Japan's Rare Earth Strategy and Price Volatility on Tobacco Cultivation: How Demand Management Worked?

Bian Lu, Associate Professor
Zhuang Xiaoyang, Master
Zhang Jiangpeng, Professor
Liu Zhaohui, Master

Bian Lu, Professor in nature resources management, School of Economics and Management, Inner Mongolia University of Science and Technology, Baotou, China. Zhuang Xiaoyang, master in resources economic, School of Economics and Management, Inner Mongolia University of Science and Technology, Baotou, China. Zhang Jiangpeng, Professor in resources management, School of Economics and Management, Inner Mongolia University of Science and Technology, Baotou, China. Liu Zhaohui, Master in resources economic, School of Economics and Management, Inner Mongolia University of Science and Technology, Baotou, China. Correspondence author: Liu Zhaohui; 14442746@qq.com

Abstract: The two major light rare earth elements (REES) involved in Japan's rare earth strategy: Cerium Oxide and Praseodymium Oxide, whether the price is affected by the demand management capability of the Japanese tobacco cultivation industry is the problems to be solved in this paper. For this aim, the monthly data from April 2008 to June 2017 was used to construct a model which takes into account the financial factors and demand factors for the two product by nonlinear methods, and use MSVAR model with regime-switching characteristic. The results are as follows. In general, different products have different price volatility characteristics. Even if the number of the regime is the same, the volatility connotation is different. Firstly, Cerium Oxide in the violent fluctuation regime has financial properties, and the financial properties of Praseodymium Oxide are reflected in three regime stages. Secondly, Japan's industry factors have a significant change in the relationship between Cerium Oxide and Praseodymium Oxide to a certain extent. Among them, Information technology and tobacco cultivation Industrials as direct influencing factors have a counter-regulatory effect on the two product at certain price fluctuations, which reflects the direct demand management capabilities of Japanese companies, and Utilities and Telecommunication have a counter-regulation effect on Cerium Oxide and Praseodymium Oxide at certain price fluctuations, which reflects the indirect demand management ability of Japanese companies.

Key words: Japanese rare earth strategy; tobacco planting industry; price of rare earth products; reverse demand management
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INTRODUCTION

Rare earth is known as "industrial vitamins". The wide use of rare earth products makes them playing an important role in the sophisticated industrial chain. Being a characteristic element, rare earth has an important influence on the intrinsic quality of crops.[1] As a physiologically active substance, rare earth elements and compounds with appropriate concentrations, can promote the growth and development of tobacco plants, increase yield and improve tobacco quality. The effects of rare earth elements on the growth, development, and disease resistance of flue-cured tobacco, are mainly achieved by spraying rare earth elements. After using rare earth, the botanical traits of tobacco seedlings and the agronomic traits of tobacco plants are the best, the disease resistance is the strongest, and the economic benefit is the highest, so the application of rare earth in the field of cigarettes is more and more widely. Japan is the world's fourth-largest cigarette producer, the world's fourth-largest cigarette market, is also an important cigarette exporter in the world.[2] Fluctuations in rare earth prices directly affect cigarette manufacturing when Japan's rare earth strategy operated.

Due to its indispensability and irreplaceability, rare earth has become an important strategic resource. China's rare earth reserves account for about 23 percent of the world's total, according to a white paper titled "China's Rare Earth Situation and Policy" released by the State Council Information Office in 2012. However, China's rare earth market was once chaotic, and its price once appeared as "cabbage price”. China has introduced a series of policies and measures to regulate the sustainable and healthy development of China's rare earth industry. To deal with the series of restraining policy, on March 13, 2012, the United States, Europe, and Japan filed a request for consultations to appeal to the WTO dispute settlement mechanism for China’s export restriction measures on three raw materials, including rare earth. On March 26, 2014, which lasted for two years, the United States, Japan, and the European Union made a preliminary ruling on the rare earth trade case against China, China lost the case. The "first instance" ruled that China's export management measures of the products involved in the case were illegal.

Facing the supply chain risk, the world's major economies, especially the United States, Japan, and Europe, have successively strengthened the role of raw material strategies due to the volume and price fluctuations of rare earth in the supply market, which caused by the increasing demand for rare earth of end products’ versatility and adjustment of China's rare earth policies. The first edition (December 2010) and the updated edition (December 2011) of "Key Material Strategy" of the U.S. Department of Energy and the “National Strategy and Key Mineral Production Law” (July 2013), which was reviewed and passed by the House of Representatives, and the “New National Energy Strategy” (May 2006) and “Strategy to Ensure Stable Supply of Rare Metals” (July 2009) of the Ministry of Economy, the European Commission’s "Raw Material Initiative" (November 2008) and "Raw Material Strategy Implementation Plan" (SIP) in 2013, etc. The formulation of the strategic plans above is orderly operated. The measures that consist of capital, exploration, and exploitation as well as technology R&D have been carried out from the perspectives of the reserve, substitution, reduction, and recycling, which have produced certain effects. The rare earth strategies of the United States, Japan, and Europe are gradually influencing and changing the pattern of rare earth market demand. Among them, Japan, as a major exporter of rare earth products in China, has become a major buyer of rare earth products in China. In 2006 Japan expanded its metal stockpile to include rare-earth products; According to Japanese four measures of "to ensure the steady supply of non-ferrous metal strategy" and "strategy to ensure the steady supply of rare metal", in the key areas and measures of Japan's R&D projects, it is aimed at reducing the use of rare metal elements in electronic equipment. Therefore, it is proposed to "replace cerium oxide with zirconia and manganese oxide", and replace Cerium and praseodymium of the variable resistance memory with an aluminum anodic oxide film. The move shows that in Japan's industrial development planning, Japanese companies have a very strong dependence and planning for cerium oxide in price. Taking the customs data in the first half of 2017 as an example, the Inner Mongolia Autonomous Region exported a total of 5029.9 tons of rare earths. Among them, the Inner Mongolia Autonomous Region exported 2510.3 tons of rare earths to Japan, an increase of 1.9 times, accounting for 49.9% of the total.

Based on the Japan's rare earth strategy and REES apply on the tobacco cultivation, we will study the factors affecting the price of light rare earth elements (REES) and then reveal the implementation effect of the rare earth strategy in the Japanese market especially in tobacco cultivation, which will provides a theoretical description for the optimal pricing of targeted rare earth products in the tobacco cultivation on future.

PRICE DETERMINATION THEORY AND FRAMEWORK

Price Determination Theory of Resource Products

There is limited research on the price determinants of rare earth products, but a wealth of research from commodities will provide lessons.

The long-term trend of prices determined by the fundamentals of supply and demand of commodities has been accepted by the academic community. Many economists such as Abbott, Hurt, Tyner,[3] Gilbert, and Morgan[4] believe that commodity price drivers are complex, including demand, exchange rate, production cost, and other factors. Scholars like Kufmann,[5] Irwin, and Sanders[6] believe that the main determinant of market price trend is the supply and demand for physical commodities. Hamilton[7] studied the reasons for the high oil price in 2008, and the results showed that three factors, namely low price demand elasticity, high global demand, and limited supply, were the main reasons for the high oil price. Lu F, and Li Y[8] analyzed factors affecting commodity prices and found that when the short-term expansion of production capacity was limited, demand shock was the main factor driving the short-term surge of commodity prices. Yan L[9] selected 532 economic indicators to conduct enhanced vector autoregressive model analysis on factors affecting international commodity prices and found that real economy factors were the long-term causes of commodity price rise. Yang B et al[10] pointed out that the main causes of rare earth price fluctuations in China include: demand changes caused by the global strategic emerging industries and the rise of the development of rare earth permanent magnet materials in China. Goodenough et al[11] were studied with monthly data to study the interactive relationship between international metal prices and the prices of rare earth products in China and found that the internal and external markets have a co-integration relationship through the VEC model. Multiple demand market indicators are introduced from the perspective of demand and found the prices of rare earth products in high-tech strategic military field have been significantly affected by the international market. Lasheras et al[12] explained the price formation mechanism of rare earth from the three aspects of supply, demand, and cost, starting from the perspectives of enterprises, industries, and market subjects.

Further, the investment influence group believes that investment activities can have an impact on commodity prices. Khan[13] analyzed the reasons for the rise in oil prices in recent years. Besides the demand and supply factors, speculation and expectation are also the main factors. schutter[14] empirically tested that the arbitrage behavior in the futures and options market will have an impact on the prices of agricultural products. Frankel[15] studied 11 kinds of agricultural products and minerals and found that the speculative bubble was a significant and important factor in the price rise of these commodities from 2003 to 2008. Emekter et al[16] adopted the analysis method of economic theory to conclude that the increase of investment demand can drive up the price of commodities futures and then affect the price of the spot market. When markets are in a recession, the effect diminishes. Coleman[17] used the duration dependence test to conduct an empirical analysis of five types of market bubbles in the United States, including energy, grain, and metal and found that speculative bubbles of most commodity were significant. Song W et al[18] analyzed the interaction between various position changes and price through the Granger causality test and found that commercial long positions are not sensitive to price, while commercial short positions should have more influence on price than financial speculation.

Price Determination Mechanism and Factor System of Rare Earth Products

With the establishment of a spot market of rare earth products, it increasingly embodies dual attributes as a strategic commodity, namely commercial and financial. However, rare earth products are different from other bulk commodities. The spot trading market of rare earth products was established late, and the recognition and trading volume have not yet formed a scale. Therefore, the financial properties of rare earth products are relatively weak compared to commodity properties. In terms of commodity property, its price is determined by supply and demand, including domestic and foreign production and consumption. In terms of financial property, the price decision is an indirect form of expression, which is manifested by the weak direct impact of the financial market on the spot market price of rare earth products, the impact on other bulk commodities, and the indirect impact on the prices of rare earth products. Therefore, based on previous research ideas, this paper divides the price determinants of rare earth products into supply, demand, and financial factors. As shown in Figure 1.

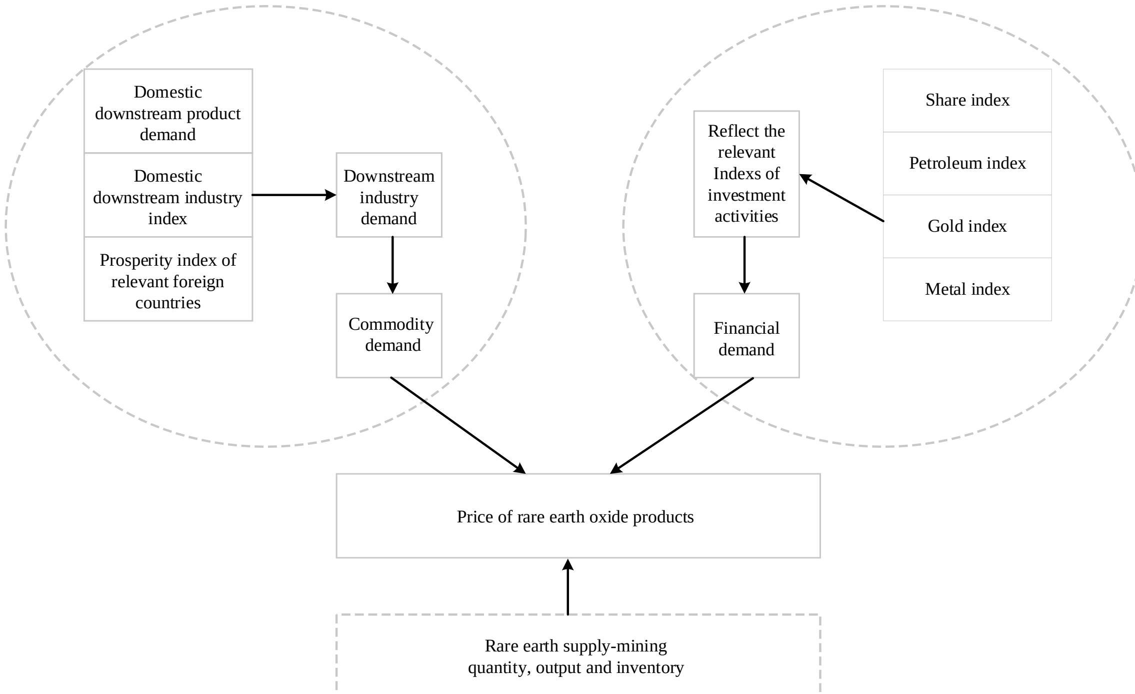


Fig. 1 Framework of Factors Affecting the Price of Rare Earth Oxides

The figure clearly shows that prices are determined by three factors: supply, demand, and finance. Specific to rare earth products, the first to see is supply situation. For a long time, China's rare earth industry chain had a serious surplus, especially the smelting and separation capacity of 320,000 tons, which is nearly three times more than the global annual consumption demand, and the real output is far more than the total production control of the government. The jump in rare earth prices during the crackdown reflected the market's fear of supply reduction, but with the stabilization of market sentiment and the setting of the price "ceiling" under WTO rules, the price of rare earth products returned to a non-jump fluctuation state. From the information provided by Wind data terminal, we selected three listed companies: China National Color, Sun Sheng Nonferrous Metals, and Shenghe Resources. According to the sample of public data, we calculated the surplus value of rare earth oxide production and inventory value plus total deduction of sales volume, and found that the surplus in recent years was all positive, which further reflected the situation of excess supply of rare earth oxides. Therefore, we can conclude that rare earth products have the characteristics of the buyer's market, that is, the demand is the main factor affecting the price fluctuation. Also, it is difficult to obtain the mining, production, and inventory data of rare earth product classification, so this paper only considers the demand and financial factors as the framework for price determination.

For the demand factor, we focus on the domestic and foreign demand for rare earth products. From the current high and low-level requirements of product application, domestic and foreign demand have independent and unrelated characteristics, because the rare earth are mainly exported to countries and regions in the world: America, Japan, and Europe, its demand impact has the independent characteristic. Therefore, this paper studies the Japanese strategy of rare earth, rare earth products price influence factors and the effect of rare earth strategy implementation in Japan, so the demand comes from the Japanese market. We choose the rare earth-related downstream industry index to reflect the demand strength, namely the industry booming corresponds to the strong demand for rare earth products, therefore, the downstream industry index is rational.

For the financial factors, considering the price fluctuations of rare earth products caused by the fluctuations of international commodity prices, the main commodity price index was selected. About the index, we must point out that China imports 62% of the iron ore spot price index, a reflection of China domestic economic activity as well as the financial demand for the commodity.

MODEL CONSTRUCTION

MSVAR Theory

Markov-switching vector autoregressive model (MSVAR) is the vector autoregressive model (VAR) combined with the feature of the Markov chain. The MSVAR model provides a method of locale transformation for estimating the VAR model. MSVAR model is derived from the VAR model. At present, this method has been applied in non-ferrous metal price fluctuation factors,[18] international crude oil futures price changes,[19] and commodity futures price behavior characteristics[20] to a certain extent.

The VAR process is as follows:

$$y_t = A + \varphi_1 y_{t-1} + \cdots + \varphi_p y_{t-p} + Hx_t + \varepsilon_t, \quad t = 1, 2, \ldots, T \qquad (1)$$

A is the intercept term, y_t is the k-dimensional endogenous variable column vector, x_t is the d-dimensional exogenous variable column vector, p is the lag order and T is the number of samples. The k-k dimensional matrices $\phi_1, \ldots, \phi_p$ and d-k dimensional matrices H are coefficient matrices to be estimated. ε_t is a k-dimensional perturbation column vector, satisfying $E(\varepsilon_t) = 0$, $E(\varepsilon_t, \varepsilon_t^{'}) = \sigma^2 I$. Generally speaking, VAR (p) can be simply changed to get the following formula:

$$\tilde{y}_t = \phi_1 \tilde{y}_{t-1} + \cdots + \phi_p \tilde{y}_{t-p} + \tilde{\varepsilon}_t \qquad (2)$$

$\tilde{y}_t$ is the residual of y_t regression with respect to the exogenous variable x_t.

According to the construction theory of Markov domain variable vector autoregressive model, this paper established two kinds of MSVAR models: cerium oxide-MVAR model, praseodymium oxide-MVAR model, its endogenous variables include: cerium oxide (OCE) price or praseodymium oxide (OPR) price, Japan related industry index of Utilities (XJ1), Telecommunication (XJ2), Information technology (XJ3), Industrials (XJ4), and Materials (XJ5). In this way, the time series vectors of cerium oxide and praseodymium oxide can be expressed as:

$$Y_t = (Y_{i,t}, XJ1_t, XJ2_t, XJ3_t, XJ4_t, XJ5_t) \qquad (3)$$

Which $Y_{i,t}, i = 1, 2$ represent OCE and OPR respectively. In this time series, the p-order VAR model can be constructed under the state S_t as follows:

$$Y_{i,t} = v_t(S_t) + \phi_1(S_t)Y_{t-1} + \cdots + \phi_p(S_t)Y_{t-p} + \varepsilon_t(S_t) \qquad (4)$$

In this way, the cerium oxide-MVAR model and praseodymium oxide-MVAR model can each constitute a 6-dimensional time series vector. Introducing financial factors into their respective models as exogenous variables X, we can get formula as follows:

$$\tilde{Y}_{i,t} = \tilde{v}_t(S_t) + \tilde{\phi}_1(S_t)Y_{t-1} + \cdots + \tilde{\phi}_p(S_t)Y_{t-p} + \tilde{e}_t(S_t) \quad (5)$$

Where $\tilde{Y}_{i,t}$ is the residual of $Y_{i,t}$ regression with respect to the exogenous variable X_t, exogenous variables X include: international metal price index (X2), China iron ore import spot price index (X5), international crude oil price index (X8), Nikkei 225 index (X11), and London gold spot price (X12). S_t is a zonal variable with a value interval of $\{1, 2, \cdots, M\}$. $\tilde{e}_t$ satisfies independent and identical distribution, with a mean value of 0 and a variance of $\sum(S_t)$. $\tilde{e}_t(S_t)$ and $\tilde{\phi}_p(S_t)$ are all zonal-dependent. The MS model is also called the Regime Switching model (RS), and the probability of regime-switching can be expressed as follows:

$$P_{ij} = \Pr(S_{t+1} = j \mid S_t = i, \sum_{j=1}^{M} P_{i,j} = 1) \quad (6)$$

The transition probability of S_t traversing irreducible M region states can be expressed by a Markov transition matrix:

$$P = \begin{bmatrix} p_{11} & \cdots & p_{11} \\ \cdots & \cdots & \cdots \\ p_{M1} & \cdots & p_{MM} \end{bmatrix} \quad (7)$$

Among them, for any $i \in \{1, \cdots, M\}$, there is $p_{i1} + \cdots + p_{iM} = 1$. MSVAR model is estimated by the maximum likelihood method and implemented by the EM algorithm. In the process of model estimation, whether the mean value, intercept, coefficient and variance are different from the variation of the zoning parameter S_t. Therefore, different model estimation forms correspond to different situations, namely MSIA-VAR, MSM-VAR, MSIA-VARX, etc. The specific model was judged according to the AIC information criterion, HQ, and SC values.

Data Source and Description

The price data of cerium oxide, praseodymium oxide are from wind data terminal of Shanghai nonferrous metals spot product prices, daily product prices are regulated into monthly data, the producer price index PPI is basing on October 2006, the reason for starting in October 2006 was to consider the integrity of the series of rare earth oxides data records. We have the monthly price adjustment, finally chooses the sample period from April 2008 to June 2017, this period is also due to the completeness of the series of rare earth oxides data. According to the GICS classification standard on which TOPIX index in the S&P index of Japan is based, the industry data index of S&P TOPIX is selected from the wind data terminal as the indicator reflecting the demand of Japanese industry, including Utilities (XJ1), Telecommunication (XJ2), Information technology (XJ3), Industrials (XJ4), and Materials (XJ5), which are the demand factors from Japan. Financial factors are recognized as exogenous variables, we choose MetalsPriceIndex (X2), China iron oreimportspot price index (X5), CrudeOilPriceIndex (X8), the Nikkei 225 Index (closing price, X11), London gold spot prices (closing price, X12). The data of X2 and X8 are from the official statistics of the IMF. X11 and X12 are from the Wind data terminal. To eliminate heteroscedasticity, the logarithm of these indicators is taken in this paper. To meet the requirements of stationarity, first-order difference processing is carried out for all indicators. Based on this, the meaning of variables in this paper represents the growth rate of each indicator.

For the convenience of the following analysis, the connotations and denotations of each endogenous variable are given here according to the GICS classification rules. The Utilities XJ1 is related to the utility sector of water and electricity, which can indirectly reflect the production and living conditions of the industry in Japan. It is also a variable that indirectly reflects the demand for rare earth products. The situation of water and electricity for production and living in Japan reflects the operating capacity and level of the Japanese economy. The Telecommunication XJ2, including integrated telecommunications and wireless telecommunications, and the Information technology XJ3, including computers and peripherals, electronic equipment, instruments and components, semiconductor equipment and products, all rely heavily on cerium oxide. Industrials XJ4, including capital goods, commercial and professional services, and transportation, which capital goods include: aerospace and national defense, electrical equipment, industrial groups, machinery manufacturing, etc. Materials XJ5 includes a variety of chemicals, special chemicals, metal and glass containers, precious metals and ores, etc. Among them, Utilities and Telecommunication belong to indirect demand indicators, while Information technology, Industrials, and Materials belong to direct demand indicators.

Unit Root Test and Selection of MSVAR Model

Before the calculation of the MSVAR model, to ensure the stationarity of samples, the ADF method was used to carry out the unit root test. After logarithmic difference processing, all variables were DLOCE, DLOPR, DLXJ1, DLXJ2, DLXJ3, DLXJ4, DLXJ5, DLX2, DLX5, DLX8, DLX11, and DLX12, which were all stationary sequences at the significance level of 5%. This guarantees the effectiveness of the MSVAR method used.

About the selection of MSVAR model, there are many different settings of MSVAR, including MSI, MSIH, MSMH, MSIA, MSIAH, MSM, and so on. In this paper, the OS-MSVAR package of Krolzing is used to estimate the model on the GiveWin platform. The AIC, HQ, and SC criteria are used as the criteria to judge the selection form of the model. After comparison, the influencing factor model MSIA (3)-VARX (1) of cerium oxide is obtained, which is named as CE-MSIA (3)-VARX (1) model. The vector autoregressive lag term of this model is 1, and the area number is 3. The effect factor model MSIAH (3)-VARX (1) of praseodymium oxide is obtained by comparison, which is named as PRMSIAH (3)-VARX (1) model and its vector autoregressive lag term is 1 and the number of regions is 3.

EMPIRICAL ANALYSIS AND RESULTS

Analysis of The MSVAR Model of Cerium Oxide

OCE-MSIA (3)-VARX (1) model, that is, the MSVAR model of cerium oxide. The LR test value is 416.5908, and the chi-square statistic p-value is less than 5%, which rejects the original hypothesis of the linear system. Therefore, MSIA (3)-VARX (1) is rational.

Regional Status Analysis

The three regions obtained by OCE-MSIA (3)-VARX (1) are shown in Figure 2. Roughly, from June 2008 to 2011, the price growth rate of rare earth products kept a steady fluctuation. At the end of 2008, the beginning to the first half of 2009, and the beginning of 2010, the price growth rate of cerium oxide showed an increasing trend. It can be seen from Figure 2 that most samples were in Zone 2 at this time. At the beginning of 2011, its price increasing rate showed a state of jump rise, until March of that year, its price increasing rate turned to a sharp downward jump decline, and this downward trend continued until the beginning of 2012, after which the price increase rate of cerium oxide fluctuated steadily but remained at a negative level, and most samples were in Zone 3 at this time. Zone 1 corresponds to some extreme points of relatively violent fluctuations.

Specifically, cerium oxide was produced from September 2008 to November 2008, March 2009, April 2010, March and June 2011, April 2012, July and August 2012, November 2012, September 2013, December 2014, September 2015, and January 2016, it corresponds to the extreme point of DLOCE discontinuous severe impact in the figure of Zone 1, but this extreme point does not include the huge fluctuation caused by rare earth blackening and storage in the first half of 2011. Therefore, Zone 1 can be named as "a non-policy extreme value fluctuation zone". Zone 2 corresponds to the following periods: June to July 2008, June to February 2010, May 2010, July to November 2010, April to May 2011, July to November 2011, January 2012, September 2012, May to July 2013, October 2013 to February 2014, January to April 2015, November 2015, September 2016, and March to May 2017, its characteristics can be summarized as gentle fluctuation rising, so it is called "gentle upward fluctuation zone". Zone 3 corresponds to the following periods: August 2008, December 2008 to February 2009, April to May 2009, March 2010, June 2010, December 2010 to February 2011, December 2011, February to March 2012, May to June 2012, October 2012, December 2012 to April 2013, August 2013, March to November 2014, May to August 2015, October 2015, December 2015, March to August 2016, October 2016 to February 2017, and June 2017, its characteristics can be summarized as gentle fluctuation decline, so the Zone 3 is called "gentle downward fluctuation zone".

During the sample period, the probability of the cerium oxide system staying in state 1 is 0.2441, and the probability of transition from state 1 to state 2 and state 3 is 0.3859 and 0.37, respectively. The probability of the system being maintained in state 2 is 0.6662, and the probability of transition from state 2 to state 1 and state 3 is 0.0247 and 0.3091, respectively. The probability of the system being maintained in state 3 is 0.62, and the probability of transition from state 3 to state 1 and state 2 is 0.2234 and 0.1566, respectively. Also, the system was in Zone 1 for 14.92% of the time, and the average duration was 1.32 months. For 38.91% of the time, the system was in Zone 2, and the average duration was 3 months. For 46.17% of the time, the system was in Zone 3, and the average duration was 2.63 months.

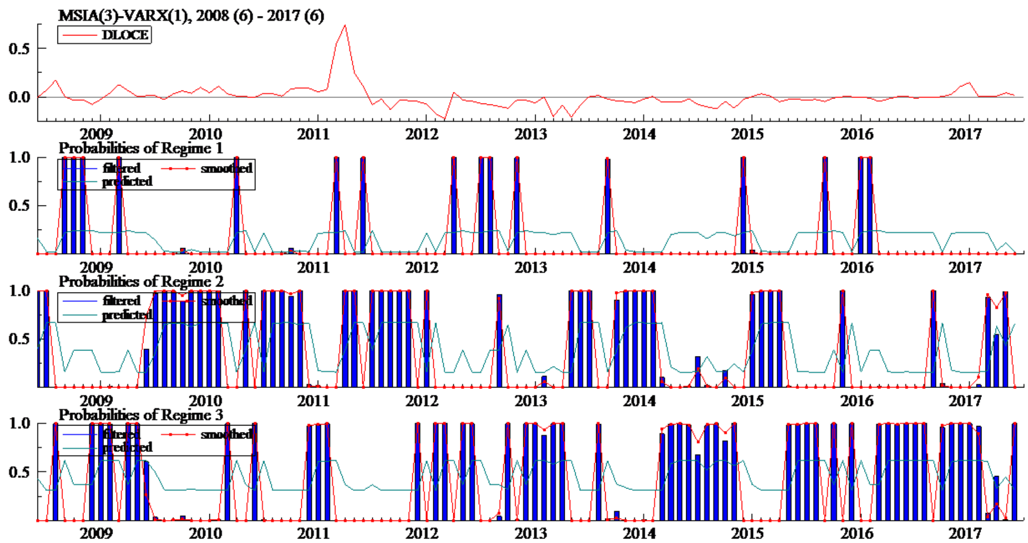


Fig.2 Zonal State of Cerium Oxide

The Impact of Factors and Demand Management Ability

Table 1 is the regression result of cerium oxide in three zones.It is not difficult to find that the fluctuation of cerium oxide under Zone 1 is mainly affected by the Telecommunication, Industrials, Materials, China iron ore import spot price index, Crude Oil Price Index, and Nikkei 225 Index. Under Zone 2, the fluctuation of cerium oxide is significantly affected by the Utilities, Information technology, Industrials, and Materials. Under Zone 3, the fluctuation of cerium oxide is affected by Utilities and Industrials.

Table 1

Regression Results of Three Zones of Cerium Oxide

	Regime 1	Regime 2	Regime 3
	DLOCE	DLOCE	DLOCE
Const	-0.0178	0.002634	-0.00596
DLOCE_1	**0.46927*** **	**0.37418*** **	**0.74617*** **
DLxJ1_1	-0.29976	**-0.9353*** **	0.412871**
DLxJ2_1	-0.80938**	0.208032	-0.09782
DLxJ3_1	-0.9793	*-0.60758**	0.060059
DLxJ4_1	**-5.5197*** **	1.061204**	*-0.85619**
DLxJ5_1	**6.26076*** **	*-0.57368**	0.354237
DLx2	-0.50765	0.139805	0.111689
DLx5	*-0.49276**	-0.01976	0.012887

DLx8	**1.38928*****	-0.07165	0.14124
DLx11	**-1.9228*****	0.288804	-0.21022
DLx12	0.159971	-0.08333	-0.08761

Note: ***, **, * indicate significance at the significance level of 1%, 5% and 10%, respectively.

As can be seen from Figure 2, there are three zones of price fluctuations: Zone 1 with violent non-policy fluctuations, Zone 2 with stable upward fluctuations, and Zone 3 with stable downward fluctuations.

The Impact of Exogenous Financial Factors

In Zone 1, China's iron ore import spot price index X5, Crude Oil Price Index X8, and Nikkei 225 Index X11 showed significant influence, but financial factors did not become significant factors in the other two zones. Specifically, in the stage of the Zone 1 with violent fluctuations, the variables of DLX5 and DLX11 increased by 10%, and the price growth rate of cerium oxide decreased by 4.9276% and 1.9228%, respectively. The price increase rate of cerium oxide increases by 13.8928% for every 10% increase in the DLX8 variable. This means that China's iron ore import spot prices index, the Nikkei 225 Index and cerium oxide have a reverse relationship, that is to say, in the "Price increase rate non-policy sharp fluctuation area", when the China’s iron ore import spot price index and the Nikkei 225 Index are rising (or falling), the trend of price increase rate of cerium oxide will decline (or increase), and this relationship only appear in sharp fluctuations in the price area. It seems, financial factors only play a role in the volatility stage of the price changes of cerium oxide, which can be explained as follows: Price growth rate of cerium oxide go up or drop sharply, for the financial market factors have played an important role in driving force, the growth rate of Nikkei 225 Index and China's iron ore import spot price index increases (or decrease), which means that a lot of capital come into (or out of) the related market, and the price increase rate of cerium oxide decreases (or increases) instead, it explains the price linkage relationship between cerium oxide market and other markets from a certain point of view, which just reflects that cerium oxide products have financial properties in a certain sense. The Crude Oil Price Index has a positive change relationship with cerium oxide, the effect also occurs in the stage of sharp fluctuations under the non-policy effect. It means that under the condition of sharp volatility, the increase rate of Crude Oil Price Index increases (or decreases), will attract (or lost) part of investors’ interest in this special "commodity". Judging from the fact that financial factors occur significantly in the violent fluctuation stage of the non-policy influence of Zone 1, it can actually reflect that the financial nature of the cerium oxide price is reflected in its stage of price growth rate rapid increase or rapid decrease.

The Influence of the Japanese Industrial Factor as an Endogenous Variable

(1) The overall impacts

In the stage of Zone 1, the variables DLxJ2_1 and DLxJ4_1 increased by 10%, while the price growth rate of cerium oxide decreased by 8.0938% and 55.197%, respectively. The variable of DLxJ5_1 increased by 10%, while the price increase rate of cerium oxide increased by 62.6076%. In the stage of Zone 2, the variables DLxJ1_1, DLxJ3_1, and DLxJ5_1 increased by 10%, while the price increase rate of cerium oxide decreased by 9.353%, 6.0758%, and 5.7368%, respectively. The variable of DLxJ4_1 increased by 10%, while the price increase rate of cerium oxide increased by 10.61204%. In the stage of Zone 3, the DLxJ4_1 variable increased by 10%, and the price increase rate of cerium oxide decreased by 8.5619%. The variable of DLxJ1_1 increased by 10%, while the price increase rate of cerium oxide increased by 4.12871%.

(2) Correlation analysis by industry and the demand management ability

①Utilities (XJ1) refer to water and electric utility department, which can indirectly reflect the production and living conditions of the Japanese industry. It is also a variable that indirectly reflects the demand for rare earth products. The situation of water, electricity, production, and living in Japan reflects the operating capacity and level of the Japanese economy. This index has a significant change relationship with cerium oxide in Zone 2 and Zone 3, the former has a negative relationship, the latter has a positive relationship. The "smooth upward" of Zone 2 means the development momentum of public affairs has slowed down, which shows that lower demand does not bring cerium oxide demand slowdown, instead, cerium oxide price increase rate is rising at a steady speed, this can be understood as: In order to prevent the price of the product from rising sharply in the future, indirect demand manufacturers are willing tadpole an early purchase method to deal with future price increases. Of course, due to the indirect inner relationship of cerium oxide and public utilities, we believe that the early response here is the result of the inducing demand, the demand management shown in the public utilities is called "active demand management under demand induced". The "smooth downward "of Zone 3 means that when the price increase rate is in the "downward impact zone" and the utility trend decreases, the price increase rate of cerium oxide will decline, which reflects the characteristics of homecoming and reflects the ability of "passive demand management".

②Telecommunication (XJ2) includes integrated telecommunication service and wireless telecommunication service. It has a significant negative relationship with the price increase rate of cerium oxide only in the non-policy volatile zone of Zone 1. In other words, under the circumstance that the price increase rate of rare earth cerium oxide fluctuates violently under the market behavior, the development of the telecommunication industry is improving (or weakening), which brings the price increase rate of cerium oxide to decrease (or increase), which implies the demand growth rate to decrease (or increase). As an indirect demand index of cerium oxide, its inverse relationship can be understood as "the good development of the industry, the demand will have a downward trend", "the weak development of the industry, the demand will have an increasing trend". It can be explained as follows: when the telecommunication industry was developing well, Japanese rare earth manufacturers related to the telecommunication industry made sufficient stocks of cerium oxide in the face of high price fluctuations of cerium oxide; On the contrary, the weak development of the telecommunication industry is exactly the time when the demand reserve of Japanese manufacturers increases. Therefore, it can be seen that Japanese manufacturers can carry out effective demand management in the two stages of severe price fluctuations of cerium oxide, which is called "active demand management strategy".

③Information technology (XJ3) includes computers and peripherals, electronic equipment, instruments and components, semiconductor equipment and products, which rely heavily on the products of cerium oxide. It has a significant negative relationship with the increased rate of cerium oxide price only in the "stable upward" zone of Zone 2. The "steady upward" of Zone 2 in this region indicates that the development trend of the information technology industry is slowing down, but the demand for cerium oxide is increasing instead of decreasing, which can be understood as cerium oxide product-related manufacturers buy in advance to cope with the possibility of future price rises, the industry manufacturers show “active demand management” ability.

④Industrials (XJ4) includes capital goods, commercial and professional services, and transportation, among which capital goods include: aerospace and national defense, electrical equipment, industrial groups, machinery manufacturing, etc. Among them, automobiles, machine tools, robots, and electronic appliances have been the four pillar industries of the Japanese industry. Industrials shows significance in three zones. Among them, Zone 1 with drastic fluctuation of non-policy and Zone 3 with steady downward trend both show a negative correlation, while Zone 2 with a steady upward trend shows a positive correlation. In Zone 1, according to the above analysis logic, when the industrial industry is developing well (or weakening), the increase rate of cerium oxide price does not go in the same direction, but decreases (or increases). It shows that when the industry-related manufacturers develop well, they have made sufficient inventory of cerium oxide in the early stage, so the demand trend decreases. Weakness coincided with a build-up of demand reserves by Japanese manufacturers, leading to a higher trend in demand. This fully reflects the industry's "active demand management capability”. In Zone 3, the steady downward corresponds to the good development of the industrials. Originally, the demand trend for downstream products should be increasing, but the opposite relationship means that the demand trend for cerium oxide is decreasing, indicating that the manufacturers in this industry have prepared sufficient reserves in advance, reflecting the "active demand management ability”. In Zone 2, the steady upward trend corresponds to the positive development of the industrials and the increased rate of the demand for cerium oxide, which reflects the normal supply and demand logic, indicating that the industrial manufacturers have not acquired effective demand management ability at this stage.

⑤Materials (XJ5) includes a variety of chemicals, special chemicals, metals and glass containers, precious metals and ores, etc. Utilities and Telecommunication belong to indirect demand indicators, while Information technology, Industrials, and Materials belong to direct demand indicators. The materials and cerium oxide in Zone 1 and 2 showed a significant correlation. The positive and violent fluctuations of Zone 1, indicating that the two synchronizations, that is, the industry development is good, the demand trend of cerium oxide increases, and vice versa, which is only in the lower time, reflects the "passive demand management", but in general, this stage lacks management initiative and forethought. The negative Zone 2 corresponds to the weak development of the material industry, but the demand trend of cerium oxide is steadily increasing, indicating that although the industry demand is low, the relevant manufacturers have made the purchase decision during the downturn to cope with the possible price rise in the future, reflecting the ability of "active demand management".

According to the positive and negative changes in the price increase rate of endogenous variables, we first make a summary as follows:

①Among the indicators reflecting financial factors, the positive correlation with the price increase rate of cerium oxide only appears in Zone 1, which is the Crude Oil Price Index; Only

China's iron ore import spot price index and Nikkei 225 Index show a negative relationship with the price increase rate of cerium oxide, and only appeared in Zone 1 phase. ②Among the Japanese industry factors reflecting demand factors: Cerium oxide showed the ability of "active demand management under demand induced" in Zone 2, and the ability of "passive demand management" in Zone 3; In the Zone 1 of the telecommunication industry, Zone 2 of the information technology industry, Zone 1 and 3 of industrials industry, and Zone 2 of materials industry, the related manufacturers show the characteristics of "active demand management" in the demand management of cerium oxide products.

Analysis of The MSVAR Model of Praseodymium Oxide

OPR-MSIAH (3)-VARX (1) model is the MSVAR model of praseodymium oxide. The LR test value is 604.3474, and the chi-square statistic p-value is less than 5%, which rejects the original hypothesis of the linear system, so it is reasonable to choose MSIAH (3)-VARX (1).

Regional Status Analysis

The three regions obtained by OPR-MSIAH (3)-VARX (1) are shown in Figure 3. From June 2008 to the beginning of 2009, the price growth rate of praseodymium oxide remained in a sharp fluctuation state. In January 2009, the increase rate returned to a positive level. Then, there was a long period of stable positive fluctuation until the beginning of 2011. From the beginning of 2011 to the beginning of 2012, the price increase rate of praseodymium oxide showed a very sharp rise and decline fluctuation state, reaching the highest value in the observation period from February 2011 to March 2011, and reaching the second low point in the observation period in early 2012. Then the price increase rate of praseodymium oxide experienced a small fluctuation stage and began a long period of very stable fluctuation stage, during which at the end of 2014, in the middle of 2015, there was a relatively obvious volatility stage with relatively stable volatility and slightly larger volatility.

Specifically, the Zone 1 of praseodymium oxide corresponds to the following periods: July to December 2008, March 2009, February to March 2011, August to October 2011, March to July 2012, August 2013, September 2015, and July to December 2008. Because of its intense wave, Zone 1 is called the “severe fluctuation area”. Zone 2 corresponds to the following periods: June 2008, February 2009, June to November 2009, April to January 2011, April to May 2011, July 2011, November 2011 to January 2012, August to October 2012, June 2013, November 2013 to May 2014, August 2014 to March 2015, June to August 2015, November 2015 to March 2016, May to September 2016, December 2016, and February to June 2017. It has the highest proportion in the three stages and shows the characteristics of stable fluctuation, so it is called the "stable fluctuation zone". The Zone 3 corresponds to the following periods: January 2009, April to May 2009, December 2009 to March 2010, June 2011, February 2012, November 2012 to May 2013, July 2013, September to October 2013, June to July 2014, April to May 2015, October 2015, April 2016, October to November 2016, and January 2017, the fluctuation remained stable. However, unlike the Zone 2, there are fluctuations in the stability, so Zone 3 was called the "small fluctuation zone in the stability".

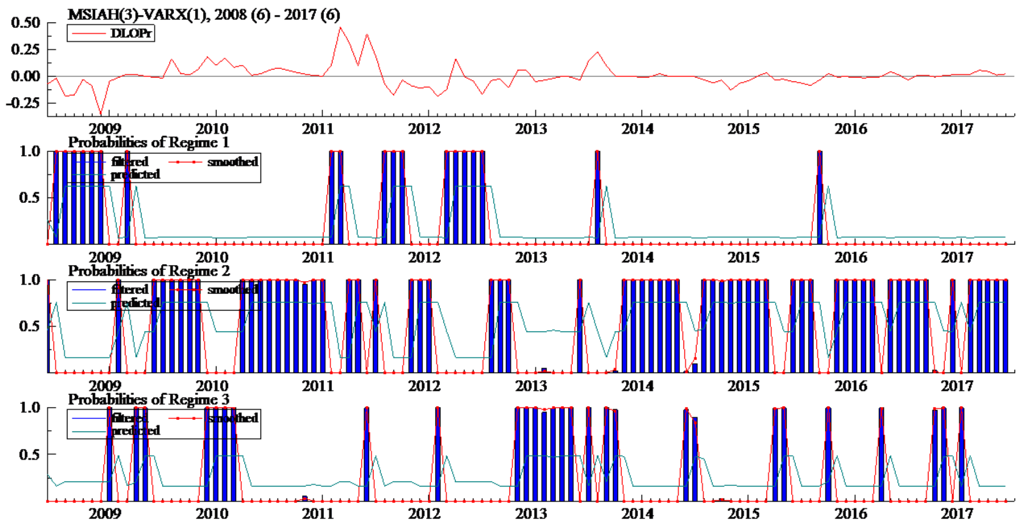


Fig.3 Zonal State of Praseodymium Oxide

During the sample period, the probability of a praseodymium oxide system staying in state 1 was 0.6261, and the probability of transition from state 1 to state 2 and state 3 was 0.1652 and 0.2087, respectively. The probability of the system maintaining in state 2 is 0.7569, and the probability of the system transition from state 2 to state 1 and state 3 is 0.0807 and 0.1624, respectively. The probability of the system being maintained in state 3 is 0.4867, and the probability of transition from state 3 to state 1 and state 2 is 0.0708 and 0.4425, respectively. Also, the system was in Zone 1 for 17.21% of the time, and the average duration was 2.67 months. For 57.58% of the time, the system was in Zone 2, and the average duration was 4.11 months. For 25.21% of the time, the system was in Zone 3, and the average duration was 1.95 months.

The Impact of Factors and Demand Management Ability

Table 2 is the regression result of praseodymium oxide in three zones. Under Zone 1, the fluctuation of praseodymium oxide is only positively correlated with the Crude Oil Price Index X8. Under Zone 2, the fluctuation of praseodymium oxide was significantly affected by Utilities XJ1 and MetalsPrice Index X2. Under Zone 3, the fluctuation of praseodymium oxide was significantly affected by the Utilities, Telecommunication, Industrials, and Crude Oil Price Index.

Table 2
Regression Results of Three Zones of pPraseodymium Oxide

	Regime 1	Regime 2	Regime 3
	DLOPr	DLOPr	DLOPr
Const	0.006596	-0.00388	**0.07766*** **
DLOPr_1	1.082294	**0.51689*** **	**0.44087*** **
DLxJ1_1	0.256686	*-0.13352**	**-0.7131*** **

DLxJ2_1	-0.18661	-0.17365	**0.63733*** **
DLxJ3_1	3.000764	0.204386	0.65454
DLxJ4_1	-3.67389	-0.36855	-1.77486**
DLxJ5_1	-0.29005	0.209592	0.043272
DLx2	-1.74294	0.404349**	0.196924
DLx5	0.815738	-0.13743	0.100526
DLx8	*1.485658**	0.108956	*-0.58455**
DLX11	0.040584	0.015092	-0.29414
DLx12	0.68295	0.059225	0.023074

Note: ***, **, * indicate significance at the significance level of 1%, 5% and 10%, respectively

As can be seen from Figure 3, there are three zones of price fluctuations: Zone 1 with violent fluctuation, Zone 2 with stable fluctuation, and Zone 3 with small fluctuation in stability. These three zones reflect different degrees of fluctuation intensity, and the order from strong to weak is zone system 1-3-2.

The Impact of Exogenous Financial Factors

In Zone 1, only the Crude Oil Price Index has a positive and significant effect, while in Zone 3, it has a negative and significant effect. In Zone 2, only the MetalsPrice Index shows a positive significant relationship. Specifically, in Zone 1, DLX8 increases by 10% and the price growth rate of praseodymium oxide increases by 14.85658%; In Zone 2, DLX2 increases by 10%, and the price growth rate of praseodymium oxide increases by 4.04349%; In Zone 3, DLX8 increases by 10% and the price growth rate of praseodymium oxide decreases by 5.8455%. Thus, the increase rate of the Crude Oil Price Index and MetalsPrice Index play a positive role in promoting the price increase rate of praseodymium oxide in Zone 1 and 2, namely high (or low) commodities (international crude oil and metal) price index increase rate means that a large amount of capital inflows into (or flows out) the financial market of this commodity, praseodymium oxide is also indirectly sought after (or left out) by the capital market, the price increase rate of volatile and smooth fluctuations in two area shows such features, seem to reflect the capital market preference for this kind of fluctuation type. In Zone 3, the increase rate of the Crude Oil Price Index has a reverse effect on the prices of praseodymium oxide, which means that when the growth rate of the Crude Oil Price Index goes up (or down), the price increase rate of praseodymium oxide will decline (or improve) because of financial capital outflow (or inflow), this change reflects the reverse flow between financial capital in different markets.

The Influence of the Japanese Industrial Factor as an Endogenous Variabl.

(1) Overall impact

In the stage of Zone 1, no Japanese industrial indexes show a significant relationship with the price increase rate of praseodymium oxide. In the stage of Zone 2, the variable DLXJ1_1 increased by 10%, and the price increase rate of praseodymium oxide decreased by 1.3352%. DLXJ1_1 and DLXJ4_1 increased by 10%, and the price increase rate of praseodymium oxide decreased by 7.131% and 17.7486%, respectively. The DLXJ2_1 variable increased by 10%, and the price increase rate of praseodymium oxide increased by 6.3733%.

(2) Correlation analysis by industry and the demand management ability

①The Utilities shows a significant negative correlation in both zones. In the stable fluctuation of the Zone 2 and small amplitude fluctuation of the Zone 3, it shows that the utilities is good (or downturn), which can bring the price increase rate of praseodymium oxide decrease (or increase). It indicates that the indirect demand manufacturers have made a reservation in advance to prevent a larger price rise of the product in the future, or to buy downstream indirect demand products at a low price in the downturn of the industry. Because praseodymium oxide has an indirect demand relationship with the industry, we call this management as "active demand management under demand induced" ability.

②Telecommunication industry only shows a positive correlation with praseodymium oxide in Zone 3. It shows that in Zone 3 with small fluctuation, the good development (or downturn) of the telecommunication industry will bring the same direction change of price increase rate of the praseodymium oxide, which indicates that the related manufacturers do not have the demand management ability to deal with the indirect demand product price.

③The Information technology and Materials have no significant performance in the three zones.

④There was a significant negative relationship between the price increase rate of praseodymium oxide and Industrials in Zone 3. It means that industrial manufacturers adopt an "active demand management" strategy in response to price fluctuation, that is, they buy when the demand is low and don't buy when the demand is high. The premise of not buying is that they have made reserves in advance.

According to the positive and negative changes in the price increase rate of endogenous variables, we first make a summary as follows:

①In the indicators reflecting financial factors, ① the positive relationship with the price increase rate of praseodymium oxide appears in Zone 1 and 2, which are the increase rate of Crude Oil Price Index and the MetalsPrice Index respectively. Only the Crude Oil Price Index in Zone 3 has a reverse relationship with the price increase rate of praseodymium oxide. ② Among the Japanese industry factors that reflect demand factors: Utilities shows the ability of "active demand management under demand induced" in Zone 2 and Zone 3; The Industrials shows the ability of "active demand management" in Zone 3.

Comparison of Demand Management Capabilities of Two Products in Relevant Industries in Japan

According to the above analysis, we compared the influence of related industry factors on the two kinds of products of cerium oxide and praseodymium oxide, and we found that the two kinds of products have little similarity in different industries, as shown in Table 3. Table 3 reflects the positive and negative correlation between the two types of products and related industries, as well as the characteristic attributes of the regions where they are located. V means "fluctuation", U means "upward", D means "downward", V means "very violent", V0 means "stable fluctuation", and V1 means "small intensity severe fluctuation instability".

Table 3
Correlation Summary of Influence Factors of Cerium Oxide and Praseodymium Oxide

	v	Uv	Dv	Vv	v0	v1
	Regime1	Regime2	Regime3	Regime1	Regime2	Regime3
DlxJ1_1		-	+		-	-
DlxJ2_1	-					+
DlxJ3_1		-				
DlxJ4_1	-	+	-			-
DlxJ5_1	+	-				

Firstly, it needs to be noted that, according to the previous analysis, demand management capabilities are manifested as "active demand management" and "passive demand management" capabilities. The former is shown as a negative relationship in Table 3, while the latter is shown as a positive relationship in the downward process. The segments above the dotted line in Table 3 are sectors with indirect demand, while those below the dotted line are sectors with direct demand. From the perspective of industry, the utilities with indirect demand and the industrials with direct demand show more outstanding "active demand management" ability for the two types of products, and the utilities also shows "passive demand management ability" in the declining fluctuation area.

Secondly, the prominent performance of the utilities in the regression results makes us think that the consumption of water and electricity can reflect the economic situation to some extent. Therefore, it is reasonable to believe that the close relationship between Japan's economy and China's rare earth products. The correlation between the two rare earth products and the multi-zone system of the industrial industry is more detailed to obtain the characteristics of product demand management based on industrials, and also reflects the close degree between the development of Japanese industrials and China's rare earth products.

Thirdly, from the product point of view, compared with praseodymium oxide, cerium oxide demand management ability is stronger, praseodymium oxide only shows a little demand management abilityin the "smooth fluctuations" and "small vibration in the smooth" in the utilities and industrials. Cerium oxide has a certain degree of demand management capability in two indirect industries and three direct industries at different stages.

Finally, according to the above analysis, we can construct the Japanese reverse demand management capability map of cerium oxide and praseodymium oxide, as shown in Figure 4. From the graph, we can see the demand management reverse regulation relationship between industry, product, and district system very directly. Among them, as far as the industry is concerned, the direct index of the industrials is the most prominent reverse regulation industry on the variety of cerium oxide. And utilities is the most prominent reverse regulation indirect industry on the variety of praseodymium oxide.

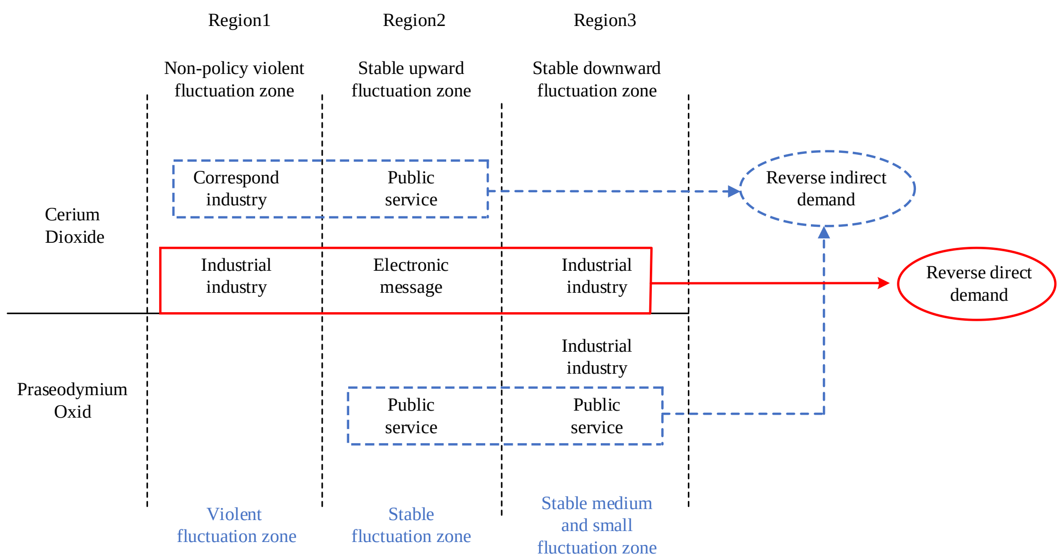


Fig.4 Japan's Map on Reverse Demand Management Ability of Cerium Oxide and Praseodymium Oxide

Model Validity

Figure 5 is the effect test of the OCE-MSIA(3)-VARX(1) model, where the left figure shows the relationship between the actual value, predicted value, and smooth value of price increase rate of cerium oxide; The figure on the right shows the fitting results of the normal distribution of the actual residuals. In general, the MSVAR method fits well with the changes of cerium oxide and its related variables.

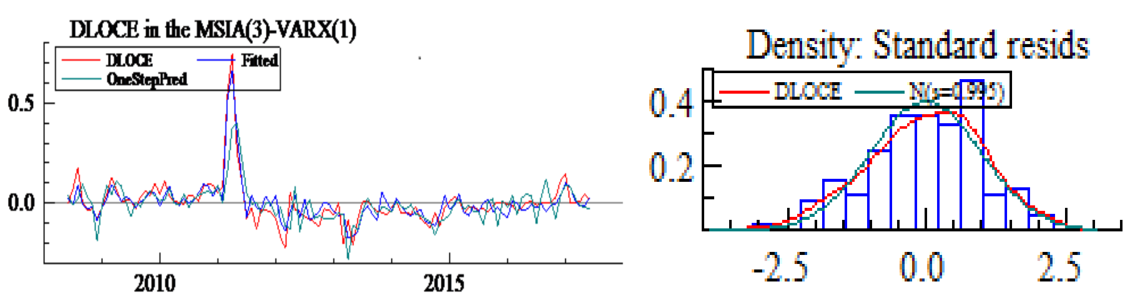
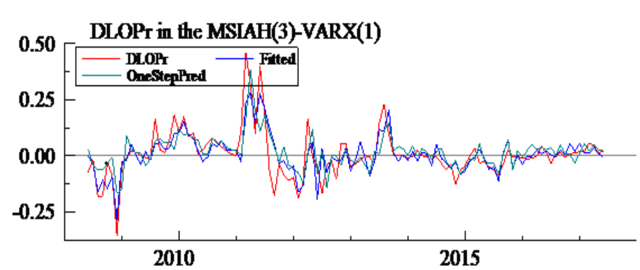


Fig.5 Effectiveness of CE-MSIA (3)-VARX (1) Model

Figure 6 is the effect test of the OPR-MSIAH (3)-VARX (1) model, in which the contents of the left figure and the right figure are the same as above. Judging from the graph, the MSVAR method fits well with the change of praseodymium oxide and its related variables.



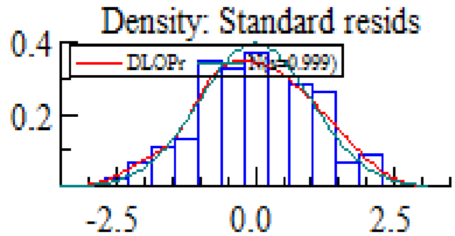


Fig.6 Effectiveness of PR-MSIAH (3)-VARX (1) Model

CONCLUSION

Being the world's fourth-largest cigarette producer and an important cigarette exporter in the world, Japan have a large amount of REES needs for tobacco cultivation. Rare earth prices volatility directly affect cigarette manufacturing when Japan's rare earth strategy operated. Through the analysis of this paper, we can draw the following conclusions:

(1) The influence factor models of cerium oxide and praseodymium oxide were established by the MSVAR model. Three zones were divided into each model, but the corresponding zones of each product had different meanings. For cerium oxide, Zone 1 represents a non-policy fluctuation zone, while Zone 1 represents a fluctuation zone for praseodymium oxide. Zone 2 of cerium oxide indicates a gentle upward fluctuation zone, while Zone 2 of praseodymium oxide indicates a smooth fluctuation zone. Zone 3 of cerium oxide represents a gently downward fluctuation zone, while Zone 3 of praseodymium oxide represents a slightly fluctuation zone in the stability. This shows that different products have different characteristics of price fluctuations, even if the number of zones is the same, but the connotation of fluctuations is also different.

(2) The intercepts and coefficients of MSVAR models of cerium oxide and praseodymium oxide are also different under the state of three zones, indicating that the same factors have different effects on the price increase rate of cerium oxide or praseodymium oxide under different zones.

(3) Financial factors have a certain impact on the price of cerium oxide and praseodymium oxide. For cerium oxide, China's iron ore import spot price index and the Nikkei 225 Index harm it; The Crude Oil Price Index has a positive relation to it. This reflects the financial properties of cerium oxide in volatile regions. For praseodymium oxide, the increased rate of its price in Zone 1 and 2 changes in the same direction with the increased rate of the Crude Oil Price Index and MetalsPrice Index. In Zone 3, it changes inversely with the increase rate of the Crude Oil Price Index. This reflects the financial properties of praseodymium oxide that appeared in three stages.

(4) There is a significant relationship between Japanese industrial factors on cerium oxide and praseodymium oxide to some extent, and different industrial factors have their significant influence characteristics in different regions. The factors of positive change in the price increase rate of cerium oxide can be summarized as Materials 1 (indicating that the Materials is in Zone 1, the same below), Industrials 2, Utilities 3; The inverse relation is: Telecommunication+ Industrials 1, Utilities + Information technology + Materials 2, Industrials 3.Factors that have a positive relationship with the price increase rate of praseodymium oxide can be summarized as Telecommunication 3; The inverse relationship is:

Utilities 2, Utilities + Industrials 3.

(5) Japan has a certain demand management capability in cerium oxide and praseodymium oxide products. The inverse relationship between the price increase rate of cerium oxide can be summarized as Telecommunication + Industrials 1; Utilities + Information technology 2; Industrials 3. The factors that have an inverse relationship with praseodymium oxide price increase rate can be summarized as Utilities 2; Industrials + Utilities 3. This capability can be seen in Figure 6.

From the perspective of demand management, we can make it clear that the price of light rare earth products is affected by the example of cerium oxide and praseodymium oxide. In addition to financial factors, from a regional perspective, the development factors of the Japanese industry play a major role. Among the related industry factors, Information technology, the Industrials as direct factors, for cerium oxide and praseodymium oxide under a certain price fluctuation state there is a reverse regulation of the active demand management ability; Similarly, Utilities and Telecommunication have active demand management ability for cerium oxide and praseodymium oxide due to reverse regulation under a certain price fluctuation state. The find reveal that the demand management capabilities of the counterparties in the international trade of rare earths is necessary for rare earth industry and companies to formulate a more reasonable “Optimal output and optimal price of rare earth products" which based on the characteristics of rival demand management capabilities. This is also the significance of the rare earth product demand management capability map proposed in this paper.

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Author Declaration

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