steps of the chameleon clustering algorithm.

2.3. Clustering Algorithm Evaluation Index

A good clustering evaluation index can make high-quality clustering, and high-quality clustering requires high similarity of objects within clusters and low similarity of objects between clusters [12].

(1) Internal evaluation indicators

The clustering quality is usually evaluated by the validity index, which is measured by the distance between clusters or the distance within clusters.

Among them, $c(f)$ is the descriptive separation distance, and $d(f)$ is the data compactness of the cluster to which the reaction belongs. It is assumed that $f \in E_j$ is the j-th cluster in the data set, the calculation formula of the silhouette coefficient is shown in Formula (8):

$$Y_f = \frac{c(f) - d(f)}{\max\{c(f), d(f)\}} \tag{8}$$

Dunn's index calculates the ratio of the minimum distance between data objects between two clusters and the maximum distance between two objects within the cluster. The larger the ratio, the farther apart the clusters are; the smaller the distance between the clusters, the tighter the data. Its formula definition is shown in Formula (9):

$$Dun = \frac{\min\limits_{0<n\neq m<L}\{\min||a_j - a_i||\}}{\max\limits_{0<n<L}\max\limits_{0<m<L}\{||a_j - a_i||\}} \tag{9}$$

The formula for calculating the Davies–Bouldin index is shown in Formula (10):

$$DBI = \frac{1}{m}\sum_{j=1}^{m} \max_{j \neq i}\left(\frac{\beta_j + \beta_i}{f(e_j, e_i)}\right) \tag{10}$$

The smaller the value of DBI, the greater the distance between clusters; the smaller the distance between clusters, the better the clustering effect.

(2) External evaluation indicators

The external evaluation criterion is that data objects with the same label should be classified into the same class, while data objects with different labels should be classified into different classes. Through the matching degree between the known clustering results and the calculated results, the clustering effect of different clustering algorithms is evaluated. External evaluation indicators mainly include the Jaccard index, F value, Rand index, etc. [13].

The idea of the F-Score is to evaluate the clustering algorithm through the combination of precision and recall in information retrieval. The calculation is shown in Formula (11):

$$F = \frac{2 \times Q \times T}{Q + T} \tag{11}$$

The calculation formula RI of the Rand index is shown in Formula (12), and the calculation formula of the Jaccard coefficient JI is shown in Formula (13):

$$RI = \frac{f_1 + f_4}{f_1 + f_2 + f_3 + f_4} \tag{12}$$

$$JI = \frac{f_1}{f_1 + f_2 + f_3} \tag{13}$$

(3) Relative evaluation index

The main evaluation indicators include SD (Standard Deviation) effectiveness index, Dunn index, fuzzy clustering measurement index, etc.

The calculation of SD is shown in Formula (14):

$$SD(E) = \eta \times Disq(E) + dis(D) \tag{14}$$

Among them, η is the weight value, $Disq(E)$ is the dispersion degree, and $dis(D)$ is the overall separation degree between clusters. The calculation formulas of dispersion and separation are shown in Formulas (15) and (16):

$$Disq(D) = \frac{1}{M}\sum_{D_M \in D} Q_L \frac{|\gamma(D_L)|}{|\gamma(D)|} \tag{15}$$

$$Dis(D) = \frac{F_{\max}}{F_{\min}\sum_{D_L \in D}\left(\sum_{D_L \in D} \mu(\lambda_L, \lambda_j)\right)^{-1}} \tag{16}$$

$F_{\max}/F_{\min}$ is the ratio of the maximum distance to the minimum distance between data objects in cluster D, and $\gamma(D_L)$ is the standard deviation of the L-th cluster. $\gamma(D)$ is the standard deviation of the data object from the cluster center point, and Q_L is the number of data objects allocated to the L-th cluster [14].

2.4. Calculation of Relative Mass of Data Points

According to the density of the data, the size of the quality is divided. In areas with dense data, the relative quality of data points is larger; in sparse areas, the relative quality of data points is smaller. Formula (17) shows the relationship between mass and potential energy:

$$\varphi_a(b) = n \times e^{-\left(\frac{||a-b||}{\varepsilon}\right)^2} \tag{17}$$

In (17), n represents the relative mass of the data point, and the mass is proportional to the potential energy. The greater the relative mass of the data point, the greater the corresponding potential energy. When the relative mass of the data point is greater than 0, $\varphi_a(b)$ represents the field source strength [15].

The index of the current data point corresponds to the index value of the existing gravitational relationship, and the gravitational relationship existing in the data field is simulated. It is assumed that there are four data points A, B, C, and D in the data space, and their gravitational relationships are shown in Figure 3.

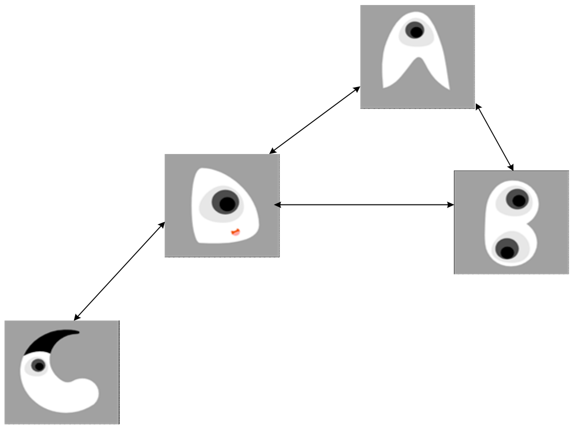


Figure 3. Diagram of the gravitational relationship between data objects.

It is assumed that the relative quality values of the data points are denoted by TN. The initial mass TN value of each data point is $1/M$, where M is the number of gravitational relationships existing in the current data point. The TN value of F can be obtained, as shown in Formula (18):

$$TN(F) = TN(E) + TN(W) + TN(U) \tag{18}$$

Since the data point E has a gravitational relationship with the two points W and F, the probability that the data point E would move to the data point F should be $1/2$, so the calculation formula of the TN value of F is as Formula (19):

$$TN(F) = TN(E)/2 + TN(W)/2 + TN(U) \tag{19}$$

In Formula (19), TN_j represents the value of the relative quality of the j-th data point, and 2 represents the TN_i value of the data point i. M_i represents the number of data points where data point i has gravity, and W_j represents the set of data points that can move to data point j [16].

3. Sustainable Development of Business Economy Based on Big Data Algorithm

3.1. Theoretical Basis of the LCE and Sustainable Development

3.1.1. Sustainable Development

(1) The idea of sustainable development

If economic development is to be in a good state, it should be based on an ecology that has the ability to develop for a long time and where everyone is equal. It should be based on having a just society and having the people actively participate in their own development decisions [17,18]. Its goal is not only to allow human beings to obtain various satisfactions but also to pay attention to the rationality of various economic activities, as shown in Figure 4. People should protect the environment and respect the laws of nature. It is necessary to reasonably adjust and control this complex system with natural, social, and economic laws. It cannot exceed the capacity of the system, and cannot threaten the survival and sustainable development of the next generation. It is necessary to comprehensively consider indicators and then use every aspect of the economy, society, environment, life, etc. to measure development [19–21].

Figure 4. Sustainable development goals.

(2) Basic principles of sustainable development

① The principle of fairness

Sustainable development is a kind of development that first eliminates the primary problem to be solved, and gives the same opportunities and interests to all people.

② The principle of continuity

The core problem of the principle of sustainability is that human beings cannot exceed the scope of environmental carrying capacity while improving the current level of economic development, and it combines the existing interests of human beings with long-term interests.

③ The principle of commonality

Although the social nature, economy, and culture of different countries vary, all human beings regard sustainable development as the unified goal of mankind. The fair, reasonable, and continuous phenomenon it shows is shared by each other.

3.1.2. LCE Theory

(1) LCE as the development trend of emerging industries

Emerging industries have the characteristics of leading, multiplying, and radiating. The future economy is a LCE, and the future competition is the competition between low-carbon industries, so it plays an important guiding role in realizing the smooth transformation of the economic structure and the sustainable development of the economy and society [22].

(2) LCE is the sublation of the traditional industrial development model

Traditional industries have brought enormous pressure on the environment and have no direction for development. High carbon emissions have become the basic cause of global environmental problems. The LCE is a new economic development model proposed in response to climate change, which represents great development potential in the economic transition period. However, due to the abundant capital investment in traditional industries, the LCE lacks certain material guarantees. Therefore, there is a certain relationship between competition and cooperation between low-carbon industries and traditional industries. It is necessary to get out of the way of achieving agricultural economic development at the expense of the ecological environment. Low-carbon agriculture as a brand new concept and strategy is proposed for the extensive road ahead.

(3) The status of the LCE in the future emerging industrial structure

The development model of a LCE would inevitably require the reduction of carbon energy consumption. This means that the development of a LCE would spawn a number of strategic emerging industries based on new energy consumption technologies and emission reduction technologies [23].

(4) Economic model of low-carbon economic cycle and operation

At present, the CGE model is widely adopted in research work on carbon dioxide gas emission reduction. CGE (Computable General Equilibrium) is a common equilibrium model, but it has a strong theoretical basis because it analyzes the economic system as a whole and emphasizes the relationship between variables in different sectors of the economy. Therefore, it can more accurately describe the interaction between the Ministry of Energy and other economic departments, which is generally difficult for partial equilibrium models. Figure 5 is a detailed description of the interactions between energy–economy–environment.

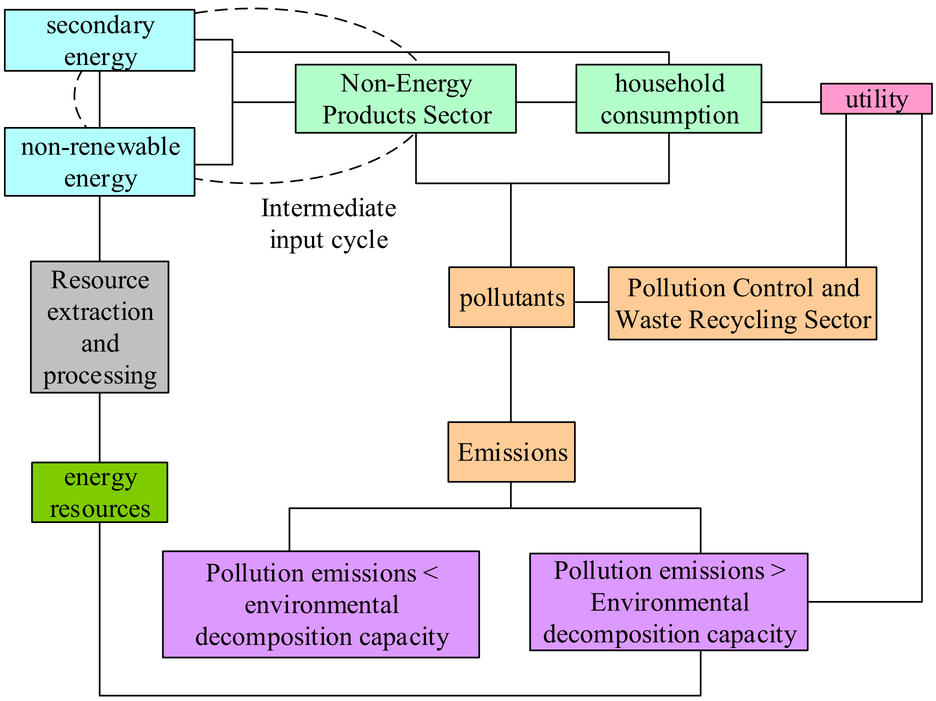
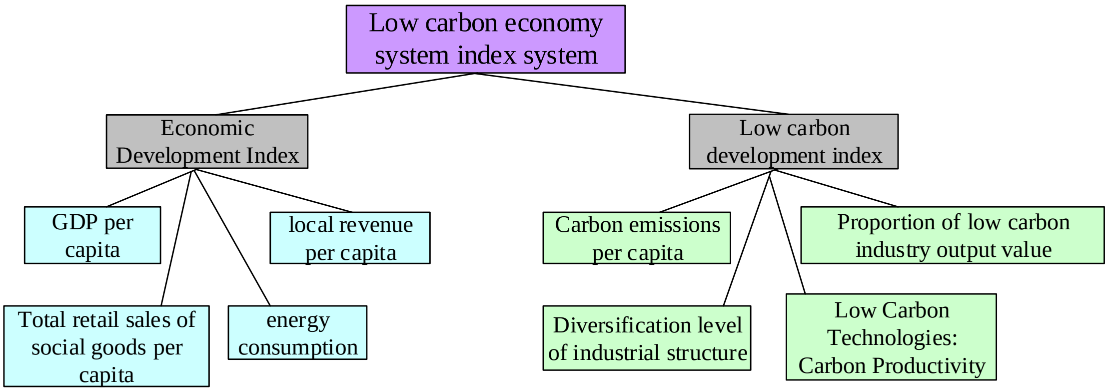


Figure 5. Schematic diagram of energy–economy–environment interactions.

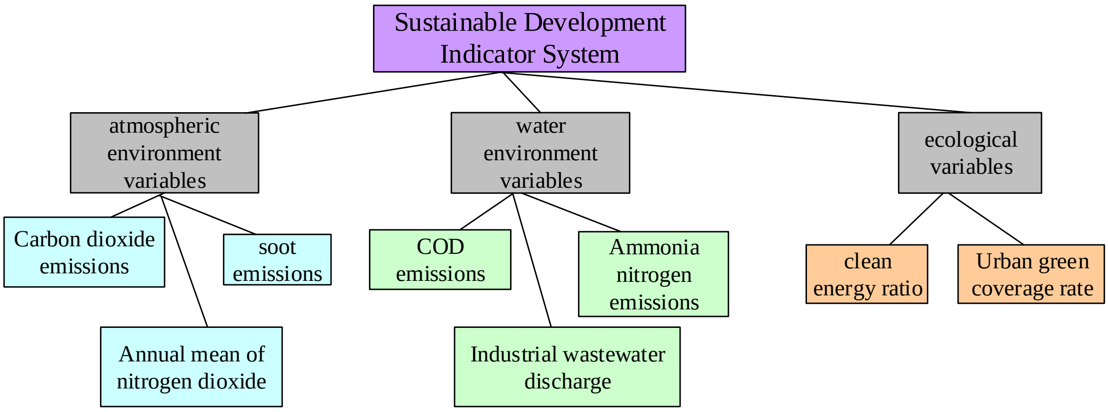
3.2. Demonstration of the LCE and the Sustainable Development Index System and Coupled Development

(1) The LCE and sustainable development index system—a coastal city is taken as an example

Based on the determination of the LCE and sustainable development index system, and according to the collected data of a coastal city, the LCE and sustainable development index system is established. The weight calculation method of the indicators adopts an Analytic Hierarchy Process (AHP) [24]. The hierarchical structure model established by AHP software is shown in Figure 6. The low-carbon economic system is shown in Figure 6a, and the hierarchical structure model of the sustainable development system is shown in Figure 6b.



(a)



(b)

Figure 6. Hierarchy model. (**a**) Tomographic structure model of the low-carbon economy subsystem. (**b**) Hierarchical model of sustainable development subsystem.

(2) Changes in the low-carbon economic system and sustainable development of a coastal city

The results of each index are shown in Table 1.

Statistical graph processing of the data in Table 1 can obtain a clear graph that reflects the development level of the economic system and the sustainable development system based on time series, as shown in Figure 7.

It can be clearly seen from Figure 7 that the low-carbon economic system in the region showed an overall upward trend from 2003 to 2012, which was related to the region's active opening-up policy. In the past ten years, the transformation of advantageous industries integrating electronics, automobile manufacturing, green food, bio-pharmacy, new material energy development, modern logistics, and service outsourcing had been formed [25]. The fluctuation trend of the sustainable development system in this region had a process of rising and falling. From 2004 to 2008, the comprehensive index of the sustainable development system was basically between 0.3 and 0.5. There was a decreasing process in 2004–2006, and a slight decrease in 2009–2010. This was because the quality of the environment was not as good as the speed of economic development [26]. After 2010, the environmental level had only improved. According to this, the score map of each classification of the system can also be obtained, as shown in Figure 8.

It can be seen in Figure 8a that, during the period from 2003 to 2012, the economic development indices of the two classifications of low-carbon economic systems increased significantly. The economic development index continued to rise, while the low-carbon development index fluctuated slightly, but showed a downward trend in 2004–2005. This was because, at the beginning of the study, the area was less populated, and low-carbon development was a low priority [27]. In 2004, heavy industry was the main industrial area, and carbon emissions were relatively large. The low-carbon technology level was low, so it showed a downward trend; after 2009, it showed a stable upward trend.

Table 1. Comprehensive score index table of the low-carbon economic system and sustainable development system.

Years	Low-Carbon Economy Composite Index	Sustainability Composite Index	Years	Low-Carbon Economy Composite Index	Sustainability Composite Index
2003	0.143	0.631	2008	0.425	0.553
2004	0.177	0.568	2009	0.478	0.535
2005	0.189	0.390	2010	0.722	0.423
2006	0.204	0.353	2011	0.779	0.592
2007	0.268	0.386	2012	0.896	0.714

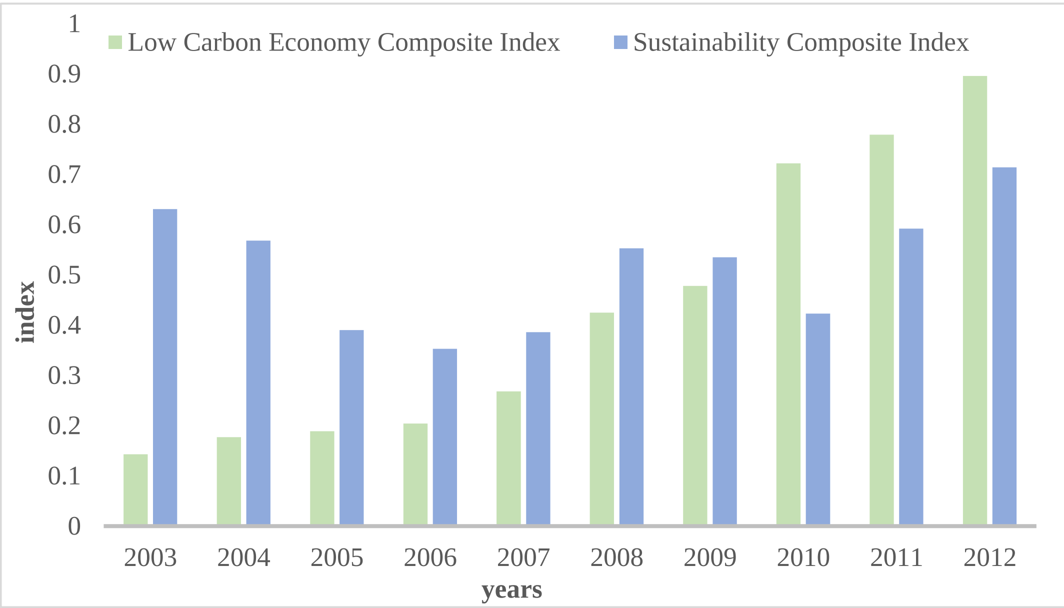


Figure 7. Comprehensive score chart of the low-carbon economic system and sustainable development system.

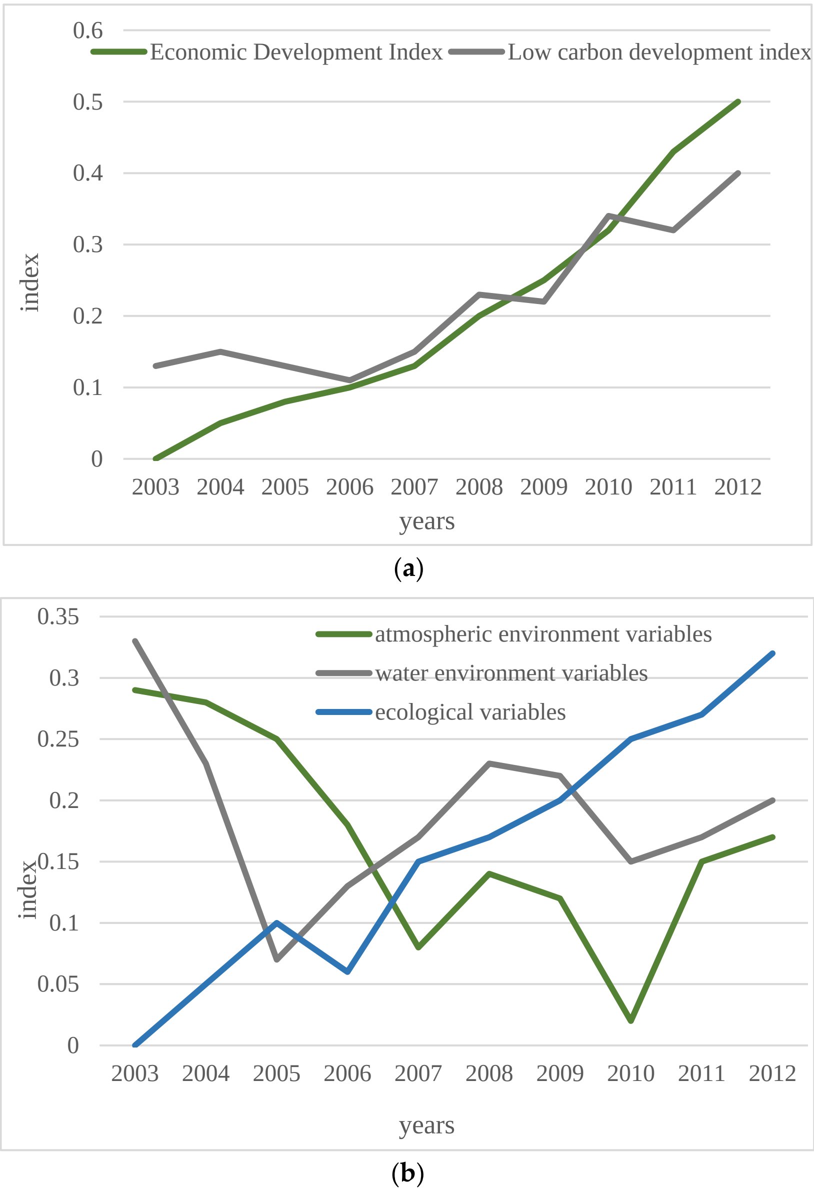


Figure 8. The score value of each classification index of the system. (**a**) Score value of each classification index of the LCE subsystem. (**b**) Score value of each classification index of the sustainable development subsystem.

Figure 8b shows that there was a clear upward trend in the levels of ecological variables in all three categories of sustainable development systems. In contrast, water and atmospheric variables showed marked fluctuations, with both decreasing and increasing trends, especially the atmospheric environment variables which had an overall downward trend from 2004 to 2010.

3.3. Experimental

(1) System development evaluation

The low-carbon economic system is on the rise as a whole [28]. The industrial foundation of this region is good, and a variety of advantageous industries have been formed at a high technical level. The high degree of opening up to the outside world attracts a large number of investment funds; the scientific and technological resources are intensive, and a large number of scientific and technological talents are concentrated; the establishment of a financial district is conducive to the low-carbon economic development of a coastal area.

(2) Coupling degree analysis of the LCE-sustainable development system

The previous formulas and sustainable development theory are used to make the coupling degree calculation as shown in Table 2. V(x) refers to the evolution rate of the LCE system; V(y) refers to the change rate of the sustainable development system; the angle value refers to the coupling evolution trend of the LCE-sustainable development system.

Table 2. Carbon economy-sustainable development system coupling.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
V(x)	0.239	0.167	0.075	0.318	0.585	0.124	0.051	0.080	0.150	0.297
V(y)	−0.097	−0.013	−0.033	1.342	0.933	−0.336	−0.209	0.399	0.206	0.269
V(x)/V(y)	−2.479	−12.85	−2.241	0.237	0.627	−0.369	−0.223	0.200	0.728	1.104
arctan	−1.561	−1.493	−1.151	0.233	0.561	−0.354	−0.220	0.197	0.629	0.835
Angle value	−90°34′	−86°27′	−66°22′	13°19′	32°5′	−21°44′	−13°24′	11°17′	36°34′	47°49′

It can be seen from Table 2 that the development level of the LCE in this region is relatively backward, and it is in the primary coupling stage. In short, the area should vigorously carry out ecological environment construction while various major construction projects are implemented. Only when the environmental planning is implemented in place and the pollution reduction planning is well completed can the forestry construction develop rapidly. In this way, the coupling degree of the LCE and sustainable development in the region can be promoted, and the coupling and coordinated development of the LCE and sustainable development can be promoted.

(3) The coupling and coordination degree of the LCE-sustainable development system

The indices of the LCE-sustainable development system in this region are shown in Table 3. Among them, the compound benefit is A, and the comprehensive development benefit is B. The coordination index is C, and the comprehensive development index is T. The coupling coordination degree is D.

Table 3. Indexes of the LCE-sustainable development system.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
A	0.090	0.101	0.074	0.072	0.104	0.235	0.256	0.305	0.461	0.640
B	0.774	0.745	0.579	0.556	0.655	0.978	1.013	1.145	1.371	0.610
C	0.054	0.073	0.0.65	0.067	0.100	0.231	0.255	0.284	0.453	0.632
T	0.387	0.373	0.290	0.278	0.327	0.489	0.506	0.572	0.686	0.805
D	0.145	0.165	0.137	0.138	0.181	0.336	0.359	0.403	0.557	0.713

From the compound benefit A, the coordination index of the low-carbon economic system and sustainable development in this region showed an overall upward trend in the period from 2003 to 2012, and there was a drop during this period. In the year 2005, the low-carbon development index declined. The low-carbon development in this region had just started, and the development level was relatively low. The environment had also been severely damaged, resulting in a decline in the coordination index of the LCE and sustainable development systems. After that, the development level of the LCE began to rise. The environment had improved, and the coordination index of the LCE and sustainable development had risen.

From 2003 to 2012, the comprehensive development index of the LCE-sustainable development system in this region generally showed an upward development trend from the comprehensive development benefit B. There was a decline in 2005–2006, which was related to the decline of the low-carbon development index in the region and the decline of various indicators of the sustainable development system, which made the comprehensive development index decline.

Through comprehensive observation of the development index T and coordination index C and the corresponding charts, the overall change trend of the coupling coordination degree D was basically synchronized with T and C. That is, when T and C decreased, the coupling coordination index D also decreased; when T and C increased, the coupling coordination index D also increased continuously. Therefore, the coordination index D also showed an upward trend in the period from 2003 to 2012, and there was a decline during this period. Due to the decline of the coordination index and the decline of the comprehensive development index, at other times, there was a stable upward trend. From 2009 to 2010, the low-carbon economic system showed a rapid upward trend, while the sustainable development system showed a slight downward trend as a whole. However, the comprehensive influence made the LCE-sustainable development system coordination index and the LCE-sustainable system comprehensive development index show a slow upward trend. These showed that the coupling coordination degree of the LCE and the sustainable development system has a strong correlation with the comprehensive development level of the low-carbon economic system and the evolution level of the sustainable development system.

The coordination degree index obtained by the coupling coordination degree function D composed of the economic system and the environmental system function showed that from 2003 to 2012, it increased from 0.145 to 0.713, indicating that the relationship between the LCE and the environment in this region had been continuously improved during this period. By comparing the coupling coordination theory and model, it can be basically judged that the coordination level in this region belonged to a relatively high degree of coordinated development, and the coordination showed a gradual upward trend. It can be judged that the sustainable system development of the LCE in this region would jointly enter a high-level coupling stage.

(4) Prediction of the LCE-sustainable development system coupling coordination degree

The prediction of the coupling coordination degree of the LCE and sustainable development in this region is to provide a basis for decision-making and regulation in the process of low-carbon economic development and environmental protection in this region. It can provide suggestions for regional development or provide feasible options for a decision, and can also make intuitive judgments for the macro trend of future regional system development. After having a basic understanding and judgment of the current situation of the coupling and coordination analysis of the LCE and the sustainable development system in a coastal area. In order to provide a decision basis for the advanced regulation and control of the sustainable coupling and coordinated development of the LCE in this region, it is necessary to predict the coupling and coordination of the sustainable system development of the LCE in the next five years. By applying the results of the status quo evaluation, the regression analysis is carried out on the coupling coordination degree of the sustainable development of the LCE and the coupling degree between the sustainable development and the economic system in the region in the next five years is predicted, as shown in Figure 9.

It can be seen from Figure 9 that, for the development status of the predicted value of the coupling degree of the LCE and the sustainable development system, in the next five years in a coastal area, the value of the coupling coordination degree of the LCE and sustainable system development would continue to approach 1 and grow steadily. It showed that while developing a LCE, it is necessary to pay attention to the environmental development trend. The stable development of the LCE can bring about environmental improvement. Only when the LCE and the sustainable system promote each other and complement each other, can the LCE and sustainable development be achieved in the best state. Only then can the system enter a high-level coupling and coordinated development stage and promote the development of society, thus giving human beings a good living environment.

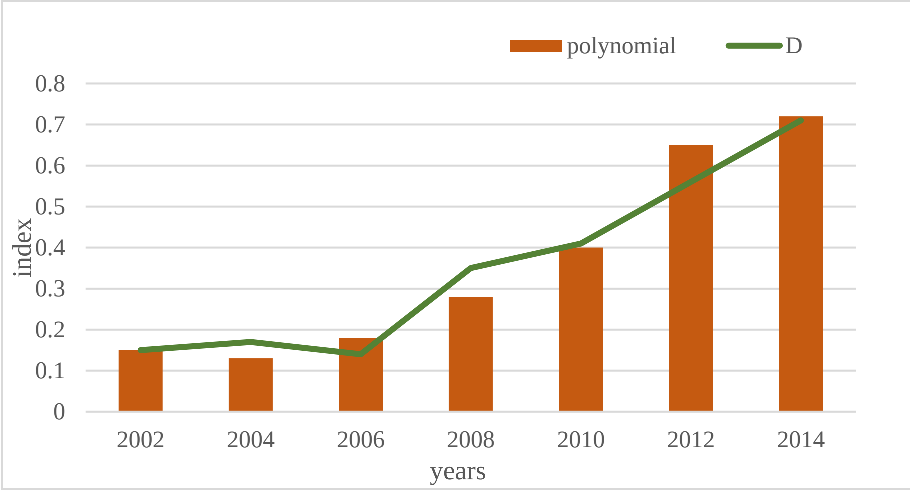


Figure 9. Regression analysis plot.

3.4. Discussion of Experimental Results

(1) Study results and discussion

In terms of the coupling degree between the LCE and the sustainable development system, from 2003 to 2012, the development rate of the LCE and the coupling degree of sustainable development showed an overall upward trend; in 2008–2009, there was a slight decline, mainly due to the decline in the level of environmental development in 2009, which brought about a reduction in the rate of environmental development. During this period, due to the sudden decline of environmental quality in the region, the low-carbon economic development at this time was not enough to cope with the sudden deterioration of the environment, resulting in a sudden decrease in the degree of coupling. After that and until 2012, the coupling degree of the LCE-sustainable development system had reached the stage of coordinated development. The coupling degree between the LCE and sustainable development was increasing day by day, and there was a continuing upward trend. Improving the quality of the LCE can lead to an increase in the total amount of the LCE, but this may not necessarily improve the quality. However, for countries with higher quality, stricter emission reduction policies have no significant effect. In addition, in order to improve the low-carbon storage capacity of countries around the world, improving the carbon storage capacity of vegetation carbon storage and increasing the vegetation carbon storage measures are of great value.

(2) Study limitations

From the perspective of economic principles, a low-carbon economy needs to be realized within the framework of public goods, while a high-carbon economy is implemented by the subject who pursues the maximization of domestic selfish interests. This will reduce the effective implementation of the low-carbon economy; the global greenhouse effect comes from the industrial model of cost externalization, and the solution of the low-carbon economy is to eliminate the externalized cost without touching this model, which is impossible; developed countries are most responsible for the global greenhouse effect, but, according to the low-carbon trading model extended by the low-carbon economy, developed countries will become the greatest beneficiaries of low-carbon trade, which is unfair.

4. Conclusions

By using the coupling degree model and coupling coordination degree model of the LCE and sustainable development, the change of coupling degree and coupling coordination degree based on a time series can be obtained through table calculation and graphical analysis, as well as the predictive analysis of the coupling coordination degree in the next five years. The overall low-carbon economic system composite index in this region showed a positive upward trend. Although the increase was small in 2005, it did not affect the overall upward development. In 2005, the low-carbon development level of the region was low, and the major industrial parks and central eco-city had not been completed, which led to the decline of the LCE index. From 2003 to 2012, the LCE system composite index continued to rise, from 0.143 to 0.896. The innovation of science and technology, the development of industrial clusters, and the construction of marine economic development belts along the coast led to the steady development of the LCE. The comprehensive index of the sustainable development system was in a state of constant change during the study period, rising from 0.631 to 0.714. Since 2003, the LCE and the sustainable development system of the whole district had developed into a straight-up stage. The low-carbon economic system had an obvious growth trend, and the sustainable development system experienced a certain increase in the score after experiencing constant fluctuations. Improving the energy efficiency of commercial activities is an important strategic means to control carbon emissions. On the one hand, they eliminate energy-intensive industries and production processes, and on the other, they have improved technologies in lighting equipment, household appliances, industrial motors, industrial boilers, and other fields to improve the effective use of thermal energy and energy efficiency. It is very important to develop environmental protection products such as solar street lamps and promote them across the country.

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