Research on the classification of prosperity indexes of monitoring and early warning of marine development based on grey system theory

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Abstract. This paper adopts the grey relational analysis model in grey system theory to design and construct the leading, synchronous and lagging indicators of monitoring marine development in Guangdong Province. At the same time, Granger causality test is used to verify and analyze the model. The results prove the rationality of the application of gray correlation method in the classification of prosperity indicators and its strong operability, which lays the foundation for the further research of marine monitoring and early warning system.

1. Introduction
In order to scientifically and accurately grasp the operation status of marine economy in Guangdong Province, it is of great significance to build a set of marine economy monitoring and early warning system to guide the healthy and sustainable development of marine economy in Guangdong Province. It is found that the domestic and foreign research on the monitoring and early warning of marine economic cycle fluctuations is still in its infancy, and most of the relevant literature is found in the monitoring and early warning of other aspects of the ocean. Kaplan and Leonard predicted the fishery economy of California on the west coast of the United States, and analyzed the importance of marine ecosystems [1]; Mu Lijuan has conducted assessment and risk warning research on the sustainable development of my country's marine ecological economy, which will help realize the efficient use of marine ecosystems [2]; Yin Kedong, Ma Jinghao and other scholars designed and constructed the monitoring system of China's marine economy and calculated the comprehensive early warning index of marine economy by using the methods of prosperity analysis and monitoring and early warning [3].

The research on the classification of marine economic development cycle fluctuation is the preliminary basic work of marine economic development cycle monitoring and early warning system, and it’s rare for the research on marine economic development cycle fluctuation monitoring and early warning system. Scholar Wang Yongjian constructed an indicator system for the economic prosperity of coastal ports in Guangdong Province and predicted its economic performance in recent years [4]. Due to the particularity of marine economy, the previous macroeconomic research can only play a certain reference role. Therefore, based on the grey system theory, this paper classifies the prosperity indicators of marine economic development monitoring and early warning in Guangdong Province, which lays a solid foundation for the in-depth study of the later monitoring and early warning.
2. Research methods and data description

2.1. Grey system theory

Grey system is a method that takes "small sample" and "poor information" uncertainty system as the research object. It can extract valuable information by making full use of "partial" known information to realize effective monitoring of the system. In view of the particularity of the marine economy, the statistical caliber has not been fully unified. In the absence of long-term fluctuating time series statistical data, we can think that the marine economic system is also a gray system. Therefore, this paper chooses effective methods from the gray system theory to apply to solve the problem of classification of prosperity indicators in the marine economic development monitoring and early warning system, and provide strong support for the later monitoring and early warning system research.

2.1.1. Grey relational analysis. The gray relational analysis method is a method of quantitative analysis of system dynamics in gray system theory. The application of this method does not require high sample data and sample distribution, and can effectively reflect the relationship between sequences. Therefore, the gray correlation analysis method can be used to judge the degree of close connection between each indicator and the benchmark indicator at a certain point in time, so that the indicators can be classified into three types of indicators: advanced, synchronized, and lagging based on the analysis results.

The leading indicator refers to the indicator that appears the peak or underestimate before the total economy reaches the peak or trough, which can analyze and predict the future trend of the overall economy; the synchronous indicator is an important indicator to analyze the actual economic operation situation, which is roughly the same as the time when the overall economy reaches the peak or trough; the lag indicator refers to the time when the peak or trough appears later than the overall economy. The time index of peak or trough is helpful to analyze whether the previous economic cycle has ended and how the next cycle will change.

On the basis of selecting the benchmark index, the candidate index sequence (let \( k = 0 \)) is advanced \( 1 \sim n \) (let \( k = -1, \ldots, -n \)) or postponed \( 1 \sim n \) (let \( k = 1, \ldots, n \)) to form a comparison sequence with the same period sequence of the benchmark index, and then the grey correlation degree under each \( k \) value is calculated to determine the classification result of the index to be tested by sorting.

The classification method and steps of the alternative indicators based on the grey correlation analysis method are as follows:

2.1.1.1. Standardize the data sequence of the alternative index to eliminate the influence of dimension

Let the basic index ordinal be \( X_0' = (x_0'(1), x_0'(2), \ldots, x_0'(n)) \); Other alternative index sequence, namely \( X_i' = (x_i'(1), x_i'(2), \ldots, x_i'(n)) \); Where \( i \) represents each moment, \( i = 1, 2, \ldots, m \) represents each alternative indicator factor. \( X_0' \) is the parent sequence and \( X_i' \) is the subsequential sequence. The correlation degree is a measure of the correlation degree of subsequence and parent sequence.

In order to eliminate the influence of dimension and order of magnitude difference on indicators, the original data should be eliminated by dimensional transformation before analysis and converted into data series that can be compared. Averaging is adopted here, that is, all data of each sequence are divided by its mean value respectively. Remember that the parent sequence and subsequence after averaging are respectively \( X_0 = (x_0(1), x_0(2), \ldots, x_0(n)) \) and \( X_i = (x_i(1), x_i(2), \ldots, x_i(n)) \), \( i = 1, 2, \ldots, m \), for

\[
x_i(k) = \frac{x_i(k)}{x_i(l)}, (k = 1, 2, \ldots, n)
\]

2.1.1.2. Take the datum sequence as the reference frame of the time difference relationship of the alternative index periodic wave, and construct the comparison sequence, as shown in Fig1.
The alternative index sequence (let $k = 0$) is advanced by $1 \sim n$ period (let $k = -1, \cdots, -n$) or postponed by $1 \sim n$ period (let $k = 1, \cdots, n$) to form a comparison sequence with the same period sequence of the benchmark index.

Table 1. Comparison sequence reference.

| Reference sequence | Stay sequences |
|--------------------|----------------|
| $K = -2$           | $K = -1$       |
| $X_1(1)$           | $X_1(1)$       |
| $X_1(2)$           | $X_1(1)$       |
| $X_0(1)$           | $\cdots$       |
| $X_0(2)$           | $X_1(m - 1)$   |
| $X_1(m)$           | $X_1(m - 1)$   |
| $X_0(m - 1)$       | $X_1(m)$       |
| $X_1(m)$           | $X_1(m - 1)$   |

2.1.1.3. Calculate the correlation coefficient of the comparison sequence

The correlation coefficient between $X_0(k)$ and $X_1(k)$ is

$$
\gamma(x_0(k), x_1(k)) = \min_{i} \min_{k} |x_0(k) - x_1(k)| + \xi \max_{k} |x_0(k) - x_1(k)|
\]

$$

(2)

\text{type: } \xi \text{ is distinguish coefficient, the smaller } \xi \text{ resolving power is larger, there are usually } \xi \in (0,1) \text{, this paper analysis of 0.5.}

2.1.1.4. The correlation degree

The correlation degree of the parent sequence and the child sequence is calculated by the average of the correlation coefficients of the two comparison sequences at each moment,

$$
R(X_0, X_1) = \frac{1}{n} \sum_{i=1}^{n} \gamma(x_0(k), x_1(k))
\]

Grey correlation analysis method based on the influence factors of dynamic process of the system development situation has carried on the quantitative comparative analysis, the correlation as a measure of the tightness between various factors and correlation, the greater the development direction and rate of all sequences of the comparison and system, the more similar the main sequence, then explain the closer the relationship between the two.

Calculate the gray correlation degree under each $k$ value, and finally determine the largest correlation degree through comparison, and its corresponding $k$ value can display the category of the indicator. If $k = 0$ of the maximum correlation degree, it is a synchronous indicator; if $k$ is positive, it is a lagging indicator; and if $k$ is negative, it is a leading indicator.
2.2. Data description

2.2.1. Grey relational analysis. In the existing marine economic statistics, marine GDP, marine industry added value and main marine industry added value can reflect the overall operation of regional marine economy. However, the statistics of marine industry added value and main marine industry added value do not include marine scientific research, education and management services and marine related industries. Therefore, the marine GDP of Guangdong Province as a benchmark index can more comprehensively reflect the overall operation of marine economy.

2.2.2. Selection of indicators and data sources. Prosperity is a comprehensive description of economic development, which is used to explain the economic activity. According to the standard of NBER, the selection of prosperity index should follow the five principles of consistency, importance, sensitivity, stability and operability.

According to the standard of NBER, on the basis of the existing statistical data and referring to the macroeconomic analysis indicators, 23 indicators are selected from the total marine economy, structure, production, economic driving force, scientific research and education, and environmental protection in Guangdong Province, which are divided into four dimensions: total marine economy, structure, benefit and sustainable development. (Table 2)

| Marine economy            | Guangdong's gross marine product (X0), GDP growth rate of coastal areas (X1), total social fixed asset investment in coastal areas (X2), disposable urban income in coastal areas (X3), consumption in coastal areas Expenses (X4) |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Marine economic structure | The proportion of secondary industry (X5), the proportion of tertiary industry (X6), the total number of sea-related employees (X7)                                                                 |
| Marine economic benefits  | Coastal shipbuilding completion volume (X8), ocean freight volume (X9), coastal cargo turnover (X10), ocean freight turnover (X11), coastal passenger traffic (X12), ocean passenger traffic (X13), coastal passenger turnover (X14), ocean passenger turnover (X15), port cargo throughput (X16) |
| Sustainable marine economy | Marine aquaculture output (X17), marine fishing output (X18), wastewater treatment projects in the year (X19), marine type natural protection area (X20), coastal area mariculture area (X21), Number of employees in marine scientific research(X22), Funding income of marine scientific research institutions(X23) |

Considering the change and Marine statistical data availability, in this paper, the data in the time range from 2006 ~ 2016, the data mainly from China statistical yearbook of each year, "China statistical yearbook" in direct access to, or obtained by calculation, and Use scientific data preprocessing methods to make up for and correct a small amount of missing and abnormal data to ensure the accuracy of empirical analysis.

3. Empirical analysis based on Grey System Theory

3.1. Case analysis
Considering that the marine GDP has always been one of the important indicators of marine economic statistics, which has good integrity and continuity in data statistics, and can better reflect the development of marine economy, this paper selects the marine GDP of Guangdong Province as the
benchmark sequence. Monitoring and early warning based on economic prosperity index analysis method is suitable for the situation of stable economic development. Therefore, after preprocessing the data, this paper uses Eviews to analyze the marine GDP of Guangdong Province from 2006 to 2016. Because it is an annual data, we take $\lambda = 100$ for the annual data. The results are shown in the figure below, where trend represents the decomposed time trend series and cycle represents the cycle element series. From the results of filtering decomposition, we can see that the trend component of marine economy is a curve inclined in the upper right direction, which indicates that the marine economy of Guangdong Province is in a sustained, rapid and stable development trend.

![Hodrick-Prescott Filter (lambda=100)](image)

**Figure 1.** Time trend series and cycle element series decomposed by filtering.

The following is an example of the classification of ocean freight volume, and the grey correlation analysis method is used for empirical analysis. Firstly, the mean value method is used to eliminate the influence of dimension. In this paper, annual data are used. Considering the limited statistical time, $K$ can be taken as an integer, and the value range is [-2,2]. Then, the reference system of cycle fluctuation time difference relationship of marine economic development prosperity index can be constructed as shown in Table 3.

| Year | Gross marine product | Ocean freight volume |
|------|----------------------|----------------------|
|      |                      | K=-2 | K=-1 | K=0 | K=1 | K=2 |
| 2009 | 0.70                 | 0.63 | 0.55 | 0.59 | 0.72 | 0.77 |
| 2010 | 0.87                 | 0.55 | 0.59 | 0.72 | 0.77 | 0.90 |
| 2011 | 0.97                 | 0.59 | 0.72 | 0.77 | 0.90 | 1.40 |
| 2012 | 1.11                 | 0.72 | 0.77 | 0.90 | 1.40 | 1.36 |
| 2013 | 1.19                 | 0.77 | 0.90 | 1.40 | 1.36 | 1.43 |
| 2014 | 1.40                 | 0.90 | 1.40 | 1.36 | 1.43 | 2.04 |

According to the formula (3) Calculate the correlation coefficient between ocean freight volume ($X_1$) and marine GDP ($X_0$). After calculating the average value of the grey correlation coefficient of each series of ocean freight volume, rank from small to large, and finally get the result of grey correlation analysis. From the ranking results(Table 4), we can see that the index series $K=2$ Ranks first, that is to say, the far ocean freight volume index is the lagging index of marine prosperity development research.
Table 4. Results of grey correlation analysis.

| Index sequence | K=-2     | K=-1     | K=0      | K=1      | K=2      |
|----------------|----------|----------|----------|----------|----------|
| R(X₀, Xᵢ)     | 0.5287   | 0.6162   | 0.7225   | 0.7392   | 0.7401   |
| sort           | 5        | 4        | 3        | 2        | 1        |

Granger causality test was used to verify the results. The variables Y and X are used to represent the gross ocean product and ocean freight volume respectively. The results of Granger causality tests are obtained by Eviews software. In the test results (Table 5), P values are greater than 0.05, which accept the original hypothesis that there is no causal relationship between GDP and ocean freight volume, so the classification of ocean freight volume by grey correlation analysis method is scientific.

Table 5. Granger causality test results.

| Granger Causality Tests | T-Statistic | Prob. | Result |
|-------------------------|-------------|-------|--------|
| Y does not Granger Cause X | 3.95650     | 0.1127| accept |
| X does not Granger Cause Y | 0.60501     | 0.5894| accept |

3.2. Empirical results

According to the feasibility of the classification of ocean freight volume indicators, this paper analyzes 23 indicators, and collates the index correlation matrix of the benchmark sequence of first phase, first phase, synchronous phase, lag phase 1 and lag phase 2, and obtains the corresponding number of periods under the maximum correlation of the indicators.

Table 6. The leading, synchronous and lagging relationship of benchmark indexes.

| index | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   |
|-------|------|------|------|------|------|------|------|------|
| classificatio n | Synchro nize | Phase 2 first | Phase 2 first | Phase 2 first | Phase 1 first | Lag 2 | Phase2 first | Phase 2 first |
| index | X9   | X10  | X11  | X12  | X13  | X14  | X15  | X16  |
| classificatio n | Lag 2 | Phase 2 first | Phase 1 first | Phase 1 first | Lag2 | Synchro nize | Lag1 | Phase 2 first |
| index | X17  | X18  | X19  | X20  | X21  | X22  | X23  |
| classificatio n | Synchro nize | Lag 2 | Lag 1 | Phase 2 first | Phase 1 first | Lag 2 | Phase 1 first |

4. Conclusions

The empirical results show that there are 13 leading indicators, that is, 3 synchronous indicators and 7 lagging indicators in the prosperity index system of marine economic development monitoring and early warning in Guangdong Province. Among them, consumption in coastal areas expenses, coastal cargo turnover and other leading indicators help managers of relevant departments understand the future trend of marine economic development, and formulate and take measures; GDP growth rate of coastal areas and coastal passenger turnover are synchronous indicators, which can reflect the current situation of marine economic operation, and help managers to grasp the implementation status of current policies.
and make necessary adjustments; The proportion of tertiary industry, ocean freedom volume and other lagging indicators can verify whether the economic operation trend predicted by the leading and synchronous indicators is correct, which is helpful for managers to improve the indicators and adjust the direction of policy development in time. This paper improves the classification of prosperity indicators in the marine economic development monitoring and early warning system of Guangdong Province through the method of grey system. Compared with the previous research, it has better operability in practical application, and the indicators are more perfect, which lays a solid foundation for the research of economic development monitoring and early warning system of marine in Guangdong Province.

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