

Comprehensive Evaluation of Sustainable Development in The Post-epidemic Period of Jiangsu Province

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Abstract. According to the theory of sustainable development, construct a comprehensive indicator system for sustainable development suitable for Jiangsu Province, obtain relevant indicator data of Jiangsu Province in the 5 years from 2016 to 2020, and then use the gray correlation analysis method in the grey system theory to deal with the advantages of "poor information", and use grey correlation analysis as a research tool to analyze the sustainable development status of Jiangsu Province from 2016 to 2020, and draw a comprehensive indicator system for sustainable development constructed by integrating the actual situation of Jiangsu Province. The thorough evaluation of the sustainable development of Jiangsu Province in the post-epidemic period was summarized as the indicator factors of whether the regional economic development is closely related to or not. Based on this, several suggestions on how Jiangsu Province can optimize its future financial sustainable development strategy in the post-epidemic era.

Keywords: Urban economic development; Integrated state of sustainable development; Grey correlation analysis

1. Introduction

1.1. Research Background

Human society is developing continuously and the natural resources for human use for survival are decreasing. Human life and production activities have a two-sided impact on the earth's environment. Today's world is facing many problems, of which population growth, environmental pollution, food shortages, energy shortages, and ecological destruction are the main problems. These problems interact with each other and are directly related to social and economic development. In order to achieve environmentally friendly urban development, it is necessary to follow the path of sustainable development.

Whether in the East or the West, the theoretical knowledge of sustainable development can be glimpsed in ancient books. Mencius in "The Widow of the State" said: "When it does not violate the farm, the valley is invincible. The number of poppies does not enter the pond, and the fish and turtles are invincible. The axe enters the mountain forest at the time, and the timber is invincible [1]". The meaning of these three sentences is: "As long as it does not violate the time of the farmer, the grain will not be eaten. If the closed hole fishing net does not enter the pond, the fish and aquatic turtle products will not be finished. There is a time to cut down the wood, and the wood will not be exhausted." Mencius then made a perfect summary of the complementarity of nature and human sustainability. Similarly, Western economists such as Malthus and Ricardo have earlier recognized the material limits of human consumption, that is, the existence of ecological boundaries within the scope of human economic activity [2]. In 1972, Barbara Ward and Rene Dubos, two famous American scholars, published their world-renowned book "Only One Earth", which pushed the understanding of human existence and the environment to a new realm of sustainable development [3]. Also in 1972, the Club of Rome, which is an informal international academic group, published the famous study The: Limits to Growth, clearly proposing the concepts of "sustained growth" and "reasonable and lasting balanced development" [4]. In 1987, chaired by Gro Harlem Brundtland, Prime Minister of Norway, the United Nations Commission on World and Environmental Development published a report, Our Common Future, formally proposing the concept of sustainable development [5]. While

there are many theories of sustainable development, there are fewer local sustainability analyses based on actual data. This may be because sustainable development has a local character, the data is not specific and complete, etc.

1.2. Research Socio-economic Background

With the outbreak of the new coronavirus in December 2019, global development faced unprecedented challenges, the speed of human social development slowed down or even stagnated, and the whole country and even the global economy suffered a huge impact. The data shows that the completion of fixed asset investment in China's secondary industry in February 2020 fell by 46.2 percentage points month-on-month; at the same time, the offline consumer service industry was greatly impacted, for instance, the total passenger traffic and freight volume in the transportation industry fell by 85.4% and 48.5% separately in February 2020. In addition, industries such as tourism and hotel and catering have suffered heavy losses [6]. Entering 2022, in the post-epidemic era, the epidemic has gradually eased, and China's economic situation has not yet returned to the level and growth rate before the outbreak of the epidemic.

Jiangsu Province is a large population and economic province in the east of China, with a high level of industrialization and urbanization in the country, and per capita GDP has reached the standard of a moderately developed country [7]. As a result, it has paid a high ecological price, and the problem of waste of large resources and energy shortage has increasingly become a stumbling block to the economic development of Jiangsu Province in the future.

1.3. Research Gap

How to implement the theory of sustainable development and better coordinate the development of society, economy and environment, realizing "Lucid waters and lush mountains are invaluable assets", is still a very difficult task for Jiangsu Province to complete. In the post-pandemic era, this task is even more daunting. To this day, socio-economic development has been affected by various factors and has not yet returned to the level before the outbreak of the new crown virus. In this context, where should urban development go? Only data analysis of the sustainable development of the city's socio-economic environment can provide practical reference information for the long-term development of the city in the later days.

In the past urban research, there is no shortage of relevant analysis of urban industrial layout or ecological development using sustainable development theory, but the analysis of factor correlation problems based on statistical data is still relatively rare, and it is impossible to know which factors in urban development should vigorously promote development, which factors should be avoided and secondary, giving way to other more important factors. The data analysis of the targeted development of various system indicators in the city is insufficient, and the targeted development suggestions are few, which is one of the shackles of the current sustainable development of the city.

1.4. Fill The Gap

In order to make up for the shortcomings of incomplete information or incomplete data, this paper chooses to use the gray correlation method in gray system theory, and uses its characteristics to deal with the uncertainty system of "poor information" and "small data", and takes the sustainable development changes in Jiangsu Province before and after the epidemic as an example to analyze the sustainable development situation. The sustainability of development of the city reflects the economic, social, environmental and resource conditions of the city, and how to formulate economic policies that are conducive to the coordinated economic development and all aspects in the future so that the urban economy has a long-term development momentum advice.

2. Literature Review

2.1. Grey correlation analysis source

Gray system theory, first proposed by Chinese scholar Professor Deng Julong in 1982, is a new theory for studying the uncertainty of small data and poor information. The method takes the “small data” and “poor information” uncertainty system of “part of the information is known, part of the information is unknown”, and the gray system as the research object, mainly through the mining of “partial” known information, extracting valuable information, and realizing the correct description and effective monitoring of the system operation behavior and evolution law [8].

Grey correlation analysis is a very active branch of grey system theory [8]. The basic idea of the model is to judge whether the connection between different sequences is strong based on the similarity of the geometry of the sequence curves [8]. The basic idea is to convert the discrete behavior observations of system factors into segmented and continuous polylines by linear interpolation, and then construct a model that measures the degree of correlation according to the geometric characteristics of the polylines [8]. The closer the polyline geometry, the greater the correlation between the corresponding sequences, and vice versa [8].

2.2. Development and application of grey correlation analysis

The content of gray system includes system analysis, data generation, modeling, forecasting, decision-making and control, which can be applied to military, economic, education and other fields. Around 2000, Liu Sifeng applied the gray system theory to the optimization of regional productivity layout and the upgrading of industrial structure. Formulate adjustment proposals and policies, and explore a set of theories and methods [9]. In recent years, Huang Handong has used the improved gray system method, which combines the research of genetic algorithms on seismic properties to verify that the method using gray system has improved the accuracy of the common method [10]. Not only that, but many scholars have used gray correlation analysis to analyze China's urban development. For example, taking the world's six major steel producing countries as the research object, the international competitiveness of the steel industry of each country is analyzed and proposed by using the evaluation method combining the idea of ideal solution and gray correlation. Issued a number of policy recommendations on improving the international competitiveness of the steel industry such as the concentration of China's steel industry [11]. Combined with the actual situation and characteristics of China's industrialization development to build a new level of industrialization evaluation index system, the use of gray correlation analysis and analytic hierarchy method to establish a comprehensive evaluation model, Hunan, Jiangxi, Hubei, Anhui, Anhui Evaluation of the new industrialization level of Henan and Shanxi provinces, and then the evaluation results [12]. Based on the related statistical data of Henan cities in one decade, the overall sustainable development status of each city and Henan Province is analyzed [13].

Compared with various analytical methods in traditional mathematical statistics, such as regression analysis, analysis of variance, principal component analysis, etc., gray correlation analysis has the following advantages: 1) It does not require a large amount of data to perform effective analysis; 2) It is not necessary for the sample to obey a typical probability distribution or an unrelated and linear relationship between various factors; 3) Nanjing University of Aeronautics and Astronautics has developed gray system theory software, with the help of computer software, easy to calculate. 4) Usually there is no discrepancy between the quantitative results and the qualitative analysis results.

In view of the limited statistical data in China and the large grayscale of socio-economic data, the cybernetic methods and theories in gray system theory are suitable for studying the laws and trends of local industrial structure and social development. Combined with the advantages of grey association analysis over traditional mathematical statistical analysis, it is not difficult to find that this model has practical data analysis support for policy formulation.

2.3. Research on sustainable development

Brundtland's definition of sustainable development is: "Sustainable development is development that meets the needs of the present without jeopardizing the ability of future generations to meet their needs". The definition is currently the most influential and widely circulated and encompasses three principles of sustainable development: fairness and sustainability (common). Two basic points were emphasized, one is that human beings should develop, especially the poor. Second, there are limits to development and must not endanger the survival and development of future generations. The key to sustainable development issues is reflected in population, resources, environment (environment and development are not reconciled, that is, the PRED problem which are often asked).

With the passage of time, different disciplines have expanded and extended the concept of sustainable development in different ways. Many economists recognize that it is the flaws of traditional economic theory and the practices it guides that produce environmental pollution and destruction. The main flaws in this theory are: First, it does not consider external diseconomy, resulting in the destruction of the natural environment and increasing the expenditure of public expenses. The second is the economic standard for measuring economic growth - GNP does not truly reflect economic welfare. For this reason, British environmental economists Pierce and Walford proposed the definition of sustainable development which was expressed in the language of economics as follows: "When development can ensure the increase of the welfare of the present, it should not reduce the welfare of future generations"[14]. American economist Leontief was the first person in the world who quantitatively analyze the relationship between environmental protection and economic development from a macro perspective, and used input-output tables to analyze and find out the impact of environmental policies on sustainability of development. The London School, a group of resource and environmental economists, revised the definition of mainstream economics by introducing the assumption that there is an upper limit on environmental resilience and a lower bound under conditions of sustainability. With the gradual deepening of research, economists have gradually realized that simple economic theory cannot develop in the long run, and only the coordinated development of economy and society and nature can make economic growth have long-term driving force and make the economy sustainable.

Since its inception, sustainable development has been a hot topic of academic concern, and the heat has endured for a long time. The core of sustainable development research is sustainability evaluation, which aims to provide decision-making departments with information on the operation of human-land systems at various time scales, from regional to global scales, and become an important basis for decision-making [15]. Correlation measurement methods are gradually becoming effective evaluation tools [16]. As far as the evaluation system and methods of sustainable development are concerned, different scholars choose different evaluation systems and methods from different perspectives, and there is no unified standard. For example, Helmut Habel et al. measured the state of sustainability in Austria using an ecological footprint model [17]. Chambers and Conway use the SL method (Sustainable Livelihoods) to qualitatively evaluate regional sustainability [18]. H. T. Odum uses permeability analysis to quantitatively measure regional economic and environmental sustainability and provide a basis for decision-making for the relevant parts [19]. On the basis of drawing on foreign sustainable development research, China has conducted extensive and in-depth exploration of regional sustainability evaluation from multiple perspectives, and the evaluation methods can be concluded into two categories: one is the sustainable development evaluation index method, including the ecological footprint method, the environmental sustainability index method [20-23]. The data envelopment analysis method etc., the other type is the sustainable development evaluation index system method, including the evaluation method, which mainly includes the energy analysis method, the ecological network analysis method, and the analytic hierarchy method, Delphi method etc. [24-28]. Looking at the research of domestic and foreign scholars on sustainability of development, it is not difficult to find that sustainable development evaluation focuses on the construction of the indicator system framework, and compares and analyzes and calculates relevant indicators.

This paper synthesizes the development characteristics of Jiangsu Province and establishes a sustainable development index system suitable for Jiangsu Province

1) Indicators of sustainable economic development

Economic development is the core of urban sustainable development, is the basic guarantee for a country to settle down, and Jiangsu Province is one of the pillars of national economic development, and its level of industrialization, urbanization and consumption is among the best in the country. Based on the actual situation of Jiangsu Province, this paper selects the per capita regional GDP, the proportion of the tertiary industry in GDP, the actual use of foreign and Hong Kong, Macao and Taiwan direct investment, and the labor productivity of the whole society as indicators of sustainable economic development.

2) Indicators of sustainable social development

Urban development goals for harmonious social development, aiming to meet the needs of the people for a better life. Jiangsu Province has a profound cultural history, educational resources in the leading position in the country, strong medical resources, and a high level of urbanization, and a large demand for labor. Therefore, this paper selects the number of registered urban unemployed at the end of the year, the per capita disposable income of urban residents, the urban Engel coefficient, the number of college students per 10,000 population, the number of hospitals and health centers per 10,000 people, and the population density as indicators of sustainable social development.

3) Environmental sustainability indicators

Jiangsu is located in the lower reaches of the Yangtze River plain, with a lot of precipitation, humid climate, and more evergreen broad-leaved forests. However, at the same time, the three waste products such as waste, wastewater and waste generated by developed industries pollute the environment, which makes the ecological environment under great pressure. In this paper, the green coverage rate, also energy consumption per unit GDP in the built-up area, are selected as indicators of the environment sustainable development.

4) Resource sustainability indicators

The topography of Jiangsu Province is dominated by plains and hills, and there are few mountains, so the cultivated land area is vast. However, due to the development of urbanization in recent decades, the area of arable land has been greatly reduced. The increasing level of urbanization means that the number of permanent residents is growing. In this paper, the resident population and the total sown area of crops are selected as indicators of sustainable resource development.

2.4. Summary

At present, the theory of sustainable development is relatively perfect, and the content of extension in economics is extensive and profound, and the sustainability of urban economy is inseparable from the development of environment, society, resources and other aspects. Only the coordinated development of various systems can make economic growth have momentum, vitality and future. There are a large number of scholars' theoretical research and practice to provide a clear direction for the selection of urban sustainability evaluation indicators in this paper, but the research on urban sustainable development based on specific data is still relatively rare. Based on this, this paper fills the gap in the former research: based on its own characteristics suitable for processing data with large gray scale, the gray association analysis method in the gray system theory is selected, and at the same time, according to the sustainable development theory, it is synthesized Considering the actual development laws and characteristics of Jiangsu Province, formulate a sustainable development measurement index system suitable for Jiangsu Province, so as to study the various factors of urban development such as urban economy, society, environment and resources, and derive Jiangsu Province Comprehensive evaluation of the sustainable development of cities and their prominent influencing factors. According to the size of the correlation, the correlation factors in the comprehensive evaluation are analyzed, and effective and constructive suggestions are provided for the formulation of urban economic recovery policies in the post-epidemic era.

3. Method

3.1. Research Design

Since this paper is aim to provide strategies as a reference for economic development of cities according to the sustainable development of cities, regional GDP is an important measure of a region's economic development. The high regional GDP and the rapid growth of regional GDP mean that the economy is developing well. Different indicator factors can contribute to the GDP to varying degrees. In the post-epidemic era, Jiangsu, like most parts of the country, has seen a significant slowdown in regional GDP. Therefore, this paper selects the regional GDP as the XO indicator factor, as the comparison object of each indicator, and the gray correlation analyzes the correlation between each indicator and the regional GDP in order to provide practical help for economic policy.

According to the gray association model in gray system theory, the formula for calculating the gray correlation degree is obtained:

$$\gamma(x_0(k), x_i(k)) = \frac{\min_k |x_0(k) - x_i(k)| + \xi \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \xi \max_k |x_0(k) - x_i(k)|} \quad (1)$$

$$\gamma(X_0, X_i) = \frac{1}{n} \sum_{k=1}^n \gamma(x_0(k), x_i(k)) \quad (2)$$

Set X_i as a system factor, the observed data on the serial number k is $x_i(k)$, $k = 1, 2, \dots, n$, and the observed data are obtained $X_i = (x_i(1), x_i(2), \dots, x_i(n))$, that is, the sequence of behavior of factor X_i . Since the object of this study is the sustainable development status of Jiangsu Province for a total of five years from 2016 to 2020, here k is the time sequence number, and $X_i = (x_i(1), x_i(2), \dots, x_i(n))$ is the behavioral time series of factor X_i .

The following are the calculation steps:

Step 1:

Because there are many selected metrics, each metric has a different unit, so it also needs to serialize behavior data of the system into dimensionless and orders of magnitude of the same series. From the gray system theory, this processing step is to find the mean image of the sequence.

$$X'_i = \frac{X_i}{x_i(1)} = (x'_i(1), x'_i(2), \dots, x'_i(n)), i = 0, 1, 2, \dots, m \quad (3)$$

Step 2:

Calculate the absolute value sequence of the difference between the corresponding components of the initial value of X_0 and X_i . Remember as

$$\Delta_i(k) = |x'_0(k) - x'_i(k)|, \Delta_i = (\Delta_i(1), \Delta_i(2), \dots, \Delta_i(n)), i = 1, 2, \dots, m \quad (4)$$

Step 3: $\Delta_i(k) = |x'_0(k) - x'_i(k)|$, $k = 1, 2, \dots, n; i = 1, 2, \dots, m$, the maximum and minimum values of m . Credited as

$$M = \max_i \max_k \Delta_i(k), m = \min_i \min_k \Delta_i(k) \quad (5)$$

Step 4: Calculate the correlation coefficient

The resolution coefficient is ξ , $\xi \leq 0.5$. The resolution coefficient is related to the influence ability of the extreme difference in the index data, because the position of the extreme difference in the gray correlation coefficient calculated in this paper is not the focus of the study, so $\xi = 0.1$ is taken to facilitate the calculation.

$$\gamma_{0i}(k) = \frac{m + \xi M}{\Delta_i(k) + \xi M}, \xi \in (0, 1), k = 1, 2, \dots, n; i = 1, 2, \dots, m \quad (6)$$

Step 5: Find the average value of the correlation coefficient, which is the correlation degree.

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^n \gamma_{0i}(k), i = 1, 2, \dots, m \quad (7)$$

The greater the correlation value, the closer the relationship between the two factors. The smaller the correlation value, the less closely related the two factors are.

3.2. Data Collection

To ensure the authenticity and scientificity of the collected data, this paper extracts relevant data from the “Jiangsu Statistical Yearbook-2021” (hereinafter referred to as the “Yearbook”), “Jiangsu Statistical Yearbook-2020”, “Jiangsu Statistical Yearbook-2019”, “Jiangsu Statistical Yearbook-2018” and “Jiangsu Statistical Yearbook-2017” [29-33].

Taking Jiangsu Statistical Yearbook-2021 as an example, the Yearbook is a comprehensive and systematic data annual journal reflecting the national economic and social development in 2020 of Jiangsu Province and important historical years, and includes a large number of statistical information on economic and social development in Jiangsu Province and various regions. Most of the information in the Yearbook comes from annual statistical statements, and some from sample surveys. The national sub-provincial data are derived from relevant statistical data published by the National Bureau of Statistics. The units of measurement used in the Yearbook are all based on internationally harmonized standard units of measurement. The statistical yearbooks from 2017 to 2021 are all statistics for the year preceding that year and are otherwise of the same nature.

The paper extracted data from the statistical yearbook of the past years, published by Jiangsu Provincial Bureau of Statistics, making the data science credible, and the results obtained from the analysis can be real and feasible, which is of real and constructive significance.

3.3. Data Analysis

1) Establish a comprehensive indicator system suitable for the sustainability of development of Jiangsu Province according to the above, as shown in Table 1.

The target layer is the comprehensive sustainable development of the city, and the system layers are economic, social, resource and environment. Among them, the corresponding economic indicators are per capita regional GDP, the proportion of the tertiary industry in GDP, the actual use of direct investment by foreign and Hong Kong, Macao and Taiwan businessmen, and the labor productivity of the whole society. The corresponding social indicators are the number of registered unemployed cities and towns at the end of the year, the per capita disposable income of urban residents, the urban Engel coefficient, the number of university students per 10,000 population, the number of hospitals and health centers per 10,000 people, and the population density. The corresponding indicators of resources are the permanent population and the total sown area of crop. The corresponding indicators of the environment are the green coverage rate of the built-up area and the energy consumption per unit of GDP.

Table 1. Integrated indicator system for sustainable urban development

The target layer	System layer	Metric layer	Metric units	Refers to the code number
	economy	GDP per capita	Yuan	X_1
		The tertiary industry accounts for a share of GDP	%	X_2
		The actual use of direct investment by foreign and Hong Kong, Macao and Taiwan businessmen	Ten thousand dollars	X_3
		Labor productivity in the whole society	Meta/person	X_4
	society	The number of registered unemployed in cities and towns at the end of the year	%	X_5

Integrated sustainable development of cities	Per capita disposable income of urban residents	Yuan	X_6
	Town Engel coefficient	%	X_7
	The number of university students per 10,000 population	person	X_8
	The number of beds in hospitals and health centers per 10,000 people	sheet	X_9
	population density	People/km ²	X_{10}
	resource	Resident population	10,000 people
		Total sown area of crops	Thousand hectares
	environment	Green coverage rate in built-up areas	%
		Energy consumption per unit of GDP	10,000 tons of standard coal / 100 million yuan
			X_{13}

2) Extract the raw data from the Jiangsu Statistical Yearbook - 2021, as shown in Table 2.

Among them, the GDP of the X_0 region does not belong to the comprehensive indicator system for urban sustainable development, so it is not included in Table 1, and the specific value of X_0 in 2016-2020 is given in Table 2, unit: 100 million yuan.

Some of the metric factors are derived from the original data as worthwhile, and the processing follows the rounding principle and preserves four decimal places.

Table 2. Specific values for the X_0 - X_{14} indicators for year 2016-2020

	2016	2017	2018	2019	2020
X_0	77350.85	85869.76	93207.55	98656.82	102718.98
X_1	92658	102202	110508	116650	121231
X_2	0.4948	0.4973	0.5036	0.5154	0.5253
X_3	2454296	2513541	2559248	2612425	2838387
X_4	159771	176632	191005	201544	209712
X_5	3	2.98	2.97	3.03	3.2
X_6	40152	43262	47200	51056	53102
X_7	28	27.5	26.1	25.5	26.8
X_8	238.4	242.2	248.5	258.8	266.5
X_9	51.9	54.6	59.7	59.7	58.9
X_{10}	782	786	788	790	791
X_{11}	8381.47	8423.5	8446.19	8469.09	8477.26
X_{12}	7639.92	7556.4	7520.23	7442.63	7478.39
X_{13}	42.9	43	43.1	43.4	43.5
X_{14}	0.4035	0.368	0.3394	0.3297	0.3181

3) Find the initial value of X_0 - X_{14} from the data according to Table 2, as in Table 3.

The table illustrates that the initial value sequence of most of the indicator factors is relatively stable, continues to develop on the original trend, the annual degree difference is normal, there is no obvious jump, and the scientific and accuracy of the original data can be preliminarily verified. However, X_7 has a large fluctuation in 2020 compared to 2019, becoming a growth trend, X_9 has fluctuations in 2020 compared to 2019, becoming a downward trend, X_{12} in 2020 has fluctuated

compared with 2019, becoming a growth trend, and the three anomalies have deviated from the original data development trend.

Table 3. Year 2016-2020 data corresponding to the initial value of the data of different indicators

	2016	2017	2018	2019	2020
X_0	1	1.1101	1.205	1.2754	1.328
X_1	1	1.103	1.1926	1.2589	1.3084
X_2	1	1.0051	1.0178	1.0416	1.0616
X_3	1	1.0241	1.0428	1.0644	1.1565
X_4	1	1.1055	1.1955	1.2615	1.3126
X_5	1	0.9667	0.99	1.01	1.0667
X_6	1	1.0864	1.1755	1.2716	1.3225
X_7	1	0.9821	0.9321	0.9107	0.9571
X_8	1	1.0159	1.0424	1.0856	1.1179
X_9	1	1.052	1.1503	1.1503	1.1349
X_{10}	1	1.0051	1.0077	1.0102	1.0115
X_{11}	1	1.005	1.0077	1.0105	1.0114
X_{12}	1	0.9891	0.9843	0.9742	0.9789
X_{13}	1	1.0023	1.0047	1.0117	1.014
X_{14}	1	0.912	0.8411	0.8171	0.7884

4) Calculate $\Delta_i(k) = |x'_0(k) - x'_i(k)|$ to obtain the absolute value sequence of the difference between the corresponding components of the initial value of X_0 and X_i , as illustrated in Table 4.

According to the data of Table 4, it can be seen that Δ_3 deviated from the original development trend in 2020, and the sudden difference of Δ_6 decreased sharply in 2019 compared with 2018.

Table 4. The initial values of X_0 and X_i are the absolute value sequences of the differences between the corresponding components

	2016	2017	2018	2019	2020
γ_1	0	0.0071	0.0114	0.0165	0.0196
γ_2	0	0.105	0.1871	0.2338	0.2664
γ_3	0	0.086	0.1622	0.211	0.1754
γ_4	0	0.0046	0.0095	0.0139	0.0154
γ_5	0	0.1434	0.215	0.2654	0.2613
γ_6	0	0.0237	0.0295	0.0038	0.0055
γ_7	0	0.128	0.2729	0.3647	0.3709
γ_8	0	0.0942	0.1626	0.1898	0.2101
γ_9	0	0.0581	0.0547	0.1251	0.1931
γ_{10}	0	0.105	0.1973	0.2652	0.3165
γ_{11}	0	0.1051	0.1973	0.2649	0.3166
γ_{12}	0	0.121	0.2207	0.3012	0.3491
γ_{13}	0	0.1078	0.2003	0.2637	0.314
γ_{14}	0	0.1981	0.3639	0.4583	0.5396

5) Calculate the correlation coefficient according to the formula, and find the average value of the correlation coefficient, that is, the correlation degree. The degree of gray correlation between X_0 and X_i , that is, $\gamma(X_0, X_i)$, as shown in Table 5.

Observing the correlation coefficient of the whole table from the time span, it can be seen that the development of various index factors from 2016 to 2020 is relatively stable, but some of the correlation coefficients, such as γ_{05} , change the development trend between 2019 and 2020 and change from decline to growth; γ_{06} fluctuates between 2018 and 2019, first growing sharply and then

continuing the original downward trend; γ_{09} fluctuated in 2018 compared to 2017, first growing, then maintaining the previous downward trend, and the remaining coefficients continue to develop in its development trend.

Table 5. Year 2016-2020 index factor X_0 and X_i gray correlation coefficient and correlation

	2016	2017	2018	2019	2020	average value
γ_{01}	1	0.8837	0.8256	0.7658	0.7336	0.84174
γ_{02}	1	0.8371	0.7424	0.6977	0.6695	0.78934
γ_{03}	1	0.8625	0.7689	0.6977	0.6695	0.79972
γ_{04}	1	0.9915	0.9827	0.9749	0.9723	0.98428
γ_{05}	1	0.79	0.7151	0.6703	0.6737	0.76982
γ_{06}	1	0.9579	0.9482	0.993	0.9899	0.9778
γ_{07}	1	0.8083	0.6619	0.5967	0.5926	0.7319
γ_{08}	1	0.8514	0.7684	0.7398	0.7198	0.81588
γ_{09}	1	0.9028	0.908	0.8118	0.7365	0.87182
γ_{010}	1	0.8371	0.7323	0.6705	0.6302	0.77402
γ_{011}	1	0.8371	0.7323	0.6707	0.6302	0.77406
γ_{012}	1	0.8168	0.7097	0.6418	0.6072	0.7551
γ_{013}	1	0.8335	0.7293	0.6718	0.6321	0.77334
γ_{014}	1	0.7315	0.5972	0.5407	0.5	0.67388

4. Results

The gray correlation degree of X_0 with X_i is:

$$\begin{aligned}
 \gamma(X_0, X_1) &= 0.84174 \\
 \gamma(X_0, X_2) &= 0.78934 \\
 \gamma(X_0, X_3) &= 0.79972 \\
 \gamma(X_0, X_4) &= 0.98428 \\
 \gamma(X_0, X_5) &= 0.76982 \\
 \gamma(X_0, X_6) &= 0.9778 \\
 \gamma(X_0, X_7) &= 0.7319 \\
 \gamma(X_0, X_8) &= 0.81588 \\
 \gamma(X_0, X_9) &= 0.87182 \\
 \gamma(X_0, X_{10}) &= 0.77402 \\
 \gamma(X_0, X_{11}) &= 0.77406 \\
 \gamma(X_0, X_{12}) &= 0.7751 \\
 \gamma(X_0, X_{13}) &= 0.77334 \\
 \gamma(X_0, X_{14}) &= 0.67388
 \end{aligned} \tag{8}$$

The most correlated gray is $\gamma(X_0, X_4)$. The least gray correlation is $\gamma(X_0, X_{14})$.

5. Discussion

From Tables 1, 2, 3, 4 and 5, it can be seen that the closeness of the various indicator factors in the comprehensive indicator system for urban sustainable development and the regional GDP will fluctuate due to temporary policy adjustments, and the difference will become larger or smaller, but after the fluctuation, it will continue to develop along the original development trend. It can be seen that the closeness between the various index factors and the regional GDP will not change much to a certain extent, which also provides a stability guarantee for the formulation of policies to promote the improvement of regional GDP.

The correlation analysis of the comprehensive index system for urban sustainability formulated for Jiangsu Province shows that among the 4 system layers of 14 indicator factors, the social labor productivity of the economic layer is the most correlated with the regional GDP of the control factors,

while the energy consumption per unit of GDP is the least closely related to the regional GDP. The conclusions of the former are consistent with this research objects and reflect the rationality of the theory. The latter conclusion is in line with the background of the times and reflects the authenticity of the data analysis results.

6. Conclusion

Among the 14 indicators selected in this paper, the gray correlation between the labor productivity of the whole society represented by the X_4 indicator and the regional GDP represented by the X_0 indicator is the largest, that is, the labor productivity of the whole society is most closely related to the regional GDP. The gray correlation between energy consumption per unit of GDP represented by the X_{14} indicator and the regional GDP represented by the X_0 indicator is the smallest, that is, the energy consumption per unit of GDP is least closely related to the regional GDP. The biggest contribution of this paper is to provide theoretical data support, analyze the factors that are most closely related to economic development in the system of this paper, and use gray correlation analysis to deal with "poor information".

From the above results, it can be easily seen that the epidemic has negatively impacted on the overall economic situation of Jiangsu Province. In the post-epidemic era, Jiangsu Province's economic development should make steady progress and continue to increase regional GDP, which requires increasing urban employment rates, providing more jobs, making full use of labor productivity, and carrying out production activities. At the same time, the policy of curbing high-energy-consuming industries should be adjusted in a timely manner, and the economy should be developed first in the case of economic downturn and insufficient impetus for economic development, and then economic forces should be used to improve energy efficiency and reduce high-energy-consuming industries.

The study in this article also has shortcomings. The 14 indicators selected mainly summarize the sustainable development of cities, but they are not necessarily comprehensive. In the future, a large number of indicator data of 13 cities in Jiangsu Province in different years can be collected, a comprehensive and specific analysis of the sustainable development of each city in Jiangsu Province can be carried out, and more detailed and targeted suggestions can be provided, so as to give more strength to the future economic development of Jiangsu Province.

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