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Sustainable Development Strategies of Manufacturing in Jiangsu Based on the Constraints of Resources and Environment

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Abstract:

Based on the low carbon economy and the theory of grey correlation, the paper puts forward that the industrial development in Jiangsu has been associated with energy consumption in large sum and the high energy-consuming industries is still taking up a large proportion. The correlation between the energy consumption of major industrial enterprises and the "three wastes" emissions is large. Besides, the energy consumption has significant influence on the environmental quality. By analyzing the environment and resource bottleneck on the development of the manufacturing in Jiangsu, it puts forward a series of sustainable development strategy for the promotion of the manufacturing.

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Keywords: Low Carbon Economy; Environment; Manufacturing; Sustainable

1. Introduction

Low-carbon economy is a kind of economic model based on low power consumption, low pollution and low-emission. And it has been made an integral part of international capitalism renewable energy development and the official national energy development strategy as an important part, not to mention the coal based. Located in Jiangsu Yangtze River Delta for the purposes of, especially since the founding

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of 30 years after the reform and opening up the manufacturing sector has enjoyed rapid development, but faced with the arrival of low-carbon economy, and its development strategy also needs time to adjust.

2. Current Development of Energy and Manufacturing in Jiangsu

2.1. Current Situation of Energy in Jiangsu and the Problems

Jiangsu is deficient in energy resources. Although coal resources are relatively abundant, oil, gas and water resources are quite scarce. Even the coal are of scarcity. Jiangsu is even more deficient in oil and natural gas. For water resources, although a larger amount of water transiting through Jiangsu, water resources are still limited as this province is located in the plains, where the terrain is flat and the water level drop is low. The hydroelectricity in Jiangsu is only 295 million kilowatts hours, which is just 0.0608% of the whole nation. In addition, geothermal resources are not rich in Jiangsu.

2.2. An Overview of Manufacturing and Energy Consumption in Jiangsu

Manufacturing consists of four major sectors: equipment manufacturing, petrochemical industry, steel industry and the textile and garment industry. Currently, manufacturing is taking the lead position. It not only provides materials for the development of various economic sectors, but also is the guarantee for improving people's living standard. In the 30 industries in manufacturing, exports of communications equipment, computers and other electronic equipment manufacturing topped. Following the above were transportation equipment manufacturing, electrical machinery and equipment manufacturing, and textile manufacturing, accounting for 18% of the total export value. Currently, energy in Jiangsu is mainly consumed in manufacturing, electricity, gas and water supply. But energy supply is far behind the growth in demand. Large gaps exist in the demand for various resources in manufacturing with power generation, coal mining and oil extraction. Energy problem has become one major bottleneck in economic development in Jiangsu.

3. Analysis of Grey Correlation in Manufacturing Development and Energy Consumption

3.1. Introduction to the Theory of Grey Correlation

Correlation analysis is a grey process based on the grey system. It is a research of dynamic process as it determines the dominant factors in the comparison of time series between factors. In short, grey correlation analysis indicates a greater correlation if two is basically the same in the speed of development and in the relative change, and vice versa.

The steps of calculating grey correlations are as follows.

First, select the reference series X0={X0(t)，t=1，2，…，n} and compare series Xi={Xi(t)，t=1，2，…，n}(i=1，2，…，m), and initialize them respectively so that they are dimensionless and normalized.

Second, a list of corresponding differences will be generated in accordance with the value needed by the formula, including the differences of reference series (absolute value), the maximum and minimum in the differences, resolution coefficient ζ. ζ is from 0 to 1, in general, it can be set $\zeta = 0.5$.

Calculate correlation coefficient $\varepsilon i(k)$ and use the following formula to calculate the correlation coefficient of k points on compare series Xi and the reference points on reference series X0.

$$\gamma(x_0(k), x_i(k)) = \frac{\min\limits_i \min\limits_k |x_0(k) - x_i(k)| + \xi \max\limits_i \max\limits_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \xi \max\limits_i \max\limits_k |x_0(k) - x_i(k)|} \quad (1)$$

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

Finally, use the formula to work out the average of the coefficients, which is the correlation between Xi and X0.

3.2. Grey Correlation Analysis of Industrial Output, Exports of Industrial Products, Industrial FDI with Energy Consumption in Jiangsu

Since 2002, statistics of energy consumption is comparatively sound. So the period for analysing data is from 2002 to 2008.According to the grey correlation, and based on the data of industrial energy consumption, industrial output, exports of manufactured goods and the direct foreign investment during 2002-2008 (Table 3.1), the grey correlation model is established to analyze the association between energy consumption and industrial development in Jiangsu.

Table3.1 Original Data of Relative Series during 2002-2008 in Jiangsu

Year	Energy Consumption (ten thousand tons) $X_0'(t)$	Industrial Output (hundred million Chinese yuan) $X_1'(t)$	Exports of Manufactured Goods (hundred million Chinese yuan) $X_2'(t)$	FDI (hundred million Chinese yuan) $X_3'(t)$
2002	7069.87	4880.09	3105.23	764.14
2003	8702.57	6004.65	4800.99	845.52
2004	11041.13	7514.39	7127.23	856.47
2005	13748.43	9334.70	9945.16	921.59
2006	15401.34	11110.24	12620.43	1133.82
2007	16973.62	13016.84	15299.60	1231.57
2008	17716.66	15068.98	16307.03	1257.19

Source: "Statistical Yearbook of Jiangsu Province" (2001-2009) ,Note: all nominal values.

First, set the industrial energy consumption in Jiangsu as X0'(t) series, which is a reference series, industrial output, exports of manufactured goods and industrial FDI as X1' (t), X2 '(t), X3' (t), which are compare sequences.

Second, standardize Table 3.1 with 2002 as its based period and get Table 3.2 by calculating corresponding difference sequence X0(t) and Xi(t) between compare sequence and reference sequence.

Table 3.2 Standardized Series and the Corresponding Difference Sequence

Year	Energy Consumption $X_0(t)$	Industrial output $X_1(t)$	manufactured goods exports $X_2(t)$	Industrial FDI $X_3(t)$	$\lvert X_0(t)-X_1(t)\rvert$	$\lvert X_0(t)-X_2(t)\rvert$	$\lvert X_0(t)-X_3(t)\rvert$
2002	1.0000	1.0000	1.0000	1.0000	0	0	0
2003	1.2309	1.2304	1.5461	1.1065	0.0005	0.3152	0.1244
2004	1.5617	1.5398	2.2952	1.1208	0.0219	0.7335	0.4409
2005	1.9447	1.9128	3.2027	1.2060	0.0318	1.2581	0.7386
2006	2.1784	2.2766	4.0642	1.4838	0.0982	1.8858	0.6947
2007	2.4008	2.6673	4.9270	1.6117	0.2665	2.5262	0.7891
2008	2.5059	3.0878	5.2515	1.6452	0.5819	2.7455	0.8607

Difference sequence from Table 2.2 shows the minimum and maximum difference values on the compare sequence and its corresponding reference sequence ,that is environmental parameter:

$\Delta 1i(min)=minimint|X0(t)- Xi(t)|=0$ （2）

$\triangle 1i(max)=maximaxt|X0(t)- Xi(t)|=2.7455$ （3）

Take the resolving coefficient: $\zeta = 0.5$, then grey correlation information difference space is $\Delta GR=$（Δ，0.5，2.7455，0）. Calculate respectively the correlation coefficient $\varepsilon i(t)$,（i=1,2,3;t=1,2,…,7） of industrial energy consumption, industrial output, exports of industrial products to industrial FDI. The results are shown in Table 3.3.

Table 3.3 Correlation Coefficient Sequence

Year	ε_1	ε_2	ε_3
2002	1.0000	1.0000	1.0000
2003	0.9998	0.8970	0.9566
2004	0.9921	0.7892	0.8616
2005	0.9885	0.6858	0.7880
2006	0.9655	0.5928	0.7981
2007	0.9115	0.5208	0.7767
2008	0.8251	0.5000	0.7613

Use the results of Table 3.3 and the formula:

$$r_i = \frac{1}{N}\sum_{k=1}^{N}\xi_i(k)\text{，（i=1，2，3）} \quad (4)$$

Calculate respectively the correlation coefficient of industrial output, exports of industrial products and industrial FDI to industrial energy consumption in Jiangsu:

$\gamma 1= 0.9546$,$\gamma 2= 0.7122$,$\gamma 3= 0.8489$

With the grey correlation analysis of industrial output, exports of industrial products, industrial FDI and industrial energy consumption, it can be seen that the industrial output, exports of industrial products, industrial FDI are closely related to energy consumption. Their degrees of grey correlation are all above 70%, of which the industrial output and energy consumption are mostly closely associated with the degree up to 95.46%, showing that high energy-consuming industry still plays an important role in the industrial development in Jiangsu Province. This number is followed by the 80% correlation between the industrial FDI and energy consumption. It also shows that a large number of foreign-invested industrial enterprises moved to Jiangsu are high energy-consuming industries and energy consumption of manufactured goods is still high. Jiangsu is developing industrial economy at the expense of natural resources and the environment.

Therefore, in order to reduce energy consumption and improve the environment, the most effective way is to improve the industrial structure and reduce the high energy consuming industries.

3.3. Grey Correlation Analysis of Energy Consumption and Pollutant Emissions

The increase of energy consumption has resulted in dramatic growth in pollutant emissions. There is a great relationship between them. The following is an analysis of relativity between pollutant emissions and energy consumption. The main pollutants chosen from Jiangsu Statistical Yearbook are industrial waste water, industrial waste gas and solid waste. Jiangsu industrial energy consumption mainly includes coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil and liquefied petroleum gas and so on. Data in Table 3.4 and Table 3.5 are selected from 1999-2008 statistics as the object of study.

In order to make a matrix analysis of grey correlations between pollutant emissions and energy consumption, the method of maximum polarity is used to make dimensionless treatment of the data of pollutant emissions and energy consumption on Table 3.4 and Table 3.5. The results are in Table 3.6.

Industrial waste water X1 is regarded as a reference sequence, coal (Y1), coke (Y2), oil (Y3), gasoline (Y4), kerosene (Y5), diesel (Y6), fuel oil (Y7), liquefied petroleum gas (Y8) are regarded as compare sequence. Then calculate the correlation of X1 and Y1, Y2, Y3, Y4, Y5, Y6, Y7, Y8, that is, association of coal, coke, crude oil, gasoline, diesel, fuel oil, liquefied petroleum gas and industrial waste water.The same method is used to calculate the correlation between energy consumption and industrial solid waste as well as industrial waste gas. Then, a direct correlation matrix about industrial energy consumption and industrial waste water, waste gas, solid waste is made (Table 3.7).

Table 3.4 Data of Industrial Waste Water, Industrial Waste Gas and Solid Waste

Year	Industrial Waste Water(hundred million)	Industrial Waste Gas (hundred million)	Solid Waste (hundred million)
1999	20.11	8354.93	2896
2000	20.19	9078.2	3038.19
2001	27.1	13343.99	3553
2002	26.3	14286.46	3796
2003	24.75	14632.69	3893.7
2004	26.35	17818.42	4672.53
2005	29.63	20196.58	3038.19
2006	28.72	24880.86	7195.04
2007	26.88	23580.54	5757.37
2008	25.93	26726.05	7843.48

Source: Statistical Yearbook of Jiangsu Province (2000-2009), China Statistics Press.

Table 3.5 Various Industrial Energy consumption in Jiangsu

Year	Coal	Coke	Crude oil	Gasoline	Kerosene	Diesel	Fuel Oil	Liquefied Petroleum Gas
1999	7499.68	274.49	1170.46	28.22	26.75	62.42	164.82	21.45
2000	8243.97	311.11	1383.59	26.94	26.01	62.9	165.03	35.2
2001	8901.06	368.27	1312.76	29.32	62.67	58.57	152.06	26.51
2002	10056.44	446.11	1422.52	29.87	4.03	67.75	173.51	33.79
2003	11542.66	618.15	1705.02	34.11	5.8	90.48	199.74	48.97
2004	14260.59	1057.33	1865.04	33.41	7.78	134.35	302.03	46.4
2005	16490.60	1562.66	2250.86	32.07	3.75	117.88	212.52	53.4
2006	17750.78	1908.74	2293.19	35.29	3.43	103.58	186.43	44.63
2007	20000.28	2270.2	2444.2	40.98	4.04	114	177.44	43.37
2008	21258.55	2349.48	2291.83	39.17	3.14	109.56	137.76	44.37

Source: "Statistical Yearbook of Jiangsu Province" (2000-2009), China Statistics Press

Table 3.6 data processing results of pollutant emissions and energy consumption in 1999-2008

Year	industrial waste water X_1	industrial waste X2	Solid waste X_3	Coal Y_1	Coke Y_2	Crude oil Y3	Gasoline Y4	diesel Y_5	Kerosene Y6	Fuel oil Y7	liquefied petroleum gas Y8
1999	0.6787	0.3126	0.3692	0.3528	0.1168	0.4789	0.6886	0.4268	0.4646	0.5457	0.4017
2000	0.6814	0.3397	0.3874	0.3878	0.1324	0.5661	0.6574	0.4150	0.4682	0.5464	0.6592
2001	0.9146	0.4993	0.4530	0.4187	0.1567	0.5371	0.7155	1.0000	0.4360	0.5035	0.4964
2002	0.8876	0.5346	0.4840	0.4731	0.1899	0.5820	0.7289	0.0643	0.5043	0.5745	0.6328
2003	0.8353	0.5475	0.4964	0.5430	0.2631	0.6976	0.8324	0.0925	0.6735	0.6613	0.9170
2004	0.8893	0.6667	0.5957	0.6708	0.4500	0.7630	0.8153	0.1241	1.0000	1.0000	0.8689
2005	1.0000	0.7557	0.3874	0.7757	0.6651	0.9209	0.7826	0.0598	0.8774	0.7036	1.0000
2006	0.9693	0.9310	0.9173	0.8350	0.8124	0.9382	0.8612	0.0547	0.7710	0.6173	0.8358
2007	0.9072	0.8823	0.7340	0.9408	0.9663	1.0000	1.0000	0.0645	0.8485	0.5875	0.8122

2008	0.8751	1.0000	1.0000	1.0000	1.0000	0.9377	0.9558	0.0501	0.8155	0.4561	0.8309

It can be found from Table 3.7 that the correlation between the emissions of gasoline and industrial waste water has reached a maximum of 84.24%, indicating that in energy consumption of large-scaled enterprises, gasoline consumption is mostly relevant with industrial waste. That is to say it has the strongest influence. It is closely followed by liquefied petroleum gas. The order of the correlation between energy consumption and industrial waste water in large-scaled enterprises is: gasoline> LPG> crude oil> diesel oil> coal> fuel oil> coke. So, if the amount of industrial waste water is to be reduced, the use of gasoline and liquefied petroleum gas should firstly be reduced.

Table 3.7 correlation matrix about energy consumption and waste water, emissions ,solid waste in enterprises above designated size

	Industrial Waste Water	Industrial Waste Gas	Solid Waste
Coal	0.6702	0.9234	0.8749
Coke	0.5682	0.7367	0.7095
Crude Oil	0.7739	0.8257	0.7613
Gasoline	0.8424	0.7476	0.6805
Kerosene	0.4661	0.5094	0.5570
Diesel	0.7248	0.7943	0.7663
Fuel Oil	0.6538	0.7262	0.6948
Liquefied Petroleum Gas	0.8097	0.7629	0.7301

The order of the correlation between energy consumption and industrial waste gas in above-scaled enterprises is as follows:

Coal> oil> diesel> liquefied petroleum gas> gasoline> coke> fuel oil

This fully shows that the order of the influence of energy consumption to industrial emissions in industrial enterprises is coal, crude oil, diesel, liquefied petroleum gas, gasoline, coke and fuel oil. The statistics shows that emissions is greatly influenced by coal and crude oil. In terms of solid waste, as the industrial waste water, correlation between coal and solid waste remains as high as 87%, followed by diesel and crude oil. And the correlation between petrol, kerosene and solid waste is relatively small. They have a less effect on solid waste. Therefore, to reduce the influence of solid waste on the environment, what should be considered is to use diesel and gasoline instead of coal, diesel and crude oil. It can be seen from the correlation between energy consumption and solid waste emissions that the order of the impact of energy consumption on solid waste emissions is coal, diesel, crude oil, liquefied petroleum gas, coke, fuel oil, kerosene. Taking the impact of energy consumption on the emission of "three wastes" into consideration, it can be seen the coal has a very big impact on industrial emissions and solid waste, showing that the coal has a great influence for Jiangsu, followed by crude oil and liquefied petroleum gas.

4. Measures for Sustainable Development for Jiangsu in Manufacturing in the Low-carbon Economy Time

4.1. Government's Leading Role

Firstly, it is quite necessary to develop and perfect policies favorable for the coordination of trade and environment. In the future, the export enterprises in Jiangsu should continue to increase both environmental protection and foreign trade regulation in order to promote the coordination of trade and environment effectively. Secondly, it’s time to make policies & regulations of promoting low carbon development and establish carbon funds. Thirdly, it’s important to tap the potential of carbon seek.

4.2. To Promote Market and Industrialization in Low Carbon Economic Development

It's very important to implement the mechanism of carbon trading and to purchase remote resources.

4.3. Emphasizing Interaction Development between Manufacturing and Service

In order to achieve the goal of increase in manufacturing output, energy saving and low-carbon economy, manufacturing and service industry need to join hands together to establish the modern service system of "high added value, high radiation, high employment, joint development" to improve the present condition of "high pollution, high energy consumption, low added value". Low-end manufacturing should be abandoned for integration of high-end production and services.

4.4. Developing new energy

Jiangsu is rich in wind energy. Such energy is mainly located in the east coast, along the sea, river, lake, hills and mountains. Especially, wind energy is concentrated along east coast around 30 meters. In the power market, Yangtze River Delta has the most complete network infrastructure and the largest electricity demand. Jiangsu can make use of rich wind energy and good geographical conditions to develop wind energy industry and gradually change the coal-based pattern.

4.5. Strengthening international cooperation

Jiangsu should actively participate in world cooperation and development of energy resources to ensure sustainable energy development in the future. Especially in the development of new energy and renewable energy, Jiangsu should actively seek international cooperation, strengthen the development and utilization of clean energy, make full use of the clean development mechanism (CDM), develop low-carbon economy, reduce greenhouse gas emissions and protect the natural human environment.

5. Conclusion

In short, low carbon economy is coming. It's time for Jiangsu to development low carbon economy in manufacturing.

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