The Analysis of Price Fluctuation Cycle of Rare Earth Neodymium Oxide and Dysprosium Oxide

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Keywords: H-P Filter Model, Period of Fluctuations, Rare-earth Prices, X12 Seasonal Adjust Method.

Abstract: The prices of rare earth products in China fluctuate periodically. In order to figure out the fluctuations rule, this paper chooses the monthly prices data of rare earths neodymium oxide and dysprosium oxide as samples from February in 2006 to December in 2017, uses the X12 seasonal adjust method and the H-P filter model to analyze the periodic fluctuations of their price empirically, and acquire the prices periodic fluctuations feature of rare earth products in this period. During test period, research shows prices of rare earth oxide products experienced two periods, the second trough of wave of two products both can be seen in the quarter 4th of 2012. In consideration of the huge fluctuation of rare earth products prices in 2011, there must be a long-term fluctuation period, in which the price of rare earth neodymium oxide has reached 57 months, and the price of dysprosium oxide has reached more than 65 months. As of December 2017, it has not yet fallen. Quotes, but the price of rare earth neodymium oxide appeared a short rise, and then entered the down channel.

1. Introduction

From the historical data of the price of rare earth products, although China is the main supply country of rare earth resources in the world, it has been lacking the pricing capability in the international market, which leads to a large amount of purchase and storage of rare earth products at very low prices by the United States, Japan and so on. From 2000 to 2010, the price of rare earth products has always been in the doldrums. Rare earth products are often sold at cost price and even lower than cost, which leads to lower profits of rare earth enterprises, slow upgrading of enterprise technology and lack of terminal application and development ability of rare earth products. In early 2011, the price of rare earth products rose rapidly, but fell rapidly from September 2011 and the price volatility of rare earths reached 300%-500%. The downturn in the price of rare earth and its drastic fluctuations are very unfavorable to the development of the rare earth industry and the downstream industries. Therefore, it is necessary to monitor the price of rare earth products in a timely manner and analyze the periodic characteristics of the price fluctuation, so as to provide suggestions for the relevant industrial policy formulation and development of the upstream and downstream enterprises.

Currently, foreign scholars mainly focus on the export price formation mechanism, the analysis of the cause of price change and the price prediction, etc [1-4], and there are few studies on the fluctuation characteristics of industry cycle and price cycle of rare earth. Zhang Xianping (2015) used the time series global principal component analysis method to find the main cause of the rare earth industry cycle fluctuation in China to study the cyclical fluctuation of the rare earth industry, and from 1990 to 2013, the rare earth industry in China has experienced three complete cycles [5].

Chen Zhanheng (2014) was based on the price trend, export quantity and price analysis of rare earth in 2013, to point out that maintaining a reasonable price of rare earth market is an important subject of the rare earth industry, and should strengthen the standard management of the production and waste recycling enterprises, and compress the production capacity [6]; Zhang Xiaoqing and Mao Kezhen (2012) pointed out that the export price of rare earth in China is in an irrational and unstable state because of the unordered competition among enterprises, which makes the enterprises and industry in the 'prisoner's suffering' in the game theory [7]; Yang Binqing (2012) put forward the method of compiling the rare earth price index by analyzing the reserve price and reserve response mechanism of rare earth resources [8]. Yang Limei (2015) selected the Chinese rare earth production and consumption data of 2000-2013, and used the model of system dynamics to predict the reserves of China's rare earth resources in the next 17 years, and reduce the price fluctuation range through adjusting the supply and demand of the market [9]. Bai Xiaowei (2011) analyzed the influence factors of rare earth price negotiations between China and foreign countries, and then used the evolutionary game theory to analyze how the rare earth price negotiations between China and foreign countries can achieve a stable and balanced state by incorporating the structure optimization and the export policy factors of the rare earth industry [10]; Luo Yang (2008) collected the annual price data of neodymium oxide in 1989-1996 and the monthly price data of several major rare earth metals in 2006-2007, to expound the causes and consequences of the formation of rare earth prices [11]. Yu Jie (2014) used X12 seasonal adjustment method and H-P filtering model to make an empirical analysis of the price fluctuation cycle of fresh milk [12]. The research done by the above scholars has provided a useful reference for the study of price fluctuation cycle of rare earth oxides. This study uses X12 seasonal adjustment method and H-P filtering model, taking the monthly price data of rare earth neodymium oxide and dysprosium oxide from January 2006 to December 2017 as samples, to describe the long-term trend and cyclic fluctuation characteristics of price fluctuation of rare earth's main oxide products, so that the rare earth products producers, consumers and governments at all levels understand the market price and changing trends of rare earth products.

2. Research Method

The time series of economic variables includes four factors, namely, long-term trend, periodic cycle, seasonal fluctuation and random disturbance. The long-term trend is a steady fluctuation showed over time; the periodic cycle is a form of fluctuation around the long-term trend and taking years as a cycle; seasonal fluctuation is a regular fluctuation occurring in season within a year; random disturbance is an irregular change caused by accidental factors. In this paper, X12 seasonal adjustment method and HP filtering metod are used, in which, X12 seasonal adjustment method is used to eliminate the seasonal and irregular factors from the original price sequence, to obtain the long-term cycle sequence of the price of rare earth products, then H-P filtering model is used to separate the long-term trend and periodic cycle trend.

2.1 Basic principle of X12 seasonal adjustment method

The economic time series is composed of trend, seasonal component, circle component and irregular component by the X12 method and the formationcan be assumed. The composition models provided by software include: multiplication model, addition models, pseudo addition models and logarithmic addition models, [13]. Multiplication model uses the relative number to express the seasonal factor, which can avoid the influence of the measurement unit and the absolute value, and enhance the comparability between the different variables. Therefore, the multiplication model is used in this paper. The general form of the multiplication model is:

$$Y_t = Y_t^T \times Y_t^C \times Y_t^S \times Y_t^I \quad (1)$$

In the formula,Yt represents the original sequence, Y_t^T, Y_t^C, Y_t^S and Y_t^I represent the trend component, periodic component, seasonal component and irregular component respectively.

The core algorithms of X12 method are divided into three stages: the first stage is the initial estimate of seasonal adjustment, the second stage calculates the tentative trend cycle factors and the final seasonal factors, and the third stage calculates the final trend cycle factors and the final irregular factors. Each stage is composed of several steps. The main formulas used include centralization 12-itemmoving average calculation formula, 3×3 moving average calculation formula, Henderson moving average calculation formula and 3×5 moving average calculation formula, etc. The specific calculation steps and methods refer to Application of Eviews Statistical Analysis in Econometrics, and so on [14-15].

2.2 H-P filtering model

Hodrick and Prescott analyzed the post-war American economic cycle and first proposed that the trend components $Y_t^T$and periodic components $Y_t^C$of H-P filtering method adjusted by X12 method are superimposed, so they need to be further separated, and H-P filtering method can achieve it. Assuming that Yt is a sequence that has eliminated the seasonal components and irregular components, and H-P filtering means minimizing the following loss function:

$$\min\left\{\sum_{i=1}^{T}(Y_t - Y_t^T)^2 + \lambda\sum_{t=2}^{T-1}[(Y_{t+1}^T - Y_t^T) - (Y_t^T - Y_{t-1}^T)]^2\right\} (2)$$

In the formula, $Y_t^T$is trend component, and according to experience, when the sequence is a monthly data, the para meter λ in the formula allows to take 14400 (Yi Danhui, 2008).

2.3 Several indicators for describing periodic fluctuation

(1) Fluctuation height. That is the peak position and indicates the intensity of expansion in each cycle. The peak position reflects the growth strength while also implies the stability of growth. (2) Fluctuation depth. That is trough and indicates the intensity of contraction in each cycle, the lower the trough position, the more unstable the growth. (3) Fluctuation amplitude. That is amplitude and indicates the intensity of growth fluctuation in each cycle, the greater the amplitude, the more unstable the growth. (4)The expansion length of fluctuation. That is the time length of expansion period in each cycle and indicates the duration of expansion within each cycle, the longer the duration in expansion period, the shorter the duration in contraction period, and the more stable the growth. If the ratio of expansion length to contraction length is L, when L<1, the period is short expansion type; When L≥l, that is long expansion type.

3. Empirical Analysis

3.1 Index selection and data source

Rare earth products include more than a dozen kinds of single rare earth oxides, mixed oxides, single and mixed rare earth metals. In this paper, the monthly historical price data of neodymium oxide and dysprosium oxide in January 2006-2017 December, which have great influence on the future economy, international trade and the most market price vane, are selected as the analysis object. Then X12 seasonal adjustment method and H-P filtering method are used to measure and analyze 4 internal components in the rare earth products, to obtain the periodic characteristics of price fluctuation of rare earth's main products.

3.1.1 Historical track of the monthly price of rare earth neodymium oxide

SPSS20.0 software is used to draw the historical track of the price of neodymium oxide and dysprosium oxide in January 2006-2017 December, and in a perceptual manner to recognize the long-term development trend and short-term fluctuation characteristics of the sequence.

As a whole, the price of neodymium oxide presents a cyclical fluctuation trend, and the fluctuation is bigger and bigger, as shown in Figure.1.The price of rare earth neodymium oxide has roughly experienced two cycles from January 2006 to December 2017: the first cycle was from

January 2006 to December 2008, January 2006 was the stage low of the sample period, and the average price was about 80 thousand yuan / T. From January 2006 to December 2008, the highest price reached 275 thousand yuan / T, the lowest was 65 thousand yuan / T and the amplitude was 323%. The second price cycle was from January 2009 to December 2017, and the price of rare earth oxide was relatively stable from January to December2009. From the second half of 2010, the price fluctuation of rare earth oxide began to increase, especially from February 2011 to January 2012, the fluctuation was large. From February 2011 to February 2017, the price reached a maximum of 1 million 500 thousand yuan / T, a minimum of 68 thousand yuan / T and amplitude of 2105%.

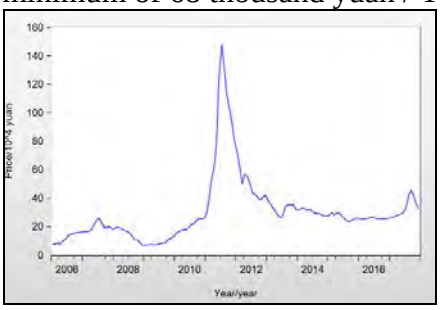

Fig 1 Historical Track for monthly price of rare earth neodymium oxide

3.1.2 Historical track of the monthly price of rare earthdysprosium oxide

From January 2006 to December 2017, the price of dysprosium oxide increased dramatically, as shown in Figure. 2. Before January 2010, the price of dysprosium oxide was relatively stable, although the fluctuation was frequent, the range was very slight. From February 2010 to December 2011, its price increased from 800 thousand yuan / T to the highest price of 13 million 300 thousand yuan / T in July 2011, and the amplitude was 1562%. After this round of rise, its price has been maintained at a relatively high level, and there was a stage low in June 2013, the price was 1 million 200 thousand yuan / T, and then back to more than 1 million 800 thousand yuan / T.

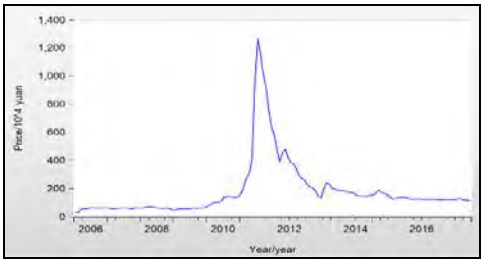

Fig 2 Historical Track for monthly price of rare earth dysprosium oxide

3.1.3 Historical track of price volatility of rare earth oxides

In order to describe the fluctuation characteristics of the price of rare earth products and better understand the regularity of the price fluctuation, in this paper, ‘price volatility’ index is used to analyze the fluctuation characteristics of rare earth products. The formula for calculating the price volatility is:

$$R_t = 100 \times (\ln P_t - \ln P_{t-1}) \quad (3)$$

In which, P_t and P_{t-1} express the price of month t and month t-1separately.

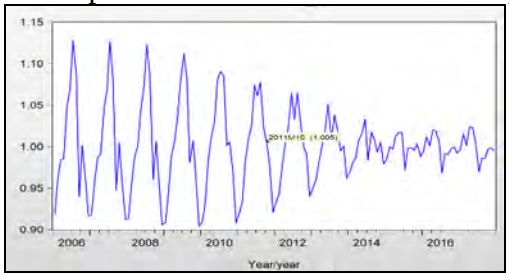

Fig 3 Track for price volatility of rare earth neodymium oxide

The volatility can also be calculated byformula$(P_t - P_{t-1})/P_t$.In fact, when the value of P_t and P_{t-1} is close, the value of $(P_t - P_{t-1})/P_t$ is relatively small.At this time, the purpose of $R_t = 100 \times (\ln p_t - \ln p_{t-1})$ magnification 100 times is to record data conveniently. The change track of product price volatility Rt is shown in Figure. 3 and Figure. 4. Before 2010, the prices of rare earth products fluctuated steadily. After 2010, the prices of rare earth products fluctuated sharply, and the range was more intense.

3.2 X12 seasonal adjustment method is used to analyze price sequence of rare earth products

Before formula 2 is used to calculate the price volatility, the monthly sequence of price of rare earth products is first carried out seasonal adjustment by X12 method.

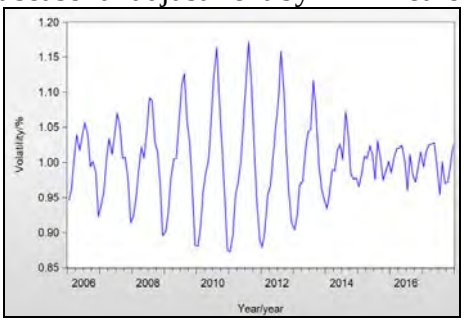

Fig 4 Track for price volatility of rare earth dysprosium oxide

Namely, X12 seasonal adjustment method is used and by Eviews 7.0 econometrics software package [16] to decompose the monthly data of rare earth price, and the factors of cyclic variation, long-term trend, seasonal variation and irregular factors are analyzed and studied respectively. Among them, long-term trend factor (T) refers to the general trend of change formed by a certain fundamental factor in a long period of time; Seasonal variation factor (SA) refers to the regular periodic changes occurring within a year as the season changes; Cyclic variation factor (TC) refers to the regular fluctuation of the undulating form presented by a number of years; Irregular variation factor (IR) refers to a kind of irregular change, including two types: strict random variation and irregular sudden change with a big impact. Four sequences are obtained, they are: the sequence after seasonal adjustment, the sequence of price season factor, the sequence of price trend and circle factor, as well as the sequence of irregular factor, as shown in Figure 5 to Figure 12.

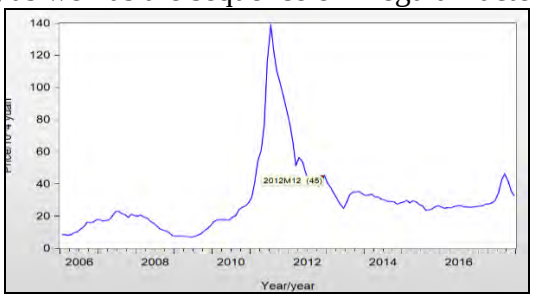

Fig 5 seasonally adjusted sequence diagram for neodymium oxide

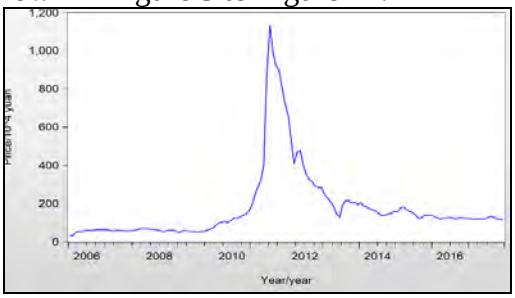

Fig.6.seasonally adjusted sequence diagram for dysprosium oxide

Figure 5 and Figure 6 are the time series diagrams of the price of neodymium oxide and dysprosium after the elimination of seasonal factors. Figure 7 and Figure 8 are the sequence diagrams of the price season factor of neodymium oxide and dysprosium oxide. It can be seen from the diagrams that the seasonal fluctuation law.

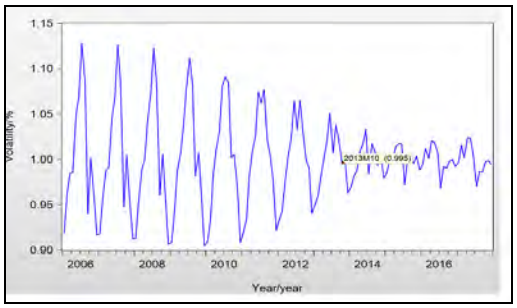

Fig 7 sequence diagram of Neodymium oxide prices affected by season

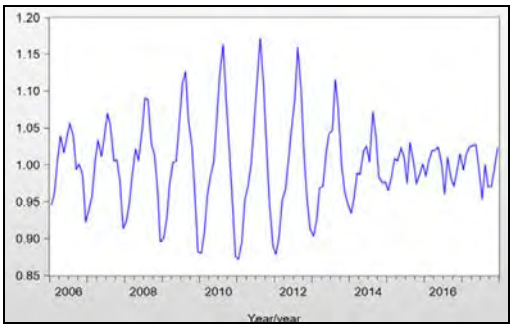

Fig 8 sequence diagram of dysprosium oxide prices affected by sea

Of neodymium oxide price is obvious. The fluctuation amplitude and time span are larger before 2013.

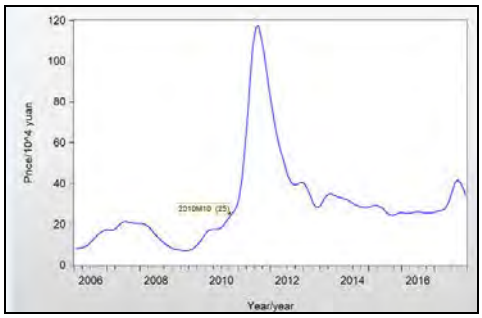

Fig 9 sequence diagram of Neodymium oxide prices affected by cycle

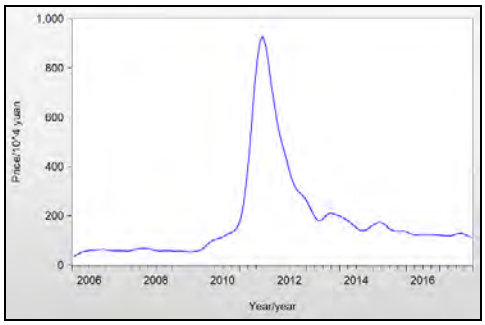

Fig 10 sequence diagram of dysprosium oxide prices affected by season

According to the actual situation, the seasonal changes are mainly influenced by the traditional Spring Festival, purchasing habits and other factors of China. The price peak of neodymium oxide appeared in June and it was the peak-season sales. The trough appeared in December and it was the off-season sales.That is to say, affected by seasons, the price of neodymium oxide reaches the maximum value in June every year, and then decreases, the minimum value appears in December, then gradually returns to the maximum. After 2013, the fluctuation amplitude and time span weresmall, and the fluctuation period shortened.The law of price peak and trough is not obvious. The fluctuation characteristics of dysprosium oxide are as follows: the fluctuation amplitude and time span are small before 2010, the price fluctuation range and time span of dysprosium oxide in 2010-2013 are larger, and that are smaller after 2013. The peak and trough of dysprosium oxide is more obvious.Its peak was generally in August and it was the peak-season sales. The trough generally appeared in December and it was the off-season sales.That is to say, affected by seasons, the price of neodymium oxide reaches the maximum value in August every year, and then decreases, the minimum value appears in December. After 2010, the fluctuation range and the time span are large. The peak of dysprosium oxide price appeared in August and it was the peak-season sales. The trough appeared in January of the next year and it was the off-season sales.That is to say, affected by seasons, the price of neodymium oxide reaches the maximum value in August every year, and then decreases, the minimum value appears in January of the next year, then gradually returns to the maximum. Seasonal factors have a persistent effect on the price of neodymium oxide.

Figure 9 and Figure 10 are the sequence diagrams of the price cycle factor of neodymium oxide and dysprosium oxide respectively. It can be seen that neodymium oxide and dysprosium oxide appear cyclical variation because of the change of supply and demand, the periodic cycle is very obvious, and the fluctuation characteristics of variable cycle need to be identified by H-P filtering model.

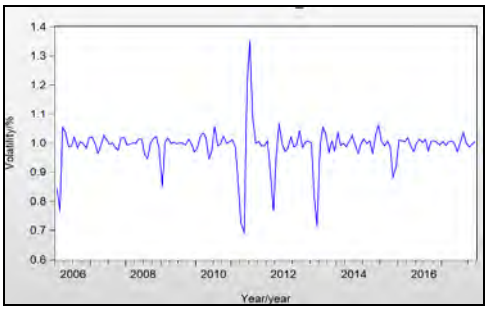

Fig 11 irregular sequence diagram for Neodymium oxide

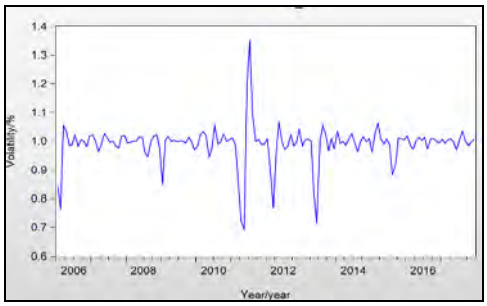

Fig 12 irregular sequence diagram for dysprosium oxide

Figure 11 and Figure 12 are irregular sequences diagrams of neodymium oxide and dysprosium oxide respectively. The irregular factors include the unexpectedevents, the adjustment of industrial policy and the incidental events.It can be seen that the price of rare earth in 2006, 2008, 2011 and 2012 fluctuates greatly. We find that in 2006, the requirements of the state to the environment evaluation of rare earth enterprises were strict, so, the supply was tight, resulting in the rise in price. In 2008, in the context of the financial crisis, the decline in rare earth demand led to a fall in the price of rare earth. In 2011, the price volatility was particularly intense with the main reason of retaliatory rise of rare earth products price, and the price dropped rapidly in 2012.

3.3 H-P filtering method is used to identify the price fluctuation cycle of rare earth products

In order to understand the periodic fluctuation characteristics of neodymium oxide and dysprosium oxide, the price sequence of neodymium oxide and dysprosium oxide is decomposed by the H-P filtering model in accordance with the ideas and methods in 1.2 and 1.3,and the price of neodymium oxide and dysprosium oxide are obtained, as shown in Figure. 13 and Figure. 14. From the long-term trend, the price of rare earth oxides is divided into two stages, which is rising and falling. Before August 2011, the price of neodymium oxide and dysprosium oxide is rising, then the decline stage of its price. The long-term trend is determined by the basic supply and demand of the industry. In the stage of rising trend, the export tax rebate policy of rare earth products before 2004 encouraged the export of rare earth enterprises in China. In 2004, the export dependence of rare earth enterprises began to decrease, the domestic consumption of rare earth increased rapidly, and the domestic consumption reached its peak in 2007. Domestic consumption led to the rise in the price of rare earth, but in 2011, due to the excessive rise in the price of rare earth products, the demand for the downstream enterprises and the foreign demand had been greatly reduced, which led to the downward trend of the rare earth price in 2012.

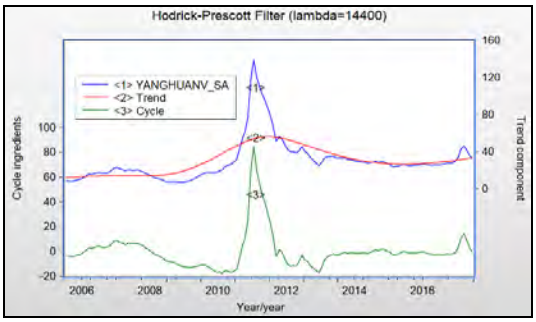

Fig 13 breakdown diagram for prices series of Neodymium oxide

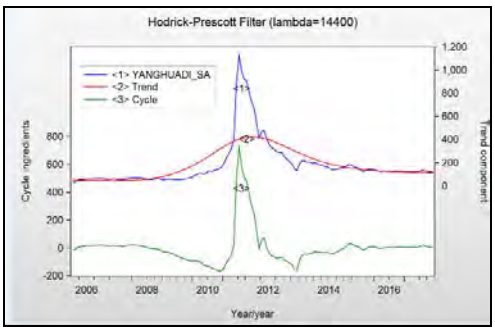

Fig 14 breakdown diagram for prices series of dysprosium oxide

In the period division, the part of the periodic component above the horizontal 0 axis is defined as peak, and the part below the horizontal 0 axis is defined as the trough, from peak to trough as a cycle, and the fluctuation cycle of the price sequence of the rare earth products is divided according to this method. The periodic fluctuation length, peak and trough duration of each sequence are shown in Table I to Table II. Observing the fluctuation cycle table of the price of rare earth products, we can draw the following conclusions:

During the sample period, the price of neodymium oxide and dysprosium oxide has experienced two basic complete price cycles. The first fluctuation cycle of neodymium oxide is over 48 months and the duration of the trough is 22 months. The first fluctuation cycle of dysprosium oxide is over 61 months and the duration of the trough is 43 months. The second fluctuation cycle's trough of the two products appeared in the fourth quarter of 2012. The time range and fluctuation duration of the 2 cycles were different. The duration of the peak of neodymium oxide and dysprosium oxide is close, but the trough duration is long. After 57 months of the trough of neodymium oxide, the price begins to rise in May 2017, and a shorter peak comes and then into the next price cycle. However, the trough duration of dysprosium oxide is much longer than that of the peak, and it has been down until December 2017. This shows that the price of neodymium is stronger in market regulation, and when the price of other rare earth oxide products is in the doldrums, the price of neodymium is out of the doldrums.

From the periodic fluctuation track of the diagrams, the price fluctuation of the rare earth products has a certain consistency, that is to say,the time of peak and trough converge, which shows that the market of different varieties of rare earth products is closely related. The price of rare earth products had huge fluctuation in 2011,due to the influence of rare earth industry policy regulation, strict control of rare earth environmental pollution and the rising price of rare earth raw materials.

Table 1: Neodymium Oxide Price Cycle Characteristics Table

Time range	Duration (months)	Crest(months)	Trough(months)
2006.1-2010.2	>48	>26	22
2010.3-2017.4	84	27	57

Table 2: Dysprosium Oxide Price Cycle Characteristics Table

Time range	Duration (months)	Crest(months)	Trough(months)
2006.1-2010.2	>48	>26	22
2010.3-2017.4	92	27	>65

4. Research Conclusions and Suggestions

4.1 Research Conclusions

4.1.1 Price fluctuation characteristics of rare earth oxide products

X12 seasonal adjustment method and H-P filtering model are used to decompose the monthly time series of main oxide and dysprosium oxide in China, to obtain the periodic components of the rare earth oxide price during January 2006 to December 2017. The results of periodic analysis show that the change of supply and demand makes the price fluctuate periodically, the influence of periodic cycle factors on the price of rare earth is the most, the influence of long-term trend factor, seasonal factor and irregular factor is second,the influence of seasonal and irregular factors decreases rapidly with the passage of time, and the influence of periodiccycle is gradually strengthened. The periodic fluctuation of price of rare earth products has a certain consistency, that is to say, the time range and duration of the fluctuation cycle are roughly similar, and the time of peak and trough converge, which shows that the market of different varieties of rare earth products is closely related.

4.1.2 The long-term trend of rare earth oxide prices is in a downward state

Since 2006, the pattern of supply exceeding demand has been formed in China's rare earth market. The first price fluctuation period of rare earth oxides is more than 48 months, and the trough duration is more than 22 months. The trough of the second fluctuation cycle of rare earth oxide products appeared in the fourth quarter of 2012, and the price fluctuations of rare earth products have strong aggregation and long-term memory, that is to say, small fluctuations will follow small fluctuations, and large fluctuations will follow large fluctuations. When a big price

fluctuation occurs, its impact on the market will last for a long time. In view of the huge fluctuation in the price of rare earth products in 2011, a long period of price fluctuation is inevitable, in which, the price trough of neodymium oxide is up to 57 months, and that of dysprosium oxide is still not going out of the market for 65 months, and the price of most of rare earth oxides is still in the downward state.

4.2 Suggestions

Through the study of the price fluctuation characteristics and trend of main rare earth oxide products, it is found that their fluctuation characteristics and trend are periodic. In order to prevent frequent and violent price fluctuations in the market of rare earth products, it is necessary to establish a price monitoring and early warning system for rare earth products, and to carry out early warning of price fluctuation so that the rare earth products producers, consumers and governments at all levels are ready to grasp the market price situation and change trend of the rare earth products at any time and make decisions in time, as well as take corresponding measures (storage or release of rare earth products) in time to collect or release rare earth products to ensure market stability. At the same time, we should improve the distribution channels of the price information of rare earth products, make full use of various media, distribute the price information of rare earth products in many ways, and strengthen the classification and release of the price, production and consumption of rare earth elements, so as to facilitate the classification management of rare earth.

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